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EFFECTS OF PRE-TREATMENT ON PHYSICOCHEMICAL PROPERTIES OF *CAPSICUM ANNUM* L. WHEN DRYING BY VACUUM TRAY DRYER AND STORAGE AT ROOM TEMPERATURE

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Graphical abstract

Abstract

Currently, the physicochemical quality of dried chillies is becoming a characteristic of consumer choice. A study was conducted to investigate the quality of physicochemical properties of dried chillies drying by vacuum tray dryer (VTD) when compared with sun drying (SD) and freeze-drying (FD). The highest capsaicin content with the lowest moisture content was achieved when drying by the VTD technique. However, the total phenolic content and antioxidant activity are highest in dried chillies drying by FD followed by VTD. Furthermore, the physiochemical properties of dried chillies that dry under VTD technique in combination with different pre-treatment techniques were investigated to study the quality of the dried red chillies during processing and storage. The fresh chillies pretreated by hot blanching(B) gave a higher capsaicin content almost 102.9% when compared with the non-treated sample. The blanched chillies samples either by B followed by soaking in citric acid solution(B+CA) showed the lowest L* indicating richness of dark red colour of dried chillies after drying by VTD. Soaking fresh chillies in citric acid solution (CA) showed an increase of a* value (redness) to 29.00 near fresh chillies' red colour. The highest retention of capsaicin content was only for 3 months of storage when chillies were soaked in CA solution and then start to deteriorate. The combination of different pretreatment techniques of fresh chillies drying by VTD is a potential drying method due to the retention of high-bioactive contents.

Keywords: *Capsicum annum* L., dried, vacuum tray dryer, pre-treatment, capsaicin, physicochemicals

Abstrak

Pada masa ini, kualiti fisiokimia cili kering menjadi ciri pilihan pengguna. Kajian untuk mengkaji kualiti pengeringan cili kering melalui kaedah pengering dulang vakum (VTD) terhadap perubahan fisiokimia cili kering dibandingkan dengan pengeringan selepas pemprosesan dibawah cahaya matahari (SD) dan pengeringan sejuk kering (FD). Kandungan capsaicin tertinggi dengan kandungan lembapan terendah dicapai apabila pengeringan dengan teknik VTD. Walau bagaimanapun, jumlah kandungan fenolik dan aktiviti antioksidan adalah tertinggi dalam pengeringan cili kering dengan FD diikuti oleh VTD. Seterusnya, ciri-

ciri fisiokimia cili kering melaui pengeringan secara VTD dan kombinasi dengan teknik prarawatan yang berbeza dikaji terhadap perubahan fisiokimia cili kering semasa proses dan penyimpanan. Cili segar yang diprarawat dengan penceluran penceluran air panas (B) memberikan kandungan capsaicin yang lebih tinggi melebihi 102.9% jika dibandingkan dengan sampel yang tidak dirawat. Sampel cili rebus sama ada secara B diikuti dengan rendaman dalam larutan asid sitrik (B+CA) menunjukkan L* terendah menunjukkan warna pekat merah tua cili kering selepas pengeringan dengan VTD. Merendam cili segar dalam larutan asid sitrik (CA) menunjukkan peningkatan nilai a* (kemerahan) kepada 29.00 hampir sama warna merah cili segar. Pengekalan tertinggi kandungan capsaicin hanya untuk 3 bulan penyimpanan apabila cili direndam dalam larutan CA dan kemudian mula merosot. Gabungan teknik prarawatan yang berbeza untuk pengeringan cili segar oleh VTD sebagai kaedah pengeringan yang berpotensi kerana pengekalan kandungan bioaktif tinggi.

Kata kunci: *Capsicum annum L.*, kering, pengering dulang vakum, prarawatan, fisiokimia

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1.0 INTRODUCTION

Chillies (*Capsicum annum* L.) one of the vegetables widely used in Asian countries commonly as spice products for flavouring and colouring in cooking [31]. Capsicum is rich in proteins, lipids, carbohydrates, fiber, mineral salts, vitamins and phytochemical compounds, such as ascorbic acid, carotenoids, flavonoids and capsaicinoids [7, 18]. The capsaicinoids have evolved in chillies peppers as a defense mechanism against mammalian predators; nevertheless, this trait is an important fruit quality attribute and one of the most important reasons chillies peppers are consumed [18]. The demand for the dried red chillies is very high all over the world. Good quality dried chillies is able to maintain the red colour, nutrients and being free from aflatoxin accumulation is necessary to sustain its influence all over the world market.

Dehydration removes moisture and stops the growth of microorganisms and is Physicochemical stable with a reduction in weight and transport costs and is very effective for handling and storage of products [22]. The most common drying method is sun drying which is often faced with fungal infection problems due to incomplete drying. Nowadays, several methods of drying have been introduced including hot air drying, oven drying and vacuum drying with a range of temperature from 45-70 °C. These methods are more hygienic and have a more uniform drying rate [9]. One of the techniques which are easy to use and consume less power than other traditional types of dryers is the vacuum drying method which uses high pressure and low temperature for drying which may also help improve the qualities of dried products such as colour, shape and nutritive values [4]. This technology is very efficient for heat-sensitive materials because drying action becomes faster as heat is easily transferred throughout the body of the dryers, due to its large surface area [4]. Furthermore, to maximize bioactive compounds in dried products the pre-treatment methods can minimize the reduction in the nutritional quality including the processing time of the dried food products [27, 30].

