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IMPACT OF BLANCHING TREATMENTS ON THE PHYSICO-CHEMICAL ATTRIBUTES OF FENUGREEK DRIED USING SOLAR TUNNEL TECHNOLOGY

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ABSTRACT

An experiment was conducted at Junagadh Agricultural University to evaluate the physico-chemical properties of fenugreek subjected to different blanching treatments within a solar tunnel dryer. The study assessed various parameters including moisture content, carbohydrate levels, ascorbic acid, ash content, crude fat, protein, crude fiber, chlorophyll content, bulk density, water solubility index (WSI), water absorption index (WAI), and recovery rate. The moisture content was recorded at 4.67%, indicating efficient drying. Carbohydrate content was the highest at 71.99%, suggesting a significant retention of nutritional quality. Ascorbic acid content was 23.31%, while ash content was measured at 6.63%, reflecting the mineral composition. The fenugreek samples contained 5.35% crude fat, 8.41% protein, and 5.02% crude fiber, highlighting their nutritional value. Chlorophyll content was 7.17%, which could influence the color and quality of the dried product. The bulk density was noted at 301 mg, contributing to the physical characteristics of the final product. The WSI and WAI were 58.37% and 346.52%, respectively, indicating good rehydration properties. The recovery rate was 24.51%, which provides insight into the efficiency of the drying process. This study highlights the potential of solar tunnel drying for preserving the quality and nutritional attributes of fenugreek under varying blanching conditions.

***Key words*:** Fenugreek, Physico-Chemical, Blanching Treatments, Solar Tunnel Dryer

Introduction

Renewable energy sources come in various forms such as solar energy, wind energy, biomass, and more. Among these, solar energy stands out as the most cost-effective, inexhaustible, and abundant source, providing a direct form of energy. It is one of the most plentiful renewable energy sources, with the sun emitting energy at a rate of 3.8×10^{23} kW of this immense output, approximately 1.8×10^{1}t kW is intercepted by Earth, a figure roughly ten times greater than the current global annual energy consumption (Tyagi *et al.*, 2012). In theory, solar energy has the potential to meet all current and future global energy demands continuously. Furthermore, solar energy is a clean, environmentally friendly, and freely available resource, accessible in sufficient quantities across almost every region of the world.

Medicinal plants, rich in secondary metabolites, serve as potent sources of drugs. India and China are major producers of medicinal plants, contributing over 40 % of global production. India, one of the world's 12 biodiversity centers, boasts over 45,000 plant species across 126 agro-climatic zones, 10 vegetation zones, 25 biotic provinces, and 426 biomes. With 80 % of the global population relying on traditional medicines derived from plants due to the high cost of Western pharmaceuticals, there is a growing need to promote and protect this traditional knowledge.

Reviving and updating traditional wisdom with modern science can lead to value-added products like medicines, nutraceuticals, and cosmeceuticals, which are crucial for human welfare. This approach will help reduce the financial burden on developing countries and ensure the sustainable use of medicinal plants.

Fig. 1: Fenugreek leaves.

Fenugreek (*Trigonella foenum graecum* L.) belongs to the family of Leguminosae (Fabaceae) sub family Papilionaceae; also known as *Methi*. Fenugreek is an important leafy vegetable cum condiment having excellent medicinal value. It also known as nature's great boon. Its regular use helps in keeping the body healthy and disease free. The green tender leaves of fenugreek are rich source of minerals (Iron and Calcium), protein, vitamin A and C. It also contains other nutrients in high quantity. It is used as vegetable alone or in combination with other vegetable. The young plants especially the tender shoots and the aromatic green leaves are also used in form of sag. The seed and dry leaves of fenugreek are used as a condiment and for medicinal purposes. Dried leaves and flowers are used for flavouring of foods.

Solar drying techniques, especially solar tunnel dryers, present a promising solution for large-scale drying of medicinal plants like fenugreek. These dryers harness solar energy efficiently, offering faster drying times, better product quality, and reduced post-harvest losses compared to traditional methods. Solar tunnel dryers use the greenhouse effect to trap heat, making them highly effective across diverse climates. Moreover, adopting pre-treatments like hot water blanching before drying enhances product quality by preserving color, texture, and nutrients. Thus, affordable, on-farm solar drying systems are essential for sustainable medicinal plant processing, reducing waste, and improving overall economic viability. The objective of this study is to assess the physio-chemical properties of fenugreek leaves, including carbohydrate, protein, fat, fiber, and ash content.

