Effects of Tray and Freeze Drying on Physico-chemical and Structural Properties of Fig Fruit Powder

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ABSTRACT

A study was conducted on the drying of fig fruits using tray-drying [50 °C, 60 °C, 70 °C for 3 h] and freeze-drying [(-)43 °C for 24 h] dehydration techniques. The physico-chemical properties of fig fruit powder were studied. Different temperatures and methods of drying had effects on the moisture content, water activity, physico-chemical properties, and structural properties. Moisture content and water activity were in the range of 6.5-8.5% (w.b.) and 0.40-0.60, respectively. Powders of 15-30 µm size range and with a flaky texture had moderate flowability. FTIR analysis exhibited peaks of varied range. XRD analysis showed that the powders were predominately amorphous in nature, and C-type starch was present.

The genus *Ficus* comprises of 800 species and is a part of the 40 genera of the mulberry family, Moraceae. *Ficus carica* L. is commonly known as ‘Fig’. The fruit is used for edible purposes. Fig is rich in vitamins and minerals. Besides, it has beneficial effects on gastrointestinal, respiratory, inflammatory, cardiovascular diseases, ulcers and cancer. They are also enriched with many phytochemical constituents such as flavonoids, antioxidants, and polyphenols (Baby and Justin, 2011). The usage of fig as a potential food additive is comparatively high but they are also used as a nutraceutical digestion aiding agent. However, the shelf life of a fig fruit, in its fresh condition harvested at the proper stage of ripening, is approximately two days at ambient storage temperature (Vieira et al., 2021) This necessitates its processing to preserve the fruit for a longer time. The main goals of fig fruit processing are to produce fruit products that are convenient, and of high quality in terms of flavour, colour, texture, and taste. Among all bakery goods, fig fruit cake has the most significance and is a favourite snack of both kids and adults. Fig fruit powder could be added to cakes and other food formulation in various forms (Dhankar, 2013).

Fig cultivation in India is done on an area of 5,600 ha with a production of 13,802 tonnes and a yield of 2.46 tonnes per hectare. The major producing states of figs in India are Maharashtra, Uttar Pradesh, Gujarat, Karnataka, and Tamil Nadu (Lokappa, 2018).

A high demand to increase the shelf life of fruits has led to recent advancements in food engineering techniques. Perishable fruits are either dried or converted into
powder form to enhance their shelf life. Drying is effective in extending the shelf-life since reduced water activity of dried fig slow down the chemical and enzymatic reactions, the primary reasons for food degradation (Athmaselvi et al., 2014). Advanced and alternate drying techniques are developed recently, which could help to obtain the powder formulations and aid in stabilising product constituents for utilisation. Fruit powders are easy to store, convenient to use, and aid in the preparation of many other products as beverages, bakery goods, weaning foods. Dehydration technique helps in achieving such formulation that functions in multiple ways to enhance the product’s attributes, lowering the transport and storage costs, and prolonging the shelf life. Therefore, the choice of the dehydration process depends on the desired properties. Freeze-drying is recognised as one of the best methods for dehydration as it removes water by the principle of sublimation of ice crystals from frozen substances (Wang et al., 2020). Ucar and Karadag (2019) showed the superiority of freeze-dried mushrooms over vacuum-dried mushroom as the former process retained the colour, rehydration aspects and size of the mushroom. Huynh et al. (2023) reported that lime powder produced using freeze-drying has similar quality characteristics as lime juice. Tray dryer is also largely used owing to its simplicity and cost effectiveness, and the equipment design allows loading of high quantities of the raw materials, which can be spread in a suitable thickness on the trays. Physical properties of fruit powders such as moisture content, water activity, bulk density, tap density, flowability, particle size and shape are important attributes that play major part in quality control and stability of the powder when stored for a considerable time.

This study was aimed at producing fig fruit powder, using tray-drying and freeze-drying techniques and evaluate the effect of drying technique on the physicochemical and structural properties.

**MATERIALS AND METHODS**

The present work was conducted at SRM University, Kattankulathur, Tamil Nadu, during 2018-19. Fresh fig fruits of local variety were purchased from a retailer. They were washed thoroughly under running tap water, shade dried at ambient temperature, and ground using a blender to obtain the fruit pulp for further analysis.

**Drying Method**

Two types of drying methods were used in this experimental study, namely tray-drying (using Everflow, India) and freeze-drying (Lark Innovation Fine Technology, Chennai, India, Model: Penguin Classic Benchtop) having 3 kg capacity.

