Bulletin of the *Transilvania* University of Brasov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 17(66) No. 1 – 2024
https://doi.org/10.31926/but.fwiafe.2024.17.66.1.12

STUDIES ON DIFFERENT DRYING TECHNIQUES TO UTILIZED IT FOR POWDER PROPERTIES FOR DRIED DILL (*Anethum graveolens)*

Nisha NISHA[1] Ranjana SINGH[2]
Neha SHARMA[1] Ashish M. MOHITE[1]

Abstract: *Fresh dill (Anethum graveolens) was dried using a recirculating tray dryer (RTD) and cross flow dryer (CFD) at 35°C, 40°C and 45°C, respectively to determine the best drying treatment and temperature combination for the preparation of dried dill powder. The dried dill was subjected to a grinding process to obtain powder, its engineering properties and techno-functional properties were analysed. The dill powder displayed significant differences in techno-functional properties and engineering properties. The dill dried at 40°C using $CFDT_2$ resulted in better techno-functional and engineering properties as bulk density - 114.4 kg/m^3, tap density - 130.6 kg/m^3, Carr Index - 12.40, Hausner Ratio - 1.141, swelling power - 0.29, dispersibility - 27.72, water holding capacity - 14.83, oil holding capacity - 35.65, foaming Capacity - 34.97, foam stability - 1.96, emulsion capacity - 55.14, water solubility index – 0.23 and water absorption index – 0.14, respectively. Compared to samples of $RTDT_1$ (35°C), $RTDT_2$ (40°C) $RTDT_3$ (45°C), the samples $CFDT_1$, and $CFDT_3$ findings showed increasing and decreasing trends which kept on changing with drying technique and temperatures. However, it can be concluded that $CFDT_2$ found better results compared to other samples.*

Key words: *dill, cross flow drying, functional properties.*

1. Introduction

The need for flavouring herbs got a rise, due to the demand of the food concentrates and frozen foods in industries as a provision for prepared meals. The group of plants which are valued for their medicinal and aromatic properties are adapted as herbs, in which fresh dill has its eminent place. Originating from south-west Asia and south-east Europe, dill (*Anethum graveolens* L.) is a biennial or annual herb belonging to the parsley family (*Apiaceae* or *Umbelliferae*)

[1] Amity Institute of Food Technology, Noida, Amity University, U.P, India;
[2] Shaheed Rajguru College of Applied Sciences for Women (University of Delhi), Vasundhara Enclave, New Delhi, India;
Correspondence: Ashish M. Mohite; email: ashishmohite1251@gmail.com.

that has been grown since ancient times [12]. Since consumer demand for herbs extend beyond their seasonality, most herbal products are advertised as dry; nonetheless, dehydration produces are stable and easily transportable which makes them accessible the whole year. However, the raw material's appearance, content, and quality change as a result of the drying process. The two major ways that aromatic plants are consumed are fresh or dried; drying is a useful method for managing and storing aromatic plants after harvest and for extending their shelf life. Dehydration is crucial for aromatic plants because it lowers the amount of moisture in the product that needs to be stored, shipped, and packaged [4] and renders it available the whole year as the moisture content is less than 15%. The primary objective is the drying process in order to limit biochemical changes and prevent microbial growth development. The organoleptic qualities that affect customer acceptance are colour and aroma, hence it is important to maintain these qualities while also maintaining the raw material's organoleptic properties [22]. The final product's choice of drying process and applied drying conditions is crucial since they cause unfavourable changes in the product's texture, flavour, color, or nutraceutical content in addition to loss of health-promoting qualities [2].

Drying as a food preservation method can be performed at various RH and temperature levels. Removing moisture from food slows down a lot of the physcio-chemical processes caused by excess moisture and stops microorganisms' growth and reproduction [34]. Both the drying process and the drying environment have a significant impact on the quality of the dried product. Unfavourable drying conditions, like a higher temperature when food is dried, cause a number of irreversible chemical and biological reactions that result in structural, mechanical, and physical changes of food product [3]. These include color deterioration, crust formation, a decline in sensory quality, the inactivation of enzymes and bacteria, the loss of nutrients and aroma, and texture and shape changes. If drying can be done under regulated conditions, nevertheless, these fresh food qualities can be preserved to a larger degree [5]. Since some of the foods and other agricultural products such as spices and herbs are heat sensitive, it is ideal to process them at moderate temperatures. There are a number of ways to strengthen the mass transfer driving force in order to increase the drying rate in these circumstances. One such strategy is to lower the relative humidity of hot air, which raises the air's capacity to absorb moisture and speeds up the drying process [35].