Fig. 2: Image of solar tunnel dryer.

Table 1: Treatment details.

Sr. No.	Type of Variable	Levels	Details
Independent Variable			
01	Crop leaves	1 levels	C – fenugreek Leaves
02	Steam blanching time	3 levels	S_1 – 0 min S_2 – 3 min S_3 – 5 min
03	Drying method	2 levels	D_1 – Solar Tunnel Drying D_2 – Sun Drying
Dependent Variable			
04	Parameters		**1.** Physical parameter: Bulk density. **2.** Biochemical parameter: Moisture content, carbohydrate, ascorbic acid, total ash, fat, fiber and protein content. **3.** Functional parameter: WSI, WAI, Recovery rate.
Treatment Details			
05	Treatments	6	
06	Repetitions	3	
07	Statistical design	3 - Factor Completely Randomised Design	

Material and Methods

Experimental Details

Procurement of medicinal plant leaves

The medicinal plants namely, *trigonellafoenum-graecum* leaves, was procured from the local farm of the Junagadh, Gujarat. harvesting of *Trigonella foenum-graecum* was carried out by a wooden rod having a sharp stainless-steel knife at the top for cutting the leaves. Then after, damaged and discoloured leaves were separated manually by hand picking.

Pre-treatments

The freshly harvested medicinal plant leaves were subjected to different levels of pre-treatment (*i.e.*, steam blanching for 3 and 5 minutes) prior to solar tunnel drying and sun-drying. Many researchers have suggested that steam blanching prior to drying will improve sensory qualities (colour, flavour, taste, fragrance, aroma, etc), permits longer storability as well as reduces the drying time.

Table 2: Treatment combination details.

Treat-ment	Treatment Details	Combi-nations
1	Fenugreek Leaves (C) + 0 min Steam blanching(S_1) + Solar Tunnel Drying (D_1)	CS1D1
2	Fenugreek Leaves (C) + 3 min Steam blanching(S_2) + Solar Tunnel Drying (D_1)	CS2D1
3	Fenugreek Leaves (C) + 5 min Steam blanching(S_3) + Solar Tunnel Drying (D_1)	CS3D1
4	Fenugreek Leaves (C) + 0 min Steam blanching(S_1) + Sun Drying (D_2)	CS1D2
5	Fenugreek Leaves (C) + 3 min Steam blanching(S_2) + Sun Drying (D_2)	CS2D2
6	Fenugreek Leaves (C_2) + 5 min Steam blanching(S_3) + Sun Drying (D_2)	C2S3D2

Physio-chemical Analysis of Raw and Dried Products

The physio-chemical analysis of the raw leaves, *i.e.*, freshly harvested leaves and that of the dried leaves powder was carried out in the Department of Food Processing Engineering, College of Agriculture Engineering and Technology, JAU, Junagadh. The parameters determined were carbohydrate content, ascorbic acid content, total ash content, fat content, protein content, crude fibre content, bulk density, recovery rate, WSI and WAI.

Carbohydrate content determination

To determine carbohydrate content, phenol sulphuric acid method was used.

Ascorbic acid content determination

To determine the ascorbic acid content in the sample, DNPH method was used as recommended by Roe (1961). In this study, 0.1 g of each of the sample was taken and extracted with 6% trichloro acetic acid (TCA) in 10 ml of 80% H_2SO_4. Aliquot of 0.2, 0.4, 0.6, 0.8 and 1.0 concentration were formed. In it, 2 ml of 2% 2,4 Dinitrophenylhydrazine (DNPH) and 10% thiourea was added and the whole set up was kept in water bath of 80°C for 15 minutes.

Ash content determination

Total ash content was determined by combustion method as described in AOAC (2005).

Crude fat content determination

Crude fat content was determined as the weight change recorded after exhaustively extracting the leaf samples with a non-polar solvent (hexane) using soxlet method (Plate 3.20), according to AOAC (2005).

Protein content determination

To determine the protein content of *Murrayakoenigii* and *Trigonella foenum-graecum*, Follin Lowry method was adopted, recommended by Waterborg (2009).

