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QUALITY CHARACTERISTICS AND VOLATILE COMPOUNDS OF FOAM MAT DRIED CORN FLOUR

LI SHING TEOH, OLA LASEKAN[1] and SHAKIRAH AZEEZ

Department of Food Technology, Faculty of Food Science & Technology, University Putra Malaysia, Serdang 43400, Malaysia

[1]Corresponding author.
TEL: +603-8946-8535;
FAX: +603-8942-3552;
EMAIL: olaniny56@gmail.com

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ABSTRACT

Foam mat drying is good in dehydrating liquid foods in a short time. The porous structure of foam material contributes to high drying rate and consequently shorter dehydration time. Corn flour was produced using foam mat drying and its quality was compared to freeze-dried corn flour. Different concentrations of egg albumen (10, 15 and 20%) and whipping time (5, 10 and 15 min) were used. Foaming characteristics of corn slurry produced were investigated. Corn slurry produced with 20% egg albumen and 15 min whipping time was chosen and the slurry was dried at different temperatures (60, 70 and 80C). Their physicochemical properties and volatile compounds were determined. Foam mat dried corn flour at 60C was found to be the overall optimum corn flour with the highest nutritional composition (protein, 21.51%; crude fat, 4.16%; and crude fiber, 7.52%). However, freeze-dried corn flour gave better color appearance and more volatile compounds.

PRACTICAL APPLICATION

This study provides some basic information necessary for the production of foam mat dried corn flour with better nutritional quality than the traditional hot air drying method. This study will enhance the availability of foam mat dried corn flour with improved physical, nutritional and sensory properties that could serve as a base material for infant formula in developing countries.

INTRODUCTION

Corn is one of the world's most important grains which boost multibillion dollar revenue. It is a widely used ingredient in the preparation of food product with different quality requirements (Zeng *et al.* 2011). This may be attributed to its low gluten content and the fact that it has similar calorie content with wheat flour. Several processing methods such as precooking, nixtamalization, fermentation, degermination and drying have been applied to corn kernel prior to milling into flour (Gwirtz and Garcia-Casal 2014). All these methods have been employed industrially with or without fortification to meet the rising demand of corn flour as substitute for wheat flour.

Freeze-drying is a complex drying process applied to food products. During freeze- drying, most of the water is dehydrated by sublimation. Freeze-drying is considered the best method for water removal when compared to other methods of drying (Genin and Rene 1995; Irzyniec *et al.* 1995). However, it is time and energy consuming and requires high operational cost (Chakraverty *et al.* 2003; Schulze *et al.* 2014).

Foam mat drying is now receiving new attention because of its ability to process hard-to-dry food materials and the retention of volatiles that may be otherwise lost during drying of non-foamed materials (Kudra and Ratti 2006). In foam mat drying, a liquid or semi-liquid material is converted into stabilized foam by whipping in edible foaming agents, and subsequently dehydrated in foam of spread sheet or material. Due to the increased liquid-gas interface, rate of drying is relatively high, despite the heat transfer being impeded by the large volume of gas that is present in the foamed mass (Chandak and Chivate 1972). The foaming renders the drying material extremely porous and more amenable to drying of its innermost layers (Rajkumar *et al.* 2007). Protein and non-protein based foaming agents have been used to produce foam mat dried products (Ibidapo and Erukainure 2012). Protein albumen in egg whites is widely used as foaming agents due to their good foaming stability property (Damodaran *et al.* 1998; Celik *et al.* 2007).

Fortification of cereal based foods has been encouraged especially in developing countries suffering from protein malnutrition (Minaeerad *et al.* 2012). Production of corn flour by foam mat drying method using egg albumen as a foaming agent will not only increase the protein content of the foam mat dried product, but also yield a better quality end product with superior color and flavor attributes. Previous studies have been done on the foaming conditions and drying behavior of various fruits juice and purees. However, there have been a few or no reports on the foaming and drying characteristics of corn slurry and the evaluation of the final end product quality. Thus, the present study aimed at (1) investigating the foaming and drying characteristics of corn slurry and (2) evaluating and comparing the physicochemical properties and volatile compounds of foam mat dried corn flour and freeze dried corn flour.

