ORIGINAL ARTICLES

The Effect of Different Drying Methods on the Nutrients and Non-nutrients Composition of zucchini (green squash) rings


Food Technology Department, National Research Centre, 12622 Cairo, Egypt

ABSTRACT

Zucchini, the richest source of macronutrient and micronutrient content among the vegetables, was dried in a solar and oven dryer to investigate the effect of SO2-pretreatment on loss of macronutrient and micronutrient content and other rehydration and color characteristics. The effect of solar and oven drying on the nutrients and non-nutrients composition of zucchini (green squash) rings was determined. Results indicated that the macronutrient and micronutrient contents were highest in SO2-treated solar and SO2-treated oven dried zucchini slices samples compared with untreated or fresh sample. Ash, carbohydrates and protein contents of solar (14.3, 54.32 and 15.55 %) and oven (15.42, 53.05 and 16.43 %) dried samples were increased compared to fresh (1.29, 2.32 and 2.58 %) samples, respectively. Solar and oven drying were found to increase energy content compared to fresh samples. Increases of all mineral elements contents upon SO2-solar and SO2-oven drying with exception of potassium were observed. SO2-solar and SO2-oven drying were found to increase vitamin C, total chlorophyll, total carotenoids and total phenol contents compared to fresh samples. The rehydrated moisture content, rehydration ratio, coefficient of rehydration and shrinkage ratio were also found to be maximum for the SO2-treated solar dried zucchini slices sample. Also, the most effective pre-treatment for the inhibition of oxidative enzymes (PPO), good colour characteristics and lower non-enzymatic browning in solar and oven dried zucchini rings was SO2-pretreated. Solar drying may be the preferred method of drying the zucchini (green squash) rings as it is faster, more hygienic and better preserves the nutrients.

Key words: zucchini; rings; vegetable; solar, oven, drying; sodium metabisulphite, color, % inhibition, browning, rehydration, mineral, PPO, ascorbic acid.

Introduction

An important challenge to ensure food security in most developing societies is making food available all year round. Most agricultural products are perishable and are abundant at a particular season but absent at other seasons (Haboub et al., 2003). Agricultural products tend to become scarce in other seasons making food preservation an important activity in households and communities.

Zucchini (Cucurbita pepo L.), a small summer marrow or green squash, has a similar shape to a ridged cucumber. It is usually marketed in fresh, being eaten raw in salads and always with skin, or served cooked in soups or other recipes. Zucchini vegetables are important in most of the daily diets and can be used to alleviate most of the micronutrient deficiencies. Zucchini vegetables are only available during the summer season in rural areas. Therefore, it is necessary to preserve them and use them during the winter season when they are scarce. The consumption of zucchini is very popular, these vegetables are a rich source of nutrients, especially natural antioxidants as beta-carotene, phenols and vitamins C. However, zucchini squash is a highly perishable vegetable that deteriorates rapidly after slicing, due to firmness loss, browning and decay, its shelf life is limited to 1–2 days (Izumi and Watada, 1995; and Brew et al., 2006). Drying chopped zucchini is also available in the market, but in what concerns texture, several improvements are still needed in the drying process or in the applied pre-treatments (blanching). When present in processed (e.g. drying) vegetables, residual endogenous enzymes may cause quality changes during storage. Polyphenol oxidase (PPO, EC 1.14.18.1), a commonly found enzyme in vegetables and a copper-containing enzyme, is present in all higher plants which causes undesirable colour modifications in fresh-cut fruit and vegetable products. It is considered to have an empirical relationship to off-flavors and off-colors in raw and unblanched drying vegetables (López et al., 1994).

Therefore, the inactivation of this enzyme increases the shelf life of vegetables. An emerging non-thermal and challenging technology concerns with the application of SO2 dipping pretreated samples. These Dipping pretreatments used as a chemical additives for reducing the browning reaction, maintaining the firmness, improving the organoleptic quality of various products or maintaining quality attributes and extend shelf life of pre-cut ones (Cocci et al., 2006). Sulfuring is a method of pretreating the foods by sodium sulfite solution or
solutions of sodium bisulfate or metabisulfite. It helps preventing losses in color, flavor and nutrients, as vitamins, etc. acting also as a disinfectant (Belessiotis and Delyannis, 2009 and 2011). Drying method is used in Egypt for preserving vegetables. Drying vegetables increases their shelf life upon storage (Eklou et al., 2006). The need for well established data on the nutrients and non-nutrients composition of food is of great importance in identifying and solving nutritional problems in the society.