Crude fibre content determination

Crude fibre percentage was determined by extraction method with the help of fibre therm (Plate 3.23), according to AOAC (2005).

Bulk density

The bulk density can be determined by the formula, as given by Anderson (1969):

Percentage recovery

The percentage recovery was determined according to the formula given by Anderson (1982).

Water solubility index (WSI)

The solubility was determined according to the method suggested by Anderson (1982).

Water absorption index (WAI)

The absorptivity was determined according to the method suggested by Anderson (1982).

Chlorophyll Content test

The chlorophylls are vital components for photosynthesis and occurs as green pigment in chloroplast of all plant tissue. The chlorophyll was determined by colorimetric method described by Sadasivam and Manickam (1996).

According to this method, 0.2 g green leaves sample was ground by adding 80% acetone. After that it was centrifuged and collected the supernant in 10 ml centrifuge tube. Repeated this procedure until the sample became colourless. The absorbance was recorded at 645 and 663 nm against blank (plate 3.16). The amount of chlorophyll present in extract was obtained using the following expression.

Results and Discussion

The physio-chemical and function properties of raw leaves and dried leaf powder of *Murrayakoenigii* and *Trigonella foenum-graecumas*, *viz.*, carbohydrate content, moisture content, fat content, fibre content, ascorbic acid content, protein content, ash content, bulk density, recovery rate, chlorophyll content, WAI and WSI were determined in the Processing and Food Engineering department of CAET, JAU, Junagadh as per the standard methods

Carbohydrate Content

The graph shows that the range of carbohydrate content vary from 67.13 to 71.99% for fenugreek leaves. The highest amount of carbohydrate content was found in fenugreek leaves which was pretreated by steam

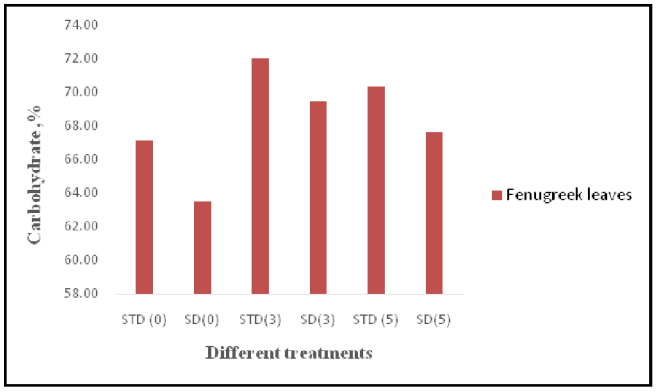

Fig. 3: Carbohydrate content of dried powder fenugreek leaves.

blanching for 3 min and dried using solar tunnel dryer and minimum carbohydrate content was found in unblanched sun dried.

Moisture Content

The graph shows that the range of Moisture content vary from 4.67% to 3.09% for fenugreek leaves. the highest amount of moisture content was found which was unblanched sun dried and minimum moisture content was found in 5 min blanched. samples.

Ascorbic Acid

The graph shows that the range of ascorbic acid content vary 23.31% to 20.21% for fenugreek leaves. The highest amount of ascorbic acid content was found which was pretreated by steam blanching for 3 min and

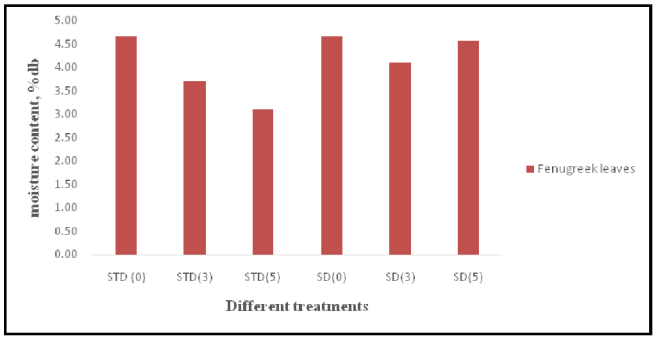

Fig. 4: Moisture content of dried powder curry and fenugreek leaves.

