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Physico-Chemical Analysis of Bitter Gourd Dried using Biomass Dryer

Sahil Shiraj Shaikh[1], Alice Ishwarbhai Kothari[1], Sumit Kumar[2*], Ishita Auddy[2], Amar Shankar[2], Bhaskar Dixit C.S.[3] and Sachin Payyanad[3]

[1]M.Tech. Scholar, Department of Food Technology, Faculty of Engineering and Technology, JAIN (Deemed -to-Be-University), Jakkasandra Post, Kanakapura Taluk, Ramanagara District (Karnataka), India.
[2]Assistant Professor, Department of Food Technology, Faculty of Engineering and Technology, JAIN (Deemed -to-Be-University), Jakkasandra Post, Kanakapura Taluk, Ramanagara District (Karnataka), India.
[3]Fire and Combustion Research Center, JAIN (Deemed -to-Be-University), Jakkasandra Post, Kanakapura Taluk, Ramanagara District (Karnataka), India.

(Corresponding author: Sumit Kumar)*
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ABSTRACT: Bitter Gourd is a vegetable which grow in huge amount across globe due to its beneficial properties. The fruit, seed, leave, vine and roots of bitter gourd have been used as food and remedy for various types of diseases. Bitter gourd is rich source of Vitamin A, Vitamin C, Total phenolic content, Iron, Amino acid, Carotenoid, Thiamin, Riboflavin, Viscin and Minerals. The presence of these important compounds makes it a good candidate for human consumption. Bitter gourd vegetable contains compounds which may improve insulin sensitivity, lower blood sugar levels, and aid in the regulation of postprandial/intestinal glucose uptake. It is used commonly as a fresh and dried vegetable of Bitter gourd in curries, baked products, pickles, filled dishes and juices. The drying of Bitter guard using biomass dryers can improve the quality and make it shelf-stable till further usage. The dried Bitter guard can be used for longer period of time compare to the fresh Bitter guard with improved quality. The cabinet dried Bitter guard found to have moisture (7.5%), fat (9.16%), ash (6.69%), protein (11.7mg), fiber (10.1 mg), vitamin A (132 mcg), vitamin C (91 mg) and total phenolic content (61μg/g) whereas surface dryer observed to have moisture (6%), fat (9.1%), ash (6%), protein (12.4 mg), fiber (10.3 mg), vitamin A (139.6 mcg), vitamin C (97.3 mg), total phenolic content (68 μg/g) are obtained. Drying pre-treatment resulted in the improved physico-chemical properties of Bitter guard which might be due to prevention in the undesirable physicochemical changes during the drying process and subsequent storage, as well as inhibiting microbiological action. The enormous price changes throughout the harvest and off-season would be mitigated if the bitter gourd is stored properly.

Keywords: Bitter guard, Drying, Biomass dryer, Drying kinetics, Physico-chemical analysis.

INTRODUCTION

The bitter gourd (*Momordica charantia*) is a member of Cucurbitaceae family which is extensively cultivated in various parts of the world majorly Asia, South America, India, the Caribbean, East Africa, Middle East, America, Mediterranean countries such as Turkey and Italy. The bitter gourd originated in Africa and was domesticated over a period in Asia which could be evidenced by Sanskrit records from the Indo-China Aryan way of life (Abhishek *et al.*, 2021). The bitter gourd is an annual vegetable also known as melon, Karela, or balsam pear. It is Turkish name is known as ‘Kudret Nary’. The fruits are 8-15 cm long and 4-10 cm wide; the surface of the fruit is rough and sharpens towards the tip. The fruit, which starts as green, matures to yellow and bright yellow and contains 20-30 dark red bean-like seeds. It is used as a natural medicine after being mixed with olive oil (Ahmad *et al.*, 2022). It has an overall production of 3.14 MT at an area of 0.192 M ha (APEDA, 2022).

The vegetable (bitter guard) is a rich source of bioactive chemical content which include ascorbic acid, phenolic acids, carotenoids, flavonoids, proteins, minerals, and dietary fibers. It consists of low sugar content which makes it more acceptable for consumption for by man beings. The presence of therapeutic properties in bitter guard makes it a valuable vegetable for human consumption (Aminah and Permatasari 2013). Bitter gourd has been scientifically proven to have anti-diabetic, 37 anti-bacterial, antiviral, and anticancer properties. Animal studies have revealed the impact of bitter gourd supplementation on weight growth and lipid metabolism. Several research has been conducted to investigate the effects of bitter gourd extracts on insulin resistance (Arun *et al.*, 2021). The production of bitter gourds suffers significantly due to the lack of post-harvest technology, processing methods and storage facilities, despite their high nutritional content and health-promoting properties. Accordingly, new technologies must be developed in order to preserve bitter gourds and reduce post-harvest losses. Dehydration is one of the most fundamental methods for preserving fruits and vegetables (Ayyappan & Mayilsamy 2010; Babu *et al.*, 2018).

