International Food Research Journal 23(Suppl): S155-S161 (December 2016)

Journal homepage: http://www.ifrj.upm.edu.my

Effect of different drying treatments on colour quality and ascorbic acid concentration of guava fruit

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Article history

Received: 7 September 2016
Received in revised form: 29 October 2016
Accepted: 30 October 2016

Keywords

Guava
Ascorbic acid
Microwave
Oven
Drying temperature
Colour quality

Abstract

Guava (*Psidium guajava* L.) is a rich source of vitamin C (ascorbic acid) having high water content (above 80%) which makes it extremely perishable, but storage, handling, processing and transporting becomes difficult due to high moisture content. Therefore, guava needs dehydration process by upholding its natural colour and minimum ascorbic acid losses. We have carried out a comprehensive study to examine the influence of different drying treatments; under direct sunlight, freezing, convection oven (50, 60, 70, 80 and 90°C) and microwave oven (100, 250, 440, 600 and 1000 watts) on ascorbic acid concentration and colour quality of guava. The mean values of ascorbic acid concentration of dried guava slices were changed significantly ($P < 0.05$) as compared to fresh guava slices. The colour of guava slices became yellowish with an increase in temperature and power of conventional and microwave ovens, respectively. We found freeze drying as the best method for the dehydration of guava in terms of ascorbic acid and natural colour preservation.

Introduction

Vitamin C (ascorbic acid) is a water-soluble compound having inability to be stored in the human body. This citrus requirement is fulfilled by the organic food and vegetables. This nutrient not only prevents many diseases in which collagen (a special type of protein) synthesis is impaired like scurvy, but also plays an important role in the making of tissues like skin, tendons, cartilages and blood vessels. It is also important for wound healing and acts as a biological antioxidant (Richard and Ferrier, 2011; Ibrahim and El-Sayed, 2016). The ascorbic acid contents in fruits may degrade due to heat, preserving duration, pH value, moisture content, direct exposure to sunlight and amount of oxygen. Previous studies proposed that the quality of dried foods depends on the quantity of ascorbic acid retained after processing (Santos and Silva, 2008; Marfil *et al*., 2008; Lee and Kader, 2000). Guava (*Psidium guajava* L.) is one of the most popular fruit trees which belong to the myrtle family (Myrtaceae). It is native to tropical America and grows well in tropical and subtropical regions (Jagtiani *et al*., 1998). Guava is a rich source of vitamin C as it contains almost 6 times more vitamin C than orange (McCook-Russell *et al*., 2012). Different varieties of guava exist all over the World having ascorbic acid concentration ranges from 37 to 1160 mg/100g (Waddington and Franklin, 1942; Wenkam and Miller, 1965; Marques *et al*., 2006). Dried guava slices can be further converted into powder which is used as a flavor and to increase the shelf life by confection industry in the making of as a flavor, fruit juices and fruit jellies.

Every fruit and drying method has its unique characteristics. The freeze drying method is considered one of the best drying treatment because due to it preserves natural colour, maximum nutrients, original flavor and aroma (Marques *et al*., 2007). Kumar and Sagar (2014) also reported freeze drying as the best method in terms of preservation of nutrients and colour quality of fruits but it is the most expensive method.

The microwave drying of fruits getting popularity due to uniform energy distribution and short drying time (Özkan *et al*., 2007). Conventional oven drying is one of the economical and controlled ways of fruit drying, but at a higher temperature, it may damage the colour quality and leads to the loss of heat labile nutrients. These are stronger reasons why research aiming to improve dehydration technologies is valid, mainly those in which the influence of food quality

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is studied. More investigation is needed to provide a better understanding of the oxidative phenomena of the ascorbic acid. Many studies have been conducted on the variation of ascorbic acid concentration in different food products during microwave drying such as Özkan *et al*. (2007) associated the decrease in the ascorbic acid concentration of the leaves with the microwave power and drying time. The same results were obtained by Karatas and Kamişli (2007) and Khraisheh *et al*. (2004) for apricot and potato drying, respectively. Khraisheh *et al*. (2004) concluded that the vitamin C contents decreased with increase in microwave power (heat) and drying time.

The direct sunlight is the most common and cheaper method of food drying in tropical and subtropical regions as compared to other instrumentation methods. Most of the heat labile and light-sensitive nutrients are lost due to direct exposure to sunlight and oxygen (Kaur *et al*., 2008; Madhlopa *et al*., 2002; Wojdyło *et al*., 2014; Aydin and Gocmen, 2015). Ndawula *et al*. (2004) reported that the drying of fruits under direct sunlight and polyethylene covered solar drying method caused 84% and 71% ascorbic acid losses, respectively.

