INTRODUCTION

Dried chili and chili powder are spices used as flavorings or condiments and are prepared from ripe chili (Capsicum spp.). The most important quality characteristics in chili are the color and pungency. The red color of chili is mainly due to carotenoid pigments (Howard et al., 2000; Topuz and Ozdemir, 2007) and its pungency results from the capsaicinoids synthesized and accumulated in the epidermal tissue of the chili placenta (Iwai et al., 1979; Suzuki et al., 1980). Some steps used in the processing of dried fruit and vegetables include blanching and drying during preparation; drying especially causes a major loss of color and texture quality of the final product (Vega-Gálvez et al., 2008). To improve the quality of dried chili, industrial dryers are used to decrease the drying time and provide uniform and hygienic processing conditions. However, drying chili with...
high temperatures leads to the loss of volatile compounds, nutrients and color (Kaleemullah and Kailappan, 2006; Di Scala and Crapiste, 2008). In general, browning in dehydrated vegetable products is a major problem found in the food industry resulting from both enzymatic and non-enzymatic oxidation of phenolic compounds as well as from the Maillard reaction (Lyengar and McEvily, 1992). The browning reactions can be prevented by pretreatment methods, such as blanching and chemical treatment (Sigge et al., 2001).

Sulfites are widely used to prevent oxidation and bacterial growth leading to the improvement of food appearance and flavor during preparation, storage and distribution, by stabilizing the product color and inhibiting discoloration (Ruiz-Capillas and Jiménez-Colmenero, 2009). Sulfiting agents such as sulfur dioxide (SO2), sodium and potassium metabisulfite (Na2S2O5, K2S2O5), sodium or potassium bisulphate (NaHSO3, KHSO3) and sodium sulfite (Na2SO3) are widely used in food products and act as antimicrobial agents, antioxidants and inhibitors of enzymatic and non-enzymatic browning. In fruits and vegetables, a sulfiting agent is used to prevent the Maillard reaction or browning in the product and to protect the dehydrated food from browning during storage. The effect of the sulfiting agent is to delay the onset of browning but if the browning reaction begins, it continues at the same rate in both sulfited and unsulfited systems (Wedzicha, 2001).

The content of a sulfiting agent recovered from a food to which it was added is less than 100% and decreases with time due to chemical reactivity in the food (Wedzicha et al., 1984). Na2S2O5 acting as an antioxidant yielded good quality of rehydrated pepper in terms of firmness and color (Vega-Gálvez et al., 2008). In addition, K2S2O5 (0.2%) was also used to retard browning in dehydrated tomato slices (Davoodi et al., 2007). Apricots pretreated with 6% K2S2O5 by soaking for 60 min prior to drying can improve and maintain the quality of dried product stored at ambient storage up to 12 mth (Mir et al., 2009).

In the case of dried chili, considerable changes in the color may lead to a decrease in its quality and marketing value because its surface color is an important criterion in a consumer’s decision to purchase. In addition, further grinding to obtain chili powder and for storage affect the quality and color of the products and thus play an important role in product development. However, the amount of sulfiting agents used is limited due to the health concerns associated with the residues remaining in the food (Sapers, 1993) and little information is available about appropriate pretreatments to produce dried chili and chili powder. Therefore, the objectives of this study were to investigate the effect of Na2S2O5 concentration and soaking time on the quality and color parameters of dried chili and chili powder. The residual amount of SO2 in dried chili after soaking in Na2S2O5 for certain periods was also evaluated. In addition, the quality of the chili powder was determined to gain information on the residual SO2 in the final chili product and changes during storage.

MATERIALS AND METHODS

Materials

Sound, red pods of fresh chili (Capsicum annuum L.) of the Jinda cultivar obtained from a wholesale market in Pathumthani province during March–June 2011 were selected, kept at 10 ± 2°C and used within 1 w. Sodium hydroxymethylsulfonate (HMS; 95% purity; Cat. No. 11270-4; Sigma–Aldrich; Steinheim, Germany) was used for the recovery assay. High vacuum grease was purchased from Dow Corning (Midland, MI, USA). All other reagents used were of analytical grade.
Dried chili preparation: soaking, drying and storage

The sound, red pods of fresh chili were washed, drained and soaked in Na$_2$S$_2$O$_5$ solutions (200, 1,000 and 2,000 mg.kg$^{-1}$) using a ratio of chili to Na$_2$S$_2$O$_5$ solution of 1:3 for different soaking times (30, 60 and 120 min) at room temperature (T = 30 ± 2°C).

