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Research Article

Study on Drying and Rehydration Characteristics of Tray Dried Beetroot (*Beta Vulgaris* L.) and Functional Properties of its Powder

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Abstract

The fresh beetroots are exposed to spoilage due to their high moisture content and needs preservation. One of the preservation methods ensuring microbial safety of biological products is drying and dehydration. An experimental study was performed to determine the drying characteristics of beetroot subjected to drying in cabinet tray dryer at 60^0C with pre-treatment indicated that T_0 (Control), T_1 (Brine solution 5%), T_2 (Sugar solution 50%), T_3 (Blanching in water at 100^0C for 3 min) and T_4 (Steam Blanching for 3 min). The entire drying process took place in the falling rate period. Drying curves were constructed using non-dimensional moisture ratio (MR) and time. Drying is the most widely used and a primary method for preservation. The result indicated that the Pretreatment T_3 (Blanching) and T_4 (Steam Blanching) was found better quality compare to other pretreatments during drying and rehydration process. The result showed that the T_3 (Blanching) and T_4 (Steam Blanching) has highest functional properties of beetroot powder compared to others powder.

Keywords: Moisture Content, Drying Rate, Moisture Ratio, Rehydration Ratio, Rehydration Rate, Swelling Capacity, Foam Capacity, Bulk Density, WAC and OAC

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Introduction

Beetroot *(Beta vulgaris L.)* is an important raw material of plant origin with proven positive effects on the human body. They can be eaten raw, boiled, steamed and roasted. Red beetroot is a rich source of minerals (manganese, sodium, potassium, magnesium, iron, copper). Beetroot contains a lot of antioxidants, vitamins (A, C, B), fiber and natural dyes. Red beetroot is also rich in phenol compounds, which have antioxidant properties. The beetroot vegetables help to protect against heart disease and certain cancers (colon cancer) [1]. Beetroots are rich in other valuable compounds such as carotenoids [2], glycine betaine [3], saponins [4], betacyanins [5], folates [6], betanin, polyphenols and flavonoids [7]. Therefore, beetroot ingestion can be considered a factor in cancer prevention [8, 9].

Drying process plays an important role in the preservation of agricultural products [10]. It enhances the shelf life and reduces water activity [11]. The post-harvest losses of fruits and vegetables are estimated to be 30-40% of the production [12]. Therefore, in many countries, large quantities of food products are dried to improve shelf life, reduce packaging costs, lower weights, enhance appearance, retain original flavour and maintain nutritional value [13]. Drying is generally evaluated experimentally by measuring the weight of a drying sample as a function of time. Drying curves may be represented in different ways; averaged moisture content versus time, drying rate versus time, or drying rate versus averaged moisture content [14]. Drying process can be described completely using an appropriate drying model, which is made up by differential equations of heat and mass transfer in the interior of the product and at its inter phase with the drying agent.

Beet root powder is reported to have medicinal properties, particularly to improve digestion and blood quality [15, 16]. It is the most powerful source of nutrient available for overall human health. It detoxifies the body faster and better than almost any other vegetable juice powder. Beet root powder has water-soluble betalain pigments that mainly comprise of betanins and betaxanthyns [17]. Beet root powder or extracted pigments are used industrially. Beet root powder as a colorant (betalain) has several applications in foods, such as ice cream, cake icings, mixes, yogurt, desserts, fruit chews, gravies, sauces, confectioneries, dry mixes and dairy products [18, 19].

Functional properties are the fundamental physico-chemical properties that reflect the complex interaction between the composition, structure, molecular conformation and physico-chemical properties of food components together with the nature of environment in which these are associated and measured [20, 21, 22, 23].

Materials and Methods

Raw material

The local variety of fresh beetroot was purchased from the Meerut market and was used in the experiments. The cleaned product was then weighed and 300 g samples were made for each methods of drying.

Pre-treatments

Fresh, good quality of Beetroot was washed to remove soil particles attached to the surface. Then sorted cleaned beetroot was cut into 1-3 mm thickness using sharp sterilized knife. Pretreatments were applied to the beetroot before drying, and an untreated sample was used as a T_0 (Control). The sliced beetroot was subjected to pre-treatment indicated that T_1 (Brine solution 5%), T_2 (Sugar solution 50%), T_3 (Blanching in water at 100^0C for 3 min) and T_4 (Steam Blanching for 3 min). In this, the beetroot slices were dipped in Brine solution at 50g of salt in 1000 ml water for 3 hours and Sugar solution at 500g of sugar in 500 ml water for 3 hours. The slices were then removed from the solution and the surface moisture was removed by blotting paper than after slices were subjected to drying in cabinet tray dryer at 60^0 C [24].