Among the various drying methods available, open-sun drying is the most common preservation practice followed where solar radiation is high. However, solar drying is an elaboration of sun drying and was the most hygienic method of drying (Bala and Woods, 1994).

Despite the widespread use of zucchini (green squash) rings information is lacking on the effect of preservation methods on its nutrient and non-nutrient contents and the best method for its preservation. The objectives of our study were to: (i) evaluate the potential of sodium metabisulfite (SO₂) for inhibition of enzymatic (PPO) and non-enzymatic browning in fresh and dried zucchini rings; (ii) study the changes in the rehydration characteristics, and (iii) study the color parameters characteristics. This study therefore aimed to compare the effects of traditional solar drying with oven drying method on the nutrient and non-nutrient composition of zucchini (green squash) rings using fresh sample for comparison.

Materials and methods

Plant Material Pre-drying zucchini treatment:

Zucchini (Cucurbita pepo L.) cv. Squash (known as zucchini), about 15–20 cm length and 5–6 cm diameter was obtained from the store of the Ministry of Agriculture, Cairo, Egypt, and was kept in cold conditions (4 °C) until needed. All zucchini vegetables were selected free of disease symptoms and defects, with uniform size and color. The Zucchini cultivar was chosen because of its wide popularity as a food and rapid browning of the slices after preparation. Zucchini fruits were washed before the treatment. Zucchini were sliced into slice rings with a uniform size and all core tissue was removed. The untreated or fresh whole zucchini samples were sliced to make slices into 1 to 1.2cm thickness from 2 to 2.5 mm by a sharp steel knife. Zucchini was graded with respect to size, shape, and level of defects, then cored and sliced into 1.0 to 1.2 cm thickness. The zucchini slices were dipped in 0.1% SO₂ for 5 min to completely inactivate PPO and then removed so as not to absorb too much SO₂ (Potter, 1978), drained, cooled, and analyzed immediately or after drying process (Deshpande and Tamhane, 1981).

Analysis of fresh and pre-treated zucchini slices:

Fresh and SO₂-treated zucchini rings were analyzed for colour using a Hunter-Colour colorimeter, Non enzymatic browning (NEB) by spectrophotometer (OD 420nm), and polyphenoloxidase (PPO) enzyme activity.

Non-enzymatic browning determination:

Non-enzymatic browning was measured spectrophotometrically by 4054 - UV/Visible spectrophotometer, (LKB-Biochrom Comp., London, England), as absorbance at 420nm using ethanol as blank according to the method of Stamp and Labuza (1983) and Birk et al., (1998).

Polyphenoloxidase enzyme activity determination:

Extraction of polyphenoloxidase (PPO) enzyme from untreated and so₂-treated zucchini slices was carried out using the method of Galeazzi et al., [1981] and the activity of PPO assayed by Oktay et al., [1995] using 0.1 mol/L catechol as a substrate.

Colour determination:

Colour of Egyptian Fresh, SO₂-pretreated fresh, SO₂-solar dried and SO₂-oven dried zucchini rings was measured using spectro-colourimeter (Tristimulus Colour Machine) with the CIE lab colour scale (International Commission on Illumination) as mentioned by Hunter (1975) and Sapers and Douglas, (1987). Colour of Fresh, SO₂-pretreated fresh, SO₂-solar dried and SO₂-oven dried zucchini rings samples was measured using a HunterLab colourimeter Hunter a*, b* and L*. Parameters were measured with a colour difference meter using a spectro-colourimeter (Tristimulus Colour Machine) with the CIE lab colour scale (Hunter, Lab Scan XE - Reston VA, USA) in the reflection mode. The instrument was standardized each time with white tile of Hunter Lab Colour Standard (LX No.16379): X= 72.26, Y= 81.94 and Z= 88.14 (L*= 92.46; a*=-0.86; b*=-0.16). The instrument (65°/0° geometry, D25 optical sensor, 10° observer) was calibrated using white and black
reference tiles. The colour values were expressed as L* (lightness or brightness/darkness), a* (redness/greenness) and b* (yellowness/blueness). The Hue (H*), Chroma (C*) and Browning Index (BI) was calculated according to the method of Palou et al. (1999) as follows:

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

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

\[ BI = \left[ 100 \left( x - 0.31 \right) \right] 10.72 \] .....................................(3)

Where:

\[ X = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*} \]

Total colour difference (TCD) and ΔΕ was determined using Eq. (5) and Eq. (6) which indicates the magnitude of the colour change after treatment and drying. Colour measurements were taken in triplicate.

\[ TCD = \sqrt{(L^*-L_0)^2 + (a^*-a_0)^2 + (b^*-b_0)^2} \] .....................................(4)

where L0 is initial value of L*, a0 is initial value of a*, and b0 is initial value of b*. L*, a* and b* values were recorded as the mean of triplicate readings.

\[ \Delta E = \left( \Delta a^2 + \Delta b^2 + \Delta L^2 \right)^{1/2} \] .....................................(5)

where: a-ao, b-bo and L-Lo; subscript "o" indicates color of control or untreated sample.

Browning capacity:

Colour was measured at zero time (~ 1 min), 15, 30, 45, 60 and 90 min. Five different zucchini slices were placed into Petri dishes at room temperature and hand-held to the colorimeter reflectance port for the determination of L*, a*, b* values and the reflectance at 420nm. Percentage inhibition was calculated using the change in a* value as compared to the control (untreated or fresh sample), which was defined as zero percentage inhibition [Sapers and Douglas, 1987; and Patricia et al., 1993].

\[ \% \text{Inhibition} = \left[ \frac{\Delta a^*_{\text{control}} - \Delta a^*_{\text{treatment}}}{\Delta a^*_{\text{control}}} \right] \times 100 \]

The percentage inhibition was calculated using the polyphenoloxidase activity values (units/min) from the control and each treatment, defining the control as zero percentage inhibition [Patricia et al., 1993].

Solar drying process:

All treatments including fruit slices treated and untreated were dehydrated by solar dehydration. Zucchini slices were dipped into 0.1% solution of sodium metabisulphite (So2) for 5 min after which they were spread on stainless trays and subjected to drying in a solar drier at 50 °C, as seen in Fig. (1).

Fig. 1: Construction of the Pilot Solar Drier.
Oven drying process:

All treatments including fruit slices treated and untreated were dehydrated by oven dehydration. The 0.1% So2 treated zucchini (green squash) slices were oven dried (50°C) using hot air oven (Shel, Lab 1370 FX, Shel Don manufacturing, Inc. and Germany) for 24 h to obtain a completely dried sample. Dehydration was continued until the moisture content of zucchini rings reached about 14%.

So2-treated solar and oven dried zucchini rings were packed in polyethylene bags, then sealed and kept in room temperature at 20 °C for use afterwards.

Chemical analysis:

Macronutrient determination:

All chemical parameters were determined using standard methods of analysis [A.O.A.C., 2000]. Moisture content was determined using method. No 966.02. The dried zucchini (3-4g) of the different samples in triplicates was weighed and dried at 125°C for 2-4 hours. After drying, the samples were placed in desiccators for 30 minutes to cool before being weighed. The moisture content was calculated from weight loss. The protein content was determined using the Kjeldahl method (method No. 930.02). The percentage of crude protein was calculated using a factor of 6.25 (Agrahar-Murugkar and Subbulakshmi, 2005; and Ouzouni et al., 2009). The fat in zucchini rings was determined by extractions using Soxhlet apparatus (method No 920.39). For ash determination the samples were incinerated in a muffle furnace (Model) at 500°C for 3 hours, until a clear ash was obtained according to A.O.A.C. methods (2000). The amount of total carbohydrates was calculated based on difference (Ouzouni et al., 2009). Total carbohydrates (%) = 100 - moisture (%) - protein content (%) - crude fat (%) - ash (%) = total carbohydrates. The energy content was calculated. All the calculations were carried out on dry weight basis of the zucchini.