After soaking in a Na$_2$S$_2$O$_5$ solution, each red chili pod sample was blanched at 100 °C for 3 min using a ratio of chili and water of 1:10 (w/w) and dried in a conventional tray dryer at 65 °C for 12 h to obtain dried chili with a final moisture content of approximately 8% on a wet basis (wb). The drying trays were rotated from time to time to facilitate uniform drying. The dried product was kept for further analysis. Untreated red chili as a control sample was only washed to remove dust, soaked in water without Na$_2$S$_2$O$_5$ solution and blanched. The soaked, blanched and dried chili samples each with a specific soaking time in a specific Na$_2$S$_2$O$_5$ concentration were sampled for SO$_2$ determination. The quality of the dried chili was analyzed for SO$_2$ determination, moisture content, water activity and CIELab color parameters.

Chili powder was obtained by grinding dried chili kept for 1 d at 5 °C. Each sample was ground at room temperature with a blender (Model LX-10A; Republic of China) for 20 s to obtain a homogeneous powder. Samples of 50 g of chili powder were packed in polypropylene (PP) bags of 0.04 mm thickness and a water vapor transmission rate of 6.41 g.m$^{-2}$ over 24 h at 38 °C and 90% relative humidity (RH). The packed chili powder samples each with a specific soaking time in a specific Na$_2$S$_2$O$_5$ concentration were stored in a controlled temperature and relative humidity chamber at 40 °C and 80% RH for 1 mth to enhance deterioration in the product. Chili powder samples kept at 5°C were used as reference material for the original quality of the product. The quality of the fresh chili powder and stored samples was examined for sulfur dioxide determination, moisture content, water activity and CIELab color parameters.

Quality determination of dried chili and chili powder

Sulfur dioxide (SO$_2$) determination: The SO$_2$ contents of the chili after soaking, blanching and drying and for the chili powder were determined according to the optimized Monier-Williams method 990.28 (AOAC, 2000) based on an acid distillation followed by vapor phase transfer of the SO$_2$ facilitated by a carrier gas stream to an oxidizing trapping solution. Soaked and blanched chili samples were cooled immediately and kept at -18 °C whereas dried chili and chili powder samples were kept at 5 °C before analysis. The chili samples (approximately 50 g fresh form or 25 g dried or powder forms) were used and ground under cool or frozen states with 100 mL of 5% ethanol (5°C) using a blender.

A three-necked, round-bottomed flask of Monier-Williams apparatus was set up (Figure 1) before starting the measurement by placing the flask in a heating mantle containing 200 mL deionized water, adding 90 mL of 4 N HCl to a separatory funnel at one neck, and then connecting a condenser with a cold water circulator (T < 15 °C) at the second neck. The gas inlet tube for flushing nitrogen into the three-necked, round-bottomed flask was inserted in the middle of three tapered joints. About 5–6 drops of 0.01 N NaOH was added into a collecting vessel containing 30 mL of 3% hydrogen peroxide (H$_2$O$_2$) and 1–2 drops of 0.25% methyl red indicator to adjust the color to yellow (end point). The collecting vessel was placed at the bubbler (the final part of the apparatus connecting with the condenser to collect SO$_2$). Then, the system was purged with N$_2$ gas for 15 min throughout the measurement after initiating flow of the condenser coolant to ensure the system was thoroughly deoxygenated and leak free. The separatory funnel was then removed to introduce ground chili samples into the round-bottomed flask (reaction flask). The
other 200 mL of deionized water was used to rinse the remainder of the sample before returning the separatory funnel to the flask. The HCl solution in the funnel was drained into the sample flask. Then, the mixture was heated and boiled for 1.75 h to convert any sulfite into SO₂ and to ensure a complete discharge of SO₂ from the sample. A stream of N₂ gas was introduced below the surface of the refluxing solution to sweep SO₂ through the water-cooled condenser. The SO₂ was oxidized to H₂SO₄ in the collecting vessel containing H₂O₂ and then the color of the solution turned pink.