Processing of beetroot powder

Fresh beetroots were washed, peeled and reduced to size (1-3 mm) using sharp knife. These slices were dried in tray dryer at 60^OC for about 7-8 h. The dried beetroot slices were subjected to grinding in grinder. Then ground material was passed through 60 mesh sieve and packed in HDPE bags, sealed and stored for further use.

Flowchart of Processing of beetroot powder:

Select fresh beetroot

↓

Washing, cleaning and peeling

↓

Cutting of slices beetroot (1-3 mm) thickness

↓

Pretreatment with Brine solution, Sugar solution, Blanching, Steam Blanching and control (untreated)

↓

Drying of Beetroot slices in Tray dryer (60^0C)

↓

Cooling of Beetroot flakes at room temperature

↓

Grinding of flakes in grinder

↓

Packaging of Beetroot powder in HDPE

Drying Characteristics of Beetroot

Drying procedure

The experimental set up used for determining the influence of drying temperature on drying behavior of beetroot slices. The slices were then weighed exactly 300 grams for each treatment. These were kept for drying in three replications. Tray dryer is a batch type twin unit for grain and tray type for food products drying. It was carried by drying the samples at 60^0C air temperatures and a constant air velocity of 1 m/s. Beetroot slices sample weighing 300 g was taken and spread uniformly over the perforated bottom trays in single layer. Drying air temperature was adjusted to the desired level using the thermostat. During drying operation, weight of the sample was taken at every 30 min interval for rest of drying period. All the measured observations were recorded for further calculations. Drying was stopped when the drying mass reached the required moisture content. The dried product was cooled to normal temperature in a desiccators containing silica gel and then packed in polyethylene bags, which were then heat-sealed and stored at room temperature [25]. The experiments were repeated twice and the average of the moisture ratio at each value was used to draw the drying curves.

Drying time and curves

During drying of beetroot slices, samples were weighed at the specified intervals mentioned above for determining moisture content. The drying curves were drawn for all moisture content (% db) were plotted against time of drying. The total time required for complete drying was also recorded in each case. The curves between drying rate and average moisture content (% db) and between drying rate (g/min) and drying time (h) were also plotted.

Moisture content

Moisture content was calculated using the following expression [26].

$$Mc = \frac{Mi - Md}{Mi} \times 100$$

Where Mi is the mass of sample before drying and Md is the mass of sample after drying

Drying rate

$$R = \frac{Mi - Md}{T} \times 100$$

Where R is the Drying rate (g/min) and T is the Time taken (h)

Moisture ratio

$$MR = \frac{M - Me}{Mci - Me} \times 100$$

Where MR is the dimensionless moisture ratio, M, Me and Mci are the moisture content at any time, the equilibrium moisture content and the initial moisture content in kg respectively.

Rehydration Characteristics of Dried Beetroot
Rehydration studies

Rehydration capacity is an important parameter to evaluate the quality of dried products. The difference is attributed to the texture and constituents of the products. Both rehydration ratio and rehydration rate indicated that mechanically dried samples

Rehydration ratio

Rehydration tests for dehydrated samples were carried out by immersing 5 g sample in 50 ml distilled water at 35°C in a 100 ml beaker kept in a hot water bath to maintain a water temperature of 35°C for 5 hr. [27]. Dehydrated samples were evaluated for rehydration ratio, from the weight before and after the rehydration.

$$R.R = \frac{C}{D}$$

Where **C** is drained weight of rehydrated sample (g) and D is test weight of dehydrated samples (g).

Functional Properties Determination of Beetroot Powder
Water absorption capacity

The water absorption capacity of the powder was determine by the method of [28]. 1 gm of sample mixed with 10 ml distilled water and allow to stand at ambient temperature (30 ± 2^oC) for 30 minute, the centrifuged 30 minute at 3000 rpm or 2000 × g. Water absorption was examined as percent water bound per gram flour. The WAC was calculated by using following formula;

$$\text{WAC (\%)} = \frac{(\text{W2-W1})}{\text{W0}} \times 100$$

Where: W_0 = the weight of the sample, g; W1 = the weight of centrifuge tube plus sample, g; and W2 = the weight of centrifuge tube plus the sediments, g.