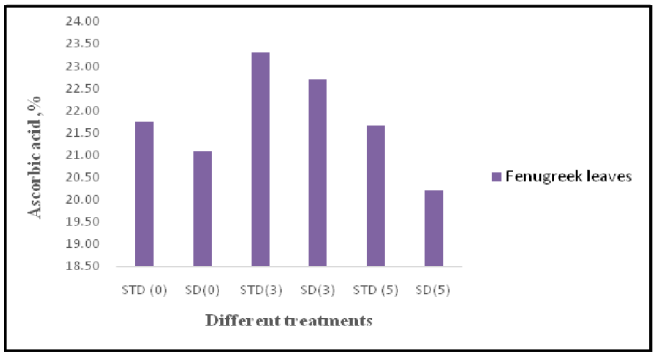

Fig. 5: Ascorbic acid content of dried powder curry and fenugreek leaves.

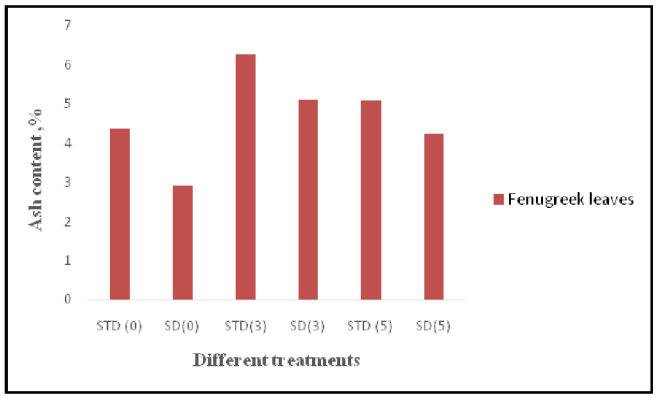

Fig. 6: Ash content of dried powder curry and fenugreek leaves.

dried using solar tunnel dryer and minimum ascorbic acid content was found in unblanched sun dried.

Total Ash

The graph shows that the range of ash content vary from 6.265% to 2.91% for fenugreek leaves. The highest amount of ash content was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum ash content was found in unblanched sun dried.

Fat Content

The graph shows that the range of fat content vary from 4.88% to 4.47% for fenugreek leaves. The highest amount of fat content was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum fat content was found in unblanched sun dried.

Protein Content

The graph shows that the range of Protein content vary from 7.93% to 8.41% for fenugreek leaves. The highest amount of protein content was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum protein content was found in unblanched sun dried.

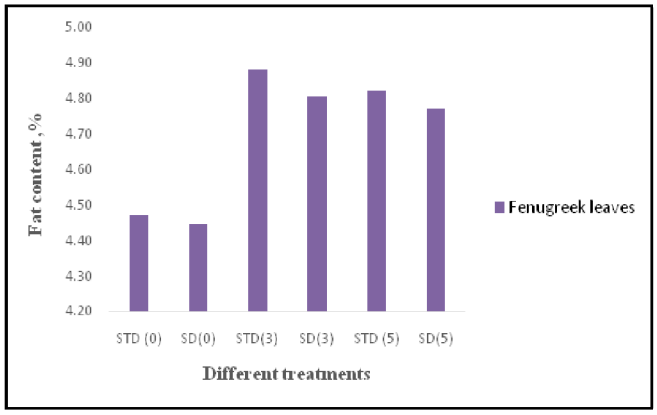

Fig. 7: Fat content of dried powder curry and fenugreek leaves.

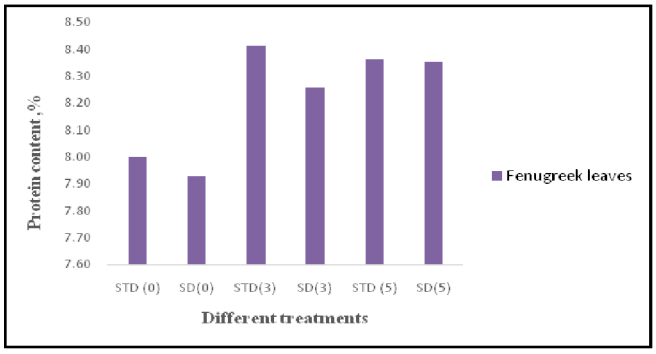

Fig. 8: Protein content of dried powder curry and fenugreek leaves.