Micronutrient determination:

Ascorbic acid was determined by A.O.A.C. (2000). Total phenols of fresh and so2- treated dried zucchini slices were determined by the method of Amerine and Ough (1980). The method described by Wettestein (1957) was used for the determination of total carotenoids and chlorophylls expressed as mg/L.

Mineral Determination:

Sodium, potassium, iron, zinc and copper contents of fresh and so2-treated dried zucchini samples were determined in the digested solution according to the method described by Jackson [1973]. Mineral content (Fe, Cu, Na, K and Zn) of fresh and So2-treated dried zucchini rings was determined using a Unicom SP 1900 atomic absorption spectrophotometer (FMD3) according to the method of [A.O.A.C. 2000 method, No 980.03].

Quality of rehydration and dehydration measurements:

The quality of rehydration was calculated according to Ranganna (1986) and included moisture content of rehydrated sample, drying ratio, rehydration ratio, shrinkage ratio and coefficient of rehydration.

Results and Discussions

Effect of pre-drying treatment (So2) on enzymatic PPO-activity and nonenzymatic browning of fresh zucchini slices:

Table (1) illustrates browning trends in the So2 - treatments of fresh zucchini slices during storage time (90 min) at room temperature. The results showed that the a*-value of the untreated or fresh zucchini slices increased sharply throughout the 90 minutes period, as compared to L*-values of Hunter color. Our results were in-agreement with the result of Dong et al., (1995) who found that the PPO-activity in fresh apple slices showed a higher correlation to a*-values than to L*-values of Hunter color. These results are in agreement also with the results of Patricia et al., (1993). The So2 –treatment of zucchini slices did not report browning result in high inhibition of enzymatic browning (PPO). The results showed that the So2 – treated zucchini slices was very slightly browning (a*-values), especial throughout the first minute’s storage at room temperature. The same results were found with determined of PPO-activity of fresh zucchini. These results are in agreement with the results of Patricia et al., (1993).
Non-enzymatic browning in fresh zucchini rings is primarily caused by degradation of ascorbic acid, which is a precursor of the Maillard reaction. Ascorbic acid loss correlates with the extent of non-enzymatic browning (Kaanan et al., 1988). As shown in Table (1), that non-enzymatic browning was most severe in fresh zucchini slices sample, whereas So2 - treatment of zucchini rings samples did not brown to the extent that would be objectionable. Browning is only one component that determines overall color and might not be a problem at low levels. The effects of So2 - treatment of zucchini samples in the inhibition of the browning reaction are listed in Tables (1). It is obvious that the So2 - treatment inhibited the development of A420nm and red colour a*values. For example, the A420nm and Delta a*-values of fresh zucchini slices were 0.868 and 0.470 compared to 0.601 and 0.005 in case of the So2 - treatment zucchini slices samples, respectively. The % inhibition of PPO by activity measurements and by hunter color parameters were 98.94 and 99.79%, respectively in so2-pretreated zucchini slices. Crandall et al., [1986] concluded that two measures of browning were used, color a* or L* and absorbance at 420nm where the higher numbers indicate increased absorbance due to the formation of brown pigments. Browning is also indicated by a decrease in the color L* toward black and an increase in the color a* toward brown or red.

Table 1: Effect of So2-predrying treatment on PPO-activity, enzymatic and non-enzymatic browning of fresh zucchini rings.

<table>
<thead>
<tr>
<th>Treatment of fresh zucchini rings</th>
<th>Hunter color values</th>
<th>NE-Browning OD420nm</th>
<th>PPO-activity <em>% inhibition unit/min</em>*% inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh zucchini rings</td>
<td>Delta a*-value**</td>
<td>% inhibition</td>
<td>0.470</td>
</tr>
<tr>
<td>So2- treated fresh rings</td>
<td>0.005</td>
<td>98.94</td>
<td>0.601</td>
</tr>
</tbody>
</table>

* Expressed that multiply 10-
** Delta a* = Difference between 90 minutes and 1 minute values.