The bitterness of bitter guard is due to Cucurrbitane tritrepenoids, such as cucurbitacin (Sapogenins) and cucurbitane glycosides (Biswas *et al.*, 2018; Chauhan *et al.*, 2018). Bitter guard is rich source of phosphorus, vitamin C, vitamin A, and iron. Regular consumption of bitter gourd leads to improve the phosphorus deficiency in the human body. Bitter gourd stimulates the liver, and splee, purifies the blood, and shows beneficial effects for diabetic patients whereas the novel technologies (power ultrasound, microwave, pulsed electric field) could affect the nutritional values of food products (Kumar *et al.*, 2023; Dhotre *et al.*, 2012). Apart from the diabetic patient, the decoction was found to be more effective in preventing stomachaches, toothaches, liver diseases, mellitus, hypertension, and cancer than the often-consumed bitter gourd meals. Bitter gourd fruit contains substances that may improve insulin sensitivity, lower blood sugar, and help regulate postprandial/intestinal glucose uptake (Chaung *et al.*, 2018; Yang *et al.*, 2020).

The dried bitter gourds are frequently used as fresh and dried vegetables in curries, baked goods, filled foods, juices, pickles, or filled meat products. It is also utilized in the production of numerous foods. To prepare tea, it can be fried, deep-fried, boiled, and dried. The ripe fruit seeds are used as a condiment (Deepa, 2015). Pre-treatments serve to improve the shelf life of dried items by preventing undesired physico-chemical and other qualitative changes which occur during the drying process, and storage, and inhibit microbial action (Dhotre *et al.*, 2012). If the bitter gourd was preserved, the significant price swings can be reduced during pick harvest and the offseason. Its availability would be extended throughout the year by processing and preserving bitter gourd as shelf-stable products through the use of appropriate drying techniques and effective utilization of the finished products (Donya *et al.*, 2007). Owing to the fact, the objective of the present study was to dry the Bitter gourd using the novel biomass based dryer and determination of its effect on the physicochemical properties.

MATERIALS AND METHODS

A. Procurement of Raw materials

Bitter gourd (*Momordica charantia*) of Arka Harit variety was procured from the jack Sandra, (Latitude: 12.9234058 and Longitude: 77.6385669), Taluka: Kanakapura, Dist: Ramanagar, Karnataka 562112 in the month of November 2022. After procuring, the samples were washed with water three times to eliminate dirt and mud residues. Then the washed bitter gourd is sliced with the help of a slicer.

B. Sample preparation

The sample was washed in running tap water to remove the dust and weighed on Digital weighing balance (NIHAR Pvt. Ltd AN ISO 9001:2003 Certified Company, Mumbai, India). Later that the sample was sliced in () slicer and its ring shape was obtained.

C. Drying method

(i) Biomass-based Surface Drying and cabinet dryer. The sample weighing (152g) was kept in a surface dryer to dry. The drying was conducted to reduce moisture content to 6.5%.

E. Proximate analysis

Standard analytical techniques were used to establish the approximate composition of dried Bitter gourd including their moisture content, crude lipid, crude protein, crude ash, dietary fiber and carbohydrates. Bitter gourds of variety (Coimbatore green) of equal ripeness, maturity, and size were obtained at a local vegetable shop in Jackkasandra, Karnataka, India. To eliminate dust, pollutants, and clinging impurities, the samples were carefully washed with water. The calyx and pedicel were detached. With the use of a stainless-steel knife, AOAC (2005) was used to assess the initial moisture content of the bitter gourd sample. The mass of the samples was measured at regular intervals, and the moisture content of the samples was estimated using mass balance calculations.

(i) Moisture content. The moisture content of fresh and dried bitter gourd samples was evaluated by oven drying them at 105°C for 24 hours. The moisture content of fresh and dried bitter gourd samples was evaluated by oven drying them at 105°C for 24 hours. (AOAC, 2005).

$$\text{Moisture content } (\%) = \frac{(\text{Weight of original sample} - \text{Weight of dried sample})}{\text{Weight of original sample}} \times 100 \quad (1)$$

(ii) Crude Ash. In a muffle furnace, the ash content of muffins was measured using the procedure outlined in AOAC (2004). A weighed quantity of the material is first burned to remove any smoke. A weighted portion of the material was burned at 550°C for 5 hours in a muffle furnace to produce white ash.

$$\text{Crude Ash } (\%) = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \quad (2)$$

(iii) Crude Fat. The Soxhlet extraction method was used to crude fat estimation. The Soxhlet device was filled with a sample coated in filter paper and free of moisture. The samples were run for two hours and the equipment flask was used to collect the fat. By placing the fat extract in the drying oven additional n-hexane was evaporated.

The crude fat was estimated using the formula:

$$\text{Crude Fat}(\%) \frac{\text{Weight of fat in sample}}{\text{Weight of sample}} \times 100 \quad (3)$$

(iv) Protein. The bitter gourd sample (1-2g) was weighed and transferred to a 500 or 800 ml Kjeldahl flask, by careful handling to avoid the sample to attach on the flask's neck. Add 0.7 g Mercuric oxide, 15 gm potassium sulphate, and 40 mL concentrated sulfuric acid (Mercuric oxide is used to accelerate organic breakdown during acid digestion). Because of environmental/safety concerns about the handling and disposal of mercury, copper sulphate can be used. Because mercury vapours may escape into the environment during the distillation process, this is crucial for safety. Missouri catalyst pills, also known as Kjeldahl tablets were employed (composition: 48.8% sodium sulphate, 48.9% potassium sulphate, and 0.3%

copper sulphate) having two to three glass beads. In the digestion chamber, place the flask in an inclined position on the stand and digest. Gently heat the flask over a low flame until the initial foaming subsides and the fluid begins to boil steadily at a reasonable rate.