Fibre content

The graph shows that the range of Fiber content vary from 5.02% to 3.64% for fenugreek leaves. The highest amount of fibre content was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum fibre content was found in unblanched sun dried, respectively.

Bulk Density

The graph shows that the range of Bulk density vary from 301 to 225.64 kg/m^3 for fenugreek leaves. The highest amount of bulk density was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum fibre content was found in unblanched sun dried.

Water Solubility Index

The graph shows that the range of Fiber content vary

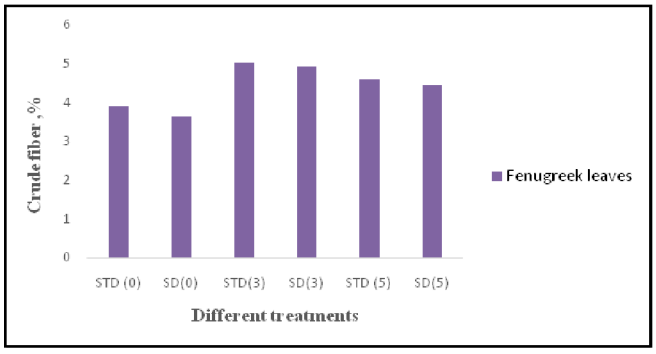

Fig. 9: Ash content of dried powder curry and fenugreek leaves.

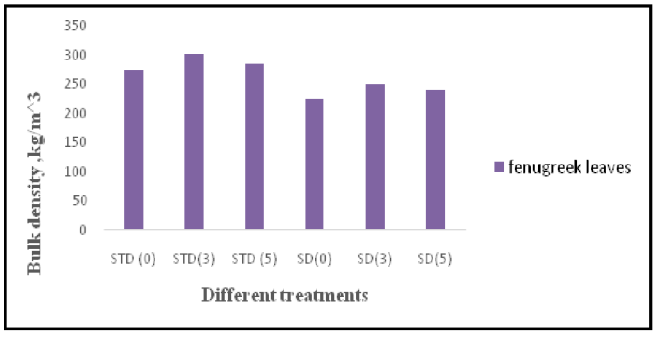

Fig. 10: Bulk density of dried powder curry and fenugreek leaves

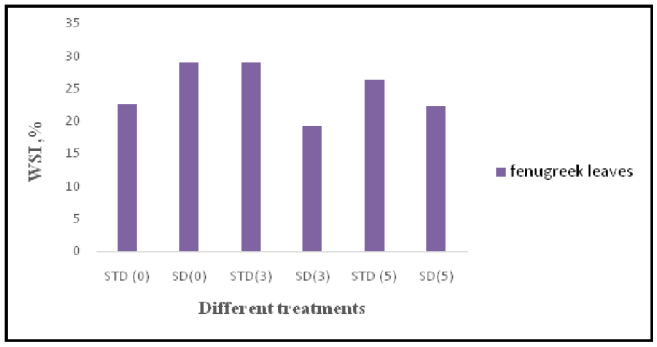

Fig. 11: WSI of dried powder fenugreek leaves.

from 28.94% to 19.22% for fenugreek leaves. The highest amount of bulk density was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum fibre content was found in unblanched sun dried.

Water Absurdity Index

The graph shows that the range of WAI vary from 346.32% to 150.98% for fenugreek leaves. The highest amount of WAI was found in fenugreek leaves which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum moisture content was found in 0 min using sun drying.

Chlorophyll Content

The graph shows that the range of chlorophyll content

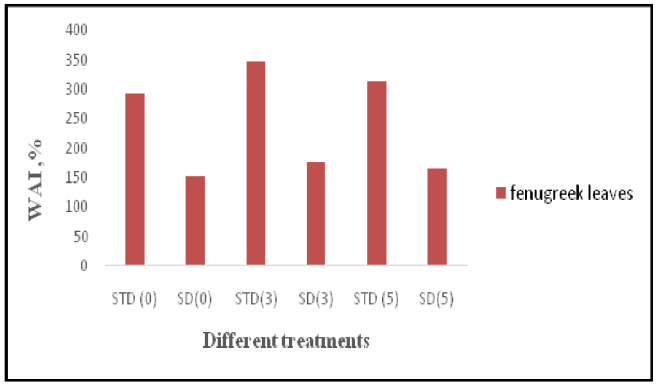

Fig. 12: WAI of dried powder fenugreek leaves.