For tray-drying, the pulp (thin layer of 5 mm) was transferred to a plate and dried for 3 h at 50, 60, and 70 °C, respectively. The product obtained was ground into powder form for further analysis. In freeze-drying technique, the pulp was transferred to a freeze drier plate and frozen for 24 hours. The frozen samples were freeze dried at (-)43 °C temperature at 3 mbar pressure for 24 hours.

**Measurement of Variables**

**Moisture analysis**

Moisture analysis of fig powder was done using hot air oven method following the AOAC standard protocol (AOAC, 1998). Water activity of fig powder was determined using a water activity meter (Novasina AG, Neuheimstrasse 12 CH-8853 Lachen, Switzerland) at constant temperature 28 °C. The samples were put into a plastic cylinder with a height of 10 mm and a diameter of 40 mm, and was then placed in the apparatus’s measuring chamber. The sensor was calibrated, and readings were taken.

**Density of fig powder**

Bulk density of fig powder was determined by dividing the mass of the powder by volume occupied. Tap density was calculated by dividing the mass of the fruit powder by its tapped volume. The volume of the powder was measured in a graduated cylinder of 250 ml. The weighed sample was gently introduced into the cylinder without compacting, and the volume level was considered to determine the bulk density. A settling apparatus capable of producing 250 taps was implemented to determine the volume for tap density calculation.

**Flowability of fig powder**

Hausner Ratio (HR) gives a measure of the flowability of a powder or granular material. It was calculated by dividing bulk density by tap density.

\[
\text{Hausner Ratio (HR)} = \frac{\text{Tapped density}}{\text{Bulk density}}
\]

Different ranges for HR in defining the flowability is (1) 1.0<HR<1.1 (free flowing powder); (2) 1.1<HR<1.25 (medium flowing powder); (3) 1.25<HR<1.4 (less
flowing powder); and (4) HR>1.4 (very less flowing powder) (Ng et al., 2012).

**Compressibility of fig powder**
Carr Index (CI) represents the compressibility of a powder, and was calculated from bulk density and tapped density according the method described by Carr (1965).

\[
\text{Carr Index (CI)} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \times 100 \quad \ldots(2)
\]

A good flowability can be expected if the CI is within 5-15%. If value of CI is above 25%, poor flowability is indicated (Carr, 1965).

**Colour of fig powder**
Colour of fig powder was determined by utilising a Hunter Colorimeter (Colour Quest XE-Di 8, Hunter Lab, India). Three (technical replicate) scans were obtained using the HunterLab colorimeter (illuminant A and 10° standard observer), and the mean readings were recorded. The results obtained were expressed in L*, a*, and b* values.

**Structural morphology**
Structural morphology of fig powder and particle size were determined using Scanning Electron Microscopy (FEI Quanta-FEG 200 SEM, USA). The experiment was performed at low vacuum of 80 torr. Each fruit powder sample was mounted on a stub using a carbon-tape. Field emission was done at 5 kV. Fourier transformed infrared spectra absorption for each sample was obtained using a Bruker Alpha Model. The samples were gently mixed with micronised KBr powder, and compressed into pellets at a force of 10 kN for 2 min using a manual tablet presser (KORSCH XP1, Germany) at room temperature.

The data were recorded at room temperature in the wavelength range of 4000-500 cm\(^{-1}\). X-ray diffraction analysis of the powder samples were done in PANalytical Xpert Pro XRD instrument in powder mode, with the source being Cu-K\(\alpha\) radiation at 1.540 Å. The spectra were scanned at a diffraction angle (20) range of 5-800 at a step size of 0.050/step and 2 sec/step (Athmaselvi et al., 2014).

**Statistical Analysis**
The values obtained and reported in the tables represent the average when the number of tests is three times. Data were analysed using a one-factor analysis of variance (ANOVA) and Tukey mean separation for multiple comparisons with the Statistical Analysis System (SAS) Program (SAS Institute, Carey, NC). Significance was accepted at p < 0.05.

**RESULTS AND DISCUSSION**

**Physico-chemical Properties of Fig Fruit Powder**
Physico-chemical properties of tray-dried and freeze-dried fig powder are summarised in Table 1. Moisture content of the powder was correlated to the dehydration temperatures and the method of dehydration (tray-drying / freeze-drying).