MATERIALS AND METHODS

Sample

Fresh yellow sweet corns were purchased from Pasar Borong, Selangor, Malaysia. The stem of yellow corn was removed to get the whole maize kernel. The whole maize kernels were stored in refrigerator (4 ± 1C) until further processing.

Preparation of Corn Slurry and Foam

Whole maize grains (1 kg) were soaked in 2 L water for 3 h to soften prior to milling. The whole grains were then milled into corn slurry using a blender (MX-801S, Panasonic, Malaysia). Clean fresh eggs were broken and the albumen was carefully separated from the egg yolk. A 10, 15 and 20% (v/v) of egg albumen were prepared for the foaming experiment. A 200 mL of corn slurry was weighed into a beaker in triplicate. The different concentrations of egg albumen were added to the weighed corm slurry. The mixtures of corn slurry and egg albumen were whipped using a blender (MX-801S, Panasonic, Malaysia) at its maximum speed of 380 rpm.

Preparation of Freeze Dried Corn Flour

Freeze dried corn flour was prepared according to Karim and Wai (1999). Corn slurry was frozen in a freezer for 6 h, after which it was transferred into a freeze dryer for 24 h. A powder was obtained by grinding the dried material using blender (Panasonic MX-801S) for 3 min and kept in high density polythene bags. The samples were stored at ambient temperature (25 ± 2C) until further analysis.

Determination of Foaming Properties

Foam Expansion. Foam expansion was used to indicate the amount of air incorporated into corn slurry during foaming and it was measured as percent increase in volume of corn slurry. Corn slurries with foaming agent were whipped for 5, 10 and 15 min. The effect of whipping duration on foam expansion at different concentrations of egg albumen was recorded. It was calculated using the following equation (Durian 1995);

$$\text{Foam expansion } (\%) = \frac{V_1 - V_0}{V_0} \text{ x } 100$$

Where, V_0 is the initial volume of corn slurry before foaming (cm^3) and V_1 is final volume of corn slurry after foaming (cm^3).

Foam Density. Foam density was determined by dividing the mass of fresh slurry by the final volume of foam (Kandasamy *et al.* 2012a);

$$\text{Foam density } \left(\text{g cm}^{-3}\right) = \frac{m}{V_1}$$

Where, m is mass of corn slurry (g) and V_1 is final volume of corn slurry after foaming (cm^3).

Drying Studies

Drying was carried out with a cabinet dryer (Malchem, Malaysia) at dry bulb temperature of 60, 70 and 80C and maximum fan speed (200 m/s). The cabinet dryer consists of a heater, fan, Mini Fogger III (Spraying System Co., Wheaton, IL, U.S.A.) water sprayer (0.9 L/h, 0.4 mPa) used to control the humidity, drying chamber, air inlet opening, air outlet opening and thermostat. The external and internal structure of cabinet dryer is illustrated in Fig. 1. The dryer was switched on for a period of time until the desired temperature inside the cabinet was reached and stabilized. Foamed corn slurry was spread on food grade stainless steel trays with thickness of 4 mm. Drying process started when both temperatures (setting temperature and temperature inside the dryer) shown in thermostat were the same. The foamed corn slurry was dried until the moisture content of the foam mat was below 5%. The moisture content (%) on dry basis was calculated as described by Chakraverty (1997);

$$\text{MC } (\% \text{ db}) = \frac{W_m}{W_d} \text{ x } 100$$

Where MC is the moisture content, (% dry basis), W_m is the weight of moisture in the sample (g) and W_d is the weight of dry matter of the sample (g).

