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Drying kinetics and quality aspects of bitter gourd (*Momordica charantia*) dried in a novel cabinet dryer

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Abstract

An attempt was taken to investigate the effect of drying air temperature and slice thickness on the drying kinetics and quality of bitter gourd (*Momordica charantia*) dried in a novel cabinet dryer (HSTU Fruit and Vegetable Dryer). Fresh bitter gourd was sorted, cleaned, and sliced at 4 mm, 6 mm, and 8 mm thickness. All the samples were blanched in boiling water at 100°C for 3 mins. Then the slices with an initial moisture content of 96.47±0.6% were dried, spreading as a thin layer in the trays of the cabinet dryer using three drying air temperatures of 60, 70, and 80°C until the desired final moisture content (MC) of 4.66±0.4% was obtained. The results indicated that the shortest drying time (2.08 hrs) was required by the sample of 4 mm thickness, which was dried at 80°C to reduce moisture from 96.47±0.6% initial (wet basis, wb) to 4.66±0.4% final moisture (wb). The sample of 8 mm thickness dried at 60°C took the longest drying time (6.67 hrs). The higher drying rate (34.32 gm H_2O/min.cm^2) was noticed at a constant drying rate period in the case of a 6 mm thick slice at 70°C. Whereas a lower drying rate (9.29 gm H_2O/min.cm^2) was observed for drying 8 mm slices using 60°C air temperature. Even though, the effect of blanching on drying characteristics of bitter gourd was not noticed so much, the drying rate was found to be increased slightly of pretreated bitter gourd thus drying time was shorter. A comparison on colour analysis of both fresh and blanched bitter gourd showed that a 6 mm slice dried at 70°C was found better in retaining green colour than other samples. The rehydration ratio (6.63±0.62) and the percentage of water uptake (86.75±0.58) of rehydrated pretreated bitter gourd were also higher in a dried sample of 6 mm. Therefore, pretreated bitter gourd is suggested to dry quickly using 70°C in a cabinet dryer slicing at 6 mm thickness to obtain a better quality dried product.

1. Introduction

Investigation of suitable operating parameters of cabinet dryer for drying bitter gourd is important as it is abundantly grown in Bangladesh. It is one of the lofty vegetables in the world that belongs to the family of Cucurbitaceae. This vegetable is well-known in southern Asia and is used in a variety of recipes. They are highly nutrient-dense and include a significant amount of protein, minerals, vitamins and polysaccharides (Aziz *et al.,* 2011). The annual production of bitter gourd is 57908 metric tons in Bangladesh (BBS, 2019). The selling price of a bitter gourd becomes very low in the peak season; consequently, growers lose their profit. It is found to be a surplus of larger quantities of this vegetable due to the massive production and supply. Any suitable preservation technique like drying of such vegetables can prevent this huge wastage and make them available in the off-season at a reasonable price. This preservation of the bitter gourd would reduce the wide fluctuation of prices in the pick harvesting period and offseason. Processing and preserving bitter gourd as shelf-stable products using efficient drying methods and effective utilization of the finished products would increase its availability throughout the year.

Naturally, fruits and vegetables are covered in a protective wax that can prevent moisture from escaping during drying. Pretreatment's primary focus is to inactivate enzymes like polyphenol oxidase, peroxidase, and phenolase, as well as to stop some undesired chemical reactions that cause a product's numerous negative effects (Hiranvarachat *et al.*, 2011). Blanching is a typical pretreatment for vegetables before they are thermally processed, frozen, or dried. It has two basic goals: inactivating naturally occurring enzymes and

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removing gases from surfaces and intercellular spaces to avoid oxidation, staining, and off-flavour development, as well as lowering the initial quantity of microbes. In many fruits and vegetables, pre-treatments are useful for permeation, enzyme inactivation, browning, and accelerating the drying process. Bitter gourds were therefore, pre-treated using various procedures, including hot water blanching, steam blanching, microwave blanching, and chemical dipping (Mitra *et al.,* 2013). Water blanching is a method of uniformly cooking vegetables by exposing them to a temperature range of 70–100ºC for 1–2 mins (Arroqui *et al.,* 2001). It has been widely used for a variety of fruits and vegetables, including bitter gourd (Choo *et al.*, 2014), pineapple (Agarry *et al.,* 2013), and bell pepper (Agarry *et al.,* 2013) (Akintunde *et al.*, 2011). Pham *et al.* (2017) stated that bitter gourd drying could extend its shelf life and prevent microbiological action by lowering moisture content. Since dried products would be suitable for food uses only if they retain good colour, flavour, texture, and nutritional value when water is added back to them, the parameters that influence drying and reconstruction must be carefully selected to inflict as little injury to it these qualities as possible.