Effect of So2 pretreatment of solar and oven drying process on macronutrients of zucchini rings:

Table (2) shows the moisture, protein, fat, ash and carbohydrates content of the dried zucchini rings as affected by the solar and solar drying processing. The obtained results showed that the moisture content was increased in solar (13.82%) and oven (12.34%) dried compared with fresh (93.56%) zucchini rings (on wet weight basis), respectively. The sulfured (So2) treated samples had the lowest moisture content in solar and oven drying which corresponded also to the duration of drying. All the drying methods were found to lowered moisture content and the oven dried samples had the lowest moisture content. The zucchini sample was a rich source of ash, which is in line with the statement that vegetables are the natural broom for the body as they are rich in ash. Ash, carbohydrates and protein contents of solar (14.3, 54.32 and 15.55 %) and oven (15.42, 53.05 and 16.43 %) dried samples were increased compared to fresh (1.29, 2.32 and 2.58 %) samples respectively, as seen in Table 2. However, Fat content was increased with drying method. Solar and oven drying were found to increase calculation of the energy content (297.57 and 302.76%) respectively compared to fresh (21.85%) samples, respectively.

Effect of So2 pretreatment of solar and oven drying processes on micronutrients of zucchini rings:

The maximum retention of total carotenoids was 0.96 mg/100g in So2-treated solar dried, 0.503 mg/100g in So2-treated solar dried and a minimum level of 0.171 mg/100g in fresh or untreated zucchini rings sample. Solar drying though took lower time than oven drying, lead to lower total carotenoids losses. The results in Table (3) show that total chlorophyll (A and B) increased from 0.592 mg/100g in fresh sample to 0.833 and 1.292 mg/100g in So2 treated solar and oven dried zucchini sample, respectively. The pre-treatment with So2 resulted in greater amount of total chlorophyll (A and B) in oven dried and of total carotenoids in solar dried zucchini rings compared with untreated or fresh sample. In addition to So2 could be responsible for inhibition of browning (PPO) by preventing from breakdown of total chlorophyll (A and B) and total carotenoids in dried zucchini rings. These results are in accordance with the results of Mazza and Miniati (1993) who reported that the ascorbic acid content and sugar degradation in fruit affect the colour intensity and stability of the total chlorophyll (A and B) and total carotenoids. However, The So2 pre-drying treatments prevented from oxidation of total chlorophyll (A and B) and total carotenoids. They also reported that total chlorophyll (A and B) and total carotenoids could be decomposed directly by PPO.
Comparison of the nutrients of fresh vegetables with the vegetables dried by the different methods shows that, of the two drying technologies (solar drying and oven drying), solar drying generally seemed better, especially with regard to total carotenoids retention followed by oven drying. This suggests that the loss in total carotenoids is a function of, among others, the drying conditions as observed in earlier studies. The difference in losses caused by the different drying processes could be attributed to the length of exposure to light, oxygen, heat and other accelerating factors. Since it could explain why more total carotenoids loss took place in oven-dried vegetables than solar dried ones (Kiremire et al., 2010).

The So2 pretreatment of solar and oven drying process increased the total phenol content from 116.485 mg/100g in fresh sample to 1419.37 and 1374.08 mg/100g in So2 - treated solar and oven dried zucchini sample respectively, as seen in Table (3). So2-solar and So2-oven drying were found to increase vitamin C, total chlorophyll, total carotenoids and total phenol contents compared to fresh samples.

The chemical instability of vitamin C acid is due to the fact that it is a strong reducing agent and can be deactivated by a wide range of oxidizing agents. The solar dried zucchini rings had a noticeable increased in the ascorbic acid from 12 mg/100g in fresh sample to 28 and 35 mg/100g in So2 - treated solar and oven dried zucchini sample, respectively. The increasing of ascorbic acid content in solar dried zucchini rings samples resulted from removing water by rehydration process (Inyang and Ike, 1998). The maximum amount of vitamin C was in solar dried zucchini rings sample; hence such technique does not expose the sample to direct heat and air.

The So2 - pre-treatments given to the zucchini vegetable before drying affected the retention of ascorbic acid (Table 3). It is observed that the loss of ascorbic acid in the control sample (untreated sample) reached the maximum, 28% in the So2 – solar and 35% in So2-oven dried samples. The greater retention of ascorbic acid in So2 – solar and oven dried treated zucchini might be due to reduced exposure of the sample in the drying air, which prevented its loss (Verma and Gupta, 2004). However, the sulphitation (So2) treatments decreased the loss of ascorbic acid from the sample. Also, leaching is another important factor that could have led to loss of soluble minerals as well as vitamin C along with the water during the drying process.