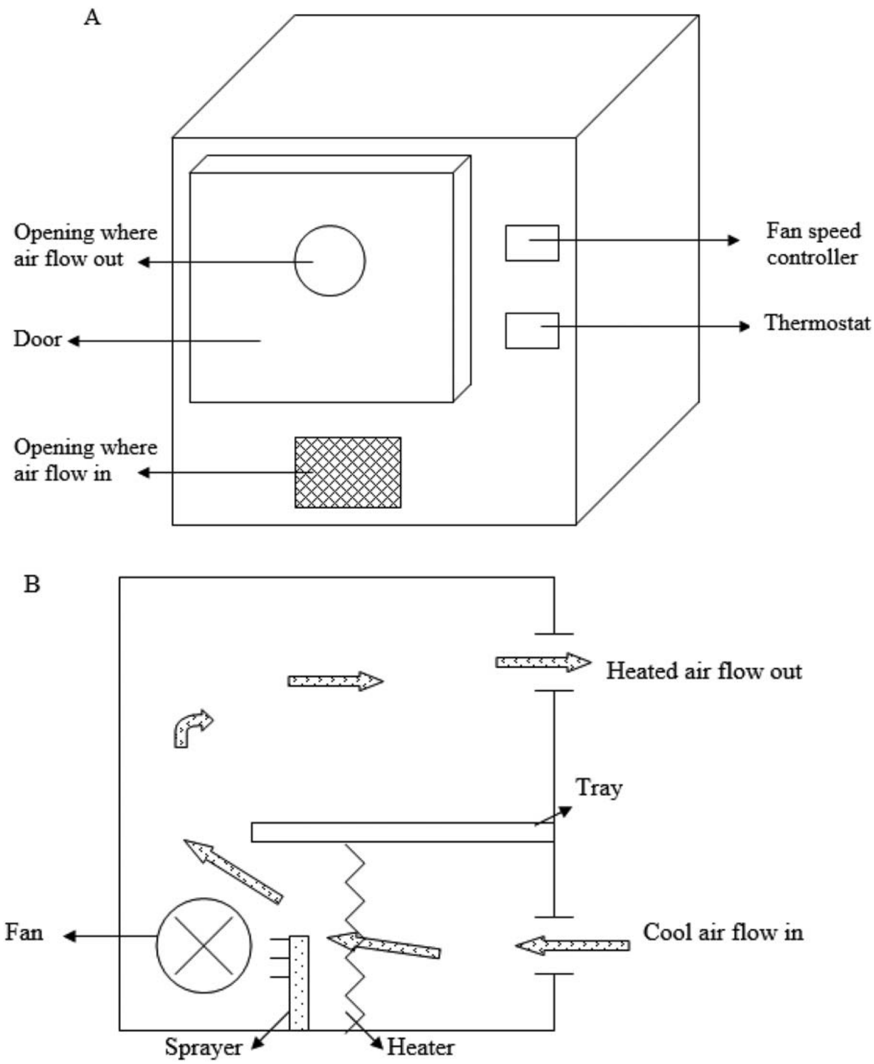

FIG. 1. STRUCTURE OF CABINET DRYER (A) EXTERNAL STRUCTURE (B) INTERNAL STRUCTURE

The dried foam was scrapped after cooling the trays to room temperature. Powder obtained from different temperatures were pulverized using a blender (MX-801S, Panasonic, Malaysia) for 3 min and then immediately packed in high density polythene bags to prevent diffusion of moist air and caking (Kandasamy *et al.* 2012b). The samples were stored at ambient temperature until further analysis.

Physico-Chemical Properties of Foam Mat Dried Corn Flour and Freeze Dried Corn Flour

Proximate analysis (moisture, crude fat, crude fiber, crude ash and crude protein) were determined using the AOAC (1990) methods. Carbohydrate content was determined by difference (AOAC 1990).

Color Measurement. The color of corn flour was measured using colorimeter (Handheld Minolta CR-300 colorimeter, Minolta Camera Co., Osaka, Japan). The instrument was calibrated against a standard white reference plate ($L^* = 98.76$, $a^* = -0.21$, $b^* = 0.02$) by pushing the head of the colorimeter towards the reference plate. The corn flour was filled into a transparent cup (3/4 of the cup volume) and measured by colorimeter. The color of corn flour was expressed in three color coordinates L^*, a^*, and b^*. L^* defines lightness, a^* denotes the red/green value and b^* the yellow/blue value.

Water Activity Measurement. The water activity of corn flour was determined using Aqualab water activity meter (Deagon Devices Inc., Washington, U.S.A.). The corn flour was filled into a cup (3/4 of the cup volume) and placed in the instrument's sample zone. The reading was recorded when digit number display was stable.