Rotate the flask many times during heating. Cook for another hour until the digest is pale blue in colour. If there are still black specks after 30 minutes, cover the vessel with aluminium foil and put aside for another 2-3 minutes. This caused black flecks to fall off the digesting mixture's walls. Remove the vessel from the heat and set aside for 10 minutes to cool if the specks remain. There is no need to adjust the heat intensity throughout the procedure. Alternatively, a few droplets of water could be dripped over the flask's edge. Allow the digest to cool before adding 200 ccs of water gently. After cooling, add a piece of granulated zinc or anti-bump granules and gradually pour enough NaOH solution (450 gm/liter) down the side of the flask to make the contents firmly alkaline (about 110 ml) before merging the acid and alkaline layers.

Connect the flask to the distillation equipment, which consists of a flash head and a condenser. Attach a delivery tube to the condenser so that it sits just below the pipette capacity of standard acid held in a conical flask recipient. (Caution: To avoid ammonia loss, keep the receiving solution below 45°C. Boil the contents of the digestion flask until 150ml has been distilled into the receiver. Titrate with 0.1 N NaOH solutions after adding 5 dropsof methyl red indicator.

Concurrently perform a blank titration 1 ml of.1 N (H_2SO_4) Equals 0.0014 gm N.

$$Nitrogen\ content\ (\%) \frac{(Blank - Titre\ value) \times Normality \times 1.4}{Weight\ of\ sample} \times 100 \quad (4)$$

Calculate protein (%): N x Conversion factor

(v) Crude Fiber. The crude fiber was assessed using the AOAC method (2000). Only 2(g) of the fat-free sample was used to test for crude fiber. It was digested by boiling 200 ml of 1.25 percent H_2SO_4 for 30 minutes, filtering it through muslin, and then washing it three times. The sample was once again digested for 30 minutes in 200 ml of boiling 1.25 percent NaOH, filtered and three times washed. The resulting residue was weighed and dried for two hours at 105°C and it was weighed. At 600±15°C temperature, the dried residue was burned, cooled, and reweighed

$$Crude\ Fiber(\%) = \frac{Weight\ after\ ignition}{Weight\ of\ sample} \times 100 \quad (5)$$

(vi) Total Carbohydrates. Using the AOAC (2004) method the following equation was applied to determine the product's carbohydrate content.:

$$Carbo\text{-}ydrates\ (\%) = 100 - [Moisture\ (\%) + As\ (\%) + Protein\ (\%) + Fiber\ (\%) + Fat\ (\%)] \quad (6)$$

E. Physio-chemical properties of Bitter gourd

(i) Determination of phenolic content. The total phenolic content (TPC) was calculated using the Folin-Ciocalteu technique. The TPC was measured calorimetrically using the Singleton and Rossi (1965) method with minor modifications. In a nutshell, an aliquot (200l) of bitter gourd Powder extract was combined with 7.5% sodium carbonate (800 l) and kept for 4 - 8 minutes. To the aliquot, 1 ml of phenol reagent solution (1:10, Folin-Ciocalteu's reagent: water) was added and forcefully shaken. After 2 hours at room temperature, the absorbance was measured at 765 nm with a microplate reader spectrophotometer. As a control, a solution of water and reagent was utilised. Total phenolic content was calculated as mg gallic acid equivalent (GAE) per 100 g fresh weight.

(ii) Determination of vitamin C concentration. Instead of distilled water, the vitamin C concentration was evaluated using the AOAC method (967.21) and aqueous metaphosphoric acid (3% w/v). DCPIP (Dichlorophenolindophenol) solution was titrated with a 5 mL portion of the sample's metaphosphoric acid extract. DCPIP is a blue dye that turns pink when it comes into contact with acid. It is reduced to a colourless molecule by ascorbic acid. Excess DCPIP resulted in a faint but distinct rose-pink tint that lasted for more than 10 seconds, marking the terminus. To standardise the DCPIP solution, a standard ascorbic acid solution was utilised. The vitamin C content was measured in milligrammes per gramme (dry basis) 2.5.3 Determination of vitamin A

The authorised technique for calculating β-carotene is shown below. A sample of 40 mL water-saturated butanol (WSB) was put into a 150 mL glass stoppered Erlenmeyer flask. To ensure thorough extraction of -carotene, the contents of the flasks were vigorously shaken for 1 minute before being stored at room temperature in the dark overnight (16-18 hours). The contents were shaken again the next day and filtered completely through Whatman no. 1 filter paper into a 100 ml volumetric flask. A spectrophotometer was used to measure the optical density of the clear filtrate at 440 nm.

As a control, the researchers used pure water-saturated butanol (WSB). Using a calibration curve based on a known amount of -carotene, the -carotene content was determined in parts per million (ppm). A 5 g/ml standard solution of - carotene (Sigma) was produced in water-saturated butanol (WSB). The WSB is made by combining 8:2 n-butanol and distilled water. A calibration curve was created by preparing known quantities of pure -carotene ranging from 0.25 g/ml to 1.5 g/ml in calibrated 10 ml volumetric flasks after dilutions of original stock with WSB (from 0.5 ml to 3 ml of standard solution in 10 ml). Each dilution's absorbance was measured, and a calibration curve was generated. A standard curve is used to determine the carotene content of unknown materials.

(iii) Length, Width and Thickness. Measure the length (L), width (W) and thickness (T) of the bitter gourd slices using a digital caliper

(iv) Weight. The bitter gourd is weighed using an electronic weighing scale with a gram accuracy, andthe reading is obtained.