The solution was then transferred to a 125 mL Erlenmeyer flask and titrated immediately with 0.01 N NaOH until a yellow color (end point) persisted for at least 20 s. The SO₂ content was calculated using Equation 1. A blank without a sample was performed before recovery assay using fortification of 10 mg.kg⁻¹ HMS. The accuracy of analytical data before the sample measurement was tested by ensuring HMS recoveries of at least 80% from the sample (AOAC, 2000).

\[ \text{SO}_2 \text{ (mg SO}_2\text{.kg}^{-1}, \text{db}) = (32.03)(V_{\text{Corr}})(N)(1000)/W_{\text{Sample}} \]

where 32.03 = Milliequivalent weight of SO₂; N = Normality of NaOH titrant; V_{\text{Corr}} = volume (mL) of NaOH required to reach end point minus the NaOH volume used in the blank titration; 1000 = Factor to convert milliequivalents to microequivalents; and W_{\text{Sample}} = sample weight, in grams on a dry basis (db).

**Moisture content:** Soaked or blanched chili (5 g), dried chili and chili powder (3 g) were weighed into aluminum cans for moisture content determination (adapted from AOAC, 2000) in a hot air oven (WTB Binder; Tuttlingen, Germany) at 105 °C for 6 h or until constant weight was obtained.

**Water activity:** Dried chili samples cut into smaller pieces and chili powder samples were measured at 25 °C using a water activity instrument (AquaLab Series 3; Pullman WA, USA). After equilibration, the \( a_w \) value was recorded. The measurements were taken in triplicate and results were averaged.

**CIELab color parameters:** The tridimensional \( L^*a^*b^* \) color space (also known as CIE \( L^*a^*b^* \)) is used to quantify the visual differences or distinguish the colors from one another (CIE, 1986). The \( L^*a^*b^* \) space consists of a luminosity layer \( L^* \) (varying from 0 = black to 100 = white) indicating the brightness value of color, chromaticity-layer \( a^* \) indicating color falling along the red (+) to green (-) axis, and chromaticity-layer \( b^* \) indicating the color falling along the blue (-) to yellow (+) axis. All of the color information is in the \( 'a^*' \) and \( 'b^*' \) layers. Surface colors of whole pods from both fresh and dried chili were measured as reflected color in the CIE \( L^*a^*b^* \) using a spectrophotometer (Minolta CM-3500d; Osaka, Japan) with standard illuminant D₆₅, CIE 10° standard observer and measuring area for reflectance of the dried chili surface or Petri dish containing chili powder using 3 and 30 mm aperture masks, respectively. The calibration of the instrument was performed by using a zero calibration box (black cylinder) followed by a white calibration plate. Then, the surface color of 15 pods (Vega-Gálvez et al., 2008) was measured. In the case of chili powder, about 10 g of each sample was transferred into a Petri dish (outside diameter 45 mm) and measurement was performed at five different positions. The sample surface of the dried chili or the Petri dish containing the chili powder was placed on the target mask with the sample area covering the aperture. Measurements were performed in triplicate for each treatment. The \( L^* \), \( a^* \) and \( b^* \) values were recorded as the mean of triplicate measurements from five different spot positions of the Petri dish. The total color difference (\( \Delta E^* \)) for both the dried chili and chili powder samples were calculated using Equation 2 (Sigge et al., 2001):

\[ \Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \]

where \( L_0^*, a_0^* \) and \( b_0^* \) were the control values.
Hue angle (h) and chroma (C*) were also calculated (Equations 3 and 4):

\[ h = \tan^{-1} \left( \frac{b^*}{a^*} \right) \]  

\[ C^* = \sqrt{a^{*2} + b^{*2}} \]

Statistical analysis

All measurements were performed using three replications. The results were reported as the mean value ± standard deviation. The data were subjected to analysis of variance using the SPSS V.12 statistical software package (SPSS (Thailand) Co., Ltd., Bangkok). Duncan’s multiple range test was also applied to determine significant differences at the 5% level of significance (\( P < 0.05 \)) between the treatment parameters associated with the properties of the chili and chili powder.

