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Microstructural, nutritional and storage evaluation of okra powder

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Abstract
Punjab – 8 variety of okra was dried in cabinet air dryer and solar tunnel dryer. The nutritional composition of cabinet air dried powder *viz*., moisture, protein, carbohydrate, fibre, ash, total polyphenolics, total carotenoids and antioxidant activity was 6.73%, 15.21%, 67.67%, 10.90%, 4.50%, 119.67 mg GAE/ 100 g, 29.0 mg/ 100 g, 57.0%, respectively while solar tunnel dried had 8.78%, 14.86%, 67.33%, 7.78%, 4.04%, 112.0 mg GAE/ 100 g, 27.30 mg/ 100 g, 38.63 per cent, respectively. The drying time for cabinet air dryer and solar dryer was 10.17 and 22.14 h, respectively. Based on these observations, we found that cabinet air drying method gave best result. Further, the dried powder was analysed for minerals like Na, Ca, K, Zn, Cu, Fe, Mn and Mg having content of 0.168%, 1.26%, 2.82%, 57.40 mg/ 100 g, 25.40 mg/ 100 g, 88.30 mg/ 100 g, 43.70 mg/ 100 g and 1.00 per cent, respectively. Heavy metals analysed by Inductively Coupled Plasma (ICP) revealed that the Cd, Co, Cr, Ni and Pb content per 100 g powder was 0.21 mg, 0.09 mg, 1.31 mg, nil and 58.40 mg, respectively. The morphology of the powder was examined under the Scanning Electron Microscopy (SEM) showed particles having broken glass structure and rough surfaces at the 500, 1200, 2000 and 4500 magnification at 15 working distance with overall observation that the cabinet dried powder was more visible in shape and size than solar dried powder. The Fourier transform-Infrared Spectroscopy (FT-IR) for the powder exhibited functional group like CH3, CH2, C=C, HC=CH for cabinet dried powder and CH3, C-O, C-OH, HC=CH for solar dried powder. The cabinet dried powder stored in polyethylene pouches up to 6 months at refrigerated (4 ^{0}C) and ambient temperature had initial moisture, fibre, ash, total polyphenolics, total carotenoids and antioxidant activity as 6.73%, 10.90%, 4.50%, 119.67 mg GAE/ 100 g, 29.0 mg/ 100 g and 57.00 per cent, respectively and non-significant difference after 6 months was observed in most of the attributes except in moisture, total phenolics, total carotenoids and antioxidant activity i.e. 8.02%, 99.10 (mg GAE/ 100 g), 18.26 (mg/ 100 g) and 44.74 per cent, respectively were observed. Overall, the quality of the powder stored under refrigeration (4 ^{0}C) was better than at ambient temperature (18-38 ^{0}C).

Keywords: drying, okra, FTIR, AAS, ICP, SEM

Introduction
Gemede *et al.* (2015) [10] reported that okra (*Abelmoschus esculentus)* is the vegetable crop which is economically important and its grown in the sub-tropical and tropical region. Okra (*Abelmoschus esculentus*) is belonging to the Malvaceae family and it is very popular vegetable crops in the Indo-Pak subcontinent. According to consumption India is the first rank but its original home is Ethiopia and Sudan as well as the north-eastern African countries (Sathish *et al*., 2013) [29]. In the different part of the world okra is known by many local named *viz*., in India it is known as bhindi, in united State of America gumbo, in England it is known as lady's finger, in Spanishguino-gomboandguibeiro in Portuguese (Ndunguru and Rajabu 2004; Sorapong and Benchasr 2012) [21, 32]. Tomoda *et al*. (1989) [33] Reported that in normal mice okra (*Abelmoschus esculentus)* polysaccharide possesses anti complementary and hypoglycemic activity. Ramachandran *et al*. (2010) [23] reported in diabetic rats, anti-diabetic activity of okra on alloxan-induced. Ramachandran and selvam Sabita *et al.* (2013) [27] has reported anti diabetic and antihyperlipidemic potential of okra peel and seed powder in streptozotocin (STZ)-induced diabetic rats. Administration of okra powder at 100 and 200 mg/kg dose in diabetic rats and found that significant reduction in blood glucose level and increase in body weight than diabetic control rats.
According to Mihretu *et al*. (2014) [19] okra is a multipurpose crop because its various uses viz. the fresh leaves, buds, flowers, pods, stems and seeds. Okra is used as salad, are consumed as vegetables, can be used in curry, soups and stews, fresh or dried, fried or boiled. It offers mucilaginous consistency after cooking because in okra mucilage content is very high than

