

# Effect of Pretreatments and Drying Methods on the Rehydration Ratio of Dried Mango (*Mangifera Indica* L.) Slices and Evaluation of Some Properties of Its Peel Flours

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## Abstract

The study was conducted to investigate the effect of selected pretreatments and drying methods on the rehydration ratio of dried mango slices and evaluation of some properties of its peel flours. Freezing and fluidized bed scored the highest rehydration values after being subjected to the pretreatments, whereas the control samples scored the lowest values. The mango peel flours had 0.49 g/ml, 0.25 and 0.11 ml/g of bulk density, water absorption and oil holding capacity respectively. The nutrient analysis showed that the mango peel flours had respective values for moisture, protein, fat, fiber, ash and carbohydrate contents (4.62%, 4.28%, 9.18%, 2.25% and 70.51%). Regarding the polyphenol of mango peel flours, the values was 564.54 mg GAE/100g. It could be inferred that the total plate and fungal count of mango peel flours were not detected during the storage period.

**Keywords:** Mango drying, Rehydration; Mango peel flours; functional properties, chemical composition

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## 1. Introduction

Mango is a fleshy tropical fruit of highly seasonal and one of the most popular fruits of the planet (Sehrawat *et al.*, 2018). Its the most likely fruit cultivation grown in Ethiopia (Neguse *et al.*, 2019). However, the processing industry in Ethiopia is unbelievably weak given the large volume of mango fruit. The loss is estimated to be between 25 to 40% (Kasso and Bekele, 2018). Different strategies must be used to eat this balanced fruit all year (Neguse *et al.*, 2019). Even if drying is attractive technology, in Ethiopia it's unknown because research and technology are not extensive (Yusufe *et al.*, 2017).

The drying process produces many unexpected changes, such as shrinking, stiffness of texture, changes in colour and decreased usability (Abano *et al.*, 2013). This is because drying can affect the cells, tissues and biochemical in foods which can impact the texture (Sehrawat, Nema, & Kaur, 2016). This can reduce market value and dried food demand (Khalloufi and Maslouhi, 2000). Rehydration is a process to ensure that the property of the raw material is properly restated when the dried material contacts with water (Tedjo, Taiwo, Eshtiaghi, & Knorr, 2002). One of the most important characteristics of dried mango slices is the capacity to rehydrate quickly and completely. Pretreating is often recommended in order to improve the quality and safety of dried goods before the drying process is carried out (Delfiya, Mohapatra, & Kotwaliwale, N., & Mishra, 2018).

The recovery of bioactive health benefits from fruit waste nowadays leads not only to increase the waste burden but also to satisfy the high public demand for phenolic compounds that are known to have protective effects against chronic diseases (Cheok *et al.*, 2018). The industrial processing of agro-food products produces high amounts of waste (Castro *et al.*, 2019). Approximately 0.5 per cent of world mango production is used for the production of derived products; hence the amount of bio-waste produced by the processing industries (Dorta, Lobo, & González, 2012). Each year large volumes of agricultural waste are generated around the world and cause a serious disposal problem (Jawad, Alkarkhi, & Norulaini, 2012). After processing, the mango waste is potentially problematic and forced to discard it. Though, the peels of the mango fruit currently causing pollution problems (Jawad *et al.*, 2012). The use of mango by-products would help to reduce waste and pollutants (Adilah, Jamilah, Noranizan, & Hanani, 2018).

Peels are the major by-products obtained during the processing of various fruits (Arumugam and Manikandan, 2011; Castro-vargas *et al.*, 2019) and each contributes about 15 – 20% of the mango fruit (Gurumeenakshi *et al.*, 2019). Research has recently been conducted on potential uses of fruit by-products such as seeds, peels. As mango peels are not currently used for any commercial purpose, they are discarded as waste and become a source of pollution in Ethiopia. Currently, several initiatives concentrate on the use of industrial waste in the production of new food ingredients with a good source of organic compounds as raw material. There is a need to develop cheap and commonly available technology for extending the shelf life of this produce (Gurumeenakshi *et al.*, 2019). When mango peels are to be used as a raw material for the recovery of functional compounds, they must be immediately dried to avoid enzyme pectin degradation and microbial spoilage.