Analysis of Volatile Compounds in Foam Mat Dried Corn Flour and Freeze Dried Corn Flour

Extraction of Volatiles. Sample was extracted using the method of Quinn et al. (2007) with slight modification in term of quantity of sample used. A 20 g sample was measured into a beaker and 50 mL of dichloromethane solvent was added. The mixture was stirred with magnetic stirrer for 3 h at room temperature. The mixture was filtered (Whatman No. 1) through Buchner funnel. The extract was concentrated under reduced pressure at 45C and 900 rpm using rotary evaporator (Laborota 4000 Efficient Eco, Heidoph, Germany). The concentrated extract was then filtered using 0.45µm membrane filter into vials and stored at 4C until further analysis.

Determination of Volatile Compounds. Volatile compounds were determined by the modification of the method of Ho *et al.* (2008). The volatile compounds of extract were identified using GC-MS (TRACE ULTRA Gas Chromatography, Thermo Scientific, U.S.A.) with DB.5 capillary column (30 m × 0.25 mm × i.d., 0.25 µm film thickness). Flow rate of helium carrier gas was 1.0 mL/min. The injector temperature was 240C. The oven temperature was programmed from 60 to 240C at 6C/min with initial and final hold times of 5 and 10 min, respectively using splitless injection mode. The compounds were identified with a quadruple mass selective detector. Mass spectral ionization was set at 180C. The mass spectrometer was operated in the electron ionization mode at a voltage of 70 eV. Volatile compounds were identified by comparing the mass spectra and retention time data with those of authentic compounds supplemented with data from MS library.

Statistical Analysis

All analyses were done in triplicate for each sample and data obtained were subjected to analysis of variance (ANOVA) (Barbosa-Cánovas and Vega-Mercado 1996). One-way analysis of variance was carried out using the Minitab 16 software. Significance differences was determined at $\alpha = 0.05$ using Tukey's test.

RESULTS AND DISCUSSION

Foaming Characteristics of Corn Slurry with Egg Albumen

Foam expansions are used to indicate the amount of air incorporated into a food material during foaming. Figure 2 shows the effect of whipping time and egg albumen concentration on the corn slurry foam expansion. The foam expansion increased significantly with an increase in egg albumen concentration and whipping time. This is an indication of the reducing power of egg albumen on the surface tension and interfacial tension at the air-aqueous interface (Prins 1988; Kandasamy *et al.* 2012b). Air bubbles at low albumen concentration were not stable, due to the low visco-elasticity of films which are generally more susceptible to rupture than high egg albumen foam (Karim and Wai 1999). However, increasing egg albumen beyond its maximum concentration to form foam produced insignificant changes in foam expansion (Kandasamy *et al.* 2012b). As the protein structure becomes disrupted by mechanical force at the interface, the albumen interacts with one another to form a more stable visco-elastic interfacial film, thereby resulting in foam formation and increasing the volume of corn slurry foam (Balasubramanian *et al.* 2012).

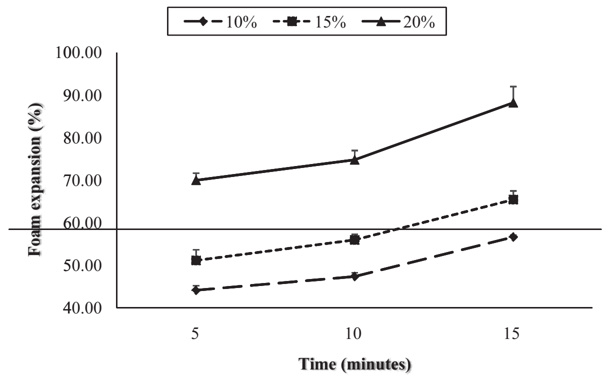

FIG. 2. EFFECT OF WHIPPING TIME AND EGG ALBUMEN CONCENTRATION ON FOAM EXPANSION
Note: Vertical lines show standard deviation from the mean.