(v) Bulk Density. Calculate bulk density by using the AOAC method formula

$$Bulk\ Density = \frac{Mass\ of\ sample}{Volume} \quad (7)$$

(vi) Rehydration ratio. Five grams of the dehydrated material were placed in a beaker with 50 ml of warm

(60°C) water. The rehydrated material's drained weight was determined after one and a half hours. The rehydration ratio was determined as

$$Rehydration\ ratio = \frac{Drained\ weight\ of\ rehydration\ sample\ (g)}{Weight\ of\ dehydrated\ sample} \quad (8)$$

(vii) Drying ratio. The drying ratio was determined by subtracting the material's fresh weight from its net dry weight (Rajan *et al.*, 2022)

$$Drying\ ratio = \frac{Fresh\ weight\ of\ the\ material}{Net\ dry\ weight\ obtained} \quad (9)$$

RESULT AND DISCUSSION

The present investigation entitled "Physio-chemical Analysis of Bitter Gourd Dried Using Biomass Dryer" was carried out in the Department of Food Science and Technology, **JAIN** (Deemed-to-be University). The obtained results in the present investigation have been reported in the chapter.

A. Drying characteristics of the Biomass-based surface dryer and cabinet dryer

The current study carried out to assess the effectiveness of a surface and cabinet biomass-based dryer. In surface drying, 152 g of bitter gourd slices was kept in biomass-based dryer for a period of 4 hr. An amount of 7 kg of fuel (biomass) was used for the drying purpose of Bitter gourd. After removal overall moisture from the Bitter gourd, the final weight of 10 g was observed in the current study. Further, amount of 1520 g of Bitter gourd sample was kept in the cabinet dryer and after drying the final weight of 100 g was observed which depicts a gradual removal of the moisture content from sample. The fuel consumption for the cabinet drier was observed to be 15.95 kg for drying the Bitter gourd. Overall, the yield of the surface and cabinet dryer was found to be 93.42 % which shows the effectiveness of the drying of biomass-based dryer. The findings have shown the improved yield of the Bitter gourd after drying in biomass-based dryer. The yield reported by researchers is less comparatively which could be due to the effectiveness of drying.

B. Physio- chemical analysis of bitter gourd

The physical and chemical properties of the bitter gourd fruits used in the experiment are listed in Table 2 and 3. The effect of drying method on the physical properties of dehydrated bitter gourd as follows.

(i) Physical analysis. The results of physical properties of the Bitter gourd are shown in Table 2. The values of the physical analysis are given for surface and cabinet dryers. The Table 1 shows the length of the bitter gourd ring was (18.33 mm) whereas the length of sample was found to be 18.94 mm for the cabinet dryer. Bitter gourd rings observed to have a width of 1.31 mm and 1.27 mm respectively for surface and cabinet dryer. The cabinet dryer had a thicker ring than the bitter guard ring (5 mm vs. 6 mm). In contrast to cabinet dryers, dried bitter guard rings had a bulk density of (0.47 g/c). The drying ratio of the bitter guard ring was 15.2 % and 16.72 % respectively for surface and cabinet dryer. The water retention of bitter guard ring was 87.00 and 88.00 for surface and cabinet dryer respectively.

(ii) Proximate analysis. The nutritional composition of Bitter gourd was determined using AOAC methods and the values of the nutritional profile is given in Table 3. The experiments were performed in triplicate and an average of triplicate results with standard deviation is shown in the Table 3. The obtained results of bitter gourd for the surface dryer observed to have a moisture content of 6.75 ± 0.18 % whereas the moisture content for the cabinet dryer was found to be 7.5 %. Further, the ash and fat content values of surface and cabinet-based biomass dryer was found to be 6.93 ± 0.15% and 9.09 ± 0.13% respectively. Furthermore, the nutritional composition of surface dryer i.e. carbohydrates, protein, fiber, vitamin A, vitamin C and total phenolic content was found to be 52.64 ± 0.33%, 12.4 ± 0.08%, 10.3 ± 0.08%, (vit A) 0.097 ± 0.47% and 0.068 ± 0.94% respectively. The ash content and fat content for surface and cabinet dryer was observed to be 6.56 ± 0.23% and 9.41 ± 0.34% respectively. Further, nutritional composition of cabinet dryer i.e. carbohydrates, protein, fiber, vitamin A, vitamin C and total phenolic content was discovered to be 54.57 ± 0.50%, 11.7 ± 0.081%, 10.1 ± 0.08%, 0.091 ± 0.81% and 0.061 ± 0.81% respectively.

C. Effect of drying method on chemical properties for cabinet dried bitter gourd

(i) Moisture content. Moisture content of Bitter gourd plays a vital role in the shelf-life because less moisture content will lead to improvement in the nutritional retention and shelf-life. The results shown in Fig. 1 (Time Vs Moisture) clearly indicates that the moisture content of bitter gourd exponentially decreases with increase in drying time, same result was found in (Vijayan *et al.*, 2020). In initial hours of drying the graph depicted a linear decrease in the moisture (% Db) content. Further, the drying continued showed a flat graph with the maximum decrease in the moisture content reaching almost zero. The flat graph was observed due to the slow loss of moisture content which might be in the cores of the dried bitter guard.