Peel is rich in phytochemicals, fibre and vitamin C (Gurumeenakshi *et al.*, 2019) which makes it suitable to be processed and used in food and pharmaceuticals (Castro-vargas *et al.*, 2019). The sensory properties and oxidative stability of fat-rich products are improved by the use of dried mango peels. In the scientific community,

mango peels have recently attracted considerable attention due to their high content of valuable compounds, such as phytochemicals, polyphenols, carotenoids, enzymes, vitamin E and vitamin C, predominantly functional antioxidant. It has also been shown that chemicals in peels of certain mango cultivars prevent the formation of fat cells by disrupting adipogenesis which is the key in the development of obesity. While these data are relevant, information on these Ethiopian mango fruits peels is lacking. Besides, studies shows that the soil, climatic conditions and varieties of different regions result in a significant difference in the composition of the fruits, and therefore data cannot simply be rented between countries. Besides, information on other vital nutrients such as functional properties, physicochemical properties, phytochemicals such as polyphenols and other such the microbial loads during storage of mango peel flours is limited if not lacking, hence this study. The data in this study may be incorporated into food nutrient databases, and also foster renewed interest in the use in product development, specifically in Ethiopia.

## 2. MATERIALS AND METHODS

Fresh, healthy and disease-free mango fruits of the *Keitt* cultivar used in this experiment was collected in plastic bags from Asossa, Benishangul Gumuz Regional State, Ethiopia.

### 2.1. Experimental Plan

The experiment was set in a 4×4 factorial arrangement involving four pretreatments, that were lemon juice, salt solution, hot water blanching and control (untreated) prior to drying and four drying methods (solar, tray, freeze and fluidized bed drying), arranged in a completely randomized design (CRD).

### 2.2. Mango Slices Preparation

The mangoes were cleaned, peeled and the flesh sliced manually in the direction parallel to their fibres to a thickness of approximately 5 mm (Adepoju & Osunde, 2017) with a sharp stainless steel knife (Inox stainless, Brazil). These slice materials were categorized into 200 g each and treated with each pretreatments before drying.

#### a) Lemon juice dips

The slices were subjected to the pretreatment of equal parts of lemon juice and distilled water mixed solution 0.5 v/v (Abano *et al.*, 2013) in the container (Op plastics, Ethiopia) ensuring full coverage of the slices and allowed for 10 minutes. The pretreated slices were removed from the solution and spread evenly over a perforated tray, allowing the excess solution to drip for 20 minutes.

#### b) Hot water Blanching

One minute hot water blanching was done by subjecting the sliced mangoes at 90 °C (Doymaz, 2010; Wang *et al.*, 2018) in a water bath (BM 30, Turkey) ensuring full coverage of the slices by water.

#### c) Salt solution dips

The samples of sliced mangoes were soaked in the solution prepared by 0.011 g/mL (Abano *et al.*, 2013) for 10 minutes in the container (Op plastics, Ethiopia) ensuring full coverage of the slices. The pretreated slices have been removed from the solution and spread evenly over a perforated tray, allowing the excess solution to drip for 20 minutes.

#### d) Control

One sample was untreated and served as the control.

### 2.3. Mango Peel Flours Preparation

The underlying pulp on the peels was removed by gently scrapping with the blunt edge of a clean knife and the peels were washed with distilled water to remove the dirt and foreign matters.

### 2.4. Drying Methods

Solar drying of mango slices was carried out in a solar dryer (YYF-2-7112P1, China). Different sides of the slices were turned to increase drying efficiency regularly. A digital hygrometer (PWT-105, China) was used to measure the temperature and relative humidity at the entrance of the collector and the drying chamber.

Tray drying of mango slices was carried out in a computer-controlled tray drying (SBANC, Madrid, Spain). The drying temperature was maintained at 70°C.

A laboratory-scale freeze dryer (Lablyo plus, Germany) was used to dry mango slices according to Izli *et al.* (2017). The drying was with total pressure and the temperature inside the vacuum chamber of 52 pa and -52°C respectively. The prepared slices were arranged in a single layer on the trays and placed inside the freeze dryer chamber. Thermocouple probes were used to control and monitor the product temperature on each tray during drying.