Oil absorption capacity

The oil absorption capacity of flour was determined by the method of [29]. 1 g of sample was mixed with 10 ml refined soybean oil and was kept at ambient temperature for 30 min and centrifuged for 30 min at 2000 rpm. Oil absorption capacity was expressed as percent oil bound per gram of the sample. The sediments were weighed after the complete removal of supernatant oil. The experiment was replicated for 3 times. The OAC was calculated by using following formula;

$$\text{OAC (\%)} = \frac{(\text{W2-W1})}{\text{W0}} \times 100$$

Where: W_0 = the weight of the sample, g; W_1 = the weight of tube plus sample, g; and W_2 = the weight of the tube plus the sediments, g.

Bulk density

The bulk density of flour was determined according to the method described by [30]. A graduated measuring cylinder of 5 ml was weighed and powder sample filled in to it by constant tapping until there was no further change in volume. The cylinder with the flour sample was weighed and the difference in weight was determined. The experiment was replicated for 3 times. The average value of bulk density is reported.

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}}$$

Foam Capacity

The foam capacity (FC) and foam stability (FS) [31]. Will be determined as described with slight modification. The 1.0 g powder sample will be added to 50ml distilled water at 30 2°C in a graduated cylinder. The suspension will be mixed and shaken for 5min to foam. The volume of foam at 30 sec after whipping will be expressed as foam capacity using the formula:

$$\text{Foam capacity (\%)} = \frac{\text{Volume of foam AW-Volume of foam BW}}{\text{Volume of foam BW}} \times 100$$

Where, A W -after whipping, BW-before whipping.

Foam stability

The volume of foam will be recorded one hour after whipping to determine foam stability as per percent of initial foam volume.

Swelling capacity

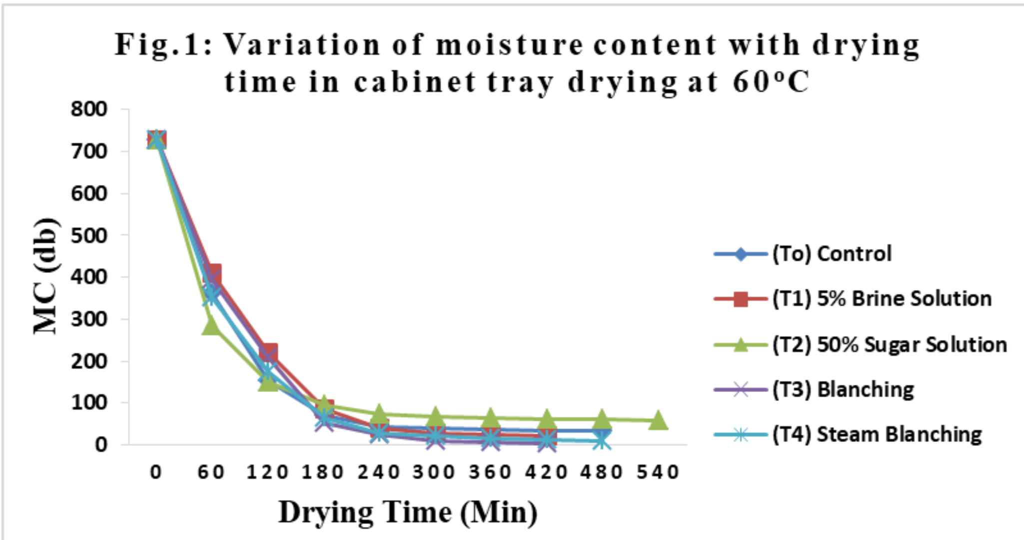
The swelling capacity was determined by the method described by [32]. 100 ml graduated cylinder was filled with the sample to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min and the volume occupied by the sample was taken after the 8th minutes 100 ml graduated cylinder was mark and Swelling capacity (ml) calculated