**Moisture content**
In the process of tray-drying, final moisture content was 8.45%, 7.80%, and 7.71% (w.b.). This showed that as the temperature increased from 50 °C to 70 °C, there was a decrease in the final moisture content of fig powder. At higher temperatures, the rate at which the heat was transferred to the particles was higher, which yielded a high efficiency from moisture evaporation. During freeze-drying, the temperature used was (-) 43 °C, and the final moisture content of the product was 6.95% (w.b.). This result coincided with that for freeze-dried pineapple with moisture content of 7% (w.b.) (Marques et al., 2011). Freeze-dried powder had lowest moisture content among all fig powder samples, establishing that freeze drying yields higher quality products.

### Table 1. Physico-chemical properties of fig fruit powder

<table>
<thead>
<tr>
<th>Drying method</th>
<th>Temperature, °C</th>
<th>Moisture content, %, w.b.</th>
<th>Water activity, (a_w)</th>
<th>Bulk density, kg.m(^{-3})</th>
<th>Tap density, kg.m(^{-3})</th>
<th>Hausner ratio</th>
<th>Carr’s Index, %</th>
<th>Flowability</th>
<th>Particle size, µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tray-drying</td>
<td>50</td>
<td>8.45</td>
<td>0.523</td>
<td>365</td>
<td>405</td>
<td>1.109</td>
<td>9.87</td>
<td>Medium</td>
<td>19.46</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>7.80</td>
<td>0.508</td>
<td>356</td>
<td>395</td>
<td>1.109</td>
<td>9.87</td>
<td>Medium</td>
<td>24.14</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>7.71</td>
<td>0.504</td>
<td>344</td>
<td>382</td>
<td>1.110</td>
<td>9.94</td>
<td>Medium</td>
<td>28.52</td>
</tr>
<tr>
<td>Freeze-drying</td>
<td>(-)43</td>
<td>6.95</td>
<td>0.478</td>
<td>168</td>
<td>210</td>
<td>1.247</td>
<td>19.85</td>
<td>Medium</td>
<td>15.23</td>
</tr>
</tbody>
</table>
Water activity

Water activity values of the powder (Table 1) measured were in the range of 0.478-0.523. Water activity in the range of 0.20-0.60 falls under the microbiologically safe category, and there will not be any development of microbiological growth (Ghosh and Mitra, 2020). The water activity values of tray dried powder at 50, 60, and 70 °C were 0.523, 0.504, and 0.508, respectively. The water activity of freeze-dried powder was 0.478. Freeze dried powders had lowest water activity among the samples, which reinstated the observation of Chetan and Barrett (2001) that freeze-dried guava fruit juice had a superior quality than those obtained by thermal treatment.

Bulk and tap density

Bulk density and tap density (Table 1) of tray-dried and freeze-dried powders were related to their moisture and particle morphologies. Bulk density was in the range of 168-365 kg.m$^{-3}$, and tap density was in the range of 210 - 405 kg.m$^{-3}$. Tray-dried samples showed higher range of bulk and tap density than those of freeze-dried powder samples. Powder with high moisture content (>10% w.b.) have particles that have the capability to adhere, resulting in greater interspatial gaps giving rise to larger bulk and tap density. Therefore, lower the moisture content, lower the bulk density and tap density of fig powder. These results were in concordance with the results of Goula and Adamopoulos (2005) for apple powder.

Flowability

Flowability and compressibility calculated by the Hausner Ratio and Carr’s Index, respectively, are related to the flowable nature of the powder.

Hausner ratio of the tray-dried fig powder and the freeze-dried fig powder were in the range of 1.1 - 1.25, which indicated that all powder samples had medium flowability. Carr’s Index of the powder was below 25%, indicating fair flow properties of the powder samples.

A free-flowing powder sample should preferably be spherical, with comparatively large particle size, and less moisture content (Nur and Gulsah, 2012). Moisture content affects the flow properties. In this case, flowability values were of highly dehydrated fig powder particles. Tray-dried samples were dehydrated at varied temperatures, and showed that the flowability was fair and intermediate. The freeze-dried samples although showed a fair and intermediate flowability had slightly different range, which could be attributed to the reduction in cohesiveness. Tray-dried fig powders showed an increase in Hausner ratio and Carr’s index with reduction in particle size, while the freeze-dried powder with low range of particle size showed a higher range on Hausner ratio and Carr’s index. These results were in line with the Hausner ratio and Carr’s index of spray-dried pitaya powder (Ng Lay et al., 2012).

