Advances in Bioresearch
Adv. Biores., Vol 14 (6) November 2023: 575-585
©2023 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.14.6.575585

Advances in Bioresearch

ORIGINAL ARTICLE

Studies on The Drying Characteristics of Spinach using Different Drying Methods

Mehr-Un-Nissa[1], Anjum Ayoub*[2], Sajad Mohd Wani [3], Aisha batool[4], Afreen wani[5]
[1]M.tech food technology student RIMT University Punjab-147301
[2*]Assistant Professor P&FE SKUAST-Jammu-180009
[3]Associate Professor, FT SKUAST-K -190025
[4-5]M.tech food technology student RIMT University Punjab-147301
*Corresponding author e mail: anjumparay77@gmail.com

ABSTRACT
The present investigation, "Studies on the drying characteristics of spinach using different drying methods (sun, shade and cabinet) were carried out in the division of Food Science and Technology SKUAST-K Shalimar campus and department of food technology RIMT university Punjab during (may-September). For drying purpose the raw material (spinach) was procured from local markets of Shalimar. After sorting and proper washing, green spinach leaves were divided into 3 equal lots for pre drying treatments. All the three lots were subjected for Sun drying (30⁰C), shade drying (25⁰C) and Cabinet drying (55±2 ⁰C) respectively. The dried sample after attaining final moisture were packed in LDPE pouches (1.75guage) and stored under ambient condition (25± 2⁰C, 72-85%) for 90 days. The samples from all the treatments were analyzed periodically for changes in physicochemical and microbial analysis at an interval of 15 days. The result of physicochemical evaluation indicated that good quality dried product can be prepared from the fresh spinach leaves by sun, shade and cabinet drier. There was a significant effect of drying methods and storage period on the overall quality of dried product, irrespective of variety. During 90 days of storage, moisture content, water activity, microbial load [total plate count and visible mold growth (cfu/g)] showed the increased trend. The results suggested that cabinet drying is more effective than sun and shade drying.
Keywords: Drying, Cabinet, Rehydration, Total Plate Count, Visible Mold Growth

Received 21.09.2023 Revised 06.10.2023 Accepted 29.11.2023

How to cite this article:
Mehr-Un-Nissa, Anjum A, Sajad M W, Aisha B, Afreen W. Studies on The Drying Characteristics of Spinach using Different Drying Methods. Adv. Biores. Vol 14 [6] November 2023. 575-585

INTRODUCTION

Locally called as "Palak," spinach (*Spinacia Oleracea*) is a green leafy vegetable from the Chenopodiaceae family. The plant, which is annual, reaches a height of 30 cm. This plant requires a temperate environment in order to survive the winter. One of the most popular green vegetables in tropical and subtropical areas, spinach is grown extensively throughout India. Compared to other green vegetables, it is more affordable and offers a higher level of nutrition. When fresh spinach is kept in the refrigerator for longer than a week, over half of its nutrients are lost. It is therefore advisable to consume it as quickly as possible. For obese and diabetic individuals, spinach is an appropriate food because it has a low-fat content. Chlorophyll, which is known to facilitate digestion [1], is another important component of it. Despite having less calories, it has higher levels of minerals, vitamins, and other phytonutrients, which are organic plant compounds with nutritional significance for humans. This dish is advocated by nutritionists and dietitians since it has lower cholesterol and saturated fat content.

In many different national healthcare systems throughout the world, individuals have begun to turn to these products for the treatment of a variety of health issues, and the usage of herbal medicines is still growing quickly. The main factors influencing all treatments currently available are herbal remedies' simplicity of preparation, lack of adverse effects, and low cost. Although the use of these herbal medications has expanded, industrialized and developing nations have substantial concerns about their quality, safety, and efficacy; as a result, traditional and folk medicines play a significant part in global health services [2].

Due to the presence of flavonoids as kampeferol, quercetin, apigenin, and luteolin, spinach offers anti-diabetic properties. The majority of medicinal plants with hypoglycemia and anti-diabetic activities are said to have flavonoids as their active biological constituents.
Spinach is a seasonal vegetable that quickly spoils after harvest and is only eaten then. The water content of spinach is high compared to other leafy greens. According to [3], one of the preservation techniques that can increase the amount of time spinach can be consumed is drying.
We used three different drying techniques, including cabinet, shade, and the sun, to extend the shelf life of spinach. Drying is a crucial method of product manufacture and preservation in which the water content and activity are reduced. The simultaneous mass and heat transfer that occurs during drying causes the material to undergo modifications. Even just 24 hours of storage at room temperature can cause considerable losses in ascorbic acid and vitamin A. The shelf life of spinach can be extended by approximately one week at 5°C.
The overall number of spinach leaves on each dish was significantly impacted by storage as well. Regardless of the drying process used, a considerable rise in the overall plate count was seen during the 90 days of storage. While the samples were in storage, very little moisture was added to them. On the dried leaves, both bacteria and fungi were discovered, although the dried samples did not appear to be rotten. Proteus mirabilis and Fusarium sp. were absent from the dried samples. All of the species found are typical environmental pollutants. On dried cassava products, Aspergillus, Penicillium, and Fusarium were also noted, according to [4]. In addition to fresh samples, only those that had been shade dried included the bacteria Lactobacillus sp. and Serratia sp.
The microbiological burden in the cabinet-dried sample is within the upper limits. The sample that was shaded and sun dried, however, showed a larger microbial burden.