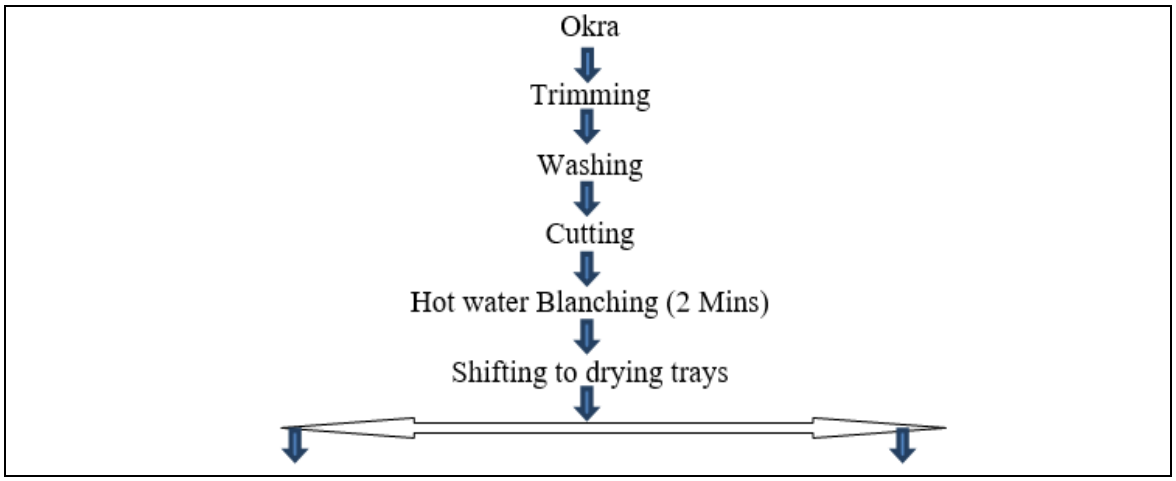
other green vegetables. After that the extract obtained from the okra is incorporate in to the different recipes such as soups, stews and sauces to increase the consistency. Okra mucilage is very important role in the medical science it has medicinal applications when used as a plasma replacement or blood volume expander. The mucilage of okra binds bad cholesterol and bile acid which is presents in our body carrying toxins dumped into it by the liver. The okra pods are also used in making pickle. The entire plant is edible and is used to have several foods (Madison, 2008 and Maramag, 2013) [15, 16]. Sanjeet *et al.* (2010) [28] reported that in past okra has been considered as a minor crop and no attention was paid to its improvement in the level of international research program. Okra, which is currently grown mainly as a vegetable crop but it has potential for cultivation as an essential oilseed crop because okra seeds contain high amount of edible approximately oil 20-40% (MEF 2013) [17]. National Research Council 2006 reported that okra is more a diet food than staple foods. Savello *et al*. (1980) [30] investigated that okra seeds from Greece are a potential source of oil, with concentrations varying from 20% to 40%, depending on the extraction method, the oil mainly consists of linoleic acid up to 47.4%. Okra seed oil is a rich source of linoleic acid, a polyunsaturated fatty acid essential for human nutrition.