Colour

The results of colour tests were given in the form of L* that represents the extent of lightness or darkness, a* that represents the extent of redness or greenness, and b* that represents the extent of blueness or yellowness.

The samples obtained using freeze-drying process were lighter in colour as the L* (60.69) values were higher. The powder products obtained by tray-drying process were darker as their L* values were low. Tray-dried powder samples obtained at various temperatures (50 °C, 60 °C, 70 °C) measured the L* values of 46.50, 43.64, and 41.39, respectively, and thus there was a marked difference in the colour between the samples dried at various temperatures. These behaviours of tray-dried samples were due to non-enzymatic browning reactions at high dehydration temperatures as compared to freeze-dried samples (Phoungchandang et al., 2008; Wongsa et al., 2023). Similar trend was observed in spray-dried pitaya by Ng Lay et al. (2012).

SEM-Based Micrographic studies

SEM-based micrographic studies of tray-dried and freeze-dried fig powder samples are shown in Figs. 1(a-h). The microstructures of all fig powder samples were scattered, flaky, and irregularly shaped. The particles were uneven flaky-type, indicating very moderate flowability. The microstructures of tray-dried fig powder samples were scattered, and exhibited irregular particles with sharp edges and considerable indentation because of crushing into powder. The tray-dried powder samples exhibited adherence of molecules in their morphology due to the action of heat.

Freeze-dried fig powder samples showed a skeletal-like structure, and were more porous with smooth structure compared to tray-dried fig powder samples. This pattern of freeze-drying powder could be attributed to the protective action of ice in the material, preventing shrinkage and collapse of the structure and shape and resulting in an insignificant change in volume (Bhatta et al., 2020).
Fig. 1: SEM Images of tray-dried and freeze-dried fig fruit powders
FTIR analysis

FTIR analysis was carried out for the tray-dried and freeze-dried fig powder samples [Figs. 2(a-d)].

Tray-dried sample

Peaks in the range of 690-515 cm\(^{-1}\) was allocated to C-Br stretch – alkyl halides. Medium peaks were absorbed at 522, 522, and 532 cm\(^{-1}\) in fig powder samples at 50, 60, and 70 °C, respectively. Peaks in the range of 610-700 cm\(^{-1}\) was assigned to \(-\text{C}=\text{C}=\text{H}:\text{C}=\text{H}\) bend-alkynes. Tray-dried fig powder dried at 50, 60, and 70 °C had strong and broad peaks, which were absorbed at 631, 632, and 630 cm\(^{-1}\). However, medium peaks were also obtained, which were assigned to the C-Br stretch-alkyl halides in the range of 690-515 cm\(^{-1}\).

Peaks in the range of 1,000-650 cm\(^{-1}\), 950-910 cm\(^{-1}\), 910-665 cm\(^{-1}\), 900-675 cm\(^{-1}\), and 850-550 cm\(^{-1}\) were assigned to \(-\text{C}=\text{H}\) bend-alkenes, O-H bend –carboxylic acids, N-H wag -1˚, 2˚ amines-H ‘oop’-aromatics, and C-Cl stretch-alkyl halides, respectively. The fig samples dried at 50, 60, 70 °C showed peaks absorbed at 777, 777, and 778 cm\(^{-1}\), respectively, which could have been strong and broad or medium peaks depending on the functional group specifications as they fall in the vast range of spectrum. Peaks were absorbed at 817, 818, and 818 cm\(^{-1}\) in the powders dried at 50, 60, 70 °C, and they were assigned to the functional groups which were allocated to the peaks absorbed at 777 cm\(^{-1}\) and 778 cm\(^{-1}\) as they fell under the same spectrum range. Peaks at 917 cm\(^{-1}\) was observed at all three tray-dried powder samples, and they could be a medium peak representing carboxylic acids due to the O-H bend falling in the 950-910 cm\(^{-1}\) range or a strong peak representing alkenes due to the \(=\text{C}=\text{H}\) bend falling in the 1,000-650 cm\(^{-1}\) range. Peaks of 1,056; 1,059 and 1,060 cm\(^{-1}\) were allocated to the C-N stretch at 1,250-1,020 cm\(^{-1}\) range, which showed either a medium peak or C-O stretch allocated to various functional groups such as alcohols, carboxylic acids, esters, and ethers; all of which come under the same spectrum range. Peaks at 1,250-1,000 cm\(^{-1}\) range giving a strong peak.