A batch type laboratory-scale fluidized bed dryer (TG 200, Germany) was used to dry the prepared mango slices and peels. An air temperature of 50°C and an airflow of 1.5 m/s was set digitally (Quintana-Zaragoza *et al.*, 2017). All the samples were dried until the moisture content of the samples dropped below 10% on a wet basis.

The peels with average initial moisture content of 56.36% on a wet basis were dried in the fluidized bed dryer with an air temperature of 50°C for 90 minutes. The dried mango peels with the final average moisture content of 4.62% on weight basis was ground into a flours. The flours obtained were then sieved and enclosed in zip lock bag and stored at a room temperature until it was required for the subsequent tests.

## 2.5. Data Collection

### 2.5.1. Rehydration Ratio

Rehydration experiments were performed according to Doymaz (2010) with some modifications. In brief, about three grams of the dried products were added to 300 ml distilled water, in a 400 ml beaker. Samples were removed after 10, 20, 35, 60, 120 and 180 minutes, dried with tissue paper and weighed using an electronic balance.

### 2.5.2. Chemical and Functional Analysis of the dried mango peel flours

The water and oil absorption capacity and bulk density of the flour were calculated according to Sosulski *et al.* (1976) and Udensi, and Okoronkwo (2006), respectively.

Proximate values for moisture, fat, protein, ash, and crude fiber of dried mango peel flour samples were determined according to AOAC (2005); carbohydrate content was calculated by difference.

The pH of the samples was measured by dipping the electrode of a digital pH meter (Inolab, pH7110, England) into the juice of the samples after proper calibration of the pH meter with the standard solution. The titratable acidity was determined by titrating the aliquot with 0.1N NaOH solution using titration kit (Jencons digitrate pro, England) to the first appearance of pink endpoint, where phenolphthalein (3-5 drops) was used as an indicator. Using a refractometer (0- 100 °Brix, Bellingham Stanley Ltd., England), total soluble solids were determined directly in each sample and expressed as °Brix by placing one to two drops of clear juice.

The color L\*, a\* and b\* of the mango peel flours were measured by a colorimeter (NR110, 3NH technology co., Ltd) per CIE L\*a\*b\* color space system. Total phenolic content was determined by spectrophotometer using Folin-Ciocalteu method following the procedure of Sogi *et al.* (2012).

### 2.5.3. Microbial loads of the dried flour during storage

The microbial loads of the mango peels flours were assessed during each month by using the total number of bacterial and fungal analyses (AOAC, 2005) for three months of storage period. All the colonies were counted using colony counter (362: ISO 9001: 2008 certified, England).

## 2.6. Statistical analysis

The data were analyzed using mean  $\pm$ Standard deviation analysis of variance using IBM SPSS Statistics version 20, Chicago, USA.

## 3. Result and Discussion

### 3.1. Effect of Pretreatments and Drying Methods on Rehydration Ratio

The rehydration curves for each pretreatments through the drying process are shown in Figures 1- 4. As shown in the figures, the dried mango showed high rehydration ratio and after rehydration, the sample mass was increased. Zou *et al.* (2013), found that the rehydration ratio values of puffed mango chips associated with different osmotic pretreatments ranged from 2.47 to 3.03 and the sample mass was doubled after rehydration. The curves showed significantly high rehydration ratio during the initial period but slowed down gradually to achieve a constant rehydration ratio. In all cases, the ratio was high at the beginning and kept on decreasing until the curve assumes horizontal position. Comparable findings have been reported by Doymaz (2010) and Yi *et al.* (2017) for dried apple and mango, respectively.

Nevertheless, from the pitches of the curves, at Figures 1, 2, 3 and 4 the rehydration ratio of control samples decelerates faster. The rehydration features depend on the composition of samples, preparation, processing and the degree of chemical-structural disturbances during drying (Nyangena, Owino, Ambuko, & Imathiu, 2019). With the exception of fluidized bed, dried samples (Figure 4) hot water blanching treatments led to increase the rehydration ratio values as compared to that other pretreatments (Figures 1, 2 and 3). Similar results have been reported for apples (Doymaz, 2010) in which indicated that blanching resulted in the highest rehydration ratio as compared to citric acid and control treatments. Cellular and structural disturbances during blanching may lead to a rehydration ratio increment (Al-amin, Hossain, & Iqbal, 2015).