Blanching is the most common pre-treatment prior to drying fruits and vegetables. The right choice of temperature and time for the blanching technique should be optimized for a good quality product [2]. Blanching at a low temperature within the range of 55-75 °C can improve the texture of dried samples and protect them from physical breakdown and sloughing during processing. It also inactivates the oxidative enzyme, which prevents greater losses during the drying process [24]. At the same time, treatment with chemicals such as sodium meta bisulphite, citric acid and ascorbic acid in certain concentrations has been found to improve the quality of the dried chillies [22]. The aims of this study were to evaluate the effect of drying fresh chillies by vacuum tray dryer when compared with others drying technique and in combination with different pre-treatment techniques on the quality of physicochemical properties of dried chillies during processing and storage at room temperature.

2.0 METHODOLOGY

Preparation of Plant Materials

Fresh red chillies (*Capsicum annum* L.) of Kulai variety were purchased from a local distributor in Pagoh, Johor. The diseased and bruised chillies were removed and the remaining chillies were washed with clean water to remove the dirt on the surface that may contaminate the experiments. The chillies were then spread on a clean cloth to remove excess water.

Screening Different Types of Drying Methods on Physicochemical Properties of Dried Chillies

As mentioned in Figure 1, three different methods were choosen to investigate which types of drying technique that can preserve maximum physichemical properties of dried chillies: sun drying (SD); vacuum tray drying (VTD) and freeze-drying (FD) were applied to dry the chillies until the required moisture content of about 10-12 % [26]. Sun drying was carried out by placing fresh chillies on the trays in a single layer and then exposed to direct sunlight at the average temperatures of 32-35.5 °C which took more than 10 days. The drying efficiency of VTD and FD was tested by experimental trial within a range of suitable temperature, pressure and time. The VTD drying was conducted based on a modified technique at a temperature of 50 °C and the atmospheric pressure at 0.28 bar for 36 hours of drying [4]. For drying by FD, the chillies were placed on a tray and were processed at -20 °C for 24 hours of drying based on modified technique [23]. The dried samples were then packed and sealed in air tight packaging in the room temperature before the analysis.

Effects of Pretreatments on Physicochemical Properties of Dried Chillies When Drying in a Vacuum Tray Dryer and when Stored at Room Temperature

There are four types of pre-treatment under investigation (Figure 1) which are non-treated (C), hot water blanching (B), soaking in citric acid solution (CA) and hot water blanching followed by soaking in citric acid solution (B+CA) [24, 25]. According to a modified method, the chillies were blanched by soaking the fresh chillies in boiling water at 100 °C for three minutes (B) and then immediately cooled in ice water for three minutes [1]. Pre-treatment using citric acid was conducted by soaking the chillies in 0.5 % citric acid for 20 minutes (CA). For treatment with blanching followed by soaking in citric acid solution (B + CA), the chillies were blanched in boiling water (100 °C) for three minutes and then soaked in 0.5 % citric acid solution at room temperature for 20 minutes. All the chillies were dried in a vacuum tray dryer at a temperature of 50°C under pressure at 0.28 bar for 36 hours based on VTD efficiency [24]. All pre-treated samples were compared against the non-treated dried chillies sample which was considered the control sample. All pre-treated dried red chillies were dried in a vacuum tray dryer (VTD) and the dried chillies were stored for 6 months at room temperature.

Storage Conditions

Dried chillies were packed and sealed in polyethylene plastic (0.08 mm thickness, 10 cm x 26 cm). All samples were stored for 6 months at room temperature conditions with relative humidity of 56 %. The samples were analysed each month.

Determination of Moisture Content

All samples were analyzed for the moisture content by weighing 5 g of dried chillies sample in the drying dish and placed in the oven for 5 hours at 105 °C until they reached constant weight [25].

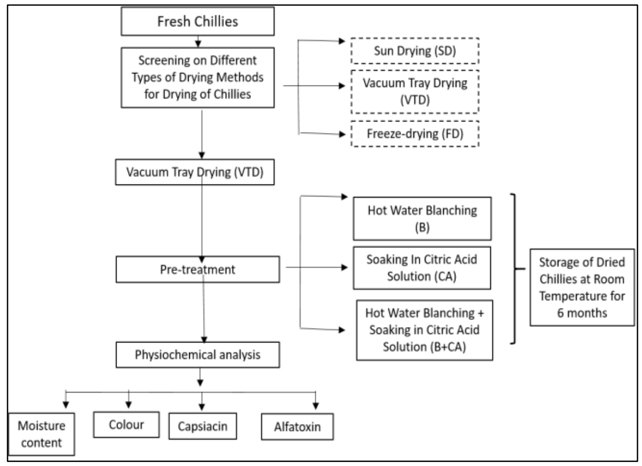

Figure 1 Design of experiments

Surface Color Measurement

The measuring of the surface colour of fresh and dried samples was carried out using the colorimeter (model PCE-CSM 1) based on three-color coordinates, i.e., L^*, a^* and b^*. The L value signifies the lightness (100 for white and 0 for black), a represents redness (-80 for green and 100 for red) while b signifies the change from blueness to yellowness (-80 for blue and 70 for yellow) [6]. Results are the average of three independent experiments performed in triplicate and color difference (ΔE) was calculated.