RESULTS AND DISCUSSION

Effect of metabisulfite treatment on dried chili quality

Fresh chili treated with soaking in Na\(_2\)S\(_2\)O\(_5\) solutions (200, 1,000 and 2,000 mg. kg\(^{-1}\)) for different soaking times (30, 60 and 120 min) at room temperature (T = 30 ± 2 °C) was sampled for SO\(_2\) determination as shown in Figure 1. The SO\(_2\) contents in soaked chili increased significantly with the soaking time and Na\(_2\)S\(_2\)O\(_5\) concentration (Figure 1A). After blanching in hot water (100 °C) for 3 min, notable losses were found in the chili obtained from soaking in high Na\(_2\)S\(_2\)O\(_5\) concentrations (1,000 and 2,000 mg.kg\(^{-1}\)) as shown in Figure 1B. For example, the SO\(_2\) content of chili soaking in the 2,000 mg.kg\(^{-1}\) Na\(_2\)S\(_2\)O\(_5\) solution for 120 min (45.5 mg.kg\(^{-1}\) SO\(_2\)) was reduced to 17.3 mg.kg\(^{-1}\) after blanching (about 62% reduction) whereas chili soaking in 200 mg.kg\(^{-1}\) Na\(_2\)S\(_2\)O\(_5\) solution reduced only 22% (from 19.6 to 15.2 mg.kg\(^{-1}\)). Since the optimized Monier-Williams method for determining SO\(_2\) in this study measures free sulfite and reproducible portion of bound sulfites according to the AOAC (2000), the notable loss indicates the loss of free SO\(_2\) content due to the thermal treatment from blanching.

After blanching, the chili was dried using a hot air oven at 65 °C for 12 h. The SO\(_2\) retention levels in all treated chili samples were lower than those of the blanched samples as shown in Figure 1C, indicating that further thermal treatment in processing reduced the SO\(_2\) content in the product. The residual SO\(_2\) content in dried chili increased with increasing Na\(_2\)S\(_2\)O\(_5\) concentration and soaking time, especially in the samples soaking in 1,000 and 2,000 mg.kg\(^{-1}\) Na\(_2\)S\(_2\)O\(_5\) solutions for at least 60 min (10.4–3.1 mg.kg\(^{-1}\) SO\(_2\)). Most of the residual SO\(_2\) in the blanched chili was expected to be in bound form due to the loss after drying being less than 30%. The results from Figure 1 suggest that the amount of SO\(_2\) retained in the chili depends on the processing steps and the concentration of the added sulfite. However, the residual SO\(_2\) contents in all the dried chili samples pretreated by soaking with 200–2,000 mg.kg\(^{-1}\) Na\(_2\)S\(_2\)O\(_5\) were lower than the limit residual level (150 mg.kg\(^{-1}\) in herbs and spices) according to the Codex Committee on Food Additives and Contaminants (Codex Alimentarius Commission, 2009).

The SO\(_2\) contents of fresh chili without soaking in sulfite solutions and after blanching and drying were also determined and revealed values of approximately 2.5 to 2.9 mg.kg\(^{-1}\) SO\(_2\). These results were consistent with Taylor et al. (1986) who reported 1–3 mg.kg\(^{-1}\) SO\(_2\) were found in many foods. Although the total SO\(_2\) content determined according to the optimized Monier-Williams method for the analysis of sulfites in foods is reported to be applicable for determining SO\(_2\) levels of 10 mg.kg\(^{-1}\) or higher, all SO\(_2\) values were presented to show the influence of metabisulfite concentration and soaking time.