The result for the freeze-dried samples after being subjected to lemon juice was in agreement with Mohamed *et al.* (2017) who stated that samples treated with ascorbic and citric acids had highest rehydration ratio values as compared to control samples. It could be because more rigid and porous structures have been created in lemon juice treated samples and rehydrated water filled the capillaries to reduce the resistance to deformation and thus encourage swelling and water absorption (Abano *et al.*, 2013). In addition, samples pretreated with salt solution had the higher rehydration ratio values as compared to control samples. Similar findings were observed by (Madan & Pare, 2014). Sodium chloride dissociates crystals, form concentrates spots of sodium and chlorine ions, and ion solvation leads to faster and improved rehydration during rehydration. Furthermore, the rehydration ratio of control

samples was shown to be the lowest in all the four drying methods. Maldonado *et al.* (2010) stated dried fruit without pretreatment presents a lower rehydration ratio. An opposite result was reported in mango chips rehydration treatment by Zou *et al.* (2013).

The samples dried by fluidized bed dryer after subjected to all of the four pretreatments achieved better rehydration ratio. This result is also coherent with other findings of Prakash *et al.* (2004), who reported the highest rehydration ratio of carrots dried by fluidized bed drying whereas the lowest was that of the solar cabinet dryer. This indicated that the samples retained good texture and absorbed more water. According to Prakash *et al.* (2004) and Madan and Pare (2014), higher rehydration might be due to the faster drying process causes less cellular and structural changes in the final product. Freeze-dried mango samples attained better rehydration ratio as compared to solar and tray dried samples. The result obtained agreed with those of Yi *et al.* (2017), who observed the highest rehydration ratio of dried mango in freeze dryer. The possible reason was that the dried samples are formed with better porous structure and higher cell membranes (Wang *et al.*, 2018). Similarly, according to Ghiafeh *et al.* (2007) uniform air drying and better heat transfer, resulting in fewer textural change during drying offered a higher rehydration ratio for the final product. The ability to rehydrate quickly and completely is one of the most important properties of dried mango (Akoy, 2014). Due to the reconstitution of most of the dried products before their final use, the rehydration properties of dried products are used as quality criteria to show physical and chemical changes due to the drying process (Abano *et al.*, 2013).

Solar and tray dried samples after those pretreatments had lower rehydration ratio. Driers were likely unable to keep the drying rate constant because air temperature changes and minor shrinkage and case hardening caused less reconstitution of the dehydrated samples (Ghiafeh *et al.*, 2007). Similarly, low rehydration can be caused by factors such as long drying times, poor product texture caused by poor relative humidity control and airflow fluctuations (Madan and Pare, 2014). The goal of drying the fruit is to make the product stable and easily handled, quickly reconstitute as close as possible to a fresh product.

The rehydration characteristics can be used as quality indices of a dehydrated product (Mishra *et al.*, 2019). Such features reflect the changes occurring during the drying that is influenced by the sample composition, conditions imposed during the drying process and any pretreatments to which the products are subjected. Similarly, according to Maldonado *et al.* (2010), rehydration loss can involve losses of vitamins, sugars, amino acids, and minerals. In this work rehydration ratio of dehydrated mango slices was affected significantly by the pre-treatments and drying methods. Pretreatments and preparation of the samples before drying, drying itself, lead to changes in the structure and composition of material tissues that change reconstitution properties (Maldonado *et al.*, 2010; Abano *et al.*, 2013). The results of present study was in good agreement with report of Zou *et al.* (2013) 2.47 to 3.03 g/g, Mishra *et al.* (2019) 2 to 5 g/g and Nyangena *et al.* (2019) 1.65 to 3.61 g/g for dried mango. But higher than 1.62 to 2.23 g/g that of Abano *et al.* (2013) for dried mango. The rehydration capacity indicates a degree of damage to foods caused by drying and were used as a quality index because they could indicate the physical and chemical changes of samples during drying (Nyangena *et al.*, 2019). It could affect the sensorial quality of products (Q. Wang *et al.*, 2019).