Extraction Procedure

Extraction of dried chillies for bioactivity analysis was conducted by weighing 10 g of dried chillies were then extracted by ethanol at the ratio of 1:10 (10:100 ml) in conical flasks. The flasks were shaken at 150 gravity (10,000 x g) to mix the samples with a solvent in an incubator for 24 h at room temperature [14]. Then, the extracts were filtered through filter paper to separate the liquid. The residue mass was then re-extracted with the same solvent to ensure complete extraction and the extract was evaporated for dryness. The crude extracts were stored at 4 °C to be used within 24 h.

Phytochemical Analysis: Capsaicin content, Total Phenolic Content and Antioxidant Activity

The capsaicin content analysis by HPLC was conditioned with gradient of acetonitrile: 0.2 % HCOOH, 0 minutes 30: 70, and 71: 29 after 10 min, flow rate 0.5 mL min^{-1}. The column used was Ascentis

Express RP-Amide 2.7 µm, 100 x 2.1 mm. The volume used for sample injection was 1µL, detected at UV wavelengths 254 nm and 280 nm at temperature of 40 °C. The calibration curve was used to determine the capsaicin content. The capsaicin content was shown as in grams of capsaicin per gram of the chillies extract. The capsaicin content in the chillies' dry weight was multiplied by the coefficient corresponding to the heat value for pure capsaicin, which is 1.6×10^7 [18].

Analysis of total phenolic content analysis (TPC) was carried out using Folin-Ciocalteu reagent assay [32]. About 30 mL of the chillies extract was introduced into 96 well ELISA plate followed by 150 mL Folin Ciocalteu reagent, which was previously diluted with distilled water (1:10) and 120 ml sodium carbonate (75 g/l). The ELISA plates were vortexed, covered with parafilm and allowed to stand for 30 min in ELISA reader at absorbance of 765 nm. TPC was expressed in gallic acid equivalents (GAE mg/100g) [10].

DPPH antioxidant analysis was conducted by using the DPPH reagent for the analysis [11]. About 8 mg DPPH was dissolved in MeOH (100 mL) for a solution concentration of 80 µl/ml. Then, 100 µL DPPH reagent was mixed with 100 µl of the chillies extract in a 96-well microplate and incubated at room temperature for 30 min to determine the scavenging activity. After incubation, the absorbance was measured at 514 nm using an ELISA plate reader and 100 % methanol was used as a control. The DPPH scavenging effect was measured using formula (1). The IC_{50} DPPH values (the concentration of sample required for inhibition of 50% of DPPH radicals) were obtained through extrapolation from regression analysis. The antioxidant activity was evaluated based on the IC_{50} value [11].

$$\left(\frac{\text{Absorbance control} - \text{Absorbance of test compound}}{\text{Absorbance control}}\right) \text{X } 100 \qquad (1)$$

Aflatoxins Test

Total aflatoxins in the samples were determined by HPLC after extraction, partitioning, and derivatisation of dried chillies [3]. A 25 g dried chillies sample was blended in a mixture of NaCl (5 g) and about 100 ml of methanol (80 %) for 2 minutes using a Waring blender then it is filtered and centrifuged at 4,000 gravity (10,000 x g) for 10 minutes. Two ml of filtrate was diluted with 20ml of 10 % Tween 20 in phosphate buffered saline (PBS). Then, the pH of the mixture was adjusted to pH 7.4. The diluted filtrate (equivalent to 0.5 g of sample) was passed through the C-18 column at a flow rate of 2 ml per minute. 20ml of phosphate buffered solution (PBS) was passed through a flow rate of approximately 5 ml per minute to wash the column. The air was passed through the column to remove residual liquid. The toxins from the column were eluted at a flow rate of 1 drop per second using 1.5 ml of 100 % methanol and collected in an amber glass vial. After that, the water with volume 1.5 ml was passed through the column and collected in the same vial to give a 3 ml total volume. Aflatoxin contents were determined by comparing peak areas with those obtained from reference solutions [3].

Statistical Analysis

All data are presented as the mean of three determinations ± standard deviation. The data were analyzed by ANOVA and Duncan's multiple-range test using SPSS statistics software (Version 21.0, SPSS IBM Corporation, USA). Statistical significance for differences was tested at a 5% probability level ($P < 0.05$) with Duncan.

3.0 RESULTS AND DISCUSSION

3.1 Screening Different Types of Drying Methods on Physicochemical Properties of Dried Chillies

The study was conducted to investigate the influence of drying methods; sun dry (SD), vacuum tray drying (VTD) and freeze-drying (FD) on dried chillies quality which is measured primarily by means of moisture content and surface colour (Table 1).While, the effect of different drying techniques on TPC, antioxidants and capsaicin is shown in Table 2.