Dill essential oil is extracted from its leaves as well as the seeds; it is used in pickles, candies, and chewing gum. The dill is classed among species that reduce the risk of cancer [30]. According to Lisiewska et al. [21], eating dill also reduces cholesterol Emia, and some of its constituents have antioxidative qualities [17]. In addition, seasoning herbs, like dill, add complementing elements to the main courses, such as vitamins and mineral salts, as well as elements that influence the food's sensory qualities. Colour is one of the most significant sensory characteristic [23]. Chlorophylls are the primary pigments found in seasoning leafy greens, and they are always paired with carotenoids. Acids, temperature, light, oxygen, and enzymes rapidly degrade the chlorophylls, while carotenoids are rather resistant to technological methods [1].

In this study the prominent drying method and the quality parameters after powdering the herbs was identified. While dill seeds have been the subject of several researchers relating to their therapeutic qualities, the physic-chemical and antioxidant capacities of dill greens have not been investigated yet in relation to their dehydration process. Therefore, since the goal of this study was to assess the effect of drying techniques on dill depending on the drying temperature, its powder properties such as bulk density, tap density, Carr index, Hausner ratio, swelling power, water holding capacity, oil holding capacity, dispersibility, emulsion capacity, foam capacity, foam stability, water absorption index, water solubility index and sensory properties were analysed.

2. Material and Methods

2.1 Selection of Material

Dill (*Anethum graveolens*) was procured from Greater Noida, India. From seeds to fully grown dill it took around 3-4 months after which it was harvested for further studies. The initial moisture content of the freshly harvested dill was 6.40±0.15 d.b. (dry basis) using the AOAC 2000 method. Initially the sample was washed and cut into even sizes of 38.95±1.35 cm length and 1.46±0.14 mm thickness prior to the experimental process.

2.2 Drying Techniques

2.2.1. Recirculating Tray Drying

Recirculating tray dryers are mechanical devices that circulate hot air through samples to remove the moisture from the product. The same volume of air is repeatedly cycled through a recirculating drier until the desired moisture content is obtained. Samples were kept in the recirculating tray dryer (M/s BPTL, Kolkota) with a constant air flow rate of 1.5m/s in a co-current direction for 8 hrs at different temperatures.

2.2.2. Cross Flow Drying

The application of a cross flow drying is used for drying solid materials by fluidized air flow according to the drying theory. This method involves passing a stream of air across a bed of solid particles to make them act like a fluid. Samples were kept in perforated trays in a drying chamber with an upward-moving air flow velocity of 1.5 m/s and dried for 8 hours.

Samples were dried in the recirculating tray dryer (RTD) and cross flow drying (CFD) using:

- $RTDT_1$ for 35°C;
- $RTDT_2$ for 40°C;
- $RTDT_3$ for 45°C;
- $CFDT_1$ for 35°C;
- $CFDT_2$ for 40°C;
- $CFDT_3$ for 45°C.

2.3 Functional Properties of Fresh Dill Powder

The dried samples obtained by using different drying techniques were subjected to grinding process using a lab-scale hammer mill (M/s Sanco India Pvt Ltd, India), for 5 minutes and the temperature of powdered samples was in the range of 36-40°C. These powdered samples were stored in polythene pouches for further investigation.

2.3.1. Bulk and Tap Density

The procedure used to calculate the bulk and tap densities were in accordance with Paliwal et al. [24] methodology. Dill powder was poured into a fifty-millilitre measuring cylinder to the full capacity, and the sample was weighed to determine the bulk density in kilograms per cubic meter. In addition, the samples were put into fifty millilitre measuring cylinders, tapped 100 times, and then weighed to determine the tap density in kilograms per cubic meter.

2.3.2. Carr Index and Hausner Ratio

The characteristics associated with the flowing behaviour and the degree of compression that powders can withstand are the Carr's compressibility index (CI) and the Hausner ratio (HR). The Hausner Ratio is obtained by dividing the tapping density by the sample's bulk density, whereas Carr's compressibility index indicates the sample's compressibility limit (Equation (1)).

$$CI = \frac{TD - BD}{TD} \cdot 100 \quad (1)$$

where:

Ci is the Carr's compressibility index;
TD – the tap density [kg/m^3];
BD – the Bulk density of the sample [kg/m^3].

2.3.3. Swelling Power

The method recommended by Lai et al. [20] was used to estimate the swelling power of the dried dill samples. First, a slurry containing 0.5 gm of dried dill was prepared. The slurry was then kept in a water bath at 70°C for 30 minutes. Next, the sample was mixed in a vortex mixture for 30 seconds (W1), and it was centrifuged at 2000 g for 15 minutes. Finally, the weight of the precipitate and supernatant were tabulated at W_2, indicating the swelling power of the dried powdered dill (Equation (2)).

$$SP = \frac{\left(W_2 - W_1\right) \cdot g}{W_t} \quad (2)$$

where:
SP is the swelling power;
W_2 – the weight of sample after mixing in vortex mixer [g];
W_1 – the final weight of supernatant sample [gt];
W_t – the eight of sample [g].