### 3.2. Functional Properties of Mango Peel Flours

The values of functional properties like bulk density, water absorption capacity and oil holding capacity are shown in Table 1. The results revealed that the mango flours had 0.49 g/ml, 0.25 and 0.11ml/g of bulk density, water absorption and oil holding capacity respectively. The results of bulk density are comparable with the reported value of (Singh, Siddiq, Greiby, & Dolan, 2013). The low bulk density value is always beneficial in the preparation of complementary food. The water absorption capacity indicates the mass of the water uptake per unit mass of dried flour. It play important role in the preparation of baked, fried, cooked snacks as well as flour based drinks and functional foods.

### 3.3. Proximate Composition of Mango Peel Flours

The moisture content of the dried mango peel flours was 4.62%, which was in agreement with the finding of Bandyopadhyay *et al.* (2014) and El-Faham *et al.* (2016), 5.34 and 5.9%, respectively. It was observed that the mean mango peel flours contains 4.28% of crude protein. The mean value of the fiber was 9.18%. As a raw material for making fiber-rich goods, mango peel flours can be used. Fiber from mango peel is a good food fiber and can be compared with fiber from citrus (Ojokoh, 2007). Mango peels can be used to produce valuable ingredients for different food applications, as researchers have reported (Ajila *et al.*, 2010). Similarly, according to Raghavendra *et al.* (2006), fibers are added to cooked meat products to improve the cooking yield owing to their water and fat retention properties and in fried food products, the addition of fiber decreases lipid retention and improves water content. Regarding the fat, ash and carbohydrates of mango peels flours were 2.37, 2.25 and 70.51%, respectively. The results are comparable with previous reports by El-Faham *et al.* (2016) in which they have reported 2.42, 3.06 and 72.56% of fat, ash and carbohydrate for dried mango peel flour. In addition, the proximate analysis was comparable to the previous reported values in mango peel powder (Bandyopadhyay *et al.*, 2014).

Jawad *et al.* (2012) stated that mango peel was investigated for its potential as a novel and potential raw material for lactic acid production. Similarly, it has shown that a thicker, denser and continuous structured film has been produced with the addition of mango peels extract in fish gelatin (Adilah *et al.*, 2018). Ahmad *et al.* (2018), concluded that mango peel powder dehydrated by different pretreatment combinations of potassium metabisulphite and ascorbic acid has maximum nutritional and sensory quality. In line with this mango peels are involved in refined food as supplements of dietary fibre, gelling and thickening agents.

### 3.4. pH, Total Soluble Solids, and Titratable Acidity of Mango Peel Flours

The pH, total soluble solids and titratable acidity of dried mango peel flours is shown in Table 1. The pH of dried mango peel flour was 4.05. It is important parameter for blending with pH sensitive food, such as milk and other dairy products. The titratable acidity and total soluble solids of the dried mango peel flours were 1.64 g/100g and 21.22 °Brix, respectively. The values of pH and titratable acidity in the present investigation were comparable to those reported by (Singh *et al.*, 2013).

### 3.5. Color and Total Polyphenol of Mango Peel Flours

Hunter colour values (L\*, a\* and b\*) of mango peels flours are shown in Table 1. The flours had 61.75, 5.58 and 28.05 of L\*, a\* and b\*, respectively. The flour showed higher lightness and more reddish and yellow. Similar results for color values of mango peels flours were reported by (Aziah, Aziz, Wong, Bhat, & Cheng, 2012). The phenol contents in these peels flours were 564.54 mg/100 g (Table 1). El-Faham *et al.* (2016) have reported polyphenol content of 512.62 mg/100 g. These peels flours show high levels of polyphenol contents. Mango peel flours has been a good source of phenolic compounds from this result. Due to polyphenolic extracts, mango peels have higher values of anti-cancer properties and glucose retardation.