3.1.1 Moisture Content

The moisture content of dried chillies under the optimum condition of all drying methods are in the range of 10 % to 12 % which is within the accepted range as recommended by the Thai Industrial Standards Institute (TISI 456-1983) [25]. It is important to keep the moisture content below 13% to prevent mould from growing on the dried chillies during processing and storage [25]. When the moisture content was controlled below 13 % it is strongly correlated with the stability of chemicals and bioactive compounds of dried chillies including prevention of colour loss during drying (Table 1).

3.1.2 Surface Colour Measurement

Table 1 shows the colour attributes (L*****, a*****, b*****) of dried chillies prepared by different drying techniques. The results indicated that drying techniques had a pronounced effect on L*, a* and b* values of dried chillies. Since the L* values were associated with the lightness of colour in dried chillies, the dried chillies drying with FD were significantly brighter than by the other drying techniques as indicated by higher L***** and a values of almost 31.52 and 25.61 respectively, very close to the value of fresh chillies red colour. From this study, there was a close relationship between L***** and a***** value with the darkening of the dried chillies' colour. The lower the L***** and a***** values, the darker the red colour of the dried chillies was observed when drying the chillies by VTD at about 28.40 and 16.82 respectively. The b* value showed significant differences (P <0.05) among the samples. The highest was the b* value of the sample convectively dried by FD (15.56) and the lowest was for the sample dried by VTD (7.23) as compared to the fresh chillies sample (12.64). The better evaluation index can be determined by aL index where the value of aL for fresh chillies should be more than 500 then the aL for fresh chillies in this study is greater than 1000 [6].

However, when subjected to different types of drying techniques its value decreased as shown in Table 1 where drying by VTD gave the lowest aL value. Furthermore, the total colour difference (ΔE) presented by dried chillies drying by VTD presented the highest ΔE value of 15.76 when compared with SD and FD dried samples only 8.69 and 6.25 respectively with respect to fresh red chillies. The chillies samples dried by VTD were significantly (P <0.05) darker in colour. The colour changes in the dried chillies caused by the thermal treatment which correlated with the drying time may be strongly related to pigment degradation and the formation of brown pigments via non-enzymatic (Maillard reaction) and enzymatic reaction [6, 33].

3.1.3 Capsaicin Content

The effect of drying on the capsaicin content of dried chillies are shown in Table 2. The results presented the lower capsaicin content when dried fresh chillies by using FD technique was at only 0.1277 %(w/w). The lower capsaicin content in FD dried chillies may be due to catalytic activity of the peroxidase enzyme [25]. The catalytic activity of peroxidase enzyme in dried FD samples was high after drying because at low temperature the freeze dryer may preserve the enzyme activity contributing to the deterioration of the capsaicin contents in dried chillies drying by FD [20]. However, the capsaicin content for chillies drying with VTD gave the highest capsaicin content followed by SD at about 0.36 % and 0.33 %, respectively (Table 2) and no significant differences (P<0.05) between these two drying methods.

This study has clearly proven that the inactivation of the catalytic activity by peroxidase enzyme in VTD at 50 °C occurred within 24 hours of exposure and at a low temperature (31-35.5°C) but drying for more than 10 days can contribute to decreasing of capsaicin content which is influenced by the temperature and time of drying techniques [5, 6]. Furthermore, the dehydration of the chillies under VTD and SD links to cell disruption during drying under the thermal process that greatly improves extractability of capsaicin during the extraction process for bioactivity assay.

Table 1 The moisture content and colour attributes of dried chillies drying under different drying techniques

Drying method*	Moisture content (%)	Surface colour				
		L*	a*	b*	aL	ΔE
SD	11.79±0.36[a]	29.88±3.04[a]	23.17±3.85 [a]	11.28± 3.25[b]	692.32±132.45[b]	8.69±4.32[c]
VTD	10.89±0.38[b]	28.40±2.08[a]	16.82±1.62[b]	7.23±2.39[c]	477.68±143.21[c]	15.76±6.67[a]
FD	11.73±0.46[a]	31.522±5.85[a]	25.61±3.20[a]	15.56±1.76[a]	807.43±113.33[a]	6.52±1.89[b]

Sun Drying (SD), Vacuum Tray Drying (VTD, Freeze Dried (FD). Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P<0.05) by Duncan's multiple range test. A colorimeter measurements: L (lightness), a* (redness/greenness), b* values (yellowness/blueness) of dried chilies, ΔE: Total colour change*

3.1.4 Total Phenolic Content (TPC)

As shown in Table 2, the total phenolic content (TPC) of all dried chillies was significantly different among the samples (P<0.05). The TPC of all dried chillies varied between 4.10 and 5.35 mg GAE/g DW. However, the FD sample was highest in TPC compared to other types of drying techniques. This result showed that the FD method significantly improved the TPC of dried chillies which causes poor internal heat transfer in the dry layer of a product. Furthermore, dried chillies by FD cause the cell wall to easily break down due to a formation of ice crystals contributing to an increase of cellular components to be released during extraction of bioactive compounds for bioactivity assay [14]. Like drying under high temperature or even at the average temperature of 21-35.5 ºC, drying for more than 10 days can cause instability of the compound contributing to a decrease of total phenolic content in the dried chillies [12, 17]. Therefore, drying under VTD and SD techniques gave low TPC at only 4.6 and 4.1 GAE/g DW, respectively when compared to drying by FD technique in Table 2.