(ii) Drying rate. The objective of drying curve is to understand the removal of moisture from food with respect to the drying rate. The drying curve gives an idea about the change in the phase after drying using the concept of falling rate period and constant rate period. In the second phase, moisture was removed smoothly compare to the other phases of drying and observed to come under the constant rate period. The third stage of drying curve depicts the removal of bound moisture within the solid matrix. In the process of drying the moisture content at the point when the drying period changes from a constant rate to falling rate is commonly known as the critical moisture content. The behavior of food materials depends on the porosity, homogeneity and hygroscopic properties of food materials.

The drying rate of 0.06 (gw/gdm/min) was observed at a moisture content of 100 % (Db) whereas the second phase from 100 to 500 % (Db) was found to have a drying rate of 0.06(gw/gdm/min). Finally, in the third stage which is known as the falling rate period observed to have 1.69 % (DB) of moisture content (Thirunavookarasu *et al.*, 2021; Thirunavookarasu *et al.*, 2022)

The drying rate for Bitter gourd using a surface dryer was found to be decreased by increasing the time from 0 – 300 mins as shown in Fig. 3. Initially the drying rate was observed to be 0.08 (gw/gdm/min) but, upon increasing the time the rate was found to be decreased by 0.02 (gw/gdm/min). A decrease in the drying rate of 0.0705, 0.0574 and 0.0496 was observed by increasing the drying time from 50, 100 and 150 mins respectively as shown in Fig. 3. The drying rate of the Bitter gourd using a surface dryer was found to be increased linearly which could be due to the removal of higher moisture content after 150 mins of drying. As shown in Fig. 3 the drying rate was observed to be reduced to 0.02 (gw/gdm/min) after 280 mins of drying. This experiment was carried out using the biomass-based surface dryer. As trend shows, the drying rate reduced to a 0.02 (gw/gdm/min) after 280 mins of drying. These experiments were carried out in the air (Thirunavookarasu *et al.,* 2022).

(iii) Effect of drying method on chemical properties of dehydrated bitter gourd by cabinet dryer. The obtained results have demonstrated that the moisture content of bitter gourd plays significant role in the bitter gourd shelf life. The biomass dryer constitutes several trays and the analysis of dried Bitter gourd samples was carried out for each level. It was observed that the tray at the fifth position gave a major moisture loss in the initial stages itself and might be due to the major heating of the tray

As the tray level decreases the amount of heating or the rate of heating decreases due to the change in the height of the tray arranged. In accordance with this the data in Fig. 4 shows the gradual decrease in the moisture value for all the trays with the maximum value of almost 490 (gw/gds.min) for T1 in 100 min while T5 shows almost 0 (gw/gds. min) at 100th min. Drying rate vs time parameter was studied in five trays (T1, T2, T3, T4, T5) as shown in Fig. 5. The highest drying rate of 0.17 gw/gds. min and lowest drying rate of 0.01 gw/gds. min were observed for tray 4 and tray 5 respectively. However, the trend of drying rate was found to be lowest for tray 3 and 5 whereas the highest drying rate trend was observed for tray 3, 4, 5 as shown in Fig. 5.

Furthermore, the trays T1, T2 and T3 received comparatively less heating since tray 4 and tray 5 was kept at the bottom of the dryer. The highest drying rate in T4 tray was found tobe 0.1714 and the lowest drying rate tray T1 is found to be 0.0286. This trend of drying rate could be due to the difference in the temperature of biomass dryer for various tray levels.

E. Comparison of Biomass dryer

(i) Moisture. Drying process involves the removal of the moisture content and increases the shelf-life of food products. Since, the impact of drying process plays a vital role in the total moisture content and the values were obtained to be 6.75 ± 0.18 % and 7.5 ± 0.32 % for biomass-based surface drying and cabinet drying respectively as shown in Table 3. Accordingly, the literature study was also carried out for the comparison of the obtained moisture content values. Study revealed that the moisture content in the bitter gourd sample which was dried using cabinet dryer, sun drying and low temperature drying provided the percentage moisture of 4.94 %, 5.16 % and 5.02 % respectively. In addition to this, a literature reported by Sagar & Kumar (2017) studied the moisture content by cabinet drying and vacuum drying which provided the value of 6.55 and 6.52 %. Furthermore, the report (Yasmin *et al.,* 2022) mentioned a result of 4.66% moisture content for bitter guard with cabinet tray dryer method. The conducted study reveals that the moisture content in the dried bitter gourd sample dried using biomass-based surface and cabinet dried sample has an upper hand when compared with the literature. The biomass derived drying provided the continuous flow of the heat which might have enhanced the activity leading to better activity.

(ii) Ash. The ash content for the bitter guard was studied with the help of biomass-based surface drier and cabinet drier and the result is given in Table 3. The surface drier gives the direct exposure to heat or sunshine leading to higher ash concentration while the cabinet drier maintains the regulated drying conditions maintaining the organic qualities for the studied biomass. The total ash content for biomass-based surface drier and cabinet drier was observed and the values obtained were 6.93 ± 0.15 % and 6.56 ± 0.23 % respectively. The reported total ash content was observed to be 6.75% and 6.83 % for sun drying and cabinet drying respectively (Tahmasebi & Hezarkhani 2010).