A cabinet dryer is one of the leading dryers for drying such products because desired temperature and airflow can be maintained at a cabinet drier compared to other dryers. This provides high production rates and yields quality products due to shorter drying time and reduced risk of microbial spoilage. A mechanical dryer is not dependent on the sun so it can be operated when necessary. A cabinet dryer is advantageous for its high thermal efficiency, suitability for applying high temperatures, reduce labour cost, and easy operation. Drying would reduce the volume and thus minimize the transportation cost to get a good quality product at a minimum price. Most modern preservation methods such as canning, freezing, and more require high initial costs for installing sophisticated machinery and equipment, a skilled workforce, and significant capital investment. However, the marginal farmers producing the perishable food items cannot invest enough money to install this machinery. They always look for low-cost technology to preserve their products. Drying is a critical process for preserving and reducing the cost of transporting and storing plant materials (Shishir *et al.,* 2018).

Numerous research on bitter gourd drying has been published, including sun drying, solar drying, and hot air drying by Mehta *et al.* (2017), freeze-drying, infrared radiation drying, and hot air drying by Yan *et al.* (2019), and microwave-assisted convective drying by Zahoor and Khan (2019). However, a novel cabinet dryer (HSTU Fruit and Vegetable Dryer) was used in this experiment for drying bitter gourd where uniform air velocity and temperature were possible to maintain in all sections and trays of the dryer resulting in a uniform and quick drying.

Hence, the present attempt aimed to investigate suitable drying parameters (temperature and product thickness) for quality dried bitter gourd. Therefore, the effect of pretreatment, slice thickness, and drying air temperature on drying kinetics of bitter gourd and its quality (in terms of colour, rehydration ratio of dried bitter gourd and percentage of water uptake of rehydrated bitter gourd) were evaluated.

2. Materials and methods

Around 5 kg of fresh bitter gourds (Kakoli F1 variety) were purchased from local farmers, ensuring the variety. These were washed in tap water and sliced at 4 mm, 6 mm, and 8 mm thickness. Seeds were removed from the slices and kept in boiling water at approximately 100°C for 3 mins (Sharma *et al.,* 2014). After blanching, the samples were cooled in the air. The blanched samples were dried at three different temperatures of 60°C, 70°C, and 80°C in a novel cabinet dryer (HSTU Fruit and Vegetable Dryer). The newly developed dryer consists of a bank of the heating coil, circulating fan, and four trays for drying where uniform air velocity and temperature are possible to maintain in all sections of all the trays as shown in Figure 1. The bitter gourd slices were loaded in a thin layer on trays of the dryer. Actual drying was considered when a stable condition for desired drying temperature was maintained. Moisture reduction was recorded after 30 mins intervals. The samples were dried until to reach equilibrium moisture content. The dried samples were then cooled in a desiccator and packaged into polyethylene bags that were heat-sealed and kept at room temperature in a desiccator. Three replicates of each experiment were performed, and an average value was calculated.

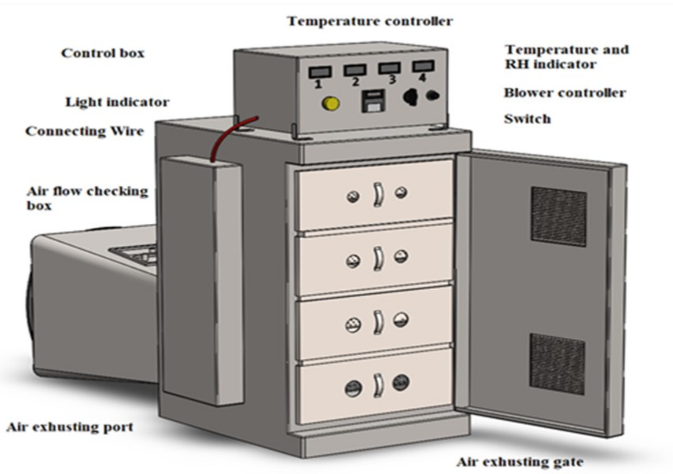

Figure 1. Experimental setup (HSTU Fruit and Vegetable Dryer) for bitter gourd drying

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2.1 Determination of moisture content

The moisture content of fresh and dried bitter gourd samples was determined using the oven drying method at a temperature of 105°C for 24 hrs (AOAC, 2005).

$$MC_{wb} = \frac{W_i - W_d}{W_i} \times 100 \quad (1)$$

Here, MC_{wb} refers to the moisture content in the wet basis of the samples, W_i is the initial weight of bitter gourd (g), and W_d is the weight of bone dried bitter gourd (g).