Table 2 The total phenolic content (TPC), antioxidant activity and capsaicin content of dried chillies drying under different drying techniques

Drying method*	TPC	Antioxidant Activity, IC50 (mg/L)	Capsaicin (%w/w)
SD	4.1±0.14[c]	3633.33±28.87[a]	0.33±0.01[a]
VTD	4.6±0.07[b]	2983.33±104.08[b]	0.36±0.022[a]
FD	5.35±0.29[a]	1100.00±28.87[c]	0.13±0.02[b]

*Sun Drying (SD), Vacuum Tray Drying (VTD, Freeze Dried (FD). Statistical analysis showing different letter (a, b, c, d) on the same column are significantly different at P< 0.05

3.1.5 Antioxidant Activity

Table 2 also presents the analysis of the variance of antioxidant activity of all dried chillies using the DPPH technique. The antioxidant activity can be affected by high temperature, drying time, UVA-UVB including drying techniques [12]. Significant differences were verified between the treatments of different drying techniques, where the use of lower temperatures gives the highest antioxidant activity. In this study, the antioxidant activities determined by DPPH were in the range of 1100 to 3633 IC_{50} (mg/L). FD showed the highest antioxidant activity followed by VTD and SD. It was observed that dried chillies from FD presented excellent antioxidant action, while the dried chillies dried by VTD and SD showed lower antioxidant activity. The low temperature used in the FD can help to retain the heat-sensitive compound in the dried samples thus resulting in maximum antioxidant level [17].

3.2 Effects of Pre-treatment on Physicochemical Properties of Dried Chillies When Drying in a Vacuum Tray Dryer

Nowadays, the demand for mass production of nutritious and good-quality dried chillies dramatically increased. VTD is the choice of drying technology formaterials that are sensitive to heat.

3.2.1 Moisture Content

In this study, the test is of drying the chillies until moisture contents is in the range of 10-12% which is within the accepted range as recommended by the Thai Industrial Standards Institute (TISI 456-1983) in order to control loss of bioactive compounds in the dried chillies during processing [25]. Therefore, the VTD technique was used to study the effect of different pre-treatment techniques to maximize the retention of the phytochemical contents of red chillies including the quality of their colours during processing. The processing condition of VTD is the same as before which was conducted at a temperature of 50 °C and atmospheric pressure at 0.28 mbar for 36 hours of drying. Table 3 shows that the moisture content levels of the dried chillies under different pre-treated methods were between 7.475 % to 8.905 %. The moisture contents among all pre-treated methods were statistically not significantly different ($p< 0.05$) but were significantly lower than non-treated chillies.

3.2.2 Capsaicin Content

In comparison with the non-treated sample, pre-treatment samples by B and CA techniques showed higher capsaicin content and both treatments showed slight differences in value which is not significant when statistically evaluated, only 0.2012 % and 0.2258 %, respectively (Table 2). This is due to the inactivation of the peroxidase enzyme, temperature during blanching in hot water or the soaking with chemicals process [21]. However, when blanching fresh chillies followed by soaking in citric acid solution (B + CA) before drying them significantly decreased the capsaicin contents to 0.0789% after drying in VTD (Table 2). Data presented in Table 3 indicated that a combination of both pre-treatments (B + CA) simultaneously could not significantly reduce the degradation of the capsaicin content. The degradation of bioactive compounds in vegetables during aqua thermal processing could be due to the leaching of these compounds because most bioactive compounds are soluble in water [15].

Therefore, pre-treating fresh chillies with blanching and soaking in citric acid solution may soften the texture or the chillies' cell membrane, which facilitated the drying process [25]. In this study, blanching in boiling water will loosen the cell membranes of the fresh chillies and further soaking in citric acid solution may hydrolyse the hydroxyl group in capsaicin's structure contributing to the deterioration of the capsaicin contents [13].

3.2.3 Surface Colour Measurement

Table 3 shows the colour loss values of dried hillies under different pre-treatment techniques when compared with non-treated fresh chillies samples. The colour of the dried chillies was dependent on the pre-treatment techniques used in the drying of the product by VTD. Table 3 shows the average values of the coordinates L*, a*, b*, for the non-treated, B, soaking in CA and B+CA of fresh chillies. The result from the ANOVA analysis of the chromatic coordinates L*, a*, b* shows significant differences ($P< 0.05$) was obtained for all of them. Therefore, there were significant differences for the coordinates between the unpre-treated, pre-treated and fresh samples when being dried by VTD. Pre-treated fresh chillies with both blanching techniques (B and B+CA) after drying by VTD showed a relatively higher effect on L* value (21.94) with respect to non-treated sample (30.24), indicating the richness of the dark red colour of the dried chillies after drying in VTD. This is related to the formation of browning compounds caused by the decomposition process which reduces the sugar and amino acid content in fresh chillies during processing [21].