Peaks in the range of 1,250-1,020 cm\(^{-1}\), 1,320-1,000 cm\(^{-1}\), and 1,300-1,150 cm\(^{-1}\) were allocated to the C-N stretch –aliphatic amines, C-O stretch –alcohols, carboxylic acids, ethers, esters and C-H wag (-CH\(_2\)X)-alkyl halides showing a medium peak. Medium peaks were absorbed at 1,415 cm\(^{-1}\) in tray-dried powder samples dried at 3 temperatures, and belonged to the C-C stretch (in ring) –aromatics group as they were placed in the 1,500-1,400 cm\(^{-1}\) range. Peaks were observed at 1,626; 1,624; and 1,630 cm\(^{-1}\) for fig powder samples dried at 50, 60, and 70 °C. It represented the N-H bend-1˚ amines, which showed medium peaks and belonged to the 1,650-1,580 cm\(^{-1}\) spectrum range.

Peaks in the range of 1,760-1,665 cm\(^{-1}\), 1,760-1,690 cm\(^{-1}\), 1,760-1,735 cm\(^{-1}\), and 1,740-1,720 cm\(^{-1}\) were assigned to the C=O stretch, which could be strong peaks of esters and saturated aliphatic or aldehydes and saturated aliphatic or carbonyls (generally), or it might also be carboxylic acids. The powders had peaks absorbed at 1,738, 1,739, and 1,736 cm\(^{-1}\) which corresponded to the above-mentioned functional groups associated to the C=O stretch. Peaks at 2,117, 2,119, 2,115 cm\(^{-1}\) were seen in the tray-dried samples at three different experimental temperatures where the \(-\text{C}=\text{C}=\text{H}\)-stretch- alkynes that exhibits a weak peak; and they fell in the range 2,260-2,100 cm\(^{-1}\); 2,928; 2,929; 2,928 cm\(^{-1}\) were medium peaks absorbed in the tray-dried powder samples at three different temperatures were allocated to the C-H stretch- alkanes present in the 3,000-2,850 cm\(^{-1}\) range.

Peaks in 3,368 cm\(^{-1}\) and 3,369 cm\(^{-1}\) absorbed at 50 °C and 60 °C tray-dried powder samples (Fig. 2a and 2b) could have belonged to the strong and broad peak of OH stretch; H bonded-alcohols and phenols and medium peak of N-H stretch -1˚ 2˚ amines falling in the range 3,500–3,200 cm\(^{-1}\) and 3,400–3,250 cm\(^{-1}\), respectively. Samples tray-dried at 70 °C had the peaks absorbed at 3,306 cm\(^{-1}\), which represented three functional groups that are 1˚ 2˚amines (N-H stretch) with a medium peak, narrow and strong peak and alcohols and phenols (O-H stretch, H bonded) showing a strong and broad peak. Powders dried at 50 °C and 60 °C had peaks at 3,399 cm\(^{-1}\) and 3,398 cm\(^{-1}\), which represented medium peak of 1˚ 2˚ amines (N-H stretch) and strong and broad peak of alcohols, phenols (O-H stretch, H bonded) at the range 3,400–3,250 cm\(^{-1}\) and 3,500–3,200 cm\(^{-1}\), respectively. However, 3,464 cm\(^{-1}\) was a separate peak found in the samples tray-dried at 70 °C, which showed a strong and broad peak specific to alcohols, phenols (O-H stretch, H bonded) falling under a single range of 3,500-3,200 cm\(^{-1}\). The presence of a unique peak absorbed at 2,362 cm\(^{-1}\) in the tray-dried powder dried at 70 °C (Fig. 2c) represented (N-H and C-H Stretch). An additional peak was at 1,077 cm\(^{-1}\), which represented either aliphatic amines (C-N stretch) group or the combined group having alcohols, carboxylic acids, esters, ethers (C-O stretch) under the range 1,250-1,020 cm\(^{-1}\) and 1,320-1,000 cm\(^{-1}\), respectively.
Fig. 2(a): FTIR spectra of tray-dried fig fruit powder dried at 50 °C

Fig. 2(b): FTIR spectra of tray-dried fig fruit powder dried at 60 °C

Fig. 2(c): FTIR spectra of tray-dried fig fruit powder dried at 70 °C

Fig. 2(d): FTIR spectra of freeze-dried fig fruit powder dried at (-) 43 °C
Freeze-dried fig powder