Therefore, it is necessary to find optimum drying conditions to dehydrate guava with minimum ascorbic acid losses and preserve its natural colour for further processing. We have dried guava in the present study with four different drying methods in combination with 10 extra treatments for conventional oven and microwave drying methods to examine the effects of drying methods and treatments on the concentration of ascorbic acid and colour quality of guava.

Materials and Methods

Fresh guava was purchased from the Seri Kembangan (Latitude 3.02 degree and Longitude 101.70 degree) nearby Universiti Putra Malaysia, Selangor, Malaysia. The fruits were washed and cut into slices of 4 mm thickness with fruit slicer (Kek *et al*., 2014). The slices were divided into 13 batches. One batch was analysed as fresh within 1 hour of arrival in the laboratory.

Preparation of guava slices

The remaining 12 batches of guava slices were immediately dried using one of the following methods. The drying process was continued until the readings were constant. After drying, samples were cooled under laboratory conditions and stored in airtight glass jars for further analysis. All drying trials were repeated three times and average values of moisture content were used for data analysis.

Microwave drying

Fifty grams of fresh guava slices was placed over a glass fiber sheet and then dried in a microwave oven (Panasonic NN-C2003S, Japan) for 5 rising levels of output power as 100, 250, 440, 600 and 1000 watts under microwave mode.

Oven drying

Fresh guava slices were spread evenly on baking sheet and placed in a conventional laboratory oven (Memmert UNB 500, Germany) at 50, 60, 70, 80 and 90ºC until the water removal rate reached at zero (Ali *et al*., 2014).

Sunlight drying

Fresh guava slices were spread over the baking sheet and placed under direct sunlight on a wooden table at an average temperature and relative humidity of 30±5ºC and 60-70%, respectively. A portable thermohygrometer with Integrated Probe (HI93640, Hanna Instruments, Inc. USA) was used to measure the temperature and humidity. The guava slices were turned after every one-hour interval for uniform drying.

Freeze drying

A freeze dryer (50 SRC 5 Gardiner, NY) was used to dry guava slices with total pressure and the temperature inside the vacuum chamber of 0.13 mbar and –30ºC, respectively. The sublimation heat was supplied by a heating plate through the tray and the frozen product. The final product temperature during the secondary drying was about 38°C. After drying for 48 hours, blocks of guava slices were removed from trays and stored in desiccators for further analysis.

Moisture content

The moisture content of guava slices was determined according to the AOAC method (AOAC, 2000). The moisture loss of guava slice was measured at 60, 30 and 1-minute intervals during sunlight, oven and microwave drying treatments. A digital balance (accuracy ± 0.001 g) was kept beside the oven to minimise reading time. The drying process was continued until the readings were constant. After drying, samples were cooled under laboratory conditions and stored in dissectors for further analysis. All drying trials were repeated three times and average values were used for data analysis.

Colour analysis

A colourimeter (CR 400, Minolta Co., Osaka, Japan) was used to analyse the colour quality of guava slices in terms of coordinates L*, a* and b*. The portable colourimeter (Minolta, CR300) was calibrated with a standard white colour calibration plate given along with the instrument and set to CIE Standard Illuminant C. The colour brightness coordinate L* is used to assess the whiteness value of a colour, ranges from black at 0 to white at 100. The chromaticity coordinate a* determines green when negative and red when positive, and the chromaticity coordinate b* measures yellow when positive and blue when negative (Claussen *et al*., 2007; Arslan *et al*., 2010). The ΔE* and a*/b* are used to express colour degradation/change value as a single numerical value. The ΔE* is defined as the magnitude of total colour differences and is calculated from following Equation 1. The minimum values of ΔE* and a*/b* are desired with dried food (Doymaz *et al*., 2006).

$$\Delta E^* = [(\Delta L^*)2+(\Delta a^*)2+(\Delta b^*)2]0.5 \qquad (1)$$

$\Delta L^* = L^*fresh - L^*dried$
$\Delta a^* = a^*fresh - a^*dried$
$\Delta b^* = b^*fresh - b^*dried$

where, L*, a* and b* are colour coordinate while ΔL*, Δb*, Δa* are difference between fresh and dried values.

Vitamin C (ascorbic acid)

The ascorbic acid contents of fresh and dried guava slice were determined according to the AOAC method No. 967.21 (AOAC, 1995). According to this method about 10 g of guava slices for fresh and 4 g for dried samples were homogenised with 100 mL of 3% metaphosphoric acid and then filtered through filter paper (Whatman No. 4). About 5 mL of filtrate was titrated with 2,6-dichlorophenol iodophenol (DCPIP) indicator Ascorbic acid content was expressed as mg/100 g of sample.