The free moisture content at any time during drying was calculated as follows:

$$X = Xt - X* \quad (2)$$

Where, Xt is the moisture content at any time and X^* is the equilibrium moisture content.

2.2 Calculation and plotting of drying rate

The drying rate in this research was considered as the amount of moisture per unit area per unit time, which was calculated using the following equation (Eheim *et al.,* 2008).

$$R = -\frac{L_s}{A_t} \times \frac{\Delta x}{\Delta t} \quad (3)$$

Here, R refers to the drying rate in gm $H_2O/min.cm^2$, L_s is the bone dry sample weight (kg), A_t is the exposed surface area in cm^2, Δx is the change of free moisture, Δt is the change of time (min). Drying rate curves were plotted R vs X.

2.3 Rehydration ratio

The rehydration ratio is defined as the mass of rehydrated and drained food to the mass of the dried material. It is generally expressed as a percentage. It was determined by soaking a known weight of dried samples of approximately 2±0.01 g in a 250 mL beaker, containing 150 mL distilled water at 65ºC (Doymaz, 2017). At the end of the rehydration time (3 hrs), the samples were taken off, and blotted with tissue paper to remove the excess water on the surface and finally their weight was taken. The rehydration ratio was calculated as:

$$RR = \frac{W_2 - W_1}{W_1} \quad (4)$$

Where, RR refers to the rehydration ratio, W_1 is the weight of dried material (g) and W_2 is the weight of rehydrated material (g).

2.4 Percentage of water in the rehydrated sample

The percentage of water content in the rehydrated material was calculated using the equation proposed by Ranganna (1986).

$$\%\ \text{water in rehydrated sample} = \frac{(\text{drained weight of a rehydrated material}) - (\text{dry matter content in the sample taken for rehydration})}{(\text{drained weight of a rehydrated material})} \quad (5)$$

2.5 Colour measurement

The colour parameters (L*, a*, b*) of the fresh and dried bitter gourd sample were determined by using a colourimeter (Minolta CM-2500d). Each colour test was replicated three times. The L*, a*, b*, and ΔE values indicate the lightness coefficient, red colour coefficient, yellow colour coefficient, and the relative colour different index. ΔE was calculated using the equation proposed by (Wu *et al.,* 2014):

$$\Delta E = \sqrt{(L* - L_o)^2 + (a* - a_o)^2 + (b* - b_o)^2} \quad (6)$$

Where, "$_o$" is the colour reading of fresh samples used as control.

2.6 Statistical analysis

A single-factor CRD design was employed for this experiment. The factor was the combination of drying air temperature and slice thickness. There were nine levels of the factor with the combination of three slice thicknesses (4 mm, 6 mm, and 8 mm) and drying air temperatures (60ºC, 70ºC, and 80ºC) and the response parameters were colour, rehydration ratio (RR) and percentage of water uptake of rehydrated bitter gourd. Each observation was repeated thrice, and results were expressed as mean±standard deviation. The obtained data were analyzed by SAS (Version 9.3) statistical software. One-way analysis of variance was done using ANOVA procedures. Significant differences among the means of response values were determined by Duncan's Multiple Range Test (DMRT) at the 95% confidence level.

3. Results and discussion

3.1 Pretreatment effect on drying time

The drying time of bitter gourds was affected by the pre-treatment method (blanching). The samples that were blanched in boiling water before drying had a shorter drying time compared with the blanched and controlled samples. At 70°C, the required drying time to obtain final moisture content (4.66%) was 2.5 hrs for the control sample (Figure 3). The blanched samples had a corresponding value of 2 hrs at the same temperature and thickness (4 mm). Similar behaviour was found in temperatures of 60°C and 80°C. These findings revealed that blanching bitter gourd slices in hot water increased the porosity of the cell membranes, resulting in an increase in water diffusivity. Previous research on the effect of pre-treatment on drying time for other biological products has also been reported by (Doymaz

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2017) for carrot slices, Bi *et al.* (2015) for apple chips. The same findings were found in apricot drying, red pepper drying (Doymaz and Pala, 2002), and ginger drying (Deshmukh *et al.* 2013).