Table 3: Effect of So2 - pretreatment of solar and oven drying process on micronutrient of zucchini rings.

<table>
<thead>
<tr>
<th>Micro Chemical compositions</th>
<th>Fresh wet</th>
<th>Fresh dry</th>
<th>Solar dried</th>
<th>Oven dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C (mg/100g)</td>
<td>12.00</td>
<td>1.77</td>
<td>28.00</td>
<td>35.00</td>
</tr>
<tr>
<td>Chlorophyll A (mg/100g)</td>
<td>0.35</td>
<td>0.43</td>
<td>0.59</td>
<td>0.87</td>
</tr>
<tr>
<td>Chlorophyll B (mg/100g)</td>
<td>0.24</td>
<td>0.19</td>
<td>0.24</td>
<td>0.42</td>
</tr>
<tr>
<td>Total Chlorophyll (A+B) (mg/100g)</td>
<td>0.59</td>
<td>0.63</td>
<td>0.83</td>
<td>1.29</td>
</tr>
<tr>
<td>Total Carotenoids (mg/100g)</td>
<td>0.17</td>
<td>0.34</td>
<td>0.96</td>
<td>0.50</td>
</tr>
<tr>
<td>Total phenol (mg/100g)</td>
<td>116.49</td>
<td>17.21</td>
<td>1419.37</td>
<td>1374.08</td>
</tr>
</tbody>
</table>

Effect of So2-pretreatment of solar and oven drying processes on mineral contents of zucchini rings:

Mineral composition of So2 - pretreatment of solar and oven dried zucchini rings (per 100 g) was given in Table (4). Fresh zucchini rings have an iron, zinc, copper, sodium and potassium content of 16.29, 6.32, 1.389, 88.29 and 0.24 ppm of fresh sample where as the mineral content of So2 -treated solar dried zucchini rings was 94.81, 75.13, 11.93, 1212.27 and 1.39 ppm in So2 -treated oven ones was 99.16, 80.21, 12.24, 1325.18 and 3.47 ppm, respectively. Maximum amount of all mineral contents were showed in the solar dried zucchini rings sample (94.81-1212.27 ppm) and in the oven dried sample (99.16-1325.18 ppm), while the lowest was in the fresh ones (0.24 - 6.32 ppm), as seen in Table 4. Increases of all mineral elements contents upon So2-solar and So2-oven drying with exception of potassium were observed.

Table 4: Effect of So2 - pretreatment of solar and oven drying process on some mineral content (ppm) of zucchini rings.

<table>
<thead>
<tr>
<th>Mineral contents</th>
<th>Fresh</th>
<th>Solar dried</th>
<th>Oven dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium (K)</td>
<td>0.24</td>
<td>1.39</td>
<td>3.47</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>88.29</td>
<td>1212.27</td>
<td>1325.18</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>16.29</td>
<td>94.81</td>
<td>99.16</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>6.32</td>
<td>75.13</td>
<td>80.21</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>1.389</td>
<td>11.93</td>
<td>12.24</td>
</tr>
</tbody>
</table>
Relationship between drying and rehydration characteristics of So2 pretreatment solar and oven dried zucchini rings:

The drying ratio for both So2-treated solar and oven dried zucchini rings was 1:15 and the rehydration ratio was ratio 1:5 and 1:4.5 in So2-treated solar and oven dried zucchini rings respectively, as seen in Table (5). The moisture content of dehydrated zucchini rings treated with So2-solar and So2-oven dried was 99.63 and 99.44%, respectively. Also, the coefficient of rehydration in So2-treated solar and So2-treated oven dried zucchini rings was 88.56 and 87.82 % respectively. The Shrinkage ratio of both So2-treated solar and So2-treated oven dried zucchini rings was 1:17, as seen in Table (5). The rehydrated moisture content, rehydration ratio, coefficient of rehydration and shrinkage ratio were also found to be maximum for the So2-treated solar dried zucchini slices sample.