(iii) Fat. Recently a report (Nguyen *et al.,* 2020) showed the total fat content of be 2.66 % and 3.86 % for Bitter gourd dried using sun drying and cabinet drying respectively. In another report (Kusat *et al.,* 2021), the total fat content was observed to be 0.93 % for the cabinet drier. The total fat content was found to be 9.09 ± 0.13 % and 9.41 ± 0.34 % respectively for biomass-based surface dryer and cabinet dryer as shown in Table 3. Dried bitter gourd undergoes a dehydration process that concentrates its nutrients, including fat. The fat content in dried bitter gourd is higher compared to fresh bitter gourd due to the removal of water. And hence a slight variation in the results could be observed.

(iv) Carbohydrates. The nutritional content and dietary management are crucial content and the total carbohydrate content in the dried bitter gourd sample was studied with the biomass-based surface dryer and cabinet dryer. The obtained results for surface dryer and cabinet dryer were 52.64 ± 0.33 % and 54.57 ± 0.50 % respectively. As per the previous report (Tahmasebi & Hezarkhani 2010), the total carbohydrate content in the sun drying and cabinet drying were of 52.61 % and 53.43 % respectively. The literature suggested that the cabinet drying sample has slightly higher amount of total carbohydrate than the surface drying sample this could be because of change in the temperature maintained during the drying process.

(v) Protein. Similar to the carbohydrate protein also has nutritional and dietary importance and the total protein in the dried bitter gourd sample in the biomass-based surface dryer and cabinet dryer was observed to be 12.4 ± 0.08 % and 11.7 ± 0.081 % respectively. In another work (Ahmad *et al.,* 2022), the total protein content was observed to be 12.98 % in a cabinet tray drying. A significant process of drying involves the loss of the water content which might have affect the total protein content. Hence, a slight variation in the results for the protein content might be observed however the higher temperatures lead to the major protein content loss. As long as the bitter guard isn't exposed to high and lengthy heating the degradation or the destruction of the protein structure is intact.

(vi) Fiber. The total crude fiber content was found to be 10.03 ± 0.08 % and 10.01 ± 0.08 % respectively for biomass-based surface dryer and cabinet dryer as illustrated in Table 3. The total amount of crude fibre reported to be 11.46 % and 13.40 % for Bitter gourd dried using sun drying and cabinet drying respectively as per study conducted (Singh & Sagar 2017; Aradhana *et al.*, 2022; Mathews *et al.*, 2022). There was less difference observed between the drying methods for total crude fiber content in Bitter gourd samples. The difference in the values between the research work discussed above and the study conducted may be due to the temperature changes in dryer Kumar *et al.* (2022).

(vii) Vitamin A. The vitamin A value of Bitter gourd was found to be 139.66 ± 1.24 mcg for the surface dryer and 132 ± 1.63 mcg for the cabinet dryer respectively. Similar results were was observed by (Tiwari *et al.*, 2021), which showed a vitamin A value of 4 mcg. Hence the results obtained from the biomass dryer depicts that the vitamin A value was found to be improved. The bioactive compounds study was conducted by Sagar & Kumar (2017), which showed similar results. Dehydrated bitter gourd rings have the potential to become a key value-added product because they are relatively inexpensive, easily and can be cooked quickly. They are also rich in numerous nutrients that are essential for human health. To find the best drying method, three different driers were used: a cabinet drier, a low-temperature drier, and a sun drier. In terms of keeping the high content of ascorbic acid, total chlorophyll, -carotene, and total carotenoids, better drying and rehydration ratio, and less moisture and NEB in the dehydrated product, the cabinet drier beat the low-temperature and solar driers. The cabinet drier gave several additional advantages, including maintaining less moisture in the product, retaining more nutritional quality components in the dehydrated bitter gourd rings, and drying the product in less time.

Furthermore, a study (Tan *et al.*, 2013) with both thermal and non-thermal drying was studied for the lipophilic and hydrophilic antioxidants capacities were studied. The different bitter guard drying methods were employed which included oven drying 60°C, oven drying 50 °C, oven drying 40°C, freeze drying, microwave drying (medium-power) and microwave drying (medium-low power). The extraction of the antioxidant compounds from dried bitter gourd was done in presence of pure hexane and acetone as solvent. The have highest values in FRAP (lipophilic fraction), DPPH scavenging activity and TPC were obtained in the freeze-dried extracts. Thermal drying raised the DPPH scavenging activity, FRAP, and TPC test values for hydrophilic extracts marginally. The freeze-dried material had greater natural antioxidant and total antioxidant values, as well as higher FRAP, DPPH scavenging activity, and TPC tests for lipophilic extracts than hydrophilic extracts.

(viii) Vitamin C. Several research studies have explored the Vitamin C content in dried bitter gourd through various drying techniques. In one instance, Nguyen *et al.* (2020) utilized a combination of low-temperature convective drying and microwave radiation, resulting in a Vitamin C content of 0.0016996 g. Other studies conducted by Sagar (2017); Kumar *et al*. (2021); employed cabinet drying methods and reported values of 0.004561 g, 0.005107 g, and 0.00518 g for Vitamin C, respectively.

In a separate, unattributed study, researchers applied surface drying and cabinet drying methods, leading to Vitamin C contents of 0.0097 ± 0.0047 g and 0.0091 ± 0.0081 g, respectively. Their comparative analysis found that these results were in line with previously reported values in the literature. Additionally, their investigation encompassed the examination of the physicochemical properties of dried green vegetables, including bitter gourd and capsicum, using three distinct drying methods: solar, hot air, and sun drying.