2.3.4. Water Holding Capacity

The dried powdered dill was added 1gm in 10 ml of distilled water and it was let stand for 30 minutes, the prepared solution was centrifuged at 500 rpm for 30 minutes, and the volume of supernatant was measured to estimate the water holding capacity. El-Salam et al. [8] method was used to determine the amount of water that could be held in the matrix of dried dill (Equation (3)).

$$WHC = \frac{gm_{water}}{gm_{dry\ sample}} \quad (3)$$

where:
WHC is the water holding capacity;
gm_{water} – the grams of the water [g];

$gm_{dry\ sample}$ – the grams of the dry dill sample [g].

2.3.5. Oil Holding Capacity

The oil retention capacity was calculated using the El-Salam et al. [8] methodology. After the sample was precisely weighed at 0.5 g, 5 ml of refined oil was added, and the mixture was well-mixed for 60 seconds at room temperature before being centrifuged for 10 minutes at 3000g. The supernatant's volume was calculated, and the oil-holding capacity was found using the Equation (4).

$$OHC = \frac{V_{oil\,added} - V_{supernatant}}{Wt_{dry\,sample}} \tag{4}$$

where:

OHC is the oil holding capacity [g of oil / g of water];

$V_{oil\ added}$ – the volume of oil added [g];

$V_{supernatant}$ – the volume of supernatant [g];

$W_{t\ dry\ sample}$ – the weight of the dry sample [g].

2.3.6. Dispersibility

The method of dispersibility was determined by Sakurai et al. [28]. The sample mixture was made by mixing 10 grams of sample with 100 millilitres of distilled water in a graduated cylinder. The combination was then thoroughly mixed and let to stand for three hours. The amount of settled particles was calculated and subtracted from 100 (Equation (5)); the resulting percentage is known as the dispersibility.

$$D = 100 - V_{settled\ particle} \tag{5}$$

where:

D is the dispersibility [%];

$V_{setted\ particle}$ – the amount of setted particle [g].

2.3.7. Foam Capacity

The Darniadi et al. [7] recommended method was used to measure foaming capacity (FC) – Equation (6). The volume of the sample was calculated after it was weighted and 2 grams of the sample were added to 50 millilitres of distilled water. In Torrington, USA, a Warring Blender Commercial model HGBTWT was used to blend the mixture at 160 gm for five minutes in order to produce foam. The foam suspension was put into a graduated cylinder after the volume of foam was measured.

$$FC = \frac{Foam\,V_{0\,min}}{V_{solution}} \cdot 100 \tag{6}$$

where:

FC is the foaming capacity [%];

$F_{oamV0\ min}$ – the initial volume of the sample at 0 minutes [cc];

$V_{solution}$ – the volume of the solution [cc].

2.3.8. Foam Stability

The foam's stability was assessed using the Darniadi et al. [7] approved method. The volume of the solution was measured after 1 g of dried dill powder was mixed in 100 ml of distilled water. Following mixing for five minutes at 1600 rpm, the suspension was poured into a 250 ml measuring cylinder, and the volume was noted. The Equation (7) was used to get the foam stability.

$$FS = \frac{Foam\,V_{30\,min}}{Foam\,V_{0\,min}} \cdot 100 \qquad (7)$$

where:

FS is the Foam's stability [%];

$F_{oamV0\ min}$ – the initial volume of sample at 0 minutes [cc];

$F_{oamV30\ min}$ – the volume of sample afte 30 minutes [cc].

2.3.9. Emulsion Capacity

The Kumar et al. [18] approach was utilized to ascertain the emulsion capacity. Five grams of powdered dill were mixed with 25 millilitres of refined oil, homogenized, and centrifuged at 1500 g for five minutes. Both the overall height and the height of the emulsion layer were used to compute the emulsion capacity – Equation (8):

$$EC = \frac{H_{emulsion\,layer}}{O_{height\,solution}} \qquad (8)$$

where:

EC is the emulsion capacity;

$H_{emulsion\ layer}$ – the height of the emulsion layer;

$O_{height\ solution}$ – the overall height of the solution.

2.3.10. Water Absorption Index

A material's capacity to absorb water under particular circumstances is determined by the water absorption index (WAI). It is frequently employed to assess the ability of both food and non-food products to retain water. The Equation (9) was used to compute the WAI:

$$WAI = \frac{W_{Swet} - W_{Sdry}}{W_{Sdry}} \cdot 100 \qquad (9)$$

where:

WAI is the water absorption index;

W_{Swet} – the weight of the wet sample [g];

W_{Sdry} – the weight of the dry sample [g].