Statistical analysis

Software "Statistix 8.1" (Analytical Software, Tallahassee FL 2317 USA) was used to analyse data statistically. All samples were run in triplicates. Analysis of variance (ANOVA) was calculated using the standard ANOVA (one-way) procedure. All data were analysed at a 5% probability level.

Results and Discussion

Moisture contents

Table 1 shows the total drying time and final moisture contents of guava slices with different drying methods and treatments. Fresh guava slice has 83.37±2.4% moisture content which makes it highly perishable. During oven and microwave treatments; drying time was decreased significantly (P < 0.05) with the increase in oven temperature and microwave power. All drying treatments were able to bring down moisture contents as low as 10% which is a favorable condition for further processing and storage of dried guava slices. Oven 90°C treatment took minimum time as 3.5±0.3 h to reach a final moisture content of 6.84±0.1 followed by oven 80, 70, 60 and 50°C took 4.5±0.4, 11±0.4, 15±0.3 and 18±0.3 h, respectively. In case of microwave heating power of 1000 watt took minimum time as 5.5±0.5 minutes to reach minimum moisture level of 6.05±0.08% followed by 600, 400, 250 and 100 watts took 8±0.5, 13.5±0.5, 18±0.9 and 26±1.0 minutes, respectively. Almost 93±4.3 h (4 days) were required to bring the moisture level below 10% during sun drying of guava slices. The freeze drying took 48 h (2 days) to bring the moisture content below 10% (Table 1). The statistical analysis (one-way ANOVA) shows that there is no significant (P < 0.05) difference between microwave powers. In the case of oven drying, the effect of drying time on final moisture content was insignificant (P < 0.05) after 80°C. The microwave took the shortest time between all drying treatments because of the magnetron of microwave converts electric current into microwaves. These microwaves bounce back and travel within microwave drying chamber due to special mesh cover. These microwaves do not generate heat, but induced a little vibration in food molecules upon penetration which produces heat within the food, not in the surrounding. The vibrating molecules have heat so; food becomes hotter with the vibrating speed of molecules. Thus the microwaves pass their energy

Table 1. Final moisture content and total drying time of guava slices dried with different drying treatments.

Treatments	Total drying time	Final moisture content (w.b), %
Fresh	-	83.37 ± 2.4^{a}
Sunlight	93 ± 4.3^{a} h	9.94 ± 3.0^{b}
Freeze	48 ± 0.0^{b} h	7.02 ± 1.6^{ef}
Oven 50 °C	18 ± 0.4^{d} h	9.21 ± 0.1^{bc}
Oven 60 °C	15 ± 0.4^{de} h	8.58 ± 0.2^{cd}
Oven 70 °C	11.0 ± 0.3^{fg} h	7.66 ± 0.2^{de}
Oven 80 °C	4.5 ± 0.3^{i} h	7.15 ± 0.1^{de}
Oven 90 °C	3.5 ± 0.3^{ij} h	6.84 ± 0.1ef
Microwave 100 W	26.0 ± 1.0^{c} min	7.19 ± 0.07^{ef}
Microwave 250 W	18.0 ± 0.9^{d} min	7.09 ± 0.08^{ef}
Microwave 440 W	13.5 ± 0.5^{ef} min	6.89 ± 0.13^{ef}
Microwave 600 W	8.0 ± 0.5^{gh} min	6.13 ± 0.06^{f}
Microwave 1000 W	5.5 ± 0.5^{hi} min	6.05 ± 0.08^{f}

Different letters in a column indicate significantly different (P < 0.05)