MATERIALS AND METHODS

The present investigation entitled "Studies on the drying characteristics of spinach using different drying methods" was carried out during spring session 2022 in the laboratory of Food Technology at the division of Food Science and Technology, SKUAST Kashmir and RIMT university department of food technology Punjab. The materials use, experimental details and techniques employed in the investigation are furnished below.

Procurement of raw material (Spinach)

Spinach was procured from the local market of Shalimar Srinagar. The material was sorted, washed and drained. The prepared material was subjected for proximate analysis. After proximate analysis of fresh sample, the material is divided into three equal lots. The three lots were subjected for sun drying (30ºC), shade drying (25ºC) and cabinet drying (55ºC).

Equipment used

The spinach leaves were dried in a laboratory-scale cabinet drier, which has a drying chamber, an electrical heater, a fan, and a temperature controller (up to 100°C).

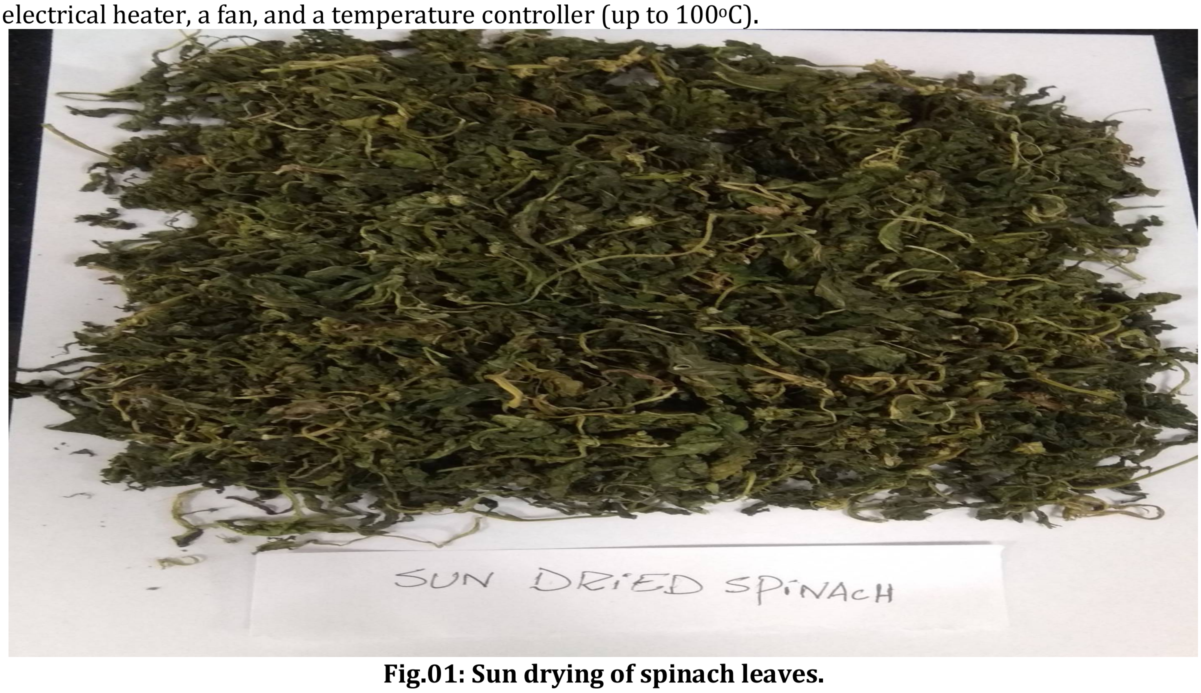

Fig.01: Sun drying of spinach leaves.