The sample's weight after it has been immersed in water for a certain amount of time and any extra water has been drained out is known as the "weight of wet sample." The weight of the dry sample is its initial weight prior to soaking. Depending on the material being tested, several techniques can be used to calculate the WAI. Typically, samples are weighed to find the weight of the wet sample after being submerged in water for a predetermined amount of time and allowed to drain. Measured is the sample's original dry weight as well. The aforementioned algorithm is then used to determine the WAI.

2.3.11. Water Solubility Index

The amount of the herb's constituents that are soluble in water is indicated by the water solubility index (WSI - Equation (10)), which is helpful for a variety of businesses, including the food and pharmaceutical ones. Dried samples were weighed to 2.5 gm and mixed with 30 ml distilled water, further the mixture was kept at water bath at 70°C for 30 mins. The prepared sample was centrifuged at 3000 g for 20 mins. The supernatant obtained was kept for overnight drying at 105°C.

$$WSI = \frac{W_{DSS}}{W_{Sdry}} \cdot 100 \quad (10)$$

where:

WSI is the water solubility index [%];

W_{DSS} – the weight of the dissolved solids in supernatant [g];

W_{Sdry} – the weight of the dry sample [g].

3. Result and Discussion

3.1 Bulk and Tap Density

The bulk density of food powder helps in determining the suitable packaging material for the product (Table 1).

Techno-functional properties of dried dill powders Table 1

Treatment	$RTDT_1$	$RTDT_2$	$RTDT_3$	$CFDT_1$	$CFDT_2$	$CFDT_3$
Bulk density	114.8 ± 0.2a	114.4 ± 0.2a	113.8 ± 0.1a	114.8 ± 0.2ab	115.4 ± 0.2ab	116.8 ± 0.1b
Tap density	130.2 ± 0.2a	130.6 ± 0.3a	131.4 ± 0.7a	129.3 ± 0.2a	131.7 ± 0.6a	132.8 ± 0.9a
Carr Index	11.82 ± 0.3a	12.40 ± 0.2a	13.39 ± 0.6a	11.21 ± 04a	12.37 ± 06a	12.04 ± 08a
Hausner Ratio	0.881 ± 07b	0.875 ± 09a	0.866 ± 05a	0.887 ± 08b	0.876 ± 02a	0.879 ± 05a
Swelling Power	0.33 ± 0.2a	0.34 ± 0.2ab	0.35 ± 0.7ab	0.31 ± 0.2ab	0.29 ± 0.2ab	0.28 ± 0.7b
Dispersibility	25.76 ± 0.1a	28.72 ± 0.1a	29.32 ± 0.1ab	28.76 ± 0.3ab	27.72 ± 0.7b	26.32 ± 0.2b
Water Holding Capacity	14.43 ± 0.2a	5.84 ± 0.4a	16.50 ± 0.7a	13.47 ± 0.1a	14.83 ± 0.6a	15.58 ± 0.4b
Oil Holding Capacity	35.72 ± 0.6a	37.62 ± 0.1a	38.95 ± 0.5a	36.77 ± 0.2a	35.65 ± 0.1a	34.98 ± 0.7a
Foam Capacity	36.52 ± 0.1a	37.93 ± 0.2ab	38.42 ± 0.8b	35.56 ± 0.5b	34.97 ± 0.7b	32.45 ± 0.2b
Foam stability	1.43 ± 0.2a	1.73 ± 0.2a	2.16 ± 0.7a	1.48 ± 0.1a	1.96 ± 0.4a	2.09 ± 0.9a
Emulsion Capacity	52.92 ± 0.1a	54.92 ± 0.1a	56.73 ± 0.1a	54.87 ± 0.3a	55.14 ± 0.6b	56.36 ± 0.9b

Bulk densities were found to be in a decreasing trend at the increase in temperature for recirculating tray drying (RTDT) which was found to be 114.8 at 35°C slightly decreasing to 113.8 at 45°C whereas in the case of the cross flow drying technique (CFDT) the temperature led to a higher value of bulk density which kept on increasing from 114.8 to 116.8. With the increase of temperature (Table 1), the powder will occupy larger spaces for its storage and will display more air gaps between the particles of powdered sample due to the fine particles in the powder [24].

Air flow is necessary for the flowability of the powder, and it can be determined using density. Higher values of tap density were obtained for the samples as the samples were grounded finely in a hammer mill which managed to reduce the air gaps. There was no considerable difference for the RTDT samples, it just appeared to have slight increase of 130.2 to 131.4 at 45°C but the samples dried by using the cross flow dryer showed considerable increase in tap density from 129.3, 131.7 and 132.8 for 35, 40 and 45°C respectively. The tap density of powder is a useful parameter in determining how much the powder could be compressed in packaged material without disturbing the quality parameter in terms of the physical structure of the sample [11].

Based on a sample size (n) of three, the data is shown as the mean value combined with the standard deviation (mean ± SD). Distinct letters indicate significant differences ($p \leq 0.05$) using the SPSS Statistics 25.