The quality of dried chili from various treatments of soaking time and Na\(_2\)S\(_2\)O\(_5\) concentration was determined. The water activity is an important factor affecting product stability. In the case of dried chili and chili products, an increase in the water activity enhanced the non-
enzymatic browning reaction during storage. The moisture contents of all the samples were approximately 7.3–8% (wb) ($P > 0.05$) with and without Na$_2$S$_2$O$_5$ soaking. Water activity values were about 0.31–0.34 and 0.31 for the chili with and without Na$_2$S$_2$O$_5$ soaking, respectively (Table 1).

Browning is a major factor contributing to quality loss in foods. The change in color is important for determining dried product quality. Sulfiting agents are widely used to control browning as they inhibit enzymatic browning by acting as PPO inhibitors and reacting with the intermediates in the Maillard reaction leading to

**Figure 1** SO$_2$ contents in chili after (A) soaking; (B) blanching; and (C) drying prepared by soaking in 200 (o), 1,000 (∆) and 2,000 (□) mg kg$^{-1}$ Na$_2$S$_2$O$_5$ for 30, 60 and 120 min. (db = Dry basis.) (D) Apparatus for optimized Monier-Williams method for SO$_2$ determination.
pigment formation prevention (Sayavedra-Soto and Montgomery, 1986). In the case of non-enzymatic browning, sulfites react with carbonyl intermediates and then block pigment formation (Wedzicha, 1987; Wedzicha, 2001).

The $L^*$, $a^*$ and $b^*$ values of dried chili significantly increased with increasing $\text{Na}_2\text{S}_2\text{O}_5$ concentration (Table 1). For each sulfite concentration soaking, the $L^*$ exhibited no significant difference among different soaking times (30 to 120 min). The saturation index or chroma ($C^*$) and the hue angle ($h$) provide more information about the spatial distribution of colors than direct values (Sigge et al., 2001). Hue values determined from $\tan^{-1}(b^*/a^*)$ exhibited no significant difference among dried chili samples obtained from different soaking times and $\text{Na}_2\text{S}_2\text{O}_5$ concentrations. The $h$ values of all dried chili were about 27.2–28.6° and close to that of fresh chili (27.2°). The $C^*$ values increased significantly with increasing $\text{Na}_2\text{S}_2\text{O}_5$ concentration (Table 1). The dried chili obtained from soaking in 2,000 mg.kg$^{-1}$ $\text{Na}_2\text{S}_2\text{O}_5$ concentration for all soaking times (30 to 120 min) exhibited values of 23.9 to 26.1 which were not significantly different. As expected, dried chili without sulfite soaking exhibited the lowest value of $L^*$ (Table 1).

The total color difference ($\Delta E^*$) of all dried chili samples with and without sulfite treatment was calculated using Equation 2. The $L_o^*$, $a_o^*$ and $b_o^*$ values of fresh chili were used as the reference. A larger value of $\Delta E^*$ indicates greater color change from the reference material. Figure 2 reveals the color change of dried chili from fresh chili was highly influenced by the $\text{Na}_2\text{S}_2\text{O}_5$ concentration and soaking time. The $\Delta E^*$ values decreased with increasing $\text{Na}_2\text{S}_2\text{O}_5$ concentrations and soaking time (Figure 2). Without soaking, dried chili exhibited the largest $\Delta E^*$. The soaking treatment with 200 mg.kg$^{-1}$ $\text{Na}_2\text{S}_2\text{O}_5$ concentration for 30 to 120 min exhibited a larger degree of color change in dried chili than those with soaking in higher sulfite concentrations (1,000 and 2,000 mg.kg$^{-1}$). The change in color of dried chili from soaking in 2,000 mg.kg$^{-1}$ $\text{Na}_2\text{S}_2\text{O}_5$ exhibited no significant difference with soaking time. The results suggest that $\text{Na}_2\text{S}_2\text{O}_5$ acted as an anti-browning agent in the chili throughout the processing steps with the SO2 retention in the final dried chili of all treatments being less than 15 mg.kg$^{-1}$ SO2.

**Table 1** Color parameters and water activity of dried chili obtained from soaking in 200, 1,000 and 2,000 mg.kg$^{-1}$ $\text{Na}_2\text{S}_2\text{O}_5$ for 30, 60 and 120 min.