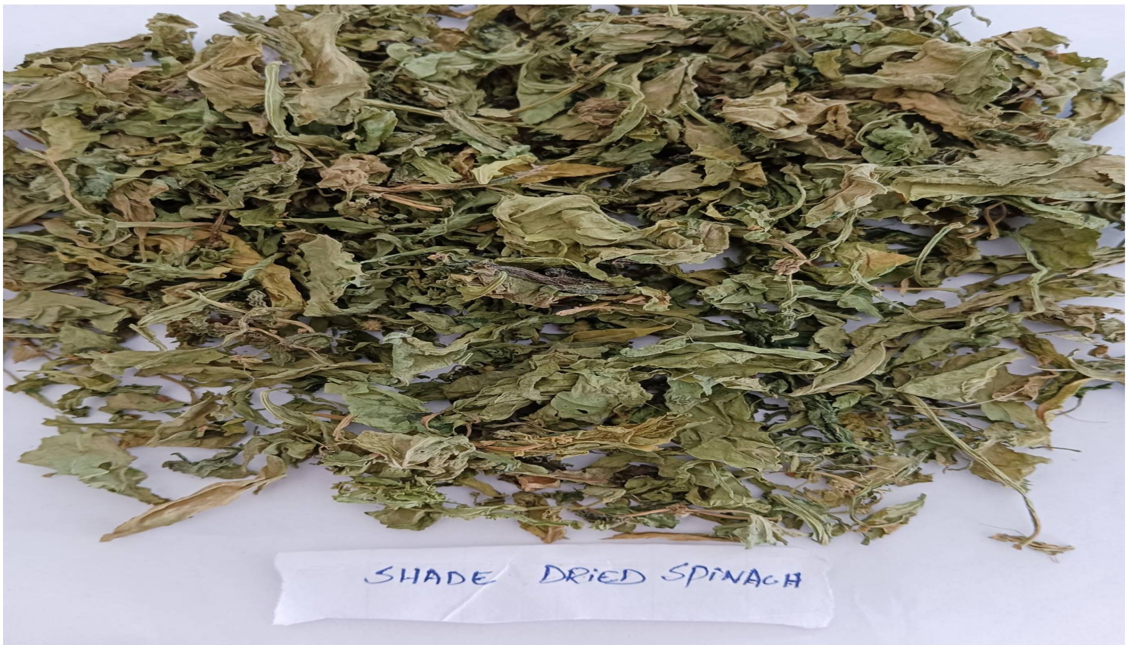

Fig.02: Shade drying of spinach leaves.

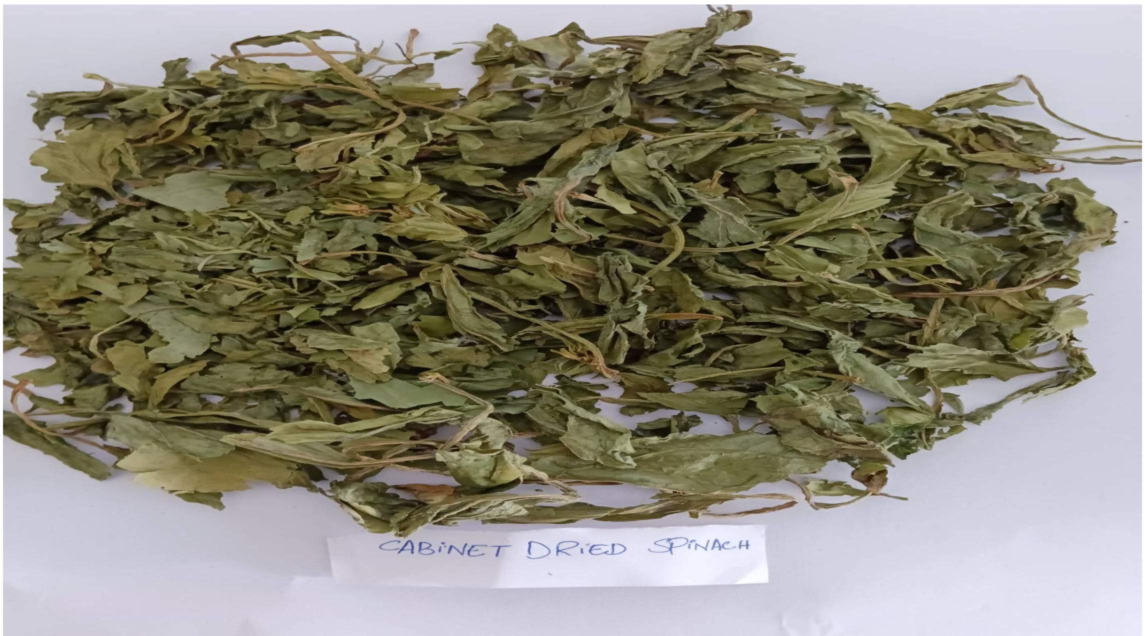

Fig.03: Cabinet drying of Spinach leaves.

Methodology

Details of technical program including variety, drying methods, etc. are specified below

Variety

One local variety spinach was selected for the present investigation
i.e., Local (v1)

Drying methods

1. D1=Sun drying (30 ∘ C)
2. D2=Shade drying (25 ∘ C)
3. D3=Cabinet drying (55±2 ∘ C)

Packaging material (LDPE)

The dried samples were stored for 90 days in low density polyethylene (LDPE) packaging material at room temperature (25ºC, 84%). The samples from all the treatments were drawn at 0, 15, 30, 45, 60, 75, and 90 days of storage for physico-chemical and microbial evaluation. The packed sample (200g/tray)

 © 2023 Author

will be stored under ambient conditions to monitor physico-chemical parameters during 90 days of storage at 7sample intervals.

Sampling intervals: 07

- S0=0days
- S1=15days
- S2=30days
- S3=45days
- S4=60days
- S5=75days
- S6=90days

Proximate analysis of raw materials (Spinach)

Water activity (aw)

Using a water activity metre, water activity was determined (PRE AQUA LAB, Water activity analyzer, SN PRE000197).

Moisture content (%)

Pre -weighed samples (2 g) of each flour were dried in hot air oven (Make: Tanco India Ltd) at130±1ºC for one hour and moisture content in percent was calculated from loss in weight as under [5]:

$$\textit{Moisture content (\%)} = \frac{\text{Weight of original sample (g)} - \text{weight of dried sample (g)}}{\text{Weight of original sample (g)}} \times 100$$

Crude protein

In order to convert nitrogen content to crude protein using the micro-Kjeldahl method, a ratio of 6.25 was utilized. In a Kjeldahl digestion flask, combined sulphuric acid (20 ml) and digestion mixture (10.0 g) are used to break down a 1.0 gram weighted sample. Before being transferred to a 250 mL volumetric flask, the ingredients were chilled. With distilled water, the volume was raised to the required level and then mixed. A predetermined amount was put into a distillation flask, and then 40.0 percent sodium hydroxide was added to it. A condenser was used to obtain ammonium borate, which was then placed in a flask with 10 ml of a 4 percent boric acid solution. A 0.1 N sulfuric acid titration was performed on the distillate. Along with the sample, a blank sample was also collected.