Foam Density. The foam density of corn slurry decreased with increase in concentration of egg albumen and whipping time (Fig. 3). During whipping process, air was incorporated

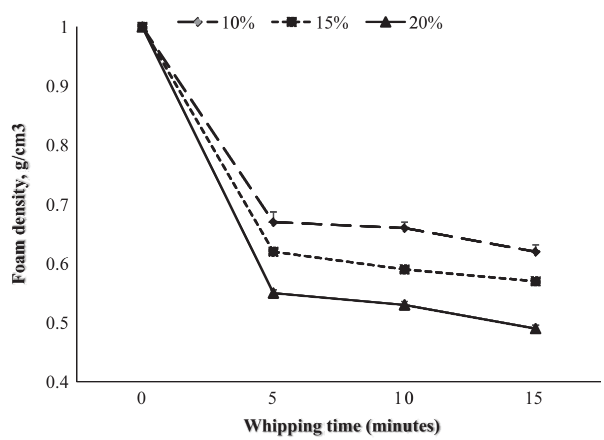

FIG. 3. EFFECT OF WHIPPING TIME AND EGG ALBUMEN CONCENTRATION ON FOAM DENSITY
Note: Vertical lines show standard deviation from the mean.

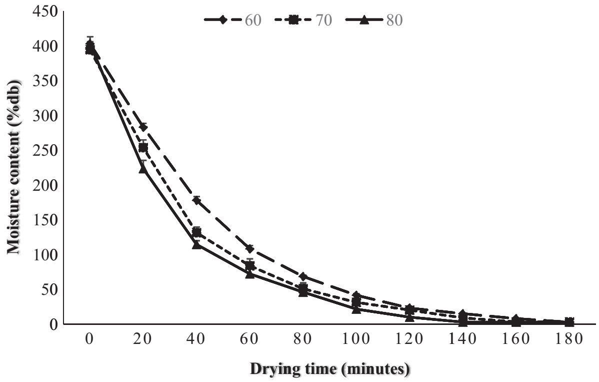

FIG. 4. DRYING CURVES OF FOAMED CORN SLURRY AT DIFFERENT DRYING TEMPERATURES AND DRYING TIME
Note: Vertical lines show standard deviation from the mean.

into the corn slurry and trapped in the liquid as bubbles. This resulted in a decrease in foam density as whipping duration increased (Thuwapanichayanan *et al.* 2008). The higher the amount of air incorporated during whipping, the higher the whippability and thus the lower the foam density (Balasubramanian *et al.* 2012). Similar foaming characteristics have been reported for a number of food products (Bates 1964; Jamil *et al.* 1988; Akintoye and Oguntunde 1991).

Drying Characteristics of Corn Foam Mat

Foam mat drying of corn slurry was carried out using the optimized level of 20% egg albumen and 15 min whipping time. It was observed that when the foamed corn slurry was dried at 60, 70 and 80C, the time required for reducing their moisture content to about $3.08 \pm 0.4\%$ (dry basis) was 180, 160 and 140 min, respectively. There was a drastic decrease (approximately 70%) in moisture content for the first 40 min of drying (Fig. 4). The drying curves drops abruptly as the moisture removal level gradually approaches equilibrium with drying rate moving towards zero for all drying temperatures used. This is an indication that the heat energy is being used to evaporate the continuous layer of moisture at the surface of the foam (Karim and Wai 1999).

Physico-Chemical Analysis of Freeze Dried and Foam Mat Dried Corn Flour

The physico-chemical properties of both freeze dried and foam mat dried corn flour at different temperatures are presented in Table 1. The moisture content for all samples range from 3.69 to 4.22% with corn flour dried at 60C having the highest moisture content (4.22%) and that of 80C having the lowest. However, there was no significant difference ($P > 0.05$) in moisture content between freeze dried and foam mat dried corn flour at different temperatures.

Ash contents of freeze dried and foam mat dried corn flours at 60, 70 and 80C were 2.20, 5.31, 4.86 and 4.54%, respectively. The ash contents of foam mat dried corn flours were relatively higher than the freeze dried corn flour. This is an indication of the additional source of minerals from the egg albumen used as the foaming agent which contributed to the increase in ash content in the foam mat dried corn flour. It was observed that ash content of foam mat dried corn flour produced at 60C was significantly ($P < 0.05$) higher than the other two samples produced at higher temperature. This may be attributed to the loss of heat labile mineral components during drying at higher temperature.