Table 3 Effect of different types of pre-treatment on the moisture content, capsaicin and colour of dried chillies when drying with VTD

Pre-treatment	Moisture (%)	Surface colour L*	a*	b*	aL	ΔE	Capsaicin (%w/w)
Non-treated (C)	10.899±0.38[b]	30.24±3.08[b]	23.29±2.74[b]	9.44±1.17[b]	710.33±148.43[b]	9.0±5.51[b]	0.0992±0.00[b]
Blanching (B)	7.515±0.09[a]	21.94±1.96[c]	9.63±3.15[c]	3.64±1.50[c]	211.56±74.49[c]	25.01±4.83[a]	0.2012±0.03[a]
Citric acid (CA)	8.905±1.25[a]	33.98±1.41[a]	29.09±3.18[a]	13.20±2.74[a]	990.54±135.88[a]	5.21±3.27[b]	0.2258±0.02[a]
Blanching + Citric acid (B + CA)	7.475±0.97[a]	23.99±2.00[c]	11.49±2.22[c]	5.14±1.47[c]	272.46±33.97[c]	23.07±4.62[a]	0.0789±0.00[b]

Statistical analysis showing different letter (a, b, c, d) on the same column are significantly different at $P< 0.05$

Furthermore, the pre-treated sample with CA showed a higher a* value of about 29.00 when compared with the non-treated sample of only 23.29 (Table 3). An increment of the a* value when treated with CA shows the capability of CA as a preserving agent and strongly accentuates the dried chillies' colour [34]. Meanwhile, pre-treated samples with both blanching techniques of B and B+CA sample causes a decrease in the redness of the dried chillies to 9.63 and 11.49, respectively when compared with un-treated sample. The same trend was observed for the b* value where pre-treated fresh chillies both with B and B+CA also caused a decrease in the b* value. Then, the aL value of chillies pre-treated with CA is higher than aL value of fresh chillies. An aL value greater than 500 shows a characteristic of red fruits colour (Table 1) and the total colour difference (ΔE) is the lowest with respect to fresh red chillies. Additionally, pre-treated fresh chillies with CA before drying in VTD had the lowest colour changes than other types of pre-treatment techniques.

3.3 Effects of Pretreatments on Physicochemical Properties of Dried Chillies by Vacuum Tray Dryer when Stored at Room Temperature

The following studies were conducted to monitor the quality of dried chillies when treated under different types of pre-treatment techniques for 6 months of storage at room temperature.

3.3.1 *Moisture Content*

It was determined that pre-treatment and storage time affected the moisture contents values which was found to slightly increase every month within the range of 11.57 to 13.51 % after 6 months of storage in Figure 2. For non-treated chillies sample (C) start showing moisture contents of more than 13.9% as shown in Figure 2 after 6 months of storage. However, the range of moisture contents after 6 months of storage for all types of the sample treated under different types of pre-treatment techniques (B, CA, B + CA) were still within the accepted range of keeping the moisture contents below 13 % to prevent mould from growing on the dried chillies [25]. In this study, only fresh chillies treated by soaking in citric acid solution (C) can maintain the moisture contents at 11.57 % after 6 months of storage at room temperature.

As shown in Figure 2, pre-treatment of fresh chillies by soaking in citric acid solution (CA) before drying is the best pre-treatment technique to preserve moisture contents below 13 % after 6 months of storage at room temperature. Therefore, all dried chillies samples dried by VTD did not exhibit any aflatoxin accumulation during storage since drying under VTD was conducted at 50 °C where the humidity is low. This can be the contributing factor to why no fungal infection was detected in all samples [16].

3.3.2 *Surface Colour Measurement*

Regarding colour variables, the pre-treatment with CA had a greater effect on the preservation of the fresh red chillies colour when compared with untreated chillies samples dried by VTD (Table 4). The values of colour parameters a* and aL were the highest when compared with untreated and other pre-treated samples. The fresh chillies treated with CA before drying by VTD's values of aL was greater than 900 which is almost the aL value of fresh chillies at 1000 which is a characteristics of red fruits. However, when compared with untreated dried chillies the aL value was only 710.33 (Table 4).

The pre-treatments with B or B+CA caused the loss of light (L*) attributed to the dark red colour in chillies and this has been associated with non-enzymatic browning [19]. The value of colour parameter a* was more affected in the pre-treatments with B and B+CA, which indicates the loss of reddish tone with a lower aL value of below 300 as compared to untreated dried chillies sample (710.33). From this study, storing all the dried samples at room temperature for 6 months shows the importance of the pre-treatment techniques on fresh chillies before drying by VTD. Pre-treatments that can restore the L*, a*, b* value and aL index of fresh chillies after drying will be able to avoid rapid colour deterioration during storage. The same trend for the loss of the red chillies colour when stored at room temperature. All samples showed a decrease of the L*, a*, b* value and aL index during the storage. Therefore, pre-treated with CA solution before drying in VTD is the best pre-treatment technique that can preserve the red chillies colour after drying. The changes of the colour variables when compared with untreated dried chillies' sample show that pre-treating with CA solution before VTD drying can prolong the restoration of the red colour after 6 months of storage since the L*, a*, b* value and aL index were highest when compared with untreated dried chillies sample (Table 4).