$$\text{Nitrogen \%} = \frac{\text{Titre value X 0.00014 X volume made}}{\text{Aliquottaken (g) X Weight of sample (g)}} \times 100$$

Crude fat (%)

To evaluate crude fat, the soxhlet extraction technique was performed. The sample's fat content was simply extracted into petroleum ether, an organic solvent, between 60 and 80 degrees Celsius, and then refluxed for six hours. The proportion of fat content was calculated using the formula.

$$\text{Crude fat percent} = \frac{\text{Ether extract amount (g)}}{\text{Weight of Sample (g)}} \times 100$$

$$= \frac{W2 - W1}{W} \times 100$$

Sample Weight = W (g)

Empty Beaker Weight = W_1 (g)

Empty Beaker weight+ content fat (ether extract) W2 (g)

Crude fibre (%)

Applying the AOAC (2012) standard method, crude fibre was calculated. 200ml of 125 percent sulphuric acid was added to a two-gram sample that had been removed from moisture and fat. Beaker was placed on a digestion apparatus with a previously controlled hot plate, and it boiled for 30 minutes.

Ash (%)

In a silica crucible that had already been pre-weighed, one gram of moisture-free sample was recovered. By gradually heating over a flame, preliminary ash was produced, allowing fat to be smoked off without being burned. The sample was burned for eight hours at 600 °C in a muffle furnace after it stopped smoking. The crucibles were removed, weighed, and then allowed to cool in a desiccator. The ash content, expressed as a percentage, was calculated using the weight in difference of the crucible wand.

$$Ash\ Per\ cent = \frac{Weiht\ of\ ash\ (g)}{Weight\ of\ Sample\ (g)} \times 100$$

Carbohydrate (%)

The total of moisture, crude protein, crude fat, ash, and crude fibre was added to get the amount of carbohydrates, which was then subtracted from 100.
Carbohydrate (%) = 100 − (% moisture + %Protein + %Fat + %Ash+ %Fibre)

Phytochemical characterization of spinach

Rehydration Ratio

The rehydration ratio was determined using the technique. Each sample, which weighed 5 grams, had been immersed in 50 ml of distilled water for 60 minutes at room temperature. Samples that had been soaked were filtered using Whatman filter paper No. 41, and the permeate was weighed. Following soaking, the capacity of the samples to reabsorb water or rehydrate was determined using the following formula:

$$\text{Rehydration ratio} = \frac{\text{weight of drained material (g)}}{\text{weight of dried residue (g)}}$$

Microbiological Examination

The serial dilution and pour plate method was used for the analysis of microorganisms.

Statistical Analysis

The mean and SD of moisture content, water activity, crude fat, crude fibre, crude protein, carbohydrates, rehydration ratio, total plate count, visible mold growth were calculated. To evaluate the significant impact (P 0.05) of rehydration and drying on the spinach, one-way analysis of variance and least significant difference were used.

RESULTS AND DISCUSSION

Physico-chemical properties of fresh spinach leaves.

The observation on physico-chemical properties of fresh spinach leaves, which included water activity, moisture content, ash, carbohydrates, crude fat, crude fibre, crude protein are presented in Table-1.
The average moisture content of spinach leaf was 89.7 per cent, water activity 0.97, ash 18.51per cent, minerals: iron 3.9mg/100g, calcium 267mg/100g, Magnesium 79mg/100g, carbohydrate 4per cent, crude fibre 2 per cent, crude fat 2 per cent, crude protein 2 per cent, total phenols 62.41mg/100g, total flavonoids 5.99mg/100g, antioxidant activity 19.80 percent, rehydration ratio 2.21, energy value 23kcal, L, a & b values are 61.0, -11.0 & 21.76 respectively.

Table-1: Physico-chemical properties of fresh spinach.

PARAMETER	VARIETY(**SPINACH**)
Water activity	0.97±0.02
Moisture (%)	89.70±0.2
Crude protein (%)	2.00±0.2
Crude fat (%)	2.00±0.02
Crude fibre (%)	2.00±2
Ash (%)	18.51±0.02
Carbohydrate (%)	4.00±2

Effect of drying methods on physico-chemical properties of dried spinach leaves.

Physicochemical observations

Table-2: Physico-chemical properties of dried spinach.

Parameter and Drying Method	**Water Activity**	**Moisture Content**	**Rehydration ratio**	**Ash Content (%)**	**Carbohydrate Content (%)**	**Crude Fibre (%)**	**Crude Protein (%)**	**Crude Fat (%)**
SUN (D1)	0.38± 0.02	10.49± 0.02	2.84± 0.02	6.31± 0.02	16.21± 0.02	8.43± 0.02	8.87± 0.02	3.89± 0.02
SHADE (D2)	0.43± 0.02	12.21± 0.02	2.40± 0.02	5.47± 0.02	15.32± 0.02	6.44± 0.02	6.01± 0.02	2.78± 0.02
CABINET (D3)	0.34± 0.02	7.89± 0.02	3.12± 0.02	9.11± 0.02	17.68± 0.02	10.76± 0.02	10.21± 0.02	4.46± 0.02

CD ($p \leq 0.05$)

D=drying

 © 2023 Author

Water activity

The data pertaining to the impact of different drying methods on water activity of spinach leaves are presented in Table 2.