The protein content of the foam mat dried corn flour also followed similar pattern as the ash content in which the foam mat dried corn flour produced at 60C had the highest protein content (21.51%), while the freeze dried corn flour had the lowest (6.77%). The protein content in foam mat dried corn flour was significantly ($P < 0.05$) higher than protein content in freeze dried corn flour. Egg albumen is rich in protein, consisting of ∼54% of total egg albumen solid. Therefore, the corn flour produced by foam mat drying had a higher protein content due to the addition of egg albumen. The use of egg albumen as foaming agent added more

TABLE 1. PHYSIOCHEMICAL PROPERTIES OF FOAM MAT DRIED CORN FLOUR AT DIFFERENT TEMPERATURE AND FREEZE-DRIED CORN FLOUR

	Freeze-dried	Foam mat (60C)	Foam mat (70C)	Foam mat (80C)
Moisture content	3.71 ± 0.18^a	4.22 ± 0.22^a	4.09 ± 0.42^a	3.69 ± 0.66^a
Ash	2.20 ± 0.13^a	5.31 ± 0.19^b	4.86 ± 0.07^c	4.54 ± 0.1250^c
Crude protein	6.77 ± 0.17^a	21.51 ± 0.76^b	18.04 ± 0.22^c	15.54 ± 0.62^d
Crude fat	3.84 ± 0.21^a	4.16 ± 0.16^a	3.91 ± 0.04^a	3.83 ± 0.03^a
Crude fibre	7.91 ± 0.32^a	7.52 ± 0.27^a	7.50 ± 0.06^a	7.39 ± 0.12^a
Carbohydrate	75.57 ± 0.40^a	57.27 ± 0.70^b	61.60 ± 0.29^c	65.01 ± 0.34^d
Color	74.11 ± 0.30^a	73.13 ± 0.40^b	72.11 ± 0.26^c	71.16 ± 0.28^d
L^*	-1.47 ± 0.09^a	$+0.95 \pm 0.07^b$	$+1.25 \pm 0.05^c$	$+1.50 \pm 0.06^d$
a^*	$+35.40 \pm 0.62^a$	$+27.46 \pm 0.76^b$	$+24.35 \pm 1.14^c$	$+23.31 \pm 0.83^c$
b^*				
Water activity	0.22 ± 0.00^a	0.30 ± 0.00^b	0.25 ± 0.00^c	0.31 ± 0.01^b

Values are means and standard deviations of duplicate analyses; Values followed by different superscript letters in a row are significantly ($P < 0.05$) different from each other.

nutritional value to corn flour produced by foam mat drying over corn flour produced by other methods. Proteins are heat labile food components which are usually denatured during thermal treatment. It was observed that the protein content decreased with increasing temperature. Prolonged exposure to high temperatures may render protein less useful in diet (Lasekan *et al.* 1996; Pendre *et al.* 2012).

There was no significant difference ($P > 0.05$) in crude fat content between freeze dried and foam mat dried corn flour at different temperatures. The fat content of foam mat dried corn flour produced at 60C had the highest value (4.16%) while the crude fat content of foam mat dried corn flour produced at 80C was the lowest value (3.83%). Corn oil is known to have high level of polyunsaturated fat (55 g) (Lasekan and Abdulkarim 2012). The crude fat content in foam mat dried corn flour decreased as the drying temperature increased, resulting in loss of energy value.

Crude fiber is usually used in evaluating the efficiency of milling and separation of bran from starch endosperm. However, whole kernel was used in producing foam mat dried corn flour, thus making its crude fiber content higher than most corn flour. The crude fiber content (Table 1) of freeze dried corn flour and foam mat dried corn flour produced at different temperatures were not significantly different ($P > 0.05$). Freeze dried corn flour was the highest with the value of 7.91% while the foam mat dried corn flour produced at 80C was the lowest with the value of 7.39%. The higher the drying temperature, the lower the crude fiber content. This may be as a result of degradation of pectin or other fiber such as cellulose or hemicelluloses during the drying process hence leading to the reduction of the crude fiber content of dried corn flour (Sengkhamparn *et al.* 2013).