However, the total colour differences (ΔE) presented by pre-treatment with CA showed a higher increase each month in value which indicates a greater colour change under this pre-treatment during storage when compared with other dried chillies samples. It was observed that, the reduction value for the total colour differences (ΔE) was low when fresh chillies were pre-treated with B and B+CA and stored at room temperature when compared to samples that were pre-treated with CA (Table 4). However, the value still lower when compared to the study conducted by Campos-Hernández *et al.* [6] when treated fresh chillies were smoke-dehydrated and had a greater colour change when compared with the dried chillies that were pre-treated with CA solution before drying.

3.3.3 Capsaicin Content

The total phytochemical contents of powdered dried chillies such as capsaicinoid and the total carotenoid decreased by 75 % and 20 % respectively, after 12 months of storage at room temperature when compared with the initial value [8]. The drying by VTD of non-treated (C) dried samples could not preserve the capsaicin content from degrading after drying and during storage at room temperature. In this study, the highest capsaicin content can only be preserved in dried chillies samples when the fresh chillies were pre-treated by CA before drying in VTD.

Pre-treatment with this technique showed almost 100 % retention of capsaicin content when compared with non-treated (C) dried chillies after three months of storage. The deterioration of the capsaicin content was observed at four months of storage with a percentage of the decomposition rate of more than 30 % per day. A combination of blanching with a citric acid solution (B + CA) started showing deterioration of capsaicin content after two months of storage in Figure 2 and did not show any significant preservation of capsaicin content during storage even though blanching is known as a good technique to prevent deterioration of bioactive compounds when drying through mechanical drying techniques [29].

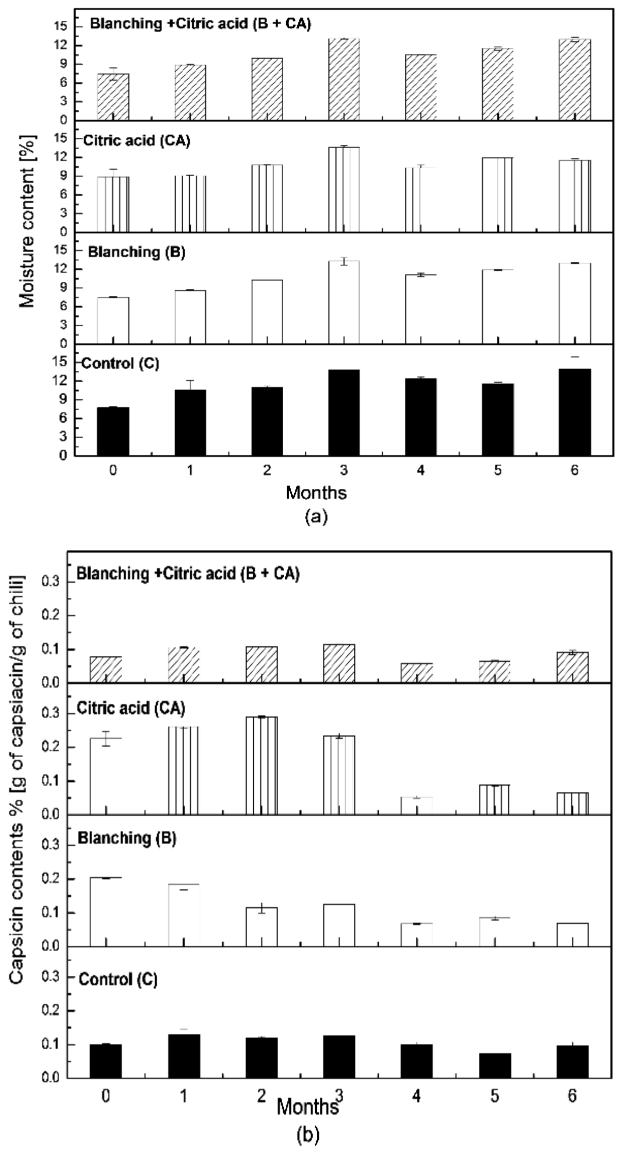

Figure 2 Effect of different types pre-treatment techniques on moisture (a) and capsaicin content (b) for six months storage at room temperature of dried chillies when drying with VTD

Table 4 Effect of different types of pre-treatment on moisture and capsaicin contents including the colour of dried chillies dried by VTD when stored at room temperature for six months