Results and Discussion

Drying and Rehydration Characteristics of Beetroot

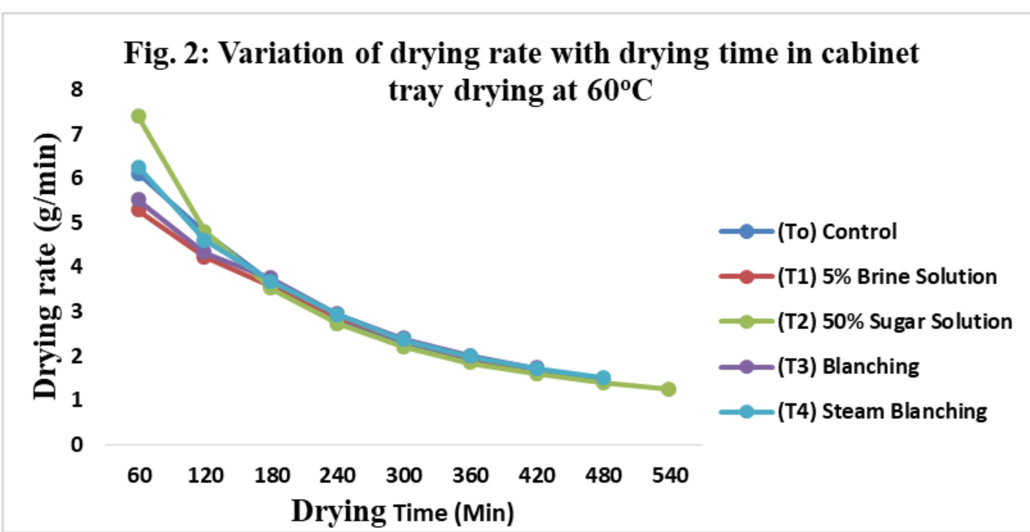
Variation of Moisture Content with Time

The initial Average moisture content of Control and Pretreated beetroot samples was 726.4463 % **Figure 1** present the variation in the moisture content as the function of drying time. It showed that the moisture content decreased continuously with drying time and increasing the drying power. Similar results were also obtained by [33]**.** Different results were obtained in which the pre-treatments affect the drying time. The pretreated samples were found to be have a shorter time as compared to control sample. It is observed that the drying time required for reducing the moisture content of pre-treated samples were taken different drying time. Thereafter, the moisture content of samples decreased slowly with increase in drying time and attained final equilibrium moisture content. With increasing the drying power level the amount of moisture removed from beetroot increased and time to achieve final moisture content in finished product was reduced. The Brine solution and blanched samples shorter time than other treatments.



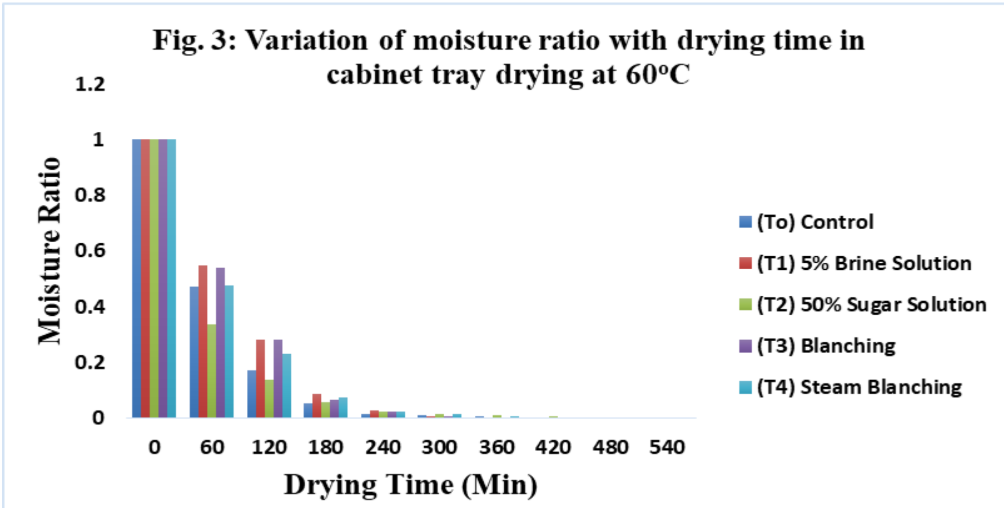
Variation of drying rate with drying time

The variation of drying rate with time under different pretreatments is shown in **Figure 2**. On examination of the plots between drying rate and drying time, it is clear that the entire drying process was accomplished in the falling rate period of drying and the constant rate period was absent like many other biological materials. This indicates that there was no free water on the product surface. Further, it can be seen that as the drying time increased the drying rate decreased. The rate was higher at the beginning of the process, which gradually reduced as the drying process progressed and the availability of moisture was reduced. On comparing the method of drying, it can be visualized that the highest drying rate was achieved with (T_1) control and other treatments least in drying rate.