Drying methods non-significantly influenced the water activity of spinach leaves. The highest water activity of 0.43 was recorded in sample dried under shade drying while lowest water activity of 0.34 was recorded in sample dried under cabinet drying and 0.38 was recorded in sample dried under sun drying.

The comparison of interaction among various factors on ash content was also evaluated .The interactions were statistically non-significant.

Moisture content (%)

The data pertaining to the impact of different drying methods on moisture content of spinach leaves are presented in Table 2.

Drying methods significantly influenced the moisture content of spinach leaves. The highest moisture content of 12.21% was recorded in sample dried under shade drying while lowest moisture content of 7.89% was recorded in sample dried under cabinet drying and 10.49% was recorded in sample dried under sun drying.

The comparison of interaction among various factors on ash content was also evaluated .The interactions were statistically non-significant.

Rehydration ratio

The data pertaining to the impact of different drying methods on the Rehydration Ratio of Spinach leaves are presented in Table 2.

Drying methods showed significant effect on rehydration ratio of spinach leaves. The highest rehydration ratio of 3.14 was recorded in sample dried under cabinet drying while rehydration ratio of 2.40 was recorded in sample dried under shade drying and 2.84 was recorded in sample dried under sun drying.

Table 2 depicts the changes in the rehydration ratio of dried spinach in all the three drying methods. The highest rehydration ratio was observed in cabinet dried spinach and lowest in shade dried spinach and in sun dried sample.

Ash (%)

The data pertaining to the influence of different drying methods on ash content of spinach leaves are presented in Table 2.

Drying methods non-significantly influenced the ash content of spinach leaves. The highest ash content of 9.11% was recorded in sample dried under cabinet drying while lowest ash content of 5.47% was recorded in sample dried under shade drying and 6.31% was recorded in sample dried under sun drying.

The comparison of interaction among various factors on ash content was also evaluated. The interactions were statistically non-significant.

Carbohydrates

The data pertaining to the influence of different drying methods on carbohydrate content of spinach leaves are presented in Table 2.

Drying methods showed significant effect on carbohydrate content of spinach leaves. The highest carbohydrate content of 17.68% was recorded in sample dried under cabinet drying while the lowest carbohydrate content of 15.32% was recorded in sample dried under shade drying and 16.21% of carbohydrate content was recorded in sample dried under sun drying.

The comparison of interaction among various factors on carbohydrate content was also evaluated. The interactions were statistically non-significant.

Crude fibre

The data pertaining to the impact of different drying methods on crude fibre content of spinach leaves are presented in Table 2.

Drying methods significantly influenced the crude fibre content of spinach leaves. The highest crude fibre content of 10.76 % was recorded in sample dried under cabinet drying while lowest crude fibre content of 6.44%was recorded in sample dried under shade drying and 8.43%of crude fibre was recorded in sample dried under sun drying. The comparison of interaction among various factors on crude fibre content was also evaluated. The interactions were statistically non-significant.

Crude protein

The data pertaining to the effect of different drying methods on crude protein content of spinach leaves are presented in Table 2.

Drying methods showed significant effect on crude protein content of spinach leaves. The highest crude protein content of 10.21 %was recorded in sample dried under cabinet drying while the lowest crude protein content of 6.01% was recorded in sample dried under shade drying and 8.87% of crude protein

 © 2023 Author

content was recorded in sample dried under sun drying. The comparison of interaction among various factors on crude protein content was also evaluated .The interactions were statistically non-significant.

Crude fat

The data pertaining to the influence of different drying methods on crude fat content of spinach leaves are presented in Table 2.

Drying methods showed significant effect on crude fat content of spinach leaves. The highest crude fat content of 4.46 was recorded in sample dried under cabinet drying while the lowest crude fat content of 2.78% was recorded in sample dried under shade drying and 3.89% of crude fat content was recorded in sample dried sun drying. The comparison of interaction among various factors on carbohydrate content was also evaluated .The interactions were statistically non-significant.

Storage values of dried spinach

Water activity

The data pertaining to the effect of different drying methods and storage periods on the water activity of spinach leaves are presented in Table 3.

Perusal of the data indicated that the drying methods showed non-significant effect on water activity of spinach leaves. Highest water activity of 0.51 was recorded in shade dried sample while the lowest water activity of 0.47 and 0.45was recorded in sun dried and cabinet dried samples.2 Storage values of dried spinach

Table -3: Effect of drying methods & storage on the water activity of the Spinach leaves

Drying methods	Variety(v)							Mean
	Storage (days)							
	S0	S1	S3	S4	S5	S6	S7	
SUN (D1)	0.38±0.02	0.41±0.02	0.43±0.02	0.47±0.02	0.51±0.02	0.54±0.02	0.59±0.02	**0.47**
SHADE (D2)	0.43±0.02	0.46±0.02	0.49±0.02	0.51±0.02	0.55±0.02	0.56±0.02	0.58±0.02	**0.51**
CABINET (D3)	0.34±0.02	0.38±0.02	0.41±0.02	0.46±0.02	0.48±0.02	0.55±0.02	0.57±0.02	**0.45**
Mean	0.38	0.41	0.44	0.48	0.51	0.55	0.58	**0.47**

CD ($p \leq 0.05$)

D=drying, S=storage, V=variety

The highest overall storage mean of water activity of 0.51 was recorded in shade dried sample at 90daysof ambient storage. The lowest overall storage mean of water activity of 0.47 and 0.45 was recorded in sun dried and cabinet dried spinach at 90 days of ambient storage. A non-significant increase in water activity was observed during 90 days of ambient storage irrespective of drying methods. The comparison of interaction among various factors on water activity in spinach leaves was statistically non-significant.