Month	Attribute	Control (C)	Blanching (B)	Citric acid (CA)	Blanching + CA (B+CA)
Fresh chili	L	34.95±0.96^{a}	35.61±1.05^{a}	34.69±1.89^{a}	34.72±2.54^{a}
	a	30.1±1.69^{a}	28.51±1.85^{a}	30.48±2.26^{a}	29.97±2.22^{a}
	b	12.64±0.83^{a}	12.40±0.86^{a}	13.10±0.98^{a}	13.50±1.46^{a}
	aL	1052.7±80.36^{a}	1016.4±95.41^{a}	1058.3±106.45^{a}	1043.9±139.34^{a}
0	L	30.24±3.08^{b}	21.94±1.96^{c}	33.98±1.41^{a}	23.99±2.00^{c}
	a	23.29±2.74^{b}	9.63±3.15^{c}	29.09±3.18^{a}	11.49±2.22^{c}
	b	9.44±1.17^{b}	3.64±1.50^{c}	13.20±2.74^{a}	5.14±1.47^{c}
	aL	710.33±148.43^{b}	211.56±74.49^{c}	990.54±135.88^{a}	272.46±33.97^{c}
	ΔE	9.0±5.51^{b}	25.01±4.83^{a}	5.21±3.27^{b}	23.07±4.62^{a}
1	L	31.61±1.16^{a}	24.95±1.32^{b}	31.07±1.00^{a}	23.01±1.70^{c}
	a	23.89±1.59^{a}	11.36±2.98^{b}	27.41±3.82^{a}	9.9±1.99^{b}
	b	9.65±1.54^{b}	4.54±1.59^{c}	12.38±2.51^{a}	3.82±0.97^{c}
	aL	754.65±47.36^{a}	200.85±85.54^{b}	851.71±126.50^{a}	231.70±62.41^{b}
	ΔE	4.33±2.49^{a}	4.86±3.76^{a}	6.47±3.86^{a}	3.94±1.89^{a}
2	L	28.51±0.88^{a}	24.74 ± 1.81^{b}	29.50 ± 1.89^{a}	21.21 ± 3.79^{c}
	a	17.89 ± 3.88^{a}	6.548±2.30^{b}	21.59 ± 3.18^{a}	10.24 ± 4.47^{b}
	b	6.69 ± 2.21^{ab}	2.10± 0.58^{c}	9.08± 2.07^{a}	4.66± 2.37^{bc}
	aL	510.11± 111.25^{a}	164.76 ± 66.16^{b}	637.58± 110.85^{a}	218.26± 117.53^{b}
	ΔE	7.66 ± 5.36^{a}	5.36± 3.21^{a}	10.14±5.39^{a}	6.22± 1.77^{a}
3	L	27.69±1.55^{a}	25.06±2.32^{a}	28.78±2.18^{a}	20.59±3.00^{b}
	a	17.63±4.05^{ab}	8.89±4.89^{c}	20.56±2.62^{a}	12.22±4.18^{bc}
	b	6.86±2.08^{ab}	3.48±1.97^{b}	9.33±1.98^{a}	5.58±2.03^{b}
	aL	491.24±126.77^{a}	211.93±147.93^{b}	592.61±98.27^{a}	256.48±105.16^{b}
	ΔE	7.64±6.40^{a}	5.53±2.81^{a}	11.35±4.20^{a}	5.66±4.13^{a}
4	L	27.13±2.40^{a}	27.41±1.56^{a}	24.94±2.84^{a}	24.57±1.33^{a}
	a	14.53±4.96^{a}	13.54±3.71^{ab}	16.53±1.20^{a}	8.89±4.01^{b}
	b	5.02±2.62^{ab}	4.45±1.72^{ab}	6.79±0.37^{a}	2.97±2.11^{b}
	aL	400.02±159.00^{a}	374.62±119.56^{a}	414.13±73.81^{a}	215.90±88.91^{b}
	ΔE	10.51±6.83^{b}	6.94±3.18^{b}	16.88±5.28^{a}	6.04±1.76^{b}
6	L	28.26 ± 0.54^{b}	27.58±1.21^{b}	31.44±1.73^{a}	26.65±1.34^{b}
	a	13.69±3.45^{ab}	9.53±5.44^{b}	18.45±3.72^{a}	10.17± 2.66^{b}
	b	4.78±1.53^{b}	3.20+±2.09^{b}	7.59±1.86^{a}	3.71±1.22^{b}
	aL	386.0±92.05^{b}	267.80±163.67^{b}	580.20±123.67^{a}	272.00±78.53^{b}
	ΔE	11.28±4.82^{a}	8.57±3.49^{ab}	12.44±5.82^{a}	4.761±1.46^{b}

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other ($P<0.05$) by Duncan's multiple range test. A colorimeter measurements: L (lightness), a* (redness/greenness), b* values (yellowness/blueness) of dried chilies, ΔE: Total colour change*

Pre-treatment with this technique showed almost 100 % retention of capsaicin content when compared with non-treated (C) dried chillies after three months of storage. The deterioration of the capsaicin content was observed at four months of storage with a percentage of the decomposition rate of more than 30 % per day. A combination of blanching with a citric acid solution (B + CA) started showing deterioration of capsaicin content after two months of storage in Figure 2 and did not show any significant preservation of capsaicin content during storage even though blanching is known as a good technique to prevent deterioration of bioactive compounds when drying through mechanical drying techniques [29].

4.0 CONCLUSIONS

In this study, the fresh chillies that are dried with a vacuum tray dryer give a lot of advantages over other drying methods. The combination of VTD drying and soaking fresh chillies with 0.5 % citric acid as a pre-treatment technique can preserve the capsaicin content during drying. The moisture content of dried chillies is still at the accepted level when compared to non-treated dried chillies samples after six months of storage. Besides that, soaking with citric acid also can maximise the red chillies' during processing and ensures free from the accumulation of aflatoxin. It was clearly demonstrated by the drying of red chillies using VTD that it is also a potential technique for drying other vegetables and fruits.

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