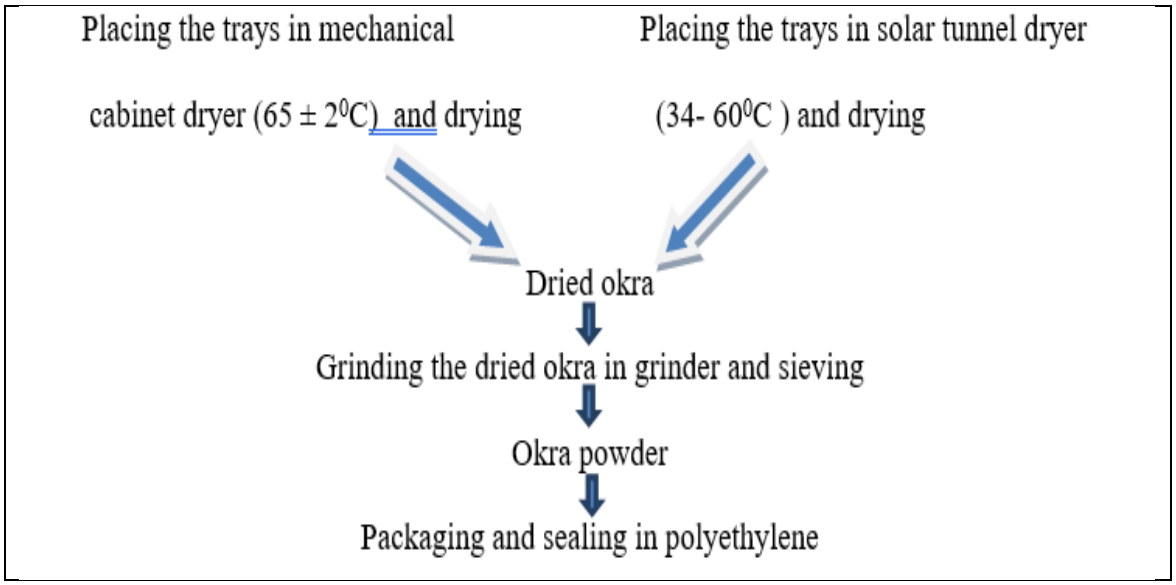
According to Holser and Bost (2004) [12] okra has been called "a perfect villager's vegetable" because of its robust nature, dietary fibre, and distinct seed protein balance because it contains both of amino acids lysine and tryptophan (unlike the proteins of cereals and pulses). Okra has also contains carbohydrates and vitamins (Owolarafe and Shotonde 2004; Gopalan *et al*., 2007; Dilruba *et al*., 2009) [22, 8, 7], and its also plays a vital role in human diet and nutrition (Kahlon*et al*., (2007) [13]. Okra seed flour could also be used in the fortification of cereal flour for the development of functional food products viz. bread, biscuit, noodles etc (Adelakun *et al*., 2009) [1]. For example, supplementing maize with okra meal increases protein, ash, oil and fiber content (Akingbal *et al*., 2003) [2].

According to Akingbal *et al*. (2003) [2] okra seeds were determined to have appreciable protein content The polysaccharides variations found in the mucilage are higher in okra pods according to (Hirose K *et al*., 2004; Sengkhamparn *et al*., 2009) [11, 31]. The high consumption of okra plant products can help in the reduction of cronic deseases such as atherosclerosis and cancer (Gosslau and Chen 2004) [9]. For the oxidative stress Vitamin E and carotenoids also contribute to first defense line against oxidative stress, because of they quench singlet oxygen. Krinsky (2001) [14] reported that Flavonoids as well as vitamin C showed a protective activity to α-atocopherolin human LDL, and they can also regenerate vitamin E, from the α-chromanoxy radical. Okra contain high fibre, which "helps to stabilize blood sugar by regulating the rate at which sugar is absorbed from the intestinal tract in the body". Because of fibre along with other nutrition, okra is helpful for the diabetic because it shows useful for minimizing blood sugar levels within the body. Rossetto *et al*. (2002) [26] conduct research and found that fibre likewise helps support blood sugar levels level simply by slowing down sugar assimilation through the intestines. If anybody is suffering from regular nosebleeds, bleeding gums, heavy menstrual bleeding, or easy bruising, your blood might be too thin they should Consider adding more vitamin K-rich foods like okra to their diet to improve their blood's ability to coagulate (Bakre and Jaiyeoba. 2009) [4]. Ndunguru *et al*. (2014) [21] reported that okra is useful to promote a healthy of the pregnancy. An incredibly essential B vitamin for creating and maintaining new cells, foliate is a vital substance for optimum pregnancy, okra is used to improves heart health the soluble fibre within okra helps you for many serious complications *viz*., to reduce serum cholesterol and therefore decreases the chance of cardiovascular disease. For maintaining the cholesterol level in the body consuming of okra is the best efficient method.