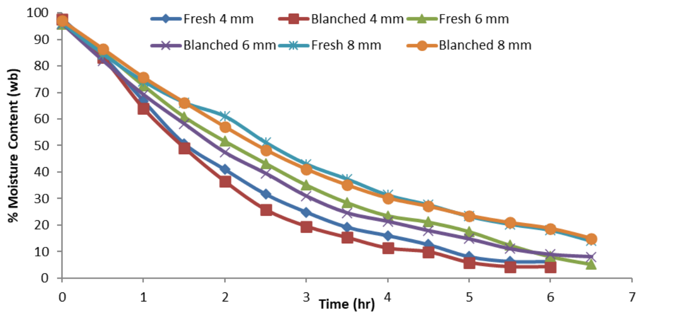

Figure 2. Effect of slice thickness on drying time of bitter gourd dried at 60°C.

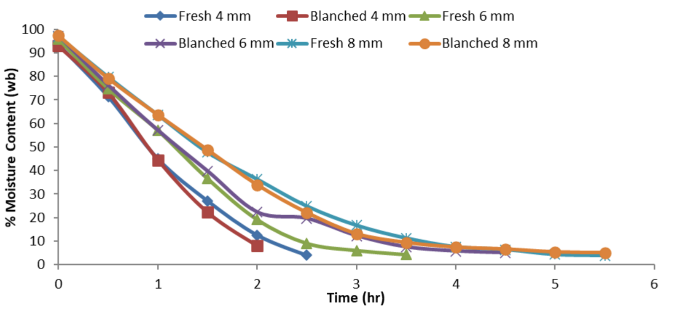

Figure 3. Effect of slice thickness on drying time of bitter gourd dried at 70°C.

3.2 Effect of slice thickness on drying time

Figure 2 to Figure 4 shows the effect of slice thickness on drying kinetics of bitter gourd in a cabinet dryer. It is evident from these curves that the moisture removal was higher at a thin slice. Almost 50% moisture was found to be removed in the first two hrs and the remaining amount was reduced within 5 to 7 hrs. This rapid moisture removal occurred in free water from the product. Drying of bound water was noticed slower. Figure 2 also shows a shorter drying time for small thicknesses and a longer drying time for thicker sliced bitter gourd at the same temperature (60°C). Blanched samples were found to be dried faster than the fresh sample. This faster drying might be the reason for the increase in the porosity of the product cell membrane due to pretreatment. Similar trends were observed in

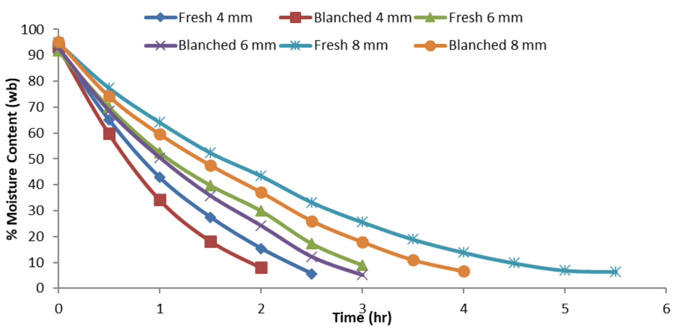

Figure 4. Effect of slice thickness on drying time of bitter gourd dried at 80°C

Figure 3 and Figure 4 shows that an 8 mm thick slice (fresh) takes a higher time (5.5 hrs) than a 4 mm thick slice (2.5 hrs) at an exact temperature of 80°C. Thinly sliced products were found to be dried faster due to the enlarged surface area exposed for a given volume of the product. Similar findings were obtained by Ertekin and Yaldiz (2004) for hot-air drying of eggplant slices, Wu *et al.* (2014) for infrared and hot-air drying of carrot slices, and Wu *et al.* (2014) for infrared and hot-air drying of carrot slices Goyal *et al.* (2006) El-Amin *et al.* (2009) for mango fruit and some other fruits and vegetables Akpinar (2003); Akanbi *et al.* (2006). This result shows that despite the rate of moisture content change decreasing with increasing thickness, the weight of moisture removal per unit time is increased.