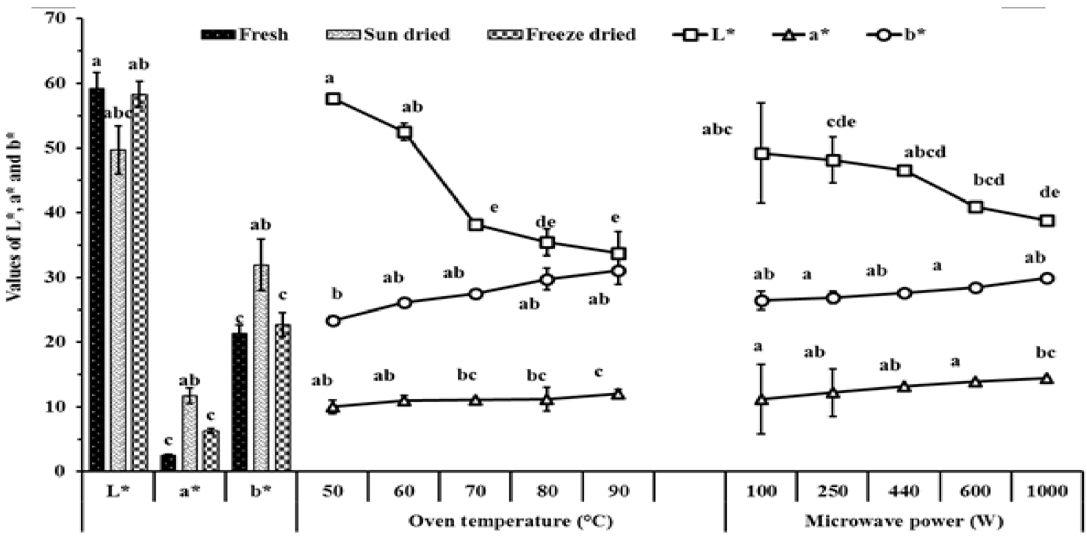

Figure 1. Color quality comparison of fresh and dried guava slices with different drying treatments. Bars and marker with different letters are significantly different (P < 0.05).

Table 2. Effects of different drying treatments on L*, a*, b*, a*/b*, and ΔE* values of guava slices.

Treatments	L*	a*	b*	a*/b*	ΔE*
Fresh	58.13±2.54^{a}	2.43±0.25^{c}	21.30±1.42^{c}	0.11e	-
Sunlight	49.70±3.52^{ab}	11.70±0.95^{a}b	31.96±3.71^{a}b	0.36^{bcd}	16.45
Freeze	54.79±1.91^{ab}	5.88±0.37^{c}	21.60±1.90^{c}	0.27^{d}	4.81
Oven 50 °C	57.67±3.74^{a}	9.97±1.19^{ab}	29.73±3.98^{b}	0.34^{bcd}	11.32
Oven 60 °C	52.47±1.76^{ab}	11.00±0.40^{ab}	33.10±1.14^{ab}	0.33^{cd}	15.64
Oven 70 °C	35.40±2.65^{e}	13.07±1.96^{bc}	27.53±1.42^{ab}	0.47^{ab}	25.86
Oven 80 °C	38.17±4.99^{de}	11.17±0.93^{bc}	26.10±2.38^{ab}	0.43^{abc}	22.32
Oven 90 °C	32.73±0.38^{e}	11.03±0.72^{c}	20.37±1.03^{ab}	0.54^{a}	26.83
Microwave 100 W	49.23±1.34^{ab}c	12.20±0.36^{a}	35.47±0.76^{ab}	0.34^{bcd}	19.37
Microwave 250 W	4cde0.93±2.06^{cde}	13.90±1.70^{ab}	30.70±1.82^{a}	0.45^{abc}	22.71
Microwave 440 W	48.17±3.33^{abcd}	13.20±2.21^{ab}	33.40±0.66^{ab}	0.40^{bcd}	19.02
Microwave 600 W	46.60±1.87^{bcd}	14.43±1.19^{a}	35.53±2.00^{a}	0.41^{abcd}	21.90
Microwave 1000 W	38.83±7.75^{de}	11.17±1.42^{bc}	26.43±5.32^{ab}	0.42^{abc}	21.80

Different letters in a column indicate significantly different (P < 0.05)

onto the molecules in the food, rapidly heating it up. While, in the case of a convection oven, the heat is conducted from the outer surface of food products (Lawandi, 2015; Woodford, 2016).

Colour analysis

Figure 1 shows, the colour differences between fresh and treated guava slices. The L* values of fresh, sunlight and freeze dried samples were 58.13±2.54, 49.70±1.91 and 56.43±3.49, respectively which indicates that sun dried guava slice became darker during the drying process. This may be due to prolong drying time and presence of oxygen. In the case of b* coordinate, the values were dried slice became increasing which means colour became more yellowish as compared to fresh, but among drying treatments, there was no significance (P < 0.05) change was occurring. The values of a colour coordinate a* also change significantly upon drying, but no significant (P < 0.05) change was seen among all drying treatments as shown in Figure 1. In the comparison of all drying treatments the freeze drying method prevent colour damage as it gave minimum values of a*/b* and ΔE* (Table 2) because the dehydration process occurs in the absence of liquid water and at low temperatures. The higher temperature of the convection oven and power of microwave damaged the colour quality of guava slice as the temperature and power increases from 70 to 80°C and 440 to 1000 W the a*/b* and ΔE* also increases (Table 2). It clearly indicates that guava slice must be dried at lower heat supply to prevent colour quality. These results are in good agreement with work done by Sumnu *et al*. (2005);

Simal *et al*. (2005); Sagrin and Chong (2013); and Doymaz *et al*. (2006) on the on carrots, kiwi fruit, banana, dill and parsley leaves, respectively. They concluded that the higher L* (lightness) and lower b* (yellowness), a*/b* and ΔE* values are desirable for further processing of fruits.