<table>
<thead>
<tr>
<th>$\text{Na}_2\text{S}_2\text{O}_5$ (mg.kg$^{-1}$)</th>
<th>Soaking time (min)</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
<th>$C^*$</th>
<th>$a_w$ (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>22.1 ± 0.0$^c$</td>
<td>18.4 ± 0.8$^d$</td>
<td>9.7 ± 0.1$^b$</td>
<td>20.9 ± 0.7$^d$</td>
<td>0.307 ± 0.002$^d$</td>
</tr>
<tr>
<td>200</td>
<td>30</td>
<td>25.7 ± 1.2$^b$</td>
<td>18.9 ± 1.2$^d$</td>
<td>9.8 ± 1.1$^b$</td>
<td>21.3 ± 1.6$^{cd}$</td>
<td>0.312 ± 0.001$^f$</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>25.7 ± 0.7$^b$</td>
<td>19.2 ± 0.6$^{cd}$</td>
<td>10.0 ± 0.1$^b$</td>
<td>21.7 ± 0.5$^{bcd}$</td>
<td>0.318 ± 0.001$^e$</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>26.7 ± 0.6$^b$</td>
<td>19.4 ± 1.5$^{bcd}$</td>
<td>10.0 ± 0.7$^b$</td>
<td>21.8 ± 1.7$^{bcd}$</td>
<td>0.323 ± 0.001$^d$</td>
</tr>
<tr>
<td>1,000</td>
<td>30</td>
<td>26.9 ± 0.2$^{ab}$</td>
<td>18.8 ± 0.4$^d$</td>
<td>10.0 ± 0.6$^b$</td>
<td>21.3 ± 0.6$^{cd}$</td>
<td>0.336 ± 0.001$^a$</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>26.4 ± 0.3$^{ab}$</td>
<td>21.4 ± 0.6$^{ab}$</td>
<td>11.1 ± 0.4$^{ab}$</td>
<td>24.2 ± 0.7$^{ab}$</td>
<td>0.335 ± 0.001$^{ab}$</td>
</tr>
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<td>120</td>
<td>27.5 ± 1.5$^{ab}$</td>
<td>22.3 ± 0.8$^a$</td>
<td>11.9 ± 0.6$^{a}$</td>
<td>25.3 ± 1.0$^a$</td>
<td>0.334 ± 0.006$^{ab}$</td>
</tr>
<tr>
<td>2,000</td>
<td>30</td>
<td>27.3 ± 0.0$^{ab}$</td>
<td>21.1 ± 1.1$^{abc}$</td>
<td>11.2 ± 1.6$^{ab}$</td>
<td>23.9 ± 1.7$^{abc}$</td>
<td>0.329 ± 0.002$^{c}$</td>
</tr>
<tr>
<td></td>
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<td>21.9 ± 0.2$^a$</td>
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<td></td>
<td>120</td>
<td>28.7 ± 0.8$^a$</td>
<td>22.8 ± 1.1$^a$</td>
<td>12.5 ± 0.8$^{a}$</td>
<td>26.1 ± 1.4$^a$</td>
<td>0.332 ± 0.001$^{abc}$</td>
</tr>
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</table>

* = Mean ± standard deviation (n = 3).

Means in the same column with different lower-case letters are significantly different ($P < 0.05$).
Effect of metabisulfite treatment on quality and storage of chili powder

The dried chili obtained from soaking in different Na$_2$S$_2$O$_5$ concentrations and soaking times was ground to obtain chili powder. The quality of fresh, prepared chili powder (0 d storage) was determined as shown in Table 2. The moisture content and water activity of all chili powder samples were about 7.2–7.5% (wb) and 0.32–0.34, respectively. The SO$_2$ retention in chili powder decreased about 3–5% compared with that in dried chili from each treatment due to the thermal loss in the grinding process. The color parameters ($L^*$, $a^*$ and $b^*$) of chili powder were measured and revealed higher values compared with those of dried chili.