Moreover, mango peels have been reported as a source of rich dietary fibre, cellulose, hemicellulose, lipids, protein, enzymes and pectin (Sogi *et al.*, 2013). In a plant that can resist oxidation, the active element is known as the phenolic and their secondary metabolites (Adilah *et al.*, 2018).

### 3.6. Microbial Loads of Mango Peels Flours during Storage

The microbiological examination such as total plate count and fungal count of the dried mango peels were done to ensure the safety of the product and shown in Table 2. Aerobic bacteria and yeast and mould were not found in during the storage of mango peel flours for the three months. Therefore, the minimum shelf life of mango peel flours were 90 days.

## Conclusion

Fluidized bed dried mango samples attained better rehydration ratio as compared to other dried samples. Except for freeze-dried samples hot water blanching treatments caused increasing in rehydration ratio values for all dried mango slices samples as compared with other treatments and control samples. The composition of mango peel flours demonstrated that it has high nutritional values as innovative functional ingredients. These results indicate that mango peel flours are rich source of carbohydrate, fiber, with good health-promoting and functional properties, thus possessing high potential to be incorporated as a functional ingredient in developing functional foods such as noodles, bread, sponge cakes, biscuits or other bakery products. The advantages of mango peels to be converted into food source can enhance the reduction of wastes, increase benefits for growers, can create jobs for people, can contribute to food security, and may encourage large scale growing of the mango fruit and industrial scale processing of products from both of the fruits and its wastes.

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## Competing interest statement

The authors declare no conflict of interest.

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**List of table and figures**

Table 1. Some Properties of Mango Peel Flours

Parameters	Contents (%)
Moisture content	4.62±0.24
Protein	4.28±0.04
Fat	2.37±0.16
Fiber	9.18±0.46
Ash	2.25±0.24
Carbohydrate	70.51±0.48
Water absorption capacity	0.25±0.02 (ml/g)
Oil absorption capacity	0.11±0.02 (ml/g)
Bulk density	0.49±0.03 (g/ml)
pH	4.05±0.35
Titrateable Acidity	1.64±0.07 (g/100g)
Total soluble solids	21.22±0.46 (°Brix)
L*	61.75±0.66
a*	5.58±0.12
b*	28.05±0.45
Polyphenol	564.54±0.96 (mg/GAE100g)

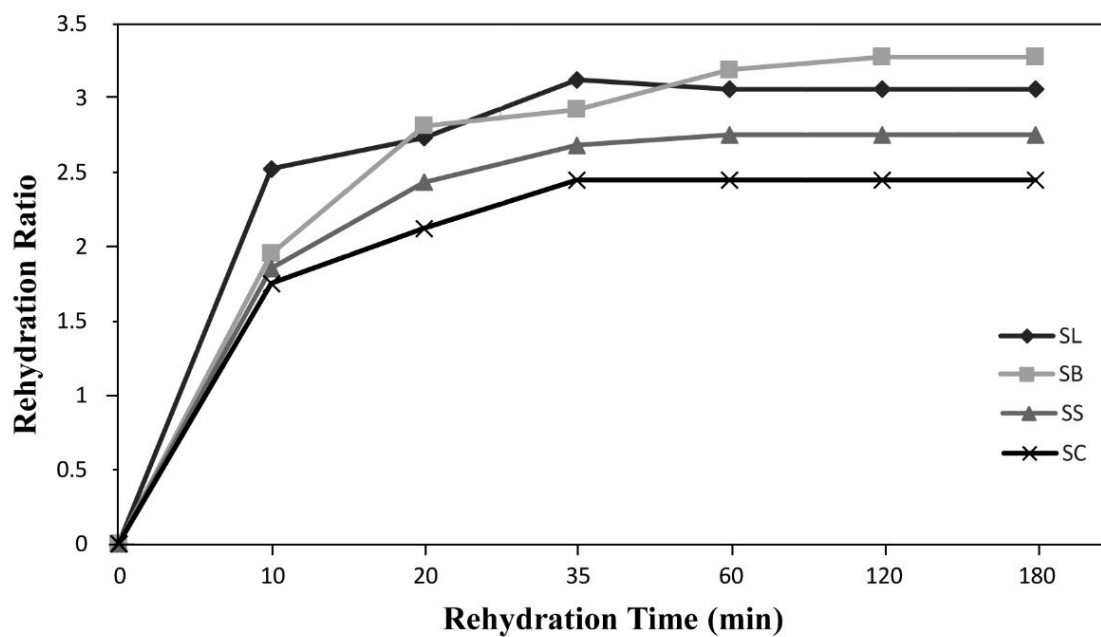


Figure 1. Rehydration curves of dried mango samples across the four pretreatments in solar drying methods.