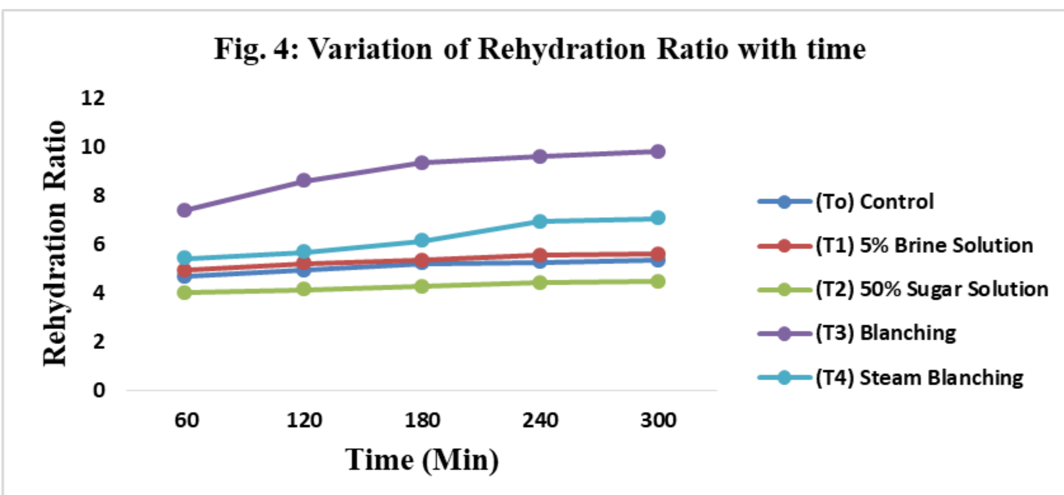
Variation of Moisture Ratio with Time

The variations in moisture ratio with time under tray drying are shown in **Figure 3**. The moisture ratio value at zero time of drying was one in all the cases and in successive drying it decreases non -linearly. So, moisture ratio versus drying time curve could better describe the drying phenomena than the curves of moisture content verses drying time (Figure 3), because the initial value of moisture ratio (MR=1) but latter have different final moisture ratio. It is clear from the graphs that moisture ratio initially decreased very rapidly and in later stage moisture ratio decreased at slower rate.



Variation of Rehydration Ratio with time

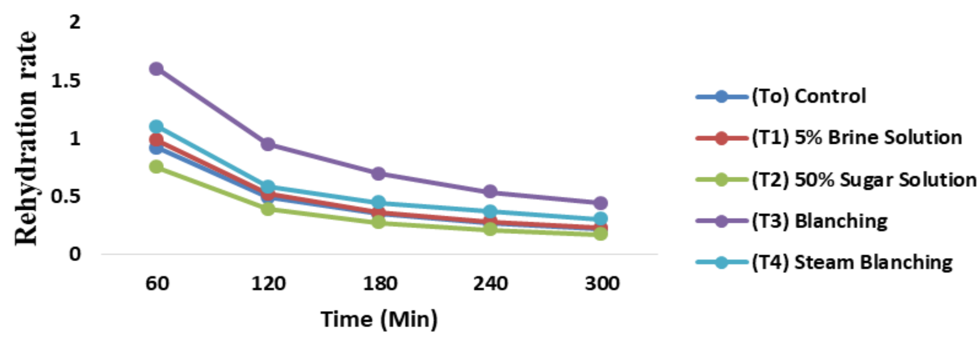
Rehydration capacity is an important parameter to evaluate the quality of dried products. **Figure 4** represents as temperature increased rehydration ratio also increased maximum to be in the range of 7.06 for steam blanching sample, 4.40 for Sugar treated sample. This is due to cellular and structural changes during drying process. It was observed that the rehydration ratio of controlled (untreated) and pretreated samples were gradually decreased day by day during storage period.



Variation of Rehydration Rate with time

Figure 5 showed that the rehydration rate decreased with increase in time but the decreasing rate was higher for T_0 Control than that other treatment. From the above figures it is also observed that the rehydration rate of mechanically beetroot is higher during the initial period and finally rate of rehydration tends to remain same as time passes indicating commencement of saturation condition. The rate of water uptake is high in the initial period because of the high water activity gradient between the sample and surrounding media (here water) and as time passes this difference reduces with consequent lower rate of rehydration. Similar behavior of rehydration rate was shown by [34].