The treatments of So2- showed that at the final stages of convection drying of zucchini might be formed an amorphous state and increased mechanical strength of the material prevents excessive shrinkage. The glassy matrix and a collapse of structure were observed when water added during re-hydration plasticizes. Further absorption of water by polymers caused swelling and a rebuilding of structure was observed. Such results were in accordance with those of (Karathanos et al., 1996 and Lewicki et al., 1997). The re-hydration ratio (index) was less in So2-treated solar and So2-treated oven dried zucchini rings sample. These results were in agreement with the results of Lewicki, (1998) who reported the more the water absorption capacity is lost and the tissue is damaged during dehydation the less is the index. This gives information on the ability of the material to absorb water.

Table 5: Effect of So2 - pretreatment of solar and oven drying process on rehydration properties of dried zucchini rings.

<table>
<thead>
<tr>
<th>Rehydration properties</th>
<th>So2-Solar dried</th>
<th>So2-Oven dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehydration ratio</td>
<td>01:05</td>
<td>01:04:5</td>
</tr>
<tr>
<td>Moisture coefficient</td>
<td>88.56</td>
<td>87.82</td>
</tr>
<tr>
<td>Moisture dehydration</td>
<td>99.63</td>
<td>99.44</td>
</tr>
<tr>
<td>Drying ratio</td>
<td>01:15</td>
<td>01:15</td>
</tr>
<tr>
<td>Shrinkage ratio</td>
<td>01:17</td>
<td>01:17</td>
</tr>
</tbody>
</table>

Colour characteristics, parameters and non-enzymatic browning (A420nm) in fresh and dried with So2 - pretreatment of zucchini rings:

The surface colour of fresh and So2-treated solar and So2-treated oven dried zucchini rings was measured with a colour difference meter, using the Hunter Lab colour scale. The Hunter colour values of zucchini rings were determined immediately after drying. Changes in L* values were inversely proportional to the changes in a*values of the Hunter colours. Absorption at 420 nm, the CIE L*, a*, b* colour parameters, hue angle (H*), chroma (C*) and BI was found to be suitable indicators for the brown pigment formation because of non-enzymatic browning after processing, as seen in Table (6). The a* values and BI for So2 -treated solar and So2 -treated oven dried zucchini rings were low in contrast to high values for fresh or untreated zucchini sample. Under all tested conditions, fresh So2 treated, So2-treated solar and So2-treated oven showed much higher efficient values based on L*, a*, b*, BI and TCD values than C*, H* and A420nm measurements, whereas the untreated or fresh sample behaved an opposite trend. Such a trend is in agreement with previous studies of Ozoglu and Bayindirh (2002). In addition, the Hunter colour a* and b* values and BI of So2 pretreatment in solar and oven dried zucchini rings was lower than that of fresh or untreated samples. These results indicated that browning (redness) increased in fresh samples than in So2 -treated solar and oven dried zucchini rings samples. However, PPO enzyme activity was higher in fresh samples than in So2 -treated solar and oven dried zucchini rings samples, as seen in Tables (6). According to our results, the main colour changes in untreated zucchini rings was because of increase in the BI and a* value, which were in high correlation to browning measurement. Other colour parameters, such as hue angle and chroma, also indicated that so2 -treated solar and so2 -treated oven dried of zucchini rings caused a slight colour changes. BI values in so2 samples were lower than in case of fresh or untreated samples. These results are in agreement with those of Palou et al., (1999), Hayta (2002) and Ozoglu and Bayindirh (2002).

It was generally found that so2 treatment improved the colour of solar and oven dried zucchini rings (Table 6). However, Fresh or untreated samples had the high increase in colour as optical density (A420nm) non-enzymatic browning compared with the So2 -treated solar and So2 -treated oven dried zucchini rings samples. The increase in colour (browning as A420nm) could be attributed to the reaction occurred between amino groups and active carbonyl groups (Maillard reaction) after solar and oven drying process. Sulfur dioxide has been shown to be effective in preventing browning by combining with carbonyl groups. From the above mentioned results, it could be concluded that pretreated zucchini rings with (So2) sulphites showed the best colour values (a* and BI) and lower non-enzymatic browning as compared with fresh or untreated sample, as seen in Table (6). Results reported that the solar and oven drying treatments did not affect non enzymatic
browning with optical density (A 420nm). However, the values of non enzymatic browning (A 420nm) confirm the data obtained for solar and oven drying treatments showed very slight differences in So2-treated zucchini rings, and no differences in solar and oven dried zucchini rings compared to control.