3.3 Effect of temperature on drying time

The moisture content versus drying time data obtained from the experiments was used to determine the effect of drying temperature on drying kinetics. Figure 5 shows that the increase in the drying air temperature from 60°C to 80°C causes a significant reduction in drying time, confirming that the total drying time is reduced with increased air temperature. For example, the drying time of 4 mm thick bitter gourd slice reduced from 6.67 to 2.08 hrs when the temperature was increased from 60 to 80°C (Figure 5). This variation might be due to the rigid texture of bitter gourd taking a long time for drying. Higher temperature resulted in increasing thermal energy in the samples thus a shorter drying time was required. However, higher thickness influenced taking longer time for moisture removal during drying. A similar trend was observed for 6 mm and 8 mm thick-sliced bitter gourd at the same temperatures (Figure 6 and Figure 7). These results agreed with the findings (Vega-Gálvez *et al.*, 2012) for apple slices, (Vega-Gálvez *et al*., 2015) for Cape gooseberry, (Xiao *et al*., 2010) for carrot cubes and

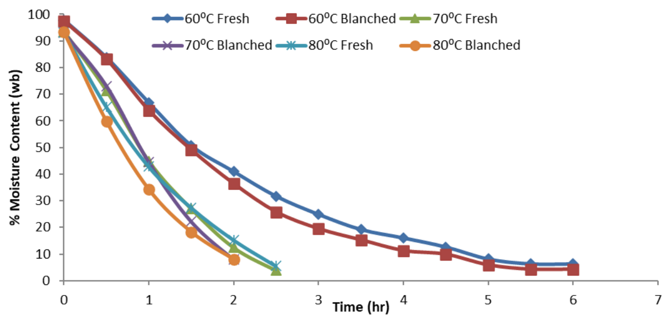

Figure 5. Effect of temperatures (60°C, 70°C and 80°C) on drying time of bitter gourd slice (4 mm thick)

(Doymaz, 2017) for carrot slices.

3.4 Drying rate of bitter gourd slice

The drying rates are presented as the quantity of moisture removed per unit time and unit area versus free

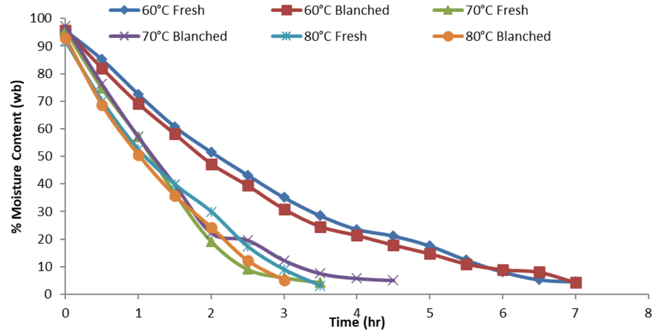

Figure 6. Effect of temperatures (60°C, 70°C and 80°C) on drying time of bitter gourd slice (6 mm thick)

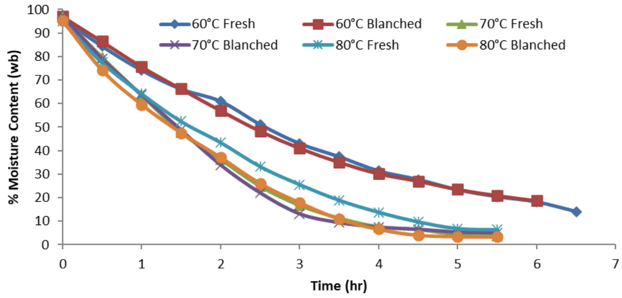

Figure 7. Effect of temperatures (60°C, 70°C and 80°C) on drying time of bitter gourd slice (8 mm thick)

moisture content, as shown in Figure 8 to Figure 10. It is noticeable that higher drying temperature showed a steeper drying rate indicating that higher temperature promotes faster drying. The drying rate decreased continuously with reducing moisture content. It was higher when the free moisture was at the highest level. The drying rate also reached its maximum value when higher drying air temperatures were applied. Coklar *et al.* (2017) reported that the boundary layer around the bitter gourd becomes thinner and the heat is transferred by hot air, increasing the drying rate and reducing the drying time. The moisture removal inside the bitter gourd slices was higher at high drying air temperatures because the movement of moisture to the surface and the evaporation rate from the surface to air slows down with decreasing the moisture from the slices, therefore drying rate of bitter gourd decreases. thus the drying rate decreases (Figure 8 to Figure 10). A slight constant drying rate period was observed in the drying curves, and the whole drying process takes place in three phases, a short primary increasing, a constant, and a falling rate drying period. This trend is due to faster removal of free moisture from bitter gourd surface and slower removal of bound water. It is seen from Figures 8 to Figure 10 that the drying rate was higher at the starting periods of drying, in constant drying rate periods (34.32 gm H_2O/min.cm^2) at 70°C (6 mm thick slice) and lower at 60°C (9.29 gm H_2O/min.cm^2) 8 mm thick slice (Figure 8 to Figure 10). These results are in agreement with the observations of earlier researchers in drying various vegetables (Wu *et al.*, 2014).