Fig. 5: Variation of Rehydration rate with time



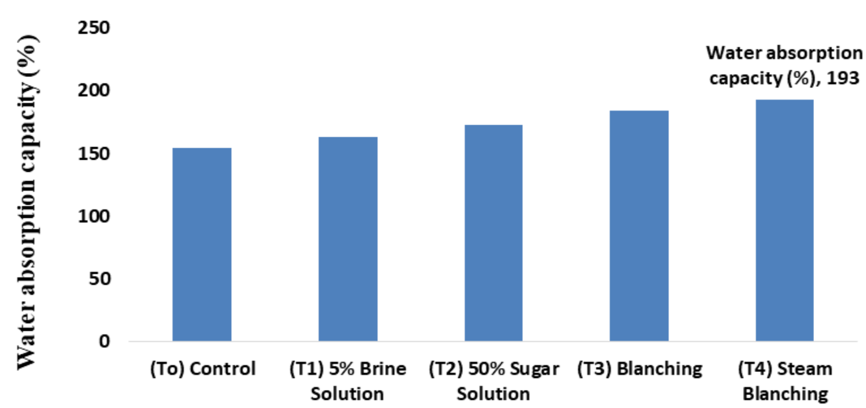
Functional Properties of Beetroot Powder

Various type of functional properties of beetroot powder were analyzed.

Water absorption capacity

The water absorption capacity (WAC) was observed highest for T_4 Steam blanching (193 %) and lowest for T_0 Control (154 %) beetroot powder are shown in **Figure 6**. Water absorption capacity or characteristics represent the ability of a product to associate with water under conditions where water is limited [35]. Increased water absorption capacity of beetroot powder observed in this study appears to be advantageous in processing, formulation and development of bakery products due to its higher protein content [36].