After storing each sample at 40 °C in a PP bag for 30 d, values for the moisture content and water activity of all stored chili powder samples increased slightly but significantly to be about 9.2–9.4% (wb) and 0.45–0.50, respectively (Table 2) as was expected from the high temperature of storage and the permeability of water vapor through the PP bag. The difference in these values was expected from the behavior of the sorption isotherm of the dried chili as a sigmoid curve (data not shown). The SO$_2$ contents in all samples also decreased to be lower than 10 mg.kg$^{-1}$ SO$_2$ after storage (Table 2). The $\Delta E^*$ was calculated using the $L_o^*$, $a_o^*$ and $b_o^*$ values of fresh prepared chili powder (0 d) from each treatment as the reference. The $\Delta E^*$ decreased with increasing Na$_2$S$_2$O$_5$ concentrations and soaking time (Figure 3) whereas that of untreated samples exhibited the highest value. The soaking treatment with 200 mg.kg$^{-1}$ Na$_2$S$_2$O$_5$ concentration for 30 to 120 min exhibited a larger degree of color change in the chili powder than in samples soaking in the higher sulfite concentrations (1,000 and

Figure 2  Total color difference ($\Delta E^*$) values of dried chili based on color of fresh chili (reference) as a function of soaking time without (soaking time = 0 min) and with Na$_2$S$_2$O$_5$ solution at 200 (o), 1,000 (Δ) and 2,000 (□) mg.kg$^{-1}$. Vertical lines show the range in standard error.

Figure 3  Total color difference ($\Delta E^*$) values of stored chili powder based on color of fresh, prepared chili powder (reference) as a function of soaking time without (soaking time = 0 min) and with Na$_2$S$_2$O$_5$ solution at 200 (o), 1,000 (Δ) and 2,000 (□) mg.kg$^{-1}$ in a controlled temperature chamber at 40 °C 80%RH for 30 d. Vertical lines show the range in standard error.
Table 2 Moisture content, water activity and SO₂ content of chili powders before and after storing at 40 °C, 80% RH for 30 d.

<table>
<thead>
<tr>
<th>Na₂S₂O₅ (mg.kg⁻¹)</th>
<th>Soaking time (min)</th>
<th>MC (% wet basis) 0 d</th>
<th>MC (% wet basis) 30 d</th>
<th>a_w (-) 0 d</th>
<th>a_w (-) 30 d</th>
<th>SO₂ (mg.kg⁻¹ dry basis) 0 d</th>
<th>SO₂ (mg.kg⁻¹ dry basis) 30 d</th>
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<tr>
<td>0</td>
<td>0</td>
<td>7.23 ± 0.01eA</td>
<td>9.26 ± 0.03cdB</td>
<td>0.316 ± 0.003bA</td>
<td>0.454 ± 0.011debB</td>
<td>2.91 ± 0.46B</td>
<td>2.98 ± 0.47B</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>7.20 ± 0.00eA</td>
<td>9.23 ± 0.03dB</td>
<td>0.322 ± 0.001abA</td>
<td>0.451 ± 0.005cB</td>
<td>7.44 ± 0.46B</td>
<td>5.62 ± 0.47eA</td>
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<tr>
<td>200</td>
<td>60</td>
<td>7.35 ± 0.04cdA</td>
<td>9.23 ± 0.04dB</td>
<td>0.326 ± 0.001abA</td>
<td>0.461 ± 0.002cdeB</td>
<td>7.77 ± 0.00deB</td>
<td>6.28 ± 0.47deA</td>
</tr>
<tr>
<td>1,000</td>
<td>120</td>
<td>7.28 ± 0.09dkaA</td>
<td>9.29 ± 0.04bcdB</td>
<td>0.327 ± 0.001abA</td>
<td>0.468 ± 0.008bcdeB</td>
<td>8.09 ± 0.45deB</td>
<td>6.62 ± 0.00cdeA</td>
</tr>
<tr>
<td>2,000</td>
<td>30</td>
<td>7.28 ± 0.03dkaA</td>
<td>9.30 ± 0.06bcdB</td>
<td>0.330 ± 0.002abA</td>
<td>0.450 ± 0.009cdeB</td>
<td>8.74 ± 0.45dbB</td>
<td>5.62 ± 0.46eA</td>
</tr>
<tr>
<td>1,000</td>
<td>60</td>
<td>7.37 ± 0.02bcA</td>
<td>9.35 ± 0.01abcB</td>
<td>0.332 ± 0.001abA</td>
<td>0.462 ± 0.015cdeB</td>
<td>10.04 ± 0.46cB</td>
<td>6.95 ± 0.47bcdeA</td>
</tr>
<tr>
<td>2,000</td>
<td>120</td>
<td>7.52 ± 0.08abA</td>
<td>9.38 ± 0.04abB</td>
<td>0.336 ± 0.003aA</td>
<td>0.498 ± 0.007abA</td>
<td>11.03 ± 0.01bcB</td>
<td>7.95 ± 0.00abcbA</td>
</tr>
</tbody>
</table>