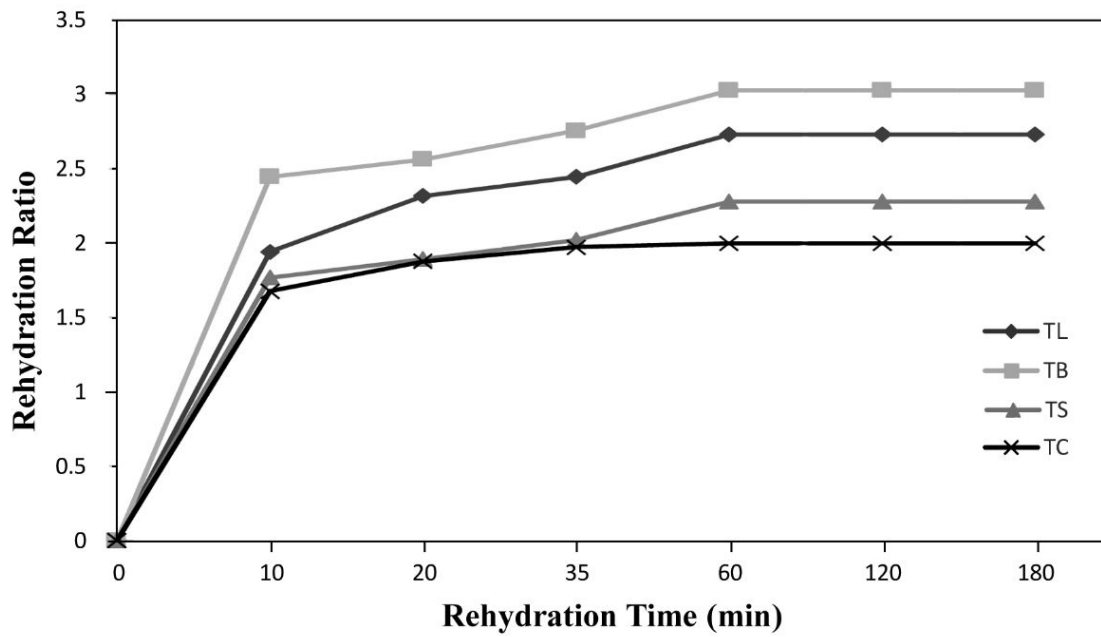


Figure 2. Rehydration curves of dried mango samples across the four pretreatments in tray drying methods.