Fig. 6: Water absorption capacity (%) of beetroot powder

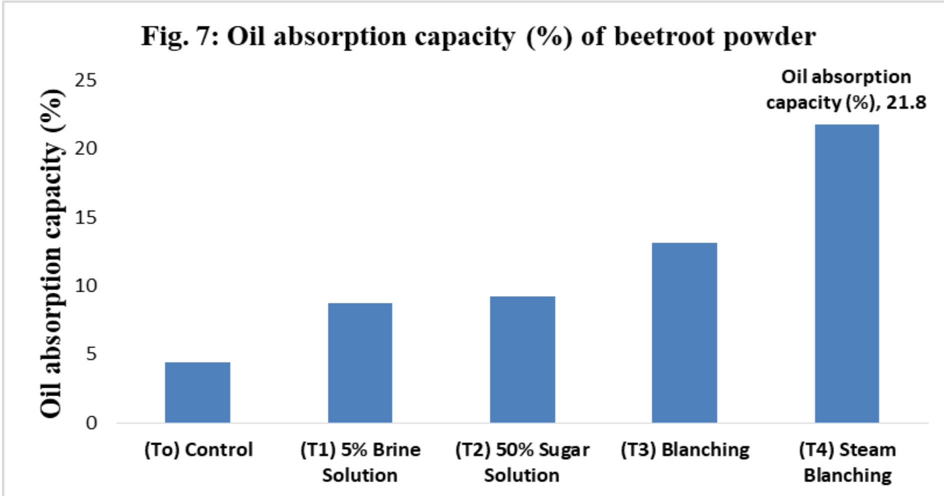


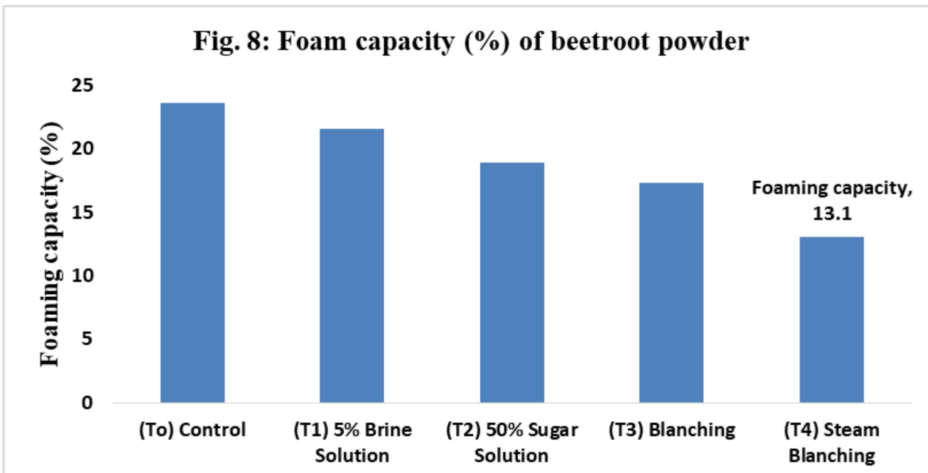
Oil absorption capacity

The oil or fat absorption capacity of powder is an important aspect as it improves the mouth feel of the product and retains the flavor [37]. The oil absorption capacity of food protein depends upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. The oil absorption capacity also makes the powder suitable in facilitating enhancement in flavor and mouth feel when used in food preparation. The ability of the proteins of these powders to bind with oil makes it useful in food system where optimum oil absorption is desired [38]**.** The fat absorption of beetroot powder T_0, T_1, T_2, T_3 and T_4 was found to be 4.4, 8.7, 9.2, 13.1 and 21.8 %, respectively. T_3 (Blanching) and T_4 (Steam Blanching) having higher oil absorption capacity could be therefore being better than the other pretreatments as flavor retainer are shown in **Figure 7** [39].

Foam capacity

The foam capacity of beetroot powder is shown in **Figure 8**. Foam capacity of beetroot powder ranged from 13.1% to 23.6%. Highest foam capacity was observed for T_0 (23.6%) and lowest T_4 (13.1%). Foam is a colloidal of many gas bubbles trapped in a liquid or solid. Small air bubbles are surrounded by thin liquid films [40]. The result of study was also indicated that the untreated sample higher value and pretreated sample lower value.





Foam stability

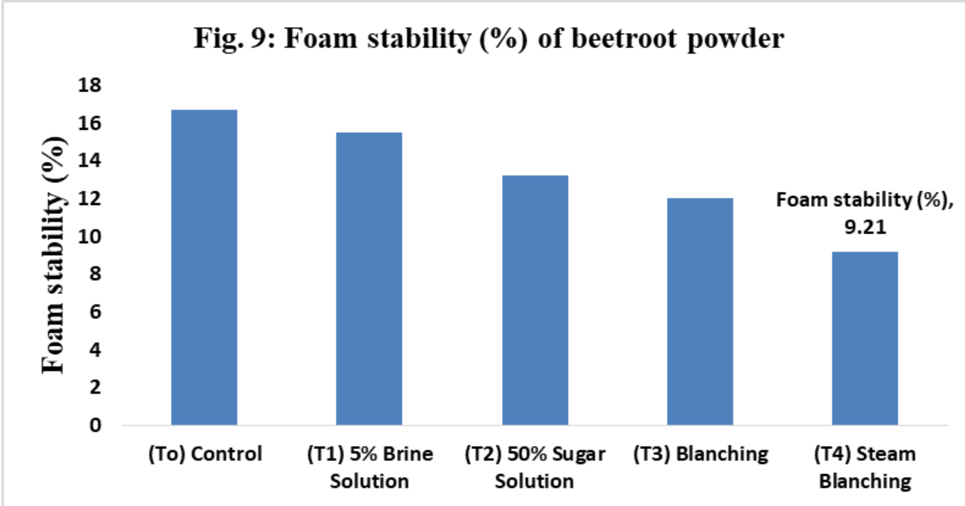
The foam stability of beetroot powder is shown in **Figure 9**. Foam stability of beetroot powder ranged from 9.21% to 16.7%. Highest foam stability was observed for T_0 (16.7%) and lowest T_4 (9.21%). Foam is a colloidal of many gas bubbles trapped in a liquid or solid. Small air bubbles are surrounded by thin liquid films. The result of study was also indicated that the untreated sample higher value and pretreated sample lower value.