Moisture content (%)

The data pertaining to the effect of different drying methods and storage periods on the moisture content of spinach leaves are presented in Table 4.

Perusal of the data indicated that the drying methods showed non-significant effect on moisture content of spinach leaves. The highest overall drying mean of 16.20 was recorded in shade dried sample while the lowest was recorded in cabinet dried samples.

Table -4: Effect of drying methods & storage on the moisture content (%) of the Spinach leaves

Drying methods	Variety(v)							Mean
	Storage (days)							
	S0	S1	S2	S3	S4	S5	S6	
SUN (D1)	10.49±0.02	12.51±0.02	13.32±0.02	14.43±0.02	15.22±0.02	15.54±0.02	16.23±0.02	**13.96**
SHADE (D2)	12.21±0.02	15.32±0.02	15.76±0.02	16.44±0.02	16.82±0.02	16.91±0.02	17.00±0.02	**15.78**
CABINET (D3)	7.89±0.02	8.65±0.02	9.24±0.02	9.30±0.02	10.48±0.02	10.99±0.02	11.00±0.02	**9.65**
Mean	10.19	12.16	12.77	13.39	14.17	14.48	14.74	**13.13**

CD ($p \leq 0.05$)

D=drying, S=storage, V=variety

A non-significant increase in moisture content was observed during 90 days of storage irrespective of drying methods. The highest overall storage mean of moisture content of 15.78% was recorded in sample dried under shade drying at 90 days of ambient storage. The lowest overall storage moisture content of 9.65% was recorded in sample dried under cabinet drying and 13.96% was recorded in sample dried under sun drying at 90 days of ambient storage. The effect of interactions amongst various factors on moisture content of dried spinach was also evaluated.

Microbial count
Total Plate Count (cfu/g)
The data pertaining to the effect of different drying methods and storage periods on the total plate count of spinach leaves are presented in Table 5.

Table-5: Effect of drying methods &storage on the Total plate count (count×10²) cfu/g of Spinach leaves.

Drying methods	Variety(v)							Mean
	Storage (days)							
	S0	S1	S2	S3	S4	S5	S6	
Sun (D1)	0.00±2	24.00±2	43.00±2	45.00±2	56.00±2	58.00±2	76.00±2	**43.14**
Shade (D2)	0.00±2	28.00±2	46.00±2	55.00±2	58.00±2	60.00±2	80.00±2	**46.71**
Cabinet (D3)	0.00±2	20.00±2	39.00±2	48.00±2	50.00±2	53.00±2	71.00±2	**40.14**
Mean	0.00	24.00	42.66	49.33	54.66	57.00	75.66	**43.33**

CD ($p \leq 0.05$)

D=drying, S=storage, V=variety

Drying methods significantly influenced the total plate count of spinach leaves. The highest overall drying mean of 46.71cfu/g was recorded in sample dried under shade drying while as 40.14cfu/g and 43.14cfu/g was recorded in samples dried under cabinet and sun drying respectively. Storage also had significant influence on total plate count of spinach leaves. A significant increase in total plate count was observed from 0 to 90days of storage irrespective of drying method applied. The comparison of interaction among various factors on total plate count was also evaluated. Some interactions were statistically significant and some were non-significant.

Visible mold growth
The data pertaining to the effect of different drying methods and storage periods on the visible mold growth of spinach leaves are presented in Table 6.

Table-6: Effect of drying methods &storage on the visible mold growth (molds) (count×10²) cfu/g of Spinach leaves.

Drying methods	Variety(v)							Mean
	Storage (days)							
	S0	S1	S2	S3	S4	S5	S6	
Sun (D1)	3.75±0.02	3.79±0.02	3.86±0.02	3.84±0.02	3.87±0.02	3.76±0.02	3.77±0.02	**3.80**
Shade (D2)	3.76±0.02	3.78±0.02	3.84±0.02	3.87±0.02	3.76±0.02	3.86±0.02	3.88±0.02	**3.82**
Cabinet (D3)	3.58±0.02	3.59±0.02	3.61±0.02	3.67±0.02	3.75±0.02	3.73±0.02	3.68±0.02	**3.65**
Mean	3.69	3.72	3.77	3.79	3.79	3.78	3.77	**3.75**

CD ($p \leq 0.05$)

D=drying, S=storage, V=variety

Drying methods significantly influenced the visible mold growth of spinach leaves. The highest overall drying mean of 3.82cfu/g was recorded in sample dried under shade drying while as 3.65cfu/g and 3.80cfu/g were recorded in samples dried under cabinet and sun drying respectively. Storage also had significant influence on total plate count of spinach leaves. A significant increase in visible mold growth was observed from 0 to 90days of storage irrespective of drying method applied. The comparison of interaction among various factors on visible mold growth was also evaluated. Some interactions were statistically significant and some were non-significant.