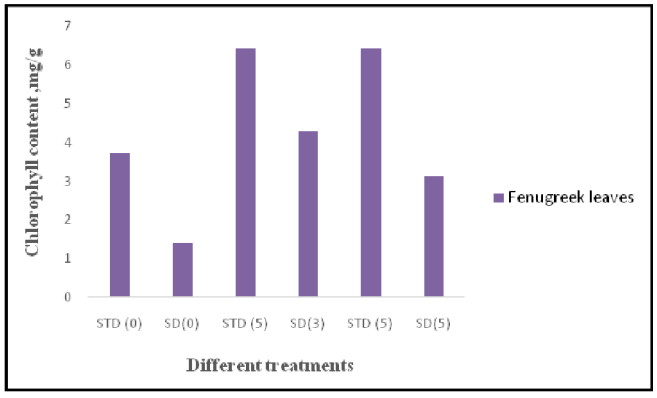

Fig. 13: Chlorophyll content of dried powder curry and fenugreek leaves.

vary from 7.17 to 1.42% for fenugreek leaves. The highest amount of chlorophyll content was found which was pretreated by steam blanching for 3 min and dried using solar tunnel dryer and minimum chlorophyll content was found in unblanched sun dried.

The drying time for fenugreek leaves was found to decrease with the increase in time of steam blanching. The average time taken for the sample without blanching to dry was 8-9 hours and the average time taken for the sample with 5-minute blanching was 6-7 hours. The biochemical analysis was carried out to determine the carbohydrate content, ascorbic acid, ash, fat, fibre and protein content of the dried samples. It was found that the samples which were blanched retained the most nutrients as well as had lower moisture content.

The minimum value of carbohydrate content, ascorbic acid, ash, fat, fibre and protein content for unblanched sun-dried leaves of Fenugreek were found to be 67.13%, 1.84%, 2.91%, 4.47%, 3.64% and 7.93%, respectively. The maximum value of carbohydrate content, ascorbic acid, ash, fat, fibre and protein content for 3-minute blanched solar tunnel dried leaves of Fenugreek were found to be 71.99%, 23.31%, 6.26%, 4.88%, 5.02% and 8.41%, respectively.

The average value of WAI for unblanched and sun-dried sample of Fenugreek was found to be 150.98%. The average value of WSI for Fenugreek leaves was found to be 19.22%. The mean value of bulk density was found to be 301.00 kg/m3 for solar tunnel dried samples of Fenugreek leaves. The mean value of recovery rate for Fenugreek leaves was found to be 22.53%. The average value of WAI for solar tunnel dried Fenugreek leaves was found to be 344.88%. The average value of WSI for fenugreek leaves was found to be 57.75%.

Conclusions

The drying time for fenugreek leaves was found to decrease with the increase in time of steam blanching. The average time taken for the sample without blanching to dry was 8-9 hours and the average time taken for the sample with 5-minute blanching was 6-7 hours. The biochemical analysis was carried out to determine the carbohydrate content, ascorbic acid, ash, fat, fibre and protein content of the dried samples. It was found that the samples, which were blanched, retained the most nutrients as well as had lower moisture content.

The minimum value of carbohydrate content, ascorbic acid, ash, fat, fibre and protein content for unbalanced sun-dried leaves of Fenugreek were found to be 67.13%, 1.84%, 2.91%, 4.47%, 3.64% and 7.93%, respectively. The maximum value of carbohydrate content, ascorbic acid, ash, fat, fibre and protein content for 3-minute blanched solar tunnel dried leaves of Fenugreek were found to be 71.99%, 23.31%, 6.26%, 4.88%, 5.02% and 8.41%, respectively.

The average value of WAI for unbalanced and sun-dried sample of Fenugreek was found to be 150.98%. The average value of WSI for Fenugreek leaves was found to be 19.22%. The mean value of bulk density was found to be 301.00 kg/m3 for solar tunnel dried samples of Fenugreek leaves. The mean value of recovery rate for Fenugreek leaves was found to be 22.53%. The average value of WAI for solar tunnel dried Fenugreek leaves was found to be 344.88%. The average value of WSI for fenugreek leaves was found to be 57.75%.

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