The most effective pre-treatment was so2 for the inhibition of oxidative enzymes (PPO), good colour characteristics and lower non-enzymatic browning in solar and oven dried zucchini rings.

Choi et al., (2002) reported that TCD values were corresponded to the noticeable differences in the visual perception of products. In the present study TCD was observed to be very distinct for the maximum treatment conditions investigated. It should be noted that changes in colour values may be regarded as a negative sensory impact of processing. A correlation between different parameters investigated is shown in Table 6.

Solar and oven drying resulted in a decrease in a*, b*, C*, BI and an increase in L* value, H*, ∆E and TCD in zucchini rings (Table 6). TCD values increased from 0 to 3.28, 4.52 and 4.50 in fresh, fresh So2-treated, solar dried and oven dried zucchini rings respectively, indicating visual colour differences. Differences in perceivable colour can be analytically classified as very distinct (TCD > 3), distinct (1.5 < TCD < 3) and small difference (TCD < 1.5). Then, the obtained results indicated that the differences in perceivable colour can be analytically classified as very distinct in all treated zucchini rings. Choi et al., (2002) indicated that a TCD > 2 corresponds to noticeable differences in the visual perception of many products. Similarly, Tiwari et al., (2008a, b) reported significant differences in perceivable colour during sonication of orange juice. Results representing the linear and quadratic effects of the independent variables for the colour parameters (L*, a*, b*, TCD, ∆E, Chroma, BI and Hue angle), are presented in Table 6.

### Table 6: Colour characteristics, parameters and non-enzymatic browning (A 420nm) in fresh and So2- pretreated dried zucchini rings.

<table>
<thead>
<tr>
<th>Samples</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>∆E</th>
<th>C*</th>
<th>H*</th>
<th>BI</th>
<th>TCD</th>
<th>A 420nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>65.26</td>
<td>2.365</td>
<td>36.73</td>
<td>68.03</td>
<td>36.80</td>
<td>86.32</td>
<td>148.06</td>
<td>-</td>
<td>11.45</td>
</tr>
<tr>
<td>Fresh-So2</td>
<td>83.47</td>
<td>-1.193</td>
<td>32.86</td>
<td>69.48</td>
<td>32.88</td>
<td>87.92</td>
<td>86.28</td>
<td>3.28</td>
<td>10.95</td>
</tr>
<tr>
<td>So2-solar</td>
<td>94.87</td>
<td>-1.594</td>
<td>31.51</td>
<td>70.38</td>
<td>31.55</td>
<td>87.10</td>
<td>69.16</td>
<td>4.52</td>
<td>11.44</td>
</tr>
<tr>
<td>So2-Oven</td>
<td>93.84</td>
<td>-1.384</td>
<td>32.18</td>
<td>71.51</td>
<td>32.21</td>
<td>87.54</td>
<td>72.30</td>
<td>4.50</td>
<td>11.41</td>
</tr>
</tbody>
</table>

Conclusion:

Micronutrient deficiencies are high in most Egyptians. To the rural poor, the most compelling and long-term strategy to address this problem is dietary diversity. However, postharvest losses and seasonal variability within key foods still hamper the community-based efforts to supply local food sources throughout the year. The objective of this study was to establish food preservation methods that could easily be adopted for preservation of zucchini vegetables in order to even out the imbalance of supplies between the summer and the winter season. With respect to retention of the nutrient content in zucchini vegetables, the So2 – pretreatments of solar and oven drying was found to be the best of the drying methods. Based on this study, So2 – pretreatment and solar drying is recommended as a method for zucchini rings preservation. Also, the most effective pre-treatment for the inhibition of oxidative enzymes (PPO), good colour characteristics and lower non-enzymatic browning in solar and oven dried zucchini rings was So2 -pretreated. Solar drying may be the preferred method of drying the zucchini (green squash) rings as it is faster, more hygienic and preserves the nutrients better.

References