Materials and Methods

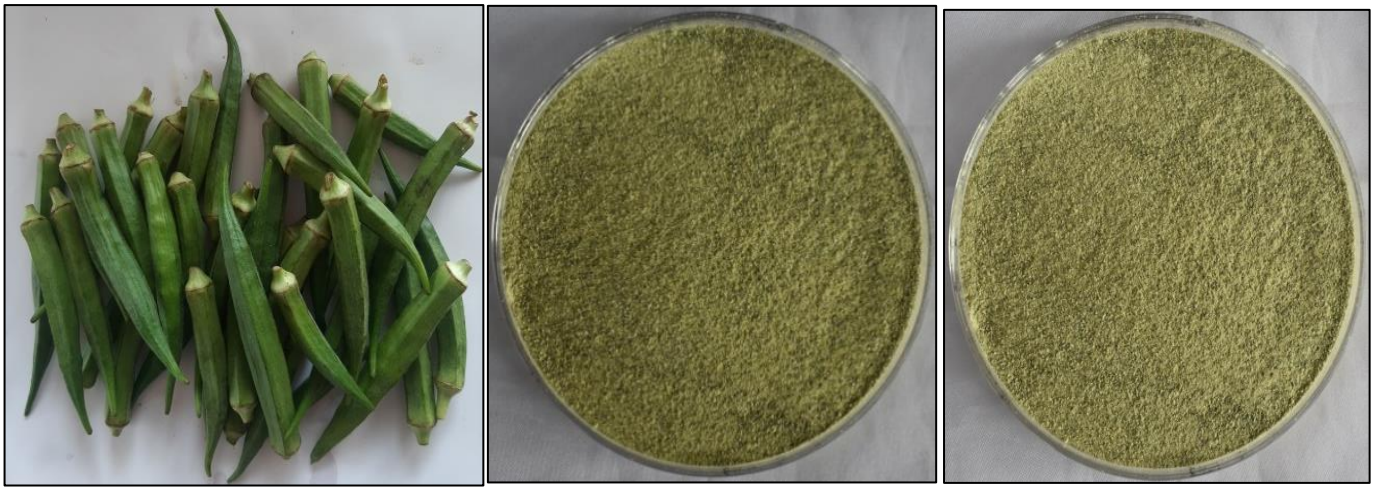
Raw okra were procured from the local market of Solan Himachal Pradesh India, and present research investigation was conducted in the Department of Food Science and Technology, minerals analysis has been done in the HP- HDP lab, Department of Soil science, heavy metals were analysed by Inductively coupled plasma (ICP) in the Department of Environmental Science, College of Forestry, Dr. YSPUHF, Solan HP, India, and for the functional groups analysis we conducted the Fourier Transform- Infrared spectroscopy (FT-IR) analysis in the Department of Pharmacy, Shoolini University, Solan HP, India. Scanning electron microscopy (SEM) was used for their microstructural quality of the developed powder from, Sophisticated Analytical Instrumentation Facility (SAIF), Punjab University, Chandigarh.





Flow Diagram of development of okra powder by mechanical cabinet air drying and solar drying methods

The Raw okra pod weighed and then remove the unwanted parts like leaf, damaged parts of okra then wash with Luke warm water, after that cutting with the knife in the uniform size after cutting the okra we were given the hot water blanching treatment for the enzymatic inactivation for 2 minute after this treatment it were shifted in drying trays for placing in dryer (cabinet air dyer and solar tunnel dryer) after drying we got the dried okra then it were grinded in electric grinder (Havells, Model MX-1155) and then it sieve (36 mesh sieve size) for the uniform size of particle after sieving were packed in polyethylene and seal it by sealing machine then stored for 6 months at refrigerated (4 ^{0}C) and ambient temperature (18-38 ^{0}C) for their nutritional quality evaluation.



A B C

Fig 1A: raw okra, **B:** Powder developed by solar dryer **C:** Powder by cabinet air dryer

In the Figure 1 B shows the developed powder by solar tunnel dryer and Figure 1 C shows The developed okra powder by cabinet air dryer, we observe that the solar tunnel dryer powder color was more dark than cabinet air dryer because there was ununiformed heating, long time for drying and also loss bioactive compounds.

Physico-chemical

Moisture (%), Fat (%), Crude fibre (%), Ash (%), Protein (%) carbohydrate (%) Minerals (ppm/100 g) were analysed by AOAC (2012) method, Total carotenoids content (mg / 100 g was estimated as per method described by Ranganna (2009) [25]. Total phenolic content (mg GAE/ 100 g) was determined by Bray and Thorpe (1954) [5], Antioxidant activity (% free radical scavenging activity) was investigated following Williams *et al.* (1995) [34] procedures.