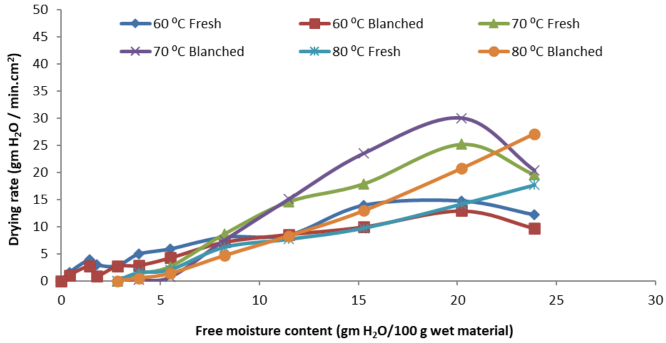

Figure 8. Drying rate of 4 mm thick bitter gourd dried at three different temperatures

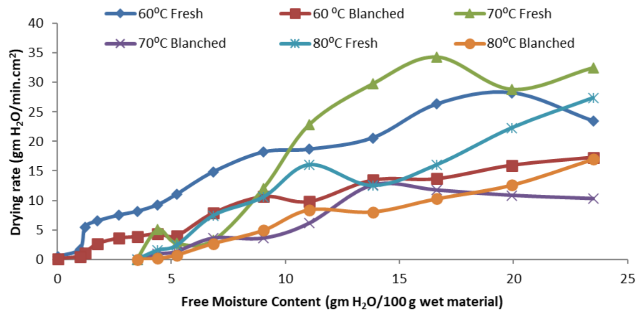

Figure 9. Drying rate of 6 mm thick bitter gourd dried at three different temperatures

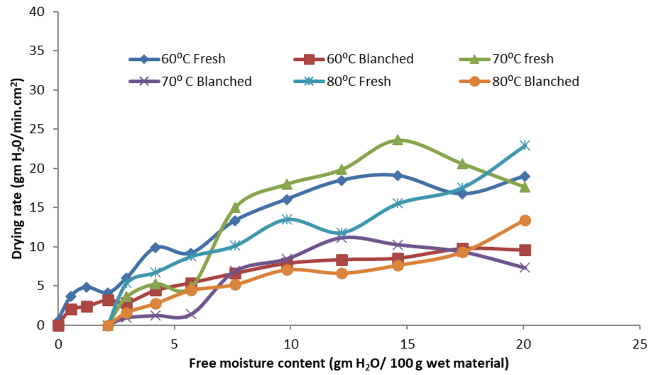

Figure 10. Drying rate of 8 mm thick bitter gourd dried at three different temperatures

3.5 Quality aspects of bitter gourd

3.5.1 Colour quality

This study showed significant differences at (P≤0.05) in colour values of fresh and dried bitter gourds (Table 1 and Table 2). Table 1 shows an apparent effect of drying on colour parameters of bitter gourds. Bitter gourd dried at 70°C and 6 mm thick slice reveals lower a* value than other dried samples (Table 1), indicating better retention of greenness in lower thickness and higher temperature. Table 2 displays a clear effect of blanching on the colour quality of bitter gourd dried at three different temperatures. Blanched samples retain greener colour than the control (fresh) sample because they prevent discolouration. Bitter gourd dried at 70°C and sliced at 6 mm contains a lower a* value (7.77±0.29) followed by other dried samples. Lower a* value

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Table 1. Colour parameter of fresh and novel cabinet dried bitter gourd

Sample	Bitter gourd 4 mm thick slice				Bitter gourd 6 mm thick slice				Bitter gourd 8 mm thick slice			
Colour Parameter	Control (Fresh)	60°C	70°C	80°C	Control (Fresh)	60°C	70°C	80°C	Control (Fresh)	60°C	70°C	80°C
L*	42.38 ±3.85^{a}	34.87 ±2.87^{cde}	38.37 ±1.00^{abc}	20.26 ±2.18^{g}	40.47 ±4.27^{ab}	32.52 ±1.78^{de}	35.69 ±0.93^{cde}	31.34 ±2.02^{e}	36.83 ±4.27^{bcd}	35.57 ±2.03^{cde}	26.44 ±1.86^{f}	32.34 ±2.02^{de}
a*	-8.74 ±0.72d^{e}	0.65 ±0.01^{c}	0.47 ±0.14^{c}	0.39 ±0.02^{c}	-8.96 ±0.15^{e}	2.89 ±0.53^{b}	0.55± 0.14^{c}	0.88 ±0.03^{c}	-8.22 ±0.18^{d}	4.31 ±0.98^{a}	0.62 ±0.06^{c}	0.88 ±0.10^{c}
b*	24.89 ±3.83^{a}	18.42 ±1.05^{cd}	21.04 ±1.46^{bc}	13.40 ±1.15^{f}	25.02± 1.30^{a}	16.77±1 .00de	22.09± 1.59^{ab}	14.74 ±1.05^{ef}	22.67 ±1.12^{ab}	20.91 ±1.00^{bc}	16.56 ±1.22^{de}	19.55 ±2.10^{bcd}