Freeze-dried powder analysed using FTIR showed peaks (Fig. 2d) representing functional groups identical to the tray-dried powder samples with mild differences. The peaks absorbed were 519 cm\(^{-1}\), 630 cm\(^{-1}\), 777 cm\(^{-1}\), 818 cm\(^{-1}\), 917 cm\(^{-1}\), 1,055 cm\(^{-1}\), 1,243 cm\(^{-1}\), 1,416 cm\(^{-1}\), 1,631 cm\(^{-1}\), 1,739 cm\(^{-1}\), 2,928 cm\(^{-1}\) in freeze-dried powder samples, and were identical to the tray-dried powder samples dried at various temperatures. The peak identified at 2,151 cm\(^{-1}\) was little distinct among all samples, but it also represented the weak nature of peaks given by the -C≡C- stretch – alkynes already present in the 3 tray-dried powder samples.

The IR spectra of fig powder samples exhibited the characteristic signs of poly-galacturonic acid, or compounds similar to them, due to the carboxylic acids present in them (Kaczmarek et al., 2007). The bands in the range of 1,250-950 cm\(^{-1}\) was characteristic to carbohydrates, which might be due to the presence of fructose, sucrose, glucose, and so forth (Osoria and Carriazo, 2011).

It could thus be concluded from the FTIR results of all samples that there was no change in the functional groups related to the drying methods or the temperatures, except with negligible differences for -C≡C- stretch – alkynes for tray-dried samples.

XRD analysis of fig fruit powder

X-ray diffraction analysis (Fig. 3) was carried out to exhibit the occurrence and characteristic features of crystalline structures of starch granules as used by Pozo et al. (2018) and Govindaraju et al. (2022) for native starch and rice starch, respectively. The starch crystal structure can be classified in to A-, B-, and C-type, which represent crystalline structure of natural starch.

The XRD patterns of A-type starches show diffraction peaks at around 15, 17, 18, and 23° in cereal starches of maize and wheat, and the B type starch is mostly present in the starch of tubers as potato with a strong diffraction peak at 17° (Adina et al., 2010). It was reported that a C type starch is a mixture of A and B starches (Teng et al., 2021; Li et al., 2022).

In the case of freeze-dried fig powder, the XRD patterns showed peaks in the range of 17-21° at 2θ, which again showed the possibility of B-type starch due to the peak at 17 degrees. The steadiness of the powders is greatly determined by the crystallization, which is found by the XRD analysis. The occurrence of diffuse and large peaks indicated the presence of amorphous material as the definition of crystalline material peaks is sharp and precise. The samples of fig powders tray-dried at 50°, 60° and 70 °C were more amorphous as the presence of sharp peaks were very insignificant. The freeze-dried fig powder exhibited a broad spectrum with more intensity, which reveals higher crystallinity index. Freeze-dried fig powder also showed opportunistic crystalline nature as the peaks were undefined and with broad spectrum, which has a positive co-relation with the morphology.

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![Fig. 3: XRD of fig fruit powder tray dried at 50, 60 and 70 °C and freeze dried at -43 °C](image-url)
of freeze-dried powder. This amorphous state could be attributed to the insufficiency of dehydration in the process, which led to crystallization time being affected (Jayasundera et al., 2011).

It was inferred from the XRD results that the relation of the drying type on the powder crystallinity and the starch type was very negligible.

CONCLUSIONS

The effects of tray-dried and freeze-dried techniques led to variations in the physico-chemical and structural properties of fig powder samples. However, the changes were not radical. The study indicated that moisture content and water activity of fig powder were in the range of 6.5-8.5% (w.b.) and 0.40-0.60, respectively. The physico-chemical properties suggested that the powders were of medium and fair flowability, with particle size range of 15-30 µm, and with flaky and scattered structure. FTIR analysis exhibited peaks of varied ranges, which could be due to carbohydrates and carboxylic acids (polygalacturonic acid) in association with the fruit powder. XRD analysis showed that the powders were predominately amorphous in nature, and that C-type starch was present. Although the changes were not extreme in the dehydration technologies, freeze-drying would be preferable for fig fruit as deterioration is less at low temperature.

AUTHOR CONTRIBUTION

P. D. Poovai: Conceptualisation, investigation
K. A. Athmaselvi: Methodology, formal analysis, resources
C. Indu Rani: Data curation
T. Arumuganathan: Writing – original draft preparation
R. Neelavathi: Writing – reviewing
Shubham Subrot Panigrahi: Writing – editing

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest in any form that could have influenced the research work reported in this paper. Competing interest in disclosure of the research work has been considered by the authors.

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