Furthermore, as a pre-treatment, the drying technique was combined with blanching (hot water and steam). Solar-dried vegetables had superior nutritional quality (vitamins A and C) than hot air and open sun-dried vegetables (0.00159 g, 0.00395 g; 0.00332g, 0.00498 g). Hot water-blanched veggies, on the other hand, exhibited much less degradation of polyphenols, flavonoids, and chlorophyll than steam-blanched vegetables combined with solar drying. Solar-dried veggies also received the best sensory acceptance rating. As a result, it may be inferred that solar drying may be a more successful strategy than hot air or open sun drying for keeping higher dried vegetable quality

(ix) Total phenolic content. A recent study (Nguyen *et al.*, 2020) found that combining low-temperature convective drying with microwave radiation resulted in a total phenolic content of 0.00441. Later a report (Sagar & Kumar 2017) with different drying processes such as microwave drying, freeze-drying, and vacuum-assisted convectional drying for bitter gourd was used and provided the value of 0.00249, 0.00101 and 0.00417. Subsequently (Tahmasebi & Hezarkhani 2010; Kumar *et al.*, 2022), the sun drying and cabinet drying method was used for drying of bitter gourd which gave result of 0.00835 and 0.00984. In comparison to this literature when we carried out surface drying and cabinet drying method, we obtained total phenolic content in 0.0068 ± 0.0012 and 0.0061 ± 0.0019. Three water-soluble bitter gourd polysaccharides (BPS-H, BPS-F, and BPS-I) were obtained from bitter gourd dried utilising the three drying techniques with varying monosaccharide compositions and molecular weights, the three polysaccharides displayed similar early structural properties. BPS-I derived from ID- dry bitter gourd contained more sugar and uranic acid than BPS-H and BPS-F. In vitro, BPS-I demonstrated more antioxidant activity and bile acid binding capability than BPS-H and BPS-F.

Table 1: Drying parameters of Biomass-based Surface and cabinet dryer.

Sr. No.	Parameters	Surface dryer value	Cabinet dryer value
1.	Initial weight(g)	152	1520
2.	Final weight (g)	10	100
3.	Drying time (min)	240	420
4.	Fuel used (kg)	7	15
5.	Yield (%)	93.42	93.42

Table 2: Physical parameters of Bitter gourd by using surface dryer and cabinet dryer.

Sr. No.	Parameters	Surface dryer values	Cabinet dryer values
1.	Length (mm)	18.00	18.94
2.	Width (mm)	1.31	1.27
3.	Thickness (mm)	5.00	6.00
4.	Bulk Density (g/c)	0.47	0.47
5.	Water Retention (%)	87.00	88.00
6.	Drying Ratio (g)	15.02	16.72

Table 3: Nutritional analysis of Surface dryer and cabinet dryer.

Sr. No.	Parameters (%)	Surface dryer	Cabinet dryer
1.	Moisture	6.75 ± 0.18	7.5 ± 0.32
2.	Ash	6.93 ± 0.15	6.56 ± 0.23
3.	Fat	9.09 ± 0.13	9.41 ± 0.34
4.	Carbohydrates	52.64 ± 0.33	54.57 ± 0.50
5.	Protein	12.4 ± 0.08	11.7 ± 0.081
6.	Fiber	10.3 ± 0.08	10.1 ± 0.08
7.	Vitamin A	0.000139 ± 0.0002	0.000132 ± 0.0002
8.	Vitamin c	0.097 ± 0.47	0.091 ± 0.81
9.	Total phenolic content	0.068 ± 0.94	0.061 ± 0.81

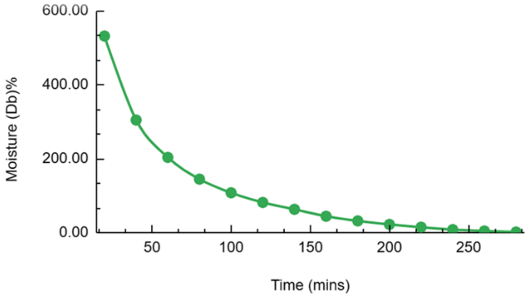

Fig. 1. Graph for moisture (% DB) vs time of bitter gourd using surface dryer.

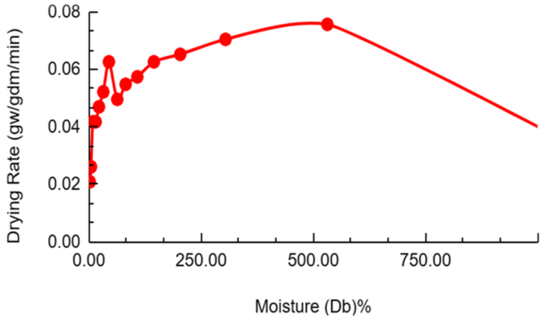

Fig. 2. Graph for moisture (Db) vs drying rate of bitter gourd using the surface dryer.

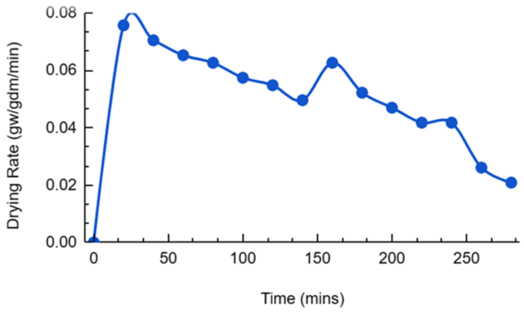

Fig. 3. Graph for drying rate vs time of bitter gourd using surface dryer.