Values are presented mean ± standard deviation of three replicates. Values with different superscripts within the same row are significantly different (P≤0.05). L* = lightness; a* = red (+)/green (-); b* = yellow (+)/blue (-)

Table 2. Colour parameter of blanched and novel cabinet dried bitter gourd

Sample	Bitter gourd 4 mm thick slice				Bitter gourd 6 mm thick slice				Bitter gourd 8 mm thick slice			
Colour Parameter	Blanched	60°C	70°C	80°C	Blanched	60°C	70°C	80°C	Blanched	60°C	70°C	80°C
L*	69.11 ±2.65^{a}	22.52 ±0.65^{e}	35.1 ±3.07^{de}	27.69 ±4.06^{e}	55.35 ±8.59^{cd}	25.27 ±5.51^{e}	48.27 ±7.54^{cd}	30.13 ±2.05^{de}	59.77 ±6.9^{ab}	25.70 ±10.79^{e}	26.83 ±3.99^{de}	29.62 ±5.20^{f}
a*	0.93 ±0.31^{e}	8.05 ±1.22^{bcd}	7.33 ±1.13^{d}	10.04 ±1.90^{bcd}	-7.13 ±3.05^{f}	17.54 ±3.35^{a}	7.77 ±0.29^{cd}	11.90 ±0.58^{b}	-2.18 ±2.92^{e}	17.03 ±0.64^{a}	11.69 ±1.71^{bc}	9.65 ±2.35^{bcd}
b*	23.99 ±1.69^{a}	3.29 ±0.89^{ef}	17.32 ±2.52^{bc}	10.9 ±4.24^{cde}	28.04 ±1.6^{a}	9.14 ±7.4^{def}	24.01 ±1.50^{ab}	14.63 ±2.30^{bc}	25.78a ±0.49^{a}	9.25 ±0.37^{def}	9.90 ±4.90^{cd}	12.89 ±5.19^{f}

Values are presented mean ± standard deviation of three replicates. Values with different superscripts within the same row are significantly different (P≤0.05). L* = lightness; a* = red (+)/green (-); b* = yellow (+)/blue (-)

indicates higher greenness of bitter gourd. Previous studies have found that pretreatments, such as blanching bitter gourd in a hot water, can block the enzymatic reaction (which causes discolouration) and act as a green colour fixing agent (Hossain and Bala, 2007). No significant difference was found in the colour value of the blanched sample.

The b* values are also shown in Table 1 and Table 2. The initial and final b* values significantly varied from 25.02±1.30 to 22.67±1.12 (fresh bitter gourd) and 22.09±1.59 and 13.40±1.15 (dried bitter gourd) as the drying air temperature increased from 60 to 80°C (Table 1). Similarly, the blanched sample contains b* values ranging from (28.04±1.6 to 23.99±1.69) and after drying, the values differ from (17.32±2.52 to 3.29±0.89) at 60 to 80°C temperature. Demiray and Tulek (2014) and Koca *et al.* (2007) revealed that the loss of b value specifies that the yellowness of samples decreased due to the application of drying air temperatures, and it may possibly be due to degradation of carotenoid pigments, non-enzymatic Maillard browning, and formation of brown pigments. In contrast, higher colour degradation in the dried sample may be due to oxidative reactions during the drying process, which is potentiated by drying air temperature.

3.5.2 Rehydration ratio

The degree of rehydration of dried products is a measure of structural quality, and it is determined by the blanching and drying conditions. From Table 3, the maximum rehydration capacities (6.63±0.62) were observed in 6 mm blanched samples dried at 70°C, followed by 4 mm and 8 mm blanched samples were 5.2±0.47 and 5.12±0.47, respectively. 6 mm blanched samples had higher rehydration ratio values than the control sample within the same drying temperature. The same findings were found in carrot drying (Doymaz, 2017) red pepper drying (Doymaz and Pala, 2002), and ginger drying (Deshmukh *et al.*, 2013). According to previous studies, this result showed that blanching prior to drying improves the rehydration capacity of dried samples. According to Prakash *et al*. (2004), mechanical drying improved the rehydration ratio by evaporating moisture faster at higher temperatures and producing reduced shrinkage of the dried bitter-gourd sample. Also, pretreatment of hot water blanching leads to a higher rehydration ratio in bitter-gourd (6.63±0.62). This is due to the fact that hot water blanching causes more molecular cell breakdown and water non-uptake, resulting in increased water absorption upon rehydration of hot water blanched vegetable samples (Ozgur *et al.,* 2011).