DISCUSSION

Limited shelf life of spinach resulting in severe economic losses that has been a cause of great concern to spinach growers all over the world. If dried, packaged, and stored appropriately, the fresh green spinach's (soft stem and leaves) availability during hard times may be increased at an appropriate cost. It could be achieved by drying [5] and by modifying the storage conditions of spinach.

Physico-chemical characteristics of fresh spinach leaves
During the course of present study, it was observed that fresh spinach leaves possessed an average moisture content of spinach leaf was 89.7 per cent, water activity 0.97, ash 18.51per cent, minerals: iron 3.90mg/100g, calcium 267mg/100g, Magnesium 79mg/100g, carbohydrate 4 per cent, crude fibre 2 per cent, crude fat 2 per cent, crude protein 2 per cent, total phenols 62.41mg/100g, total flavonoids

5.99mg/100g, antioxidant activity 19.80 percent, rehydration ratio 2.21, energy value 17 kcal, L, a & b values are 61.0, -11.0 & 21.76 respectively.

Physico- chemical characters of dried spinach leaves

Physical properties

Rehydration ratio

Drying methods showed significant effect on the rehydration ratio of spinach leaves. Highest rehydration ratio of 3.12 was recorded in sample dried under cabinet drying while lowest rehydration ratio of 2.40 was recorded in sample dried under shade drying and 2.84 was recorded in sample dried under sun drying.

Maximum rehydration ratio in cabinet dried samples has been associated with efficient, even heat transmission and quick water elimination, which leads to less textural changes during dehydration and higher final product rehydration ratio [6].

Chemical properties

The present study indicated that the drying methods and storage had significant influence on various chemical parameters of spinach leaves. During the course of 90 days of storage under ambient conditions. However, the drying methods varied significantly from one another in their impact on chemical parameters, which are discussed as under:

Moisture content (%)

Drying methods significantly influenced the moisture content of spinach leaves. The highest moisture content of 12.21% was recorded in sample dried under shade drying while lowest moisture content of 7.89% was recorded in sample dried under cabinet drying and 10.49% was recorded in sample dried under sun drying

Drying methods also showed non- significant effect on moisture content of spinach leaves during 90 days of ambient storage. Highest moisture content15.78%was recorded in sample dried under shade drying and lowest moisture content of 9.65%was recorded in sample dried under cabinet drying and 13.96%was recorded in sample dried under sun drying at 90 days of storage.

Regardless of the drying procedures used, the moisture level of all the dried spinach samples increased gradually as the storage duration advanced.

The effective and rapid removal of water from spinach leaves may be the cause of the low moisture content in cabinet dried spinach. Again the increase in the moisture content of the samples during storage can be due to the hygroscopic nature of the product and ingress of water vapor through the micro-cracks and leaves which develop in packaging material during long storage. The moisture content gradually increased on storage. to Similar results were reported by [7].

Water activity

Drying methods significantly influenced the water activity of spinach leaves. The highest water activity of 0.43 was recorded in sample dried under shade drying while the lowest water activity of 0.34 was recorded in sample dried under cabinet drying and 0.38 was recorded in sample dried under sun drying.

Drying methods also showed non- significant effect on water activity of spinach leaves during 90 days of ambient storage. Highest water activity of 0.51 was recorded in sample dried under shade drying while lowest 0.45of water activity was recorded in sample dried under cabinet drying and 0.47of water activity was recorded in sample dried under sun drying at 90 days of ambient storage.

With advancement of storage period there was a gradual increase in water activity of all the dried spinach samples irrespective of drying methods.

Due to different drying techniques, the water activity value reduced from 0.96 at the beginning to 0.47 at the end, and it slightly grew during the course of three months of storage. The efficient and rapid elimination of water from spinach leaves due to homogenous heat transfer as opposed to shade and sun drying could be the reason of the lowest water activity in cabinet dried samples. Again, the nature of the product and ingress of water vapor through the micro-cracks and leaves which develop in packaging material during long storage. [8] reported similar findings in green leafy and yellow succulent vegetables during drying and subsequent ambient storage.

Ash (%)

Drying methods showed non- significant effect on ash content of spinach leaves during 90 days of ambient storage. Highest ash content of 9.11% was recorded in sample dried under cabinet drying while lowest ash content of 5.47% was recorded in sample dried under shade drying and 6.31% of ash content was recorded in sample dried under sun drying.

Cabinet drying resulted in higher ash content than sun drying. The results are in conformity with the findings of [9] in drying of drumstick leaves.

 © 2023 Author

Carbohydrates (%)
Drying methods showed significant effect on carbohydrate content of spinach leaves. Highest carbohydrate content of 16.68% was recorded in sample dried under cabinet drying while the lowest carbohydrate content of 15.32% was recorded in sample dried under shade drying and 17.21% of carbohydrate content was recorded in sample dried under sun drying. Similar results were reported by [9].

Crude Fibre (%)
Drying methods showed significant effect on the crude fibre content of spinach leaves. The highest crude fibre content of 10.76 % was recorded in sample dried under cabinet drying while lowest crude fibre content of 6.44%was recorded in sample dried under shade drying and 8.43%of crude fibre was recorded in sample dried under sun drying.