Vitamin C (ascorbic acid) analysis

Vitamin C contents are used as reference or indicator for the preservation of nutrients in dried food items because it is extremely heat sensitive vitamin and evaporates easily. Thus, if vitamin C is well maintained during the drying process, other nutrients are probably also preserved (Lin *et al*., 1998). **Figure 2** shows the ascorbic acid concentration in mg/100g of fresh and dried samples of guava slices. The highest concentration of ascorbic acid was found in freeze-dried samples followed by microwave 100 W and oven 80°C treatments. We found Freeze drying is considered as one of the most accurate method to preserve nutrients in fruits and vegetables (Ratti, 2001) but due to high operational cost, this method is used as a reference method rather than commercial one (Stralsjö, 2003). Shadle *et al*. (1983) and Yang and Atallah (1985) conducted the similar methods for carrots and blueberries. They concluded that freeze drying method preserve more ascorbic acid contents as compared to convection and microwave ovens. The comparison among oven treatments (Figure 2), evidently indicates that short drying duration preserves more ascorbic acid contents as compared to low drying temperature. On the other hand, the comparison among microwave drying treatments of 440 versus 1000 W and 100 versus 600 W treatments are non-significant ($P < 0.05$) with each other. It indicates that during 100 and 440 W treatments, heat supply was less, but drying duration was more while during 600 and 1000 W treatments the heat supply was more but drying duration was short. Which means that drying duration and heat supply has a significant effect on ascorbic acid degradation. The ascorbic acid content in sun dried guava slices was lower as compared to all other drying treatments. The lowest value of sun-dried samples indicates that the ascorbic acid in guava fruit is highly sensitive to sunlight, oxygen and drying duration. The direct sunlight, may be considered as the commonly drying methods for fruits, leaves and vegetables all over the world because it is relatively cheaper as compared to other methods. Although sun drying is cheaper, but not good for fruits in terms of nutrient preservation, especially fruits having high concentration of vitamin C. These results are consistent with the findings of Marques *et al*. (2006) on tropical fruits.

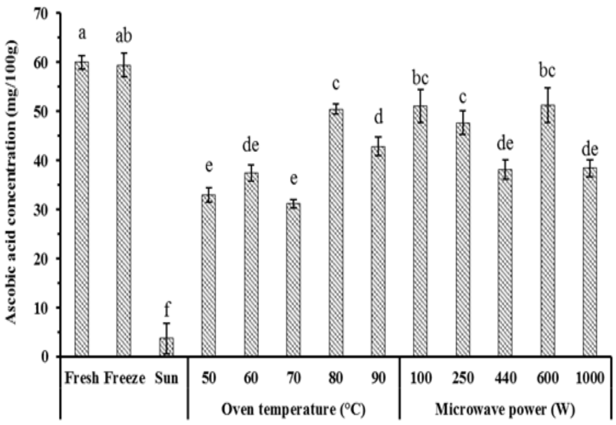

Figure 2. The ascorbic acid concentration of fresh and dried guava slice samples under different treatments. Bars with different letters are significantly different ($P < 0.05$).

Previous studies on fruits (apricot and kiwi) and vegetable (potato) drying by microwave and convection oven on ascorbic acid concentration also concluded that the degradation of ascorbic acid was heat and time dependent (Khraisheh *et al*., 2004; Özkan *et al*., 2007; Karatas and Kamişli, 2007; Diamante *et al*., 2010). Jayaraman and Das Gupta (1995) also concluded that fast drying preserves maximum ascorbic acid contents than slow drying.

Conclusion

The guava slices were dried with 12 different drying treatments and studied the effect of drying methods, heat supply, drying time, light and oxygen exposure. We found drying temperature and drying time are the key parameters which directly affect the ascorbic acid concentration in guava. The present study negates the sun drying method not only due to its less preservation of ascorbic acid contents but also damages the colour quality of slices. We found freeze-drying treatment as the most suitable procedure to preserves maximum ascorbic acid content and colour quality of guava, but it is quite expensive technique as compared to convection and microwave oven methods.

Acknowledgements

The present research work was funded by the Fundamental Research Grant Scheme (FRGS) with project code 03-02-13-1289FR. The authors gratefully acknowledge the Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia for laboratory facilities and University of Agriculture of Faisalabad. M.A. Ali also acknowledge the support from Government of Pakistan for providing PhD scholarship.

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