The carbohydrate content of freeze- dried corn flour was higher than other dried samples. The carbohydrate value of freeze-dried corn flour was closer to the industrial processed corn flour, which is 76.90%. For the foam mat dried corn flour, the carbohydrate content was much lower as compared to the freeze dried corn flour due to the addition of egg albumen. Carbohydrate content decreased as the protein content of the corn flour increased. The carbohydrate content in foam mat dried corn flour produced at 60, 70 and 80C were 57.27, 61.60 and 65.01%, respectively. There was no significant difference ($P > 0.05$) in carbohydrate content among the four different types of corn flour.

Color Evaluation

Color is an indicator of quality parameter evaluated by consumers and is critical in the acceptance of the food product (Leon *et al.* 2006). Based on the results shown in Table 1, the freeze dried corn flour was the brightest with L^* value closer to 100, followed by foam mat corn flour dried at 60 and 70C whereas foam mat corn flour dried at 80C was the darkest. The difference in lightness was statistically significant ($P < 0.05$) for the four samples. It was observed that as the drying temperature increased, the foam mat dried corn flour became darker, this could be attributed to non-enzymatic browning and caramelization which occurs in foods that consist mainly of sugar and protein during thermal treatment. Similar trend was reported by Karim and Wai (1999) for foam mat and freeze-dried starfruit powders; and by Jakubczyka *et al.* (2011) for apple puree powder produced from non-foamed freezed dried method.

The value of a^* for the foam mat corn flour dried at 80C (+1.50) was positive and the highest, followed by foam mat corn flour dried at 70C (+1.25) and 60C (+0.95). The a^* value of freeze dried corn flour (−1.47) was negative, showing that the color of the corn flour tends towards green. From visual inspection, it can be seen that the color of foam mat dried corn flour was slightly brown. This may be an indication of non-enzymatic browning or caramelization of the sugars.

The b^* value of all samples were positive which means all the corn flour produced were yellow in color. The b^* value of freeze dried corn flour (+ 35.40) was significantly higher ($P < 0.05$) than foam mat dried corn flour (+27.46, +24.35, and 23.31 for foam mat dried corn flour at 60, 70 and 80C, respectively), which means it was more yellowish than others. This may be due to non-thermal treatment received. The b^* value decreased as the foam mat drying temperature increased, making the intensity of yellowness to reduce with increasing temperature. However, there was significant difference ($P < 0.05$) between foam mat corn flour dried at 60C and foam mat corn flour dried at 70 and 80C.

Water Activity

Water activity determines the lowest limit of available water for microbial growth. It is an important parameter in food processing as it affects the stability of powdered and dehydrated product. The water activity (Table 1) of freeze dried corn flour and foam mat dried corn flour were inconsistent and significantly different ($P < 0.05$). The water activity for all four samples were in the range of 0.22–0.31 which is considered microbiologically stable (Fennema 1996; Abbas *et al.* 2009). However, the corn flour was observed to be hydroscopic in nature. Thus, suitable packaging material such as air-tight pouch is recommended in order to prevent moisture uptake from surroundings which can result in caking of corn flour.

Analysis of Volatile Compounds

A total of nine volatile compounds were found in freeze-dried corn flour and foam mat dried corn flour (Table 2) by gas chromatography mass spectrometry (GCMS). Identification