The higher crude fibre content under cabinet drying method maybe due to the greater cell disruption and rupture of cell in the cabinet drying [10].

Crude Protein (%)
The crude protein content of dried spinach leaves was significantly affected by the drying techniques. Drying methods showed significant effect on crude protein content of spinach leaves. The highest crude protein content of 10.21 %was recorded in sample dried under cabinet drying while the lowest crude protein content of 6.01% was recorded in sample dried under shade drying and 8.87% of crude protein content was recorded in sample dried under sun drying. The outcomes match the leafy vegetables Amaranthus viridis that have been previously identified [11].

Crude Fat (%)
The crude fat content of spinach leaves was significantly affected by the drying techniques. The sample dried under cabinet drying had the highest crude fat content (4.46), whereas the sample dried under shade drying had the lowest crude fat content (2.78%), and the sample dried under the sun had the highest crude fat content (3.89%). All of the green leafy vegetables that were evaluated had nearly identical amounts of fat, ranging from 2.180.09% for M. pentaphylla to 4.750.22% for C. halicacabum. This is consistent with the widespread finding that leafy greens are low in fat and help prevent obesity [11].

Microbial count

Total Plate Count (cfu/g)
Drying methods significantly influenced the total plate count of spinach leaves. The highest overall drying mean of 46.71cfu/g was recorded in sample dried under shade drying while as 40.14cfu/g and 43.14cfu/g was recorded in samples dried under cabinet and sun drying respectively. Similar findings were reported by [4].

Visible Mold Growth
Drying methods significantly influenced the visible mold growth of spinach leaves. The highest overall drying mean of 3.82cfu/g was recorded in sample dried under shade drying while as 3.65cfu/g and 3.80cfu/g were recorded in samples dried under cabinet and sun drying respectively.

Storage also had significant influence on total plate count of spinach leaves. A significant increase in visible mold growth was observed during 90days of storage irrespective of drying method applied. These results are in conformity with [4].

CONCLUSION
It was concluded from the present study that there was no varietal effect on the quality of the dried product. However, the samples dried in cabinet drier (55ºC) were superior in terms of quality viz. physico-chemical and nutritional attributes during ambient storage of 90 days than sun dried and shade dried samples. The cabinet dried sample has a microbial load within maximum permissible limits. However the sun dried and shade sample had higher microbial load.

ACKNOWLEDGEMENTS
Authors would like to thank department of food technology RIMT University and division of FST SKUAST K and for their technical assistance and cooperation in this research. This study is a part of the M.tech thesis research work of first author

Conflict of interest
No conflict of interest exists among authors.

 © 2023 Author

REFERENCES

1. Gaikwad, P.S. Shete, R.V. and Otari, K.V. (2010). Spinacia oleracea Linn: A pharmacognostic and pharmacological overview. *International Journal of Research in Ayurveda and Pharmacy*. **1**(1), 78-84.
2. Jadhav, V.D. Talele Swati, G. Bakliwal Akshada, A. and Chaudhari, G.N. (2015). Formulation and evaluation of herbal gel containing leaf extract of Tridax procumbens. *Journal of Pharmaceutical and Biosciences*. **3**, 65-72.
3. Ozkan, I.A., Akbudak, B. and Akbudak, N. (2007). Microwave drying characteristics of spinach. *Journal of Food Engineering* 78, 577– 583.
4. Wareing, P.W., A. Westby, J.A. Gibbs, L.T. Allotey and M. Halm, (2001). Consumer preferences and fungal mycotoxin contamination of dried cassava products from Ghana. *International Journal of Food Science and Technology* **36**: 1-10.
5. Kaur, P., Kumar,A., Arora,S. and Ghuman, B.S. (2006). Quality of dried coriander leaves as affected by pretreatments and method of drying. *Eurasian Food Research Technology* **223** (2): 189-194.
6. Chandra,S. and Shamsher,S. (2002). Studies on quality of dehydrated oyster mushroom (*Pleurotus flabellatus)*as influenced by various pre-treatments and drying methods. *Mushroom research* 11**(2)**: 107-112.
7. Khatoniar, S.,Bairooah,M,S., Das, M., (2018). Formulation and evaluation of dehydrated greens incorporated value added products. *International Journal of current Microbiology and Applied Sciences*, **7**.
8. Mdziniso, P., Hinds, M.J. and Bellmer, D.D. (2006). Physical quality and carotene content of solar-dried green leafy and yellow succulent vegetables. *Plant Foods and Human Nutrition* **61** (1):13-21.
9. Satwase, A.N., Pandhre, G.R., Sirsat P.G. Wade, Y.R. (2013). Studies on the drying characteristics and nutritional composition if drumstick leaves by sun, shadow, cabinet and oven drying Methods. *Open acess Scientific Reports* **2** (1):1-4.
10. Carranza-Concha, M. Benlloch., M.M. Camacho., N. Martínez-Navarrete.2012. Effects of drying and pretreatment on the nutritional and functional quality of raisins. *Food and Bioproducts Processing* 90(C2).98-104
11. Nisha, S., Gupta, P.C. and Rao, C.V. (2012). Nutrient Content, Mineral Content and Antioxidant Activity of *Amaranthus viridis* and *Moringa oleifera* Leaves, *Research Journal of Medicinal Plants* **6**: 253-259

Copyright: © 2023 Author. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.