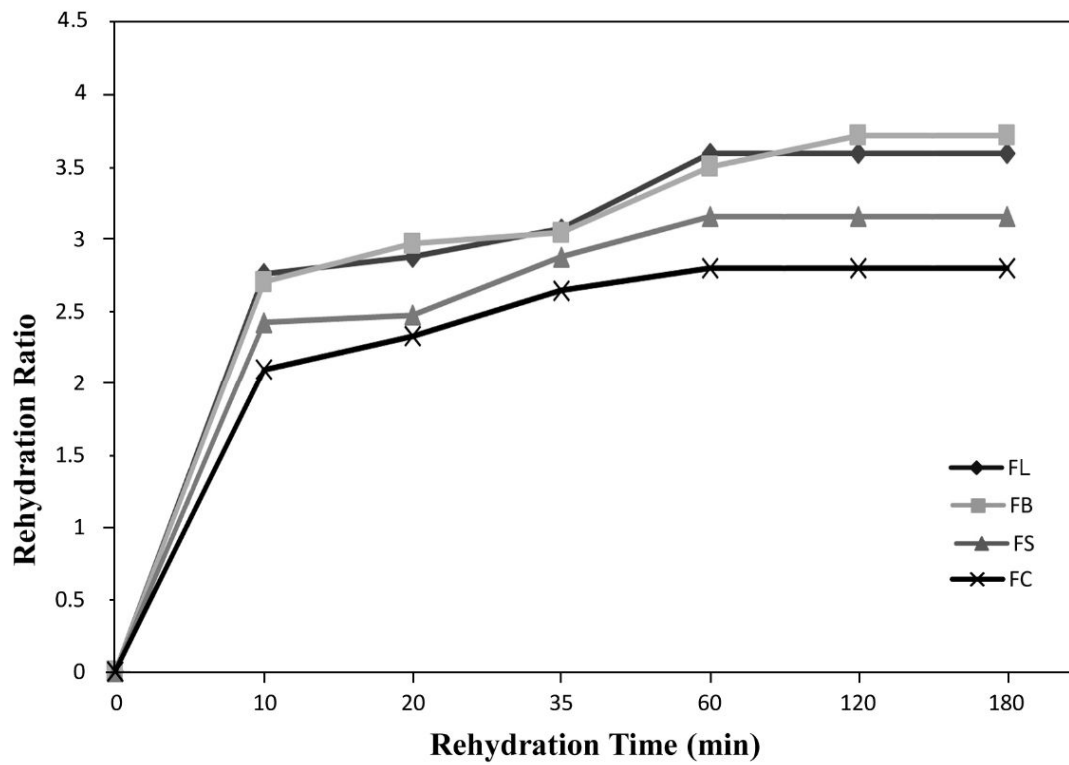


Figure 3. Rehydration curves of dried mango samples across the four pretreatments in freeze-drying methods.

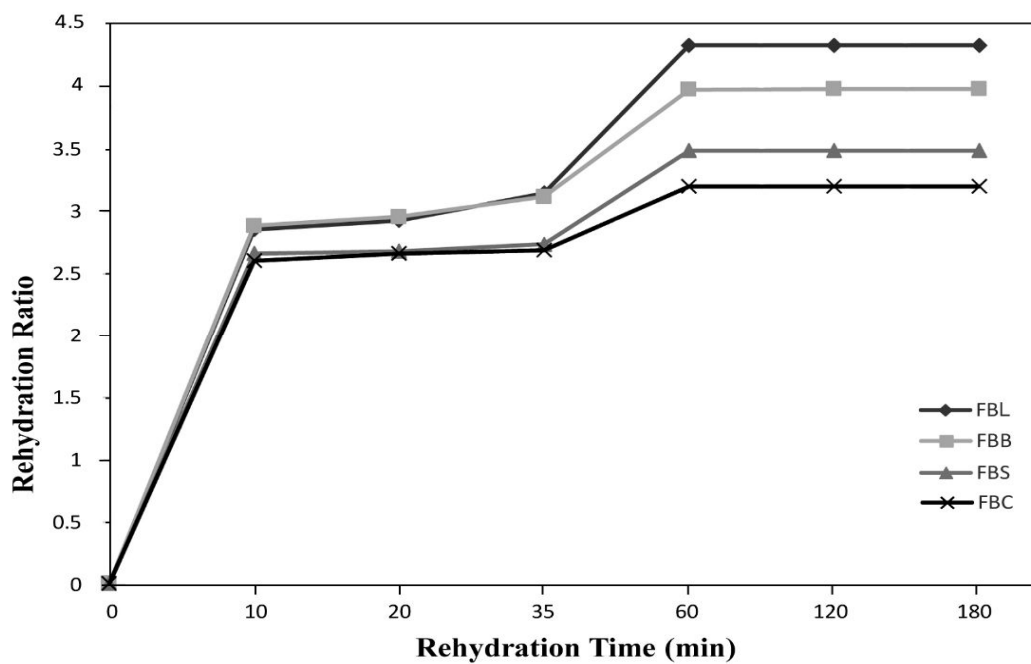


Figure 4. Rehydration curves of dried mango samples across the four pretreatments in fluidized bed drying methods.