TABLE 2. COMPARISON OF VOLATILE COMPOUNDS BETWEEN FOAM MAT DRIED CORN FLOUR AND FREEZE DRIED CORN FLOUR

					Drying method		Relative peak area (%)	
No	Retention time	Compound	Compound nature	Odor	Foam mat dried corn flour	Freeze dried corn flour	Foam mat dried corn flour	Freeze dried corn flour
1.	31.73	n-Hexadecanoic acid	Fatty acid	Oily	+	+	16.42	11.59
2.	32.64	Hexadecanoic acid, ethyl ester	Ester	Fatty	+	+	1.69	6.50
3.	34.33	(E)−9-octadecenoic acid, ethyl ester	Ester	Unknown	-	+	-	17.01
4.	36.14	Oleic acid	Fatty acid	Fatty	+	+	73.39	2.03
5.	36.42	17-Octadecynoic acid	Fatty acid	Fatty	+	+	0.11	51.88
6.	37.98	Docosanoic acid, ethyl ester	Ester	Fatty	-	+	-	0.12
7.	41.24	9.12,15-Octadecatrienoic acid, 2-(acetyloxy)−1-[(acetyloxy) methyl]ethyl ester, (Z,Z,Z)-	Ester	nd	+	+	0.13	0.24
8.	42.32	9.12,15-Octadecatrienoic acid, 2[(trimethylsilyl) oxy]-1-[[(trimethylsilyl) oxy]methyl]ethyl ester, (Z,Z,Z)-	Ester	nd	+	-	0.08	-
9.	49.05	1-Heptatriacotanol	Alcohol	nd	-	+	-	0.18

Key = +, Present; - , Absent; nd, not determine.

was done by comparing the mass spectra and retention time of compounds with those of authentic compounds supplemented with data from MS library. The relative peak area (RPA) was used to determine the intensity of the volatiles and aroma notes. However, the RPA of volatile compounds below 0.5% could also be potential aroma impact compounds (Asikin *et al.* 2014). There were more volatile compounds present in freeze dried corn flour than foam mat dried corn flour. This can be attributed to the loss of volatiles during drying at higher temperatures. Organic acids found in both products were n-hexadecanoic acid, oleic acid, and 17-octadecynoic acid. N-hexadecanoic acid also known as palmitic acid is the most common saturated fatty acid found in animal, plants and microorganisms (Gunstone *et al.* 2012). Palmitic acid gives a faint oily aroma to the product. The relative peak area of n-hexadecanoic acid in foam mat dried corn flour was higher than freeze dried corn flour. Oleic acid was the predominant volatile compound found in foam mat dried corn flour with relative peak area of 73.39%. It gives a fatty odor to the product. These two organic acids were present in both corn flour products and are mainly contributed by the fat and oil of the germ.

Esters were the most important flavor compound in corn flour. Ethyl ester was the most prominent representative of the ester group. (E)−9-octadecenoic acid, ethyl ester, 9.12,15-Octadecatrienoic acid, 2-(acetyloxy)−1-[(acetyloxy) methyl]ethyl ester, (Z,Z,Z)-, and 9.12,15-Octadecatrienoic acid, 2[(trimethylsilyl)oxy]-1-[[(trimethylsilyl)oxy]methyl]ethyl ester, (Z,Z,Z)- are derivative compounds of octadecanoic acid and ethyl ester. 1-Heptatriacotanol was the only alcohol found in freeze dried corn flour. Hexadecanoic acid, ethyl ester and 9, 12,15-octadecatrienoic acid, 2-(acetyloxy)−1-[(acetyloxy) methyl]ethyl ester, (Z,Z,Z)-, were present in both foam-mat dried corn flour and freeze dried corn flour. However, (E)−9-octadecenoic acid, ethyl ester and docosanoic acid, ethyl ester were present only in freeze dried corn flour, whereas 9, 12, 15-Octadecatrienoic acid, 2[(trimethylsilyl)oxy]-1-[[(trimethylsilyl)oxy]methyl]ethyl ester, (Z,Z,Z)- were only found in foam mat dried corn flour.

CONCLUSIONS

The optimum level of egg albumen was found to be 20% and whipping time of 15 min for foam mat drying of corn slurry, as it exhibited the highest foam expansion percentage (88.16%) and lowest foam density (0.49). Foam mat corn flour dried at 60C had the highest amount of ash, crude protein, and carbohydrate. In terms of color, foam mat corn flour dried at 60C gave better visual color, which was brighter, less brownish, and more yellowish as compared with foam mat corn flour dried at 70 and 80C. The freeze dried corn flour contained more volatile compounds than foam mat dried corn flour. Overall, both processing methods are advantageous to food industries. However, foam mat drying method produced a more nutritious product due to the addition of egg albumen which is a good source of protein. In addition, the method is relative simple, cheap and energy saving.

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