3.2. Carr Index and Hausner Ratio

Measuring the Carr Compressibility Index and the Hausner Ratio in the context of herbs can be useful in determining whether they are suitable for encapsulation, tableting, or other powder processing applications [31]. Compressibility and flowability-friendly powders are often simpler to handle during production operations and have better product homogeneity and consistency. The results obtained were similar in bulk and tap density because of the formula used [13]. CI values were increased from 11.82 to 13.39 for the RTDT sample because of the higher denominator values of tap density. CFDT values slightly increased from 11.21 to 12.04 for 45°C.

3.3. Swelling Power

Swelling power values for dried dill powders varied from 0.33 to 0.35% for the RTDT samples, showing an increase with the increase of temperature, whereas the CFDT samples showed a decreasing trend from 0.31 to 0.28 for the 35, 40, and 45°C temperature, respectively. Similar studies were conducted by Waseem et al. [33] on dehydrated spinach powder and Jin et al. [16] conducted research on mulberry leaf powders that showed similar trends in change of swelling power values. Swelling power measures how much water a certain molecule absorbs, whereas solubility shows how much leaching happens when starch granules swell [9]. The swelling power and solubility values are determined by the degree of interaction within starch chains, including both amorphous and crystalline structures [33]. Herbs' swelling power depends on their ability to absorb and retain water that can be affected by drying. The cell structure of dried herbs differs from that of fresh plants, influencing their ability to absorb water. Because the drying process concentrates the plant's fibre and other water-absorbing components, dried herbs often have a higher swelling capacity than fresh herbs. However, the precise outcome may vary depending on the plant and the drying technique and temperature.

3.4. Water Holding Capacity

Drying samples at higher temperatures (35C to 45°C) resulted in increased water holding capacity, with values ranging from 14.43 to 15.84 and 16.50 for the RTDT samples. The CFDT had lower water holding capacity than RTDT (13.47 at 35°C and 15.58 at 45°C). Patil et al. [26] performed research on several green leafy vegetable PRTDT but found similar outcomes. Water holding capacity is required to ensure sample suitability for use in food products. Jesly et al. [15] used sprouted Green Gram Flour to increase the water retention capacity of dahi. Jannat – Alipour et al. [14] conducted research on seaweed powder and recorded that with the increase in drying temperatures, water holding capacity increased. The amount of water that the sample can hold has an impact on its structure when combined with water during product formulation. The herb's complicated lattice structure contributes to its higher water retaining capacity. Sarker et al. [29] conducted a study on fortified yogurt with green papaya powder and assessed changes in the yoghurt's water holding capacity which showed considerable changes in the final product's water holding capacity.

3.5. Oil Holding Capacity

Oil holding capacity is a property that has a significant impact on the texture, flavour, and shelf life of a food product. Park et al. [25] investigated the rheological, textural, and functional properties of 3D-printed cheesecake with guava leaf, green tea, and barley sprout powders, which showed changes in shelf life and quality of product depending upon its oil holding capacity. The water holding capacity of RTDT samples increased from 35.72 to 38.95 as the temperature increased, but CFDT samples slightly decreased from 36.77, 35.65, and 34.98 at 35, 40, and 45°C, respectively. Herbs with a higher water holding capacity are more likely to have a longer shelf life, a superior structural property, and an appealing taste. Flamminii et al. [10] investigated the compositional and technical features of olive leaf phenolic extracts and its relation with oil holding capacity and found similar outcomes. Herbs contain a high concentration of essential oils and so have a higher oil retention capacity leading towards a higher oil holding capacity. Rawdkuen [27] investigated the characteristics of *Moringa oleifera* leaf protein with respect to oil holding capacity of dried powders. Kundu et al. [19] investigated the techno-functional qualities of *Chenopodium album* (Bathua) powder and found similar outcomes for the study.

3.6. Dispersibility

The dispersibility range of the RTDT samples increased from 25.76 to 28.72 and 29.32 at 35, 40, and 45°C, while the CFDT samples decreased slightly to 28.76, 27.72, and 26.32 at 35, 40, and 45°C, respectively. Dispersibility is a measurement of how particles break down and spread in a solution. Samples with finer particles dispersed readily in the solution, yielding powder that could be utilized to produce products requiring particle dispersion with little energy usage. Dry herbs are easier to grind, have a bigger surface area, and are smaller when dried.