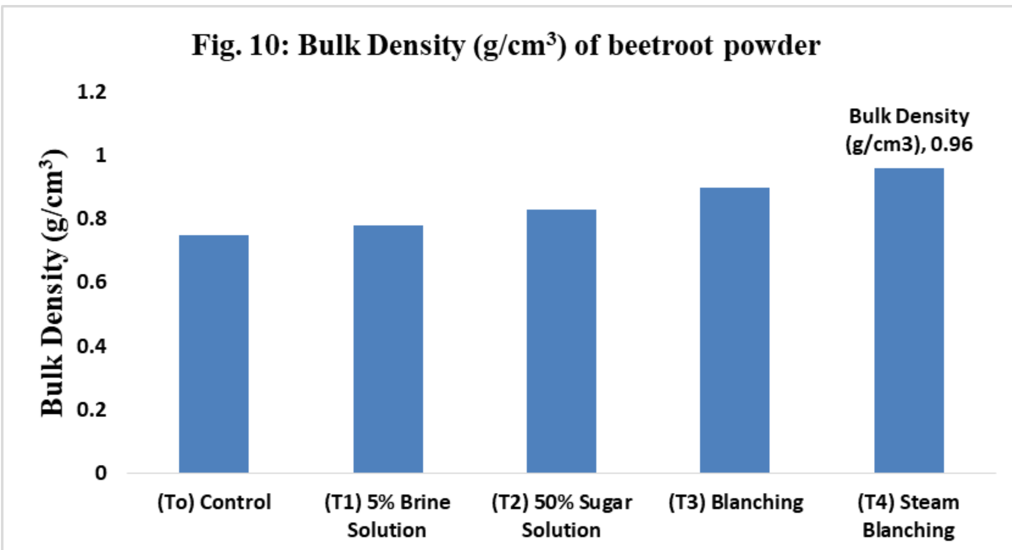
Bulk Density

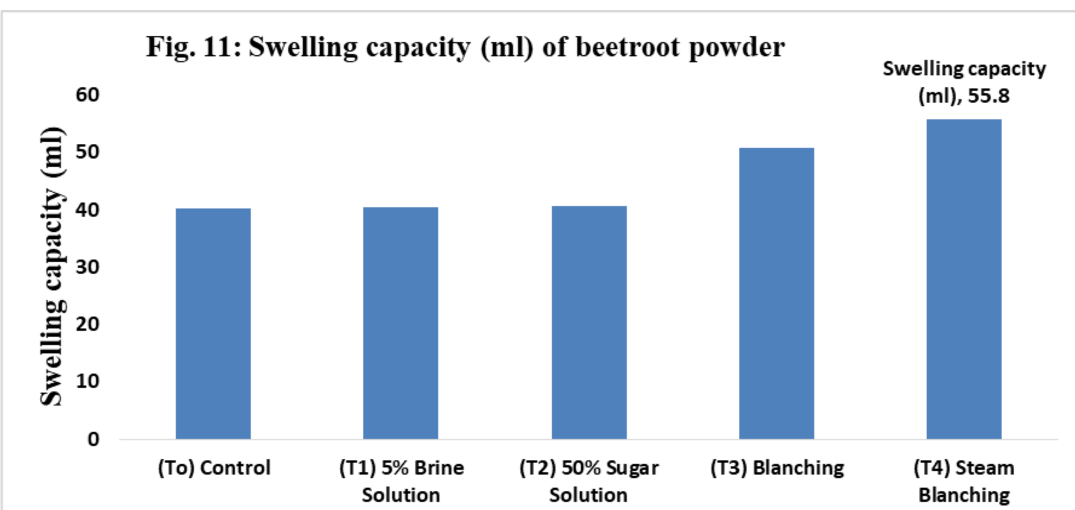
The bulk density in powders is an important parameter for packaging and storage. Lower bulk density implies greater volume for packaging and reduces the shelf life because as the more occluded air exist the greater is the possibility for oxidation [41]**.** Values for the bulk density property can be observed in **Figure 10**. Bulk density was observed highest for T_4 Steam blanching (0.96 g/cm^3) and lowest for T_0 Control (0.75 g/cm^3) beetroot powder. The values for the samples ranged between 0.75 – 0.96 g/cm^3 with sample recording the least value. Bulk density is generally affected by the particle size and density of the powder and it is very important in determining the packaging requirement, material handling and application in wet processing in the food industry [42]**.**

Swelling capacity

The swelling capacity (%) of beetroot powder from 40.2 to 55.8 ml are shown in **Figure 11**. The value of swelling capacity was found in beetroot powder followed by T_0 (40. 2ml), T_1 (40.5ml), T_2 (40.7ml), T_3 (50.8ml) and T_4 (55.8ml) respectively. The swelling capacity of composite flours depends on size of particles and types of processing methods**.**







Conclusion

In conclusion, The Pretreatment T_3 and T_4 were more efficient than T_0, T_1 and T_2. The rehydration ratio and rehydration rate indicated that Pretreatment T_3 and T_4 showed better reconstitution properties than those others pretreatment. Pretreatment T_3 and T_4 is better time saving gives better results obtained during drying and rehydration process. The functional properties of beetroot powder such as swelling capacity, water absorption capacity, oil absorption capacity, foam capacity, foam stability and bulk density were increased with increase in pretreatments. The result showed that the T_3 (Blanching) and T_4 (Steam Blanching) has highest functional properties of beetroot powder compared to others powder.

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