*= Mean ± standard deviation (n = 3).
Means in the same column with different lowercase letters (a-f) between different soaking time and sulfite concentration and in the same row with different uppercase letters (A-B) between 0 and 30 d for moisture content, water activity and SO₂ are significantly different (P < 0.05).
2,000 mg kg\(^{-1}\)). Stored chili powder from soaking in 1,000 and 2,000 mg kg\(^{-1}\) Na\(_2\)S\(_2\)O\(_5\) exhibited no significant difference in \(\Delta E^*\) with soaking time.

A decrease in the SO\(_2\) level determines the practical shelf life of a dried product with regard to non-enzymatic browning. Storage of products at high temperatures requires residual sulfites to prevent darkening and browning during storage which is inversely proportional to the SO\(_2\) content (Van et al., 1973). Therefore, a relationship between \(\Delta E^*\) and SO\(_2\) retention in dried chili and stored chili powder was determined. A linear relationship with negative slope between \(\Delta E^*\) and SO\(_2\) was observed for both dried chili and stored chili powder (Figure 4) indicating higher SO\(_2\) retention retarded the total color difference of the samples.

With the chili powder stored at 40 ºC, a decrease in the \(L^*\) value indicated a brightness loss related to the formation of browning compounds, since red pepper contains considerable amounts of reducing sugars and amino acids (Lee et al., 1991). Therefore, relationships between the SO\(_2\) residue and the color parameters (\(L^*, a^*, b^*, C^*, h\)) were investigated as shown in Figure 5. All correlations were positive between the residual SO\(_2\) content and the color parameters of chili powder samples kept for 30 d storage. It was clear that SO\(_2\) retention had a strong influence on the \(L^*, a^*, b^*\) and \(C^*\) values because the slopes of the curves were 0.740, 0.413, 0.885 and 0.952, respectively.

**CONCLUSION**

Na\(_2\)S\(_2\)O\(_5\) concentrations of 1,000 mg kg\(^{-1}\) or more with soaking time of at least 30 min can be used to soak fresh chili to prevent the browning of dried chili occurring during blanching and drying. The amount of SO\(_2\) retained in the chili depended on the processing steps and the concentration of added sulfite agent. The \(\Delta E^*\) values of dried chili decreased with increasing Na\(_2\)S\(_2\)O\(_5\) concentrations.

![Figure 4](image4.png)  
**Figure 4** Relationships between SO\(_2\) contents and total color difference (\(\Delta E^*\)) values of dried chili (o) and chili powder (♦) kept at 40 ºC and 80% RH for 30 d. The values of chili products obtained from soaking in all levels (200, 1,000, 2,000 mg kg\(^{-1}\)) of Na\(_2\)S\(_2\)O\(_5\) for 30 to 120 min. (db = Dry basis.)

![Figure 5](image5.png)  
**Figure 5** Relationships between SO\(_2\) contents and color parameters (\(L^*, a^*, b^*, C^*, h\)) of stored chili powder at 40 ºC 80% RH for 30 d obtained from soaking in 200, 1,000, 2,000 mg kg\(^{-1}\) for 30 to 120 min. (R\(^2\) = Correlation coefficient.)
and soaking time. Stored chili powder with a higher SO₂ content decreased the changes observed in the total color difference.

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LITERATURE CITED


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