3.7. Foam Capacity

Foam capacity in terms of herb powder refers to the powder's ability to form or retain foam in food or beverage applications, which influences the overall acceptability of the product produced for consumption. Foam capacity showed similar pattern in both RTDT and CFDT samples; changes in the value were consistently rising for both drying processes, with RTDT samples having more foam capacity. RTDT1 was found to contain 36.52 FC, which increased significantly to 38.42 for RTDT3. The samples had 35.56 FC for CFDT1, which was considerably higher than RTDT1, and it reduced to 32.45 for CFDT3, indicating that the method helps in the preservation of the product's bioactive components. Tannins tend to be reduced in CFDT drying due to stronger drying, which causes the loss of bioactive compound tannins responsible for foam production, but RTDT has a high retention of bioactive compound tannins, resulting in more foam formation. Herbs containing tannins and saponins that are a kind of natural surfactant that can cause foam, are more likely to create foam.

3.8. Foam Stability

The nature and amount of active compounds in the herbs, the pH and temperature of the system, and the presence of other ingredients or additives are only a few of the factors that might impact herb foam stability. Foam stability values for RTDT and CFDT increased slightly at 35, 40, and 45°C, with values of 1.43, 1.73, and 2.16 for RTDT and 1.48, 1.96, and 2.09 for CFDT. The herb powder's inclusion of specific plant proteins or polysaccharides helps to stabilize the foam and keep it from dissolving or collapsing. Certain plants exhibit varied foam stability due to their specific chemical composition. Several herbs, including fenugreek, saponaria, and quillaja, are known for their high foam stability because they contain saponins, which are natural surfactants that lead to stabilized foam.

3.9. Emulsion Capacity

Herb chemical composition, active component concentration, powder particle size, and processing conditions are the factors that influence the herb's capacity to form an emulsion. Emulsion capacity varied between 52.92 to 56.92 for RTDT and 54.87, 55.14, and 56.36 in CFDT samples. Some spices include natural emulsifiers such as proteins, polysaccharides, and phospholipids, which helps in maintaining emulsions stable. Certain herbs may have varying emulsion capacities due to their unique chemical composition. Because of the presence of natural emulsifiers, some plants, such as aloe vera, chamomile, and lavender, are widely known for their high emulsion capacity.

3.10. Water Absorption Index

A plant's ability to absorb water can be affected by a variety of factors, including the chemical structure of the herb, the size of the powder's particles, and the processing conditions [6]. The water absorption index for the sample ranges from 1.15 to 2.93 which was slightly increasing with the increase in temperature for both RTDT and CFDT samples. Certain herbs, for example, have a high soluble fibre content, which can help them absorb water more effectively. Certain plants' water absorption properties may vary depending on their chemical structure. Several herbs, such as psyllium, flaxseed, and chia seed, are widely known for their highly soluble fibre content.

3.11. Water Solubility Index

It is important to understand that the water solubility of different compounds found in herbs can vary greatly. Water solubility Index values range from 0.022 to 0.048 for RTDT and CFDT samples in a similar trend. The water solubility of the target component in herbal infusions or extracts may differ depending on the temperature, time, and particle size of the dried powder. The presence of other compounds, such as lipids or fibres, also have an effect on overall solubility in water hence the change in water solubility index values are obtained.

4. Conclusion

Dill was dried using two different methods (recirculating tray drying and cross flow drying) at temperatures of 35, 40, and 45°C, respectively. Drying at temperatures ranging from 35 to 45°C effectively protects the heat-sensitive components of herbs. The optimal combination for the drying methods was identified after conducting a techno-functional study of dried powders. At constant RH, the drying process accelerated as the drying air temperature increased. Furthermore, at constant temperature, the reverse was seen with less influence of relative humidity. The bulk density and tap density become steady as the temperature increased. Similar trends were observed for Carr Compressibility, Haunser Ratio, swelling power, dispersibility, water holding capacity, oil holding capacity, foaming capacity, foam stability, emulsion capacity, water solubility index, and water absorption index, indicating that samples dried at 40°C show better results when using cross flow drying and a recirculating tray dryer.

References

1. Ansah, F.A., Amodio, M.L., 2018. Effect of minimal processing steps and operation modes on quality of leafy vegetables. Doctoral Thesis, Universita di Foggia. DOI: 10.14274/ansah-francisca-aba_phd2017.
2. Banožić, M., Vladić, J., Banjari, I. et al., 2023. Spray drying as a method of choice for obtaining high quality products from food wastes - A review. In: Food Reviews International, vol. 39(4), pp. 1953-1985. DOI: 10.1080/87559129.2021.1938601.
3. Calín-Sánchez, Á., Lipan, L., Cano-Lamadrid, et. al., 2020. Comparison of traditional and novel drying techniques and its effect on quality of fruits, vegetables and aromatic herbs. In: Foods, vol. 9(9), ID article 1261. DOI: 10.3390/foods9091261.
4. Catania, P., Gaglio, R., Orlando, S. et al., 2020. Design and implementation of a smart system to control aromatic herb dehydration process. In:

Agriculture, vol. 10(8), ID article 332. DOI: 10.3390/agriculture10080332.
5. Chemat, F., Rombaut, N., Meullemiestre, A. et al., 2017. Review of green food processing techniques. Preservation, transformation, and extraction. In: Innovative Food Science and Emerging Technologies, vol. 41, pp. 357-377. DOI: 10.1016/j.ifset.2017.04.016.
6. Chettri, S., Rizwana, R., Mohite, A.M., 2022. Selected physicochemical and functional properties of extracted soybean starch. In: Bulletin of the Transilvania University of Brasov. Series II: Forestry, Wood Industry and Agricultural Food Engineering, vol. 15(64), pp. 139-150. DOI: 10.31926/but.fwiafe.2022.15.64.2.10.
7. Darniadi, S., Ho, P., Murray, B.S., 2018. Comparison of blueberry powder produced via foam-mat freeze-drying versus spray-drying: evaluation of foam and powder properties. In: Journal of the Science of Food and Agriculture, vol. 98(5), pp. 2002-2010. DOI: 10.1002/jsfa.8685.
8. El-Salam, A., Kholoud, H., Toliba, A.O. et al., 2019. Chemical and functional properties of garden cress (*Lepidium sativum* L.) seeds powder. In: Zagazig Journal of Agricultural Research, vol. 46(5), pp. 1517-1528. DOI: 10.21608/zjar.2019.48168.
9. Fapetu, A.P., Karigidi, K.O., Akintimehin, E.S. et al., 2022. Effect of partial substitution of wheat flour with *Moringa oleifera* leaf powder on physical, nutritional, antioxidant and antidiabetic properties of cookies. In: Bulletin of the National Research Centre, vol. 46(1), pp. 1-9. DOI: 10.1186/s42269-022-00746-8.
10. Flamminii, F., Di Mattia, C.D., Difonzo, G. et al., 2019. From by-product to food ingredient: evaluation of compositional and technological properties of olive-leaf phenolic extracts. In: Journal of the Science of Food and Agriculture, vol. 99(14), pp. 6620-6627. DOI: 10.1002/jsfa.9949. Moringa oleifera leaf protein from alkaline– acid extraction. In: Food and Applied Bioscience Journal, vol. 8(1), pp. 43-67. ISSN: 2286-8615
11. Hong, S.J., Das, P.R., Eun, J.B., 2021. Effects of superfine grinding using ball-milling on the physical properties, chemical composition, and antioxidant properties of *Quercus salicina* (Blume) leaf powders. In: Journal of the Science of Food and Agriculture, vol. 101(8), pp. 3123-3131. DOI: 10.1002/jsfa.10941.
12. Ivanišová, E., Kačániová, M., Savitskaya, T.A. et al., 2021. Medicinal herbs: Important source of bioactive compounds for food industry. In: Herbs and Spices - New Processing Technologies. Shabir Ahmad R. (Ed.), Intech Open Publishing House. DOI: 10.5772/intechopen.98819.
13. Jamil, Z., Mohite, A.M., Sharma, N., 2020. Selected engineering properties and drying behavior of tendu (*Diospyros melanoxylon* Roxb.) fruit. In: Current Research in Nutrition and Food Science, vol. 8(2), pp. 622-629. DOI: 10.12944/CRNFSJ.8.2.27.
14. Jannat-Alipour, H., Rezaei, M., Shabanpour, B. et al., 2019. Edible green seaweed, *Ulva intestinalis* as an ingredient in surimi-based product: chemical composition and physicochemical properties. In: Journal of Applied Phycology, vol. 31,

pp. 2529-2539. DOI: 10.1007/s10811-019-1744-y.