3.5.3 Percentage of water uptake of rehydrated bitter gourd

Table 4 indicate the percentage of water absorbed by the dried sample reached the highest level during the 90 mins duration, followed by a gradual increase in the water content. The bitter gourd slices (6 mm blanched) dried at 70°C, noted the highest water absorption (86.75±0.58%) up to 90 mins of soaking followed by control (fresh), the lowest water uptake (69.78±0.22%). The rehydration of the dehydrated bitter gourd (4 mm blanched) dried at 80°C indicated that the moisture content was 85.75±1.25% after 90 mins of soaking. Among the three drying temperatures, the maximum reconstitution after rehydration of dried bitter gourd slices was observed in samples dried at 70°C. Vega-Galvez *et al.* (2015) stated that the ability of dried products to reconstitute depends on the cell structure of the food sample and the amount of water holding components (starch and proteins) damaged during drying.

4. Conclusion

Drying characteristics of bitter gourd slices dried in a

Table 3. Rehydration ratio of fresh and blanched bitter gourd

Sample	Bitter gourd dried at 60°C			Bitter gourd dried at 70°C			Bitter gourd dried at 80°C		
Thickness	4 mm	6 mm	8 mm	4 mm	6 mm	8 mm	4 mm	6 mm	8 mm
Fresh	6.22±1.67^{a}	4.22±1.34^{bcd}	2.31±0.02^{e}	5.50±0.79^{ab}	4.87±0.13^{abc}	3.01±0.15^{de}	4.50±0.25^{bcd}	3.29±0.3^{de}	3.58±0.6^{cde}
Blanched	5.11±0.29^{ab}	5.10±0.7^{ab}	6.20±2.60^{a}	5.20±0.47^{ab}	6.63±0.62^{a}	5.12±0.47^{ab}	6.03±0.29^{ab}	5.58±0.9^{ab}	4.13±0.67^{b}

Values are presented mean ± standard deviation of three replicates. Values with different superscripts within the same row are significantly different (P≤0.05).

Table 4. Percentage of water uptake of the rehydrated bitter gourd

Sample	Bitter gourd dried at 60°C			Bitter gourd dried at 70°C			Bitter gourd dried at 80°C		
Thickness	4 mm	6 mm	8 mm	4 mm	6 mm	8 mm	4 mm	6 mm	8 mm
Fresh	85.65± 3.27^{a}	80.0± 5.0^{bcd}	69.78± 0.22^{f}	84.47± 1.88^{a}	82.97± 0.36^{ab}	75.02± 0.92^{e}	81.79± 0.83^{abc}	76.62± 1.63^{e}	77.92± 2.88^{cde}
Blanched	83.60± 0.76^{ab}	83.46± 1.9^{ab}	84.85± 5.30^{a}	83.96± 1.22^{ab}	86.75± 0.58^{a}	83.59± 1.25^{ab}	85.75± 0.58^{a}	84.61± 2.17^{ab}	80.30± 2.54^{b}

Values are presented mean ± standard deviation of three replicates. Values with different superscripts within the same row are significantly different (P≤0.05).

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novel cabinet dryer at various temperatures of 60°C, 70°C, and 80°C were investigated. The drying air temperature, slice thickness and pretreatment had significant effects on drying time, rehydration, and colour quality characteristics. The drying process of almost all bitter gourd samples followed falling rate periods except very few that followed a slightly constant rate. The highest drying rate (34.32 gm H_2O/min.cm^2) was found in bitter gourd dried at 70°C and sliced at 6 mm. On the other hand, the lowest drying rate (9.29 gm H_2O/min.cm^2) was observed at 60°C temperature and 8 mm pretreated thick slice. Bitter gourd sliced at 6 mm thickness and dried at 70°C temperature exhibited better colour, rehydration ratio and percentage of water uptake after rehydration. Therefore, pretreated bitter gourd is suggested to dry quickly using 70ºC in a cabinet dryer slicing in 6 mm thickness for obtaining a good quality dried product.

Conflict of interest

The authors have declared no conflict of interest.

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