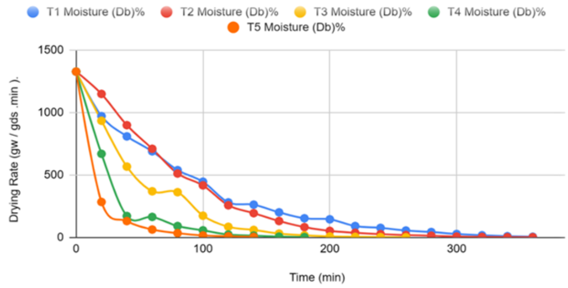

Fig. 4. Graph for moisture vs time of bitter gourd using cabinet dryer.

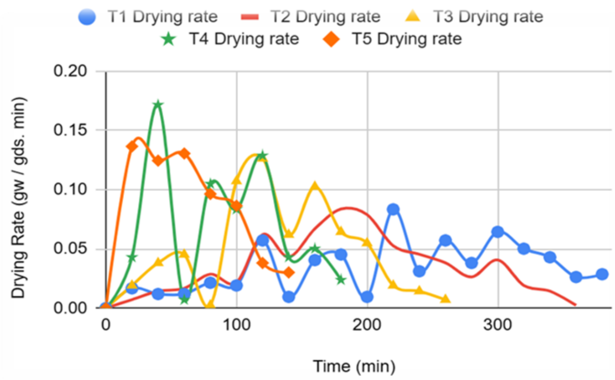

Fig. 5. Graph for drying rate vs time of bitter gourd using cabinet dryer.

CONCLUSIONS

The various drying methods such as convective, fluidized bed, solar, and microwave drying are used in the food industry. While hot air drying negatively affects food characteristics, novel methods like biomass dryers offer efficiency and lower energy consumption. The bitter gourds are widely used in curries, baked goods, filled dishes, juices, pickles, or stuffed meat products as fresh and dried vegetables. Additionally, it is used in the creation of many other dishes. Drying characteristics were analyzed based on factors such as moisture content and drying time. In surface dryer 152gm of bitter gourd slice at 60-70° required 240 minutes. Whereas, for cabinet dryer at 1552 gm of bitter gourd slice required 420 minutes. The slice of bitter gourd where subjected to physicochemical analysis and finally, they were packed in low-density polyethylene (LDPE) and stored at ambient temperature. The moisture content in a bitter gourd by cabinet drying and surface drying was found to be 6.75 ± 0.18 % and 7.5 ± 0.32 % respectively. The ash content in a bitter gourd by cabinet drying and surface drying was found to be 6.39 ± 0.15 % and 6.56 ± 0.23 % respectively. The fat content in a bitter gourd by cabinet drying and surface drying was found to be 9.09 ± 0.13 % and 9.41 ± 0.34 % respectively.

The carbohydrate content in a bitter gourd by cabinet drying and surface drying was found to be 52.64 ± 0.18 % and 54.57 ± 0.50 % respectively. The protein content in a bitter gourd by cabinet drying and surface drying was found to be 12.4 ± 0.18 % and 11.7 ± 0.08 % respectively. The fiber content in a bitter gourd by cabinet drying and surface drying was found to be 10.3 ± 0.8 %and 10.1 ± 0.08 % respectively. The vitamin A content in a bitter gourd by cabinet drying and surface drying was found to be 0.000139 ± 0.0002 % and 0.000132 ± 0.0002 % respectively. The vitamin C content in a bitter gourd by cabinet drying and surface drying was found to be 0.097 ± 0.47 % and 0.091 ± 0.81 % respectively. The total phenolic content in a bitter gourd by cabinet drying and surface drying was found to be 0.068 ± 0.94 % and 0.061 ± 0.81 % respectively.

FUTURE SCOPE

The potential benefits and opportunities for drying bitter gourd with biomass drier are numerous

Sustainable and Renewable Energy: Biomass dryers use organic waste products as a source of fuel, such as agricultural wastes or special energy crops. This is in line with the growing attention being paid globally to clean and renewable energy sources, making biomass dryers a green choice.

Energy Efficiency: Biomass dryers can be made to be very energy-efficient, reducing energy use while the material is drying. Because of this efficiency, the procedure is more economically viable, especially for small-scale farmers or rural areas.

Preservation: Bitter gourd drying with a biomass drier can assist improve the quality of the finished product and aid in its preservation. The vegetable's nutritional value, colour, and flavor can be better preserved through the regulated drying process. As a result, the dried bitter gourd can maintain its excellent qualities for a longer period of time.

Increased Marketability: Dried bitter gourd can be used to make herbal teas, dietary supplements, and traditional medicines, among other things. Farmers may efficiently produce dried bitter gourd of a high standard using a biomass dryer, potentially increasing its marketability and demand.

Income Generation and Value Addition: Farmers and business owners may be able to add value by employing a biomass dryer to dry their products. The value of dried bitter gourd can be increased by further processing it to create other goods like powdered extracts or capsules.

Local and Regional Development: Using biomass drying systems locally or regionally can help the economy. It may promote business development, the production of jobs, and the development of biomass supply networks. This decentralized strategy can help rural economies expand and lessen reliance on centralized food processing facilities.

Research and Technological Advancements: As biomass drying technologies advance, ongoing study and new developments in technology may result in even greater gains in drying speed, efficiency, and product quality.

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Conflict of Interest. None.

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