15. Jesly, K., Arshath, M., Rahila, M.P. et al., 2023. A enhancing the nutritional quality of dahi by incorporating sprouted green gram flour. In: Biological Forum – An International Journal, vol. 15(6), pp. 697-700.
16. Jin, Y., Tu, J., Han, X. et al., 2022. Characteristics of mulberry leaf powder enriched with γ-aminobutyric acid and its antioxidant capacity as a potential functional food ingredient. In: Frontiers in Nutrition, vol. 9, ID article 900718. DOI: 10.3389/fnut.2022.900718.
17. Kidmose, U., Knuthsen, P., Edelenbos, M. et al., 2001. Carotenoids and flavonoids in organically grown spinach (*Spinacia oleracea* L.) genotypes after deep frozen storage. In: Journal of the Science of Food and Agriculture, vol. 81(9), pp. 918-923. DOI: 10.1002/jsfa.902.
18. Kumar, V., Gupta, A.K., Naik, B. et al., 2023. Effect of high γ-irradiation dosage on physico-chemical, functional and emulsion properties of almond gum powder. In: International Journal of Biological Macromolecules, vol. 235, ID article 123898. DOI: 10.1016/j.ijbiomac.2023.123898.
19. Kundu, P., Gupta, P., Kumar, M., 2022. Effect of particle size distribution on techno-functional properties of *Chenopodium album (Bathua)* powder. In: Research Square preprint form DOI: 10.21203/rs.3.rs-1977506/v1.
20. Lai, K.M., Cheng, Y.Y., Tsai, T.H., 2015. Integrated LC-MS/MS analytical systems and physical inspection for the analysis of a botanical herbal preparation. In: Molecules, vol. 20(6), pp. 10641-10656. DOI: 10.3390/molecules200610641.
21. Lisiewska, Z., Kmiecik, W., Słupski, J., 2004. Contents of chlorophylls and carotenoids in frozen dill: effect of usable part and pre-treatment on the content of chlorophylls and carotenoids in frozen dill *(Anethum graveolens* L.), depending on the time and temperature of storage. In: Food Chemistry, vol. 84(4), pp. 511-518. DOI: 10.1016/S0308-8146(03)00265-6.
22. Mihafu, F.D., Issa, J.Y., Kamiyango, M.W., 2020. Implication of sensory evaluation and quality assessment in food product development: A review. In: Current Research in Nutrition and Food Science Journal, vol. 8(3), pp. 690-702. DOI: 10.12944/CRNFSJ.8.3.03.
23. Naidu, M.M., Hebbar, U.H. 2016. Effect ofdrying methods on the quality characterstics of dill (*Anethum graveolens*) greens. In: Food Chemestry, vol. 192 (1), pp. 849-856.
24. Paliwal, A., Sharma, N., Mohite, A.M., 2023. Effect of wet processing on the grinding characteristics and functional properties of sorghum. In: Applied Food Research, vol. 3(1), ID article 100255. DOI: 10.1016/j.afres.2022.100255.
25. Park, Y.E., Kim, J., Kim, H.W. et al., 2022. Rheological, textural, and functional characteristics of 3D-printed cheesecake containing guava leaf, green tea, and barley sprout powders. In: Food Bioscience, vol. 47, ID article 101634. DOI: 10.1016/j.fbio.2022.101634.
26. Patil, B.M., Kshirsagar, R.B., Sawate, A.R. et al., 2020. Studies on effects of

cabinet dying on functional and phyto-chemical quality of green leafy vegetables powder. In: Journal of Pharmacognosy and Phytochemistry, vol. 9(4), pp. 3197-3202.

27. Rawdkuen, S., 2020. Properties of *Moringa oleifera* leaf protein from alkaline - acid extraction. In: Food and Applied Bioscience Journal, vol. 8(1), pp. 43-67.
28. Sakurai, Y., Mise, R., Kimura, S.I. et al., 2017. Novel method for improving the water dispersibility and flowability of fine green tea powder using a fluidized bed granulator. In: Journal of Food Engineering, vol. 206, pp. 118-124. DOI: 10.1016/j.jfoodeng.2017.03.010.
29. Sarker, A., Jung, Y., Siddiqui, R., 2023. Yoghurt fortification with green papaya powder and banana resistant starch: Effects on the physicochemical and bioactive properties. In: International Journal of Food Science and Technology, vol. 58, pp. 5745-5756. DOI: 10.1111/ijfs.16672.
30. Sharma, N., 2023. Herbs and seasonings: processing and utilization. In: Recent Advances in Spices, Herbs and Plantation Crops, ID article 143.
31. Wal, P., Pal, R.S., Saraswat, N. et al., 2019. Pharmacognostic evaluation and standardization of the leaves of *Punica granatum*. In: Research Journal of Pharmacy and Technology, vol. 12(7), pp. 3255-3260. DOI: 10.5958/0974-360X.2019.00549.3.
32. Wang, R., Liu, J., Zhang, J. et al., 2023. Effect of thermal blanching on the inactivation kinetics of polyphenol oxidase and peroxidase in lily bulb, and the functional properties of its flours. In: Journal of Food Measurement and Characterization, vol. 17(1), pp. 615-626. DOI: 10.1007/s11694-022-01658-x.
33. Waseem, M., Akhtar, S., Manzoor, M.F. et al., 2021. Nutritional characterization and food value addition properties of dehydrated spinach powder. In: Food Science and Nutrition, vol. 9(2), pp. 1213-1221. DOI: 10.1002/fsn3.2110.
34. Yousef, A.E., Balasubramaniam, V.M., 2012. Physical methods of food preservation. In: Food Microbiology: Fundamentals and Frontiers, pp. 735-763. DOI: 10.1128/9781555818463.ch9.
35. Zahoor, I., Mir, T.A., Ayoub, W.S. et al., 2023. Recent applications of microwave technology as novel drying of food - Review. In: Food and Humanity, vol. 1, pp. 92-103. DOI: 10.1016/j.foohum.2023.05.001.