Results and Discussion

The present investigation was conducted in the department of Food Science and Technology College of Horticulture Dr. YS. Parmar University of horticulture and forestry Solan, HP, India.

Table 1: Physico chemical analysis of raw okra

Parameter	**Mean** ± Standard Error
Physical	
a. Weight (g)	10.36 ± 0.35
b. Width (cm)	2.85 ± 0.12
c. Length (cm)	8.78 ± 0.33
Biochemical	
Moisture content (%)	89.36 ± 1.49
Protein content (%)	2.55 ± 0.27
Fibre content (%)	1.64 ± 0.23
Ash content (%)	1.61 ± 0.21
Carbohydrate (%)	8.50 ± 0.36
Total polyphenolics (mg GAE/100 g)	149.67 ± 3.76
Total carotenoids (mg / 100 g)	37.67 ± 2.73
Antioxidant activity (%)	67.67 ± 1.45

In the present investigation the physical analysis has done and find the weight, width, and length, 10.36 ± 0.35g, 2.85 ± 0.12cm, 8.78 ± 0.33cm respectively, the chemical composition of okra pod is, moisture, protein, fibre, ash content, carbohydrate, total polyphenolics, total carotenoids, antioxidant activity, 89.36±1.49%, 2.55±0.27%, 1.64 ± 0.23%, 1.61 ± 0.21%, 8.50 ± 0.36%, 149.67 ± 3.76 mg GAE/ 100 g and 37.67 ± 2.73 mg/ 100 g, 67.67 ± 1.45 per cent, respectively which is shows in the Table. 1.

Table 2: Nutritional evaluation of developed okra powder by cabinet air dryer and solar dryer

Parameter	**Mean** ± SE	
	Cabinet air drying	**Solar drying**
Drying time (h)	10.17 ± 0.44	22.14 ± 0.70
Moisture content (%)	6.73 ± 0.20	8.78 ± 0.41
Protein content (%)	15.21 ± 0.60	14.86 ± 0.48
Carbohydrate (%)	67.67 ± 1.45	67.33 ± 1.20
Fibre (%)	10.90 ± 1.05	7.78 ± 0.15
Ash content (%)	4.50 ± 0.29	4.04 ± 0.32
Total polyphenolics (mg GAE/ 100 g)	119.67 ± 8.45	112.00 ± 4.16
Total carotenoids (mg/ 100 g)	29.00 ± 1.73	27.30 ± 1.80
Antioxidant activity (%)	57.00 ± 1.53	38.63 ± 1.79

In the present investigations were conduct comparative nutritional evaluation of developed okra powder by mechanical cabinet air dryer and solar tunnel dryer there is huge difference in the time of drying and total phenolic content besides the other component there is much difference, composition of powder by mechanical cabinet air dryer, drying time, moisture content, protein content, carbohydrate, fibre, ash content, Total polyphenolics, Total carotenoids, antioxidant activity, 10.17 ± 0.44h, 6.73 ± 0.20%, 15.21 ± 0.60%, 67.67 ± 1.45%, 10.90 ± 1.05%, 4.50 ± 0.29%, 119.67 ± 8.45 mg GAE/ 100 g, 29.00 ± 1.73 mg /100g, 57.00 ± 1.53 per cent, respectively and by solar tunnel dryer 22.14 ± 0.70h, 8.78 ± 0.41%, 14.86 ± 0.48%, 67.33 ± 1.20%, 7.78 ± 0.15%, 4.04 ± 0.32%, 112.00 ± 4.16 mg GAE/ 100 g, 27.30 ± 1.80 mg/100 g, 38.63 ± 1.79 per cent respectively which is shown in the Table 2.

Table 3: Minerals and heavy metals analysis of okra powder developed by the cabinet air dryer

Minerals	**Amount (mg/100 g)**
Na (%)	0.16
Ca (%)	1.26
K (%)	2.82
Mg (%)	1.00
Cu	15.40
Fe	18.30
Mn	23.70
Zn	17.40
Heavy metals	
Cd	0.21
Co	0.09
Cr	1.31
Ni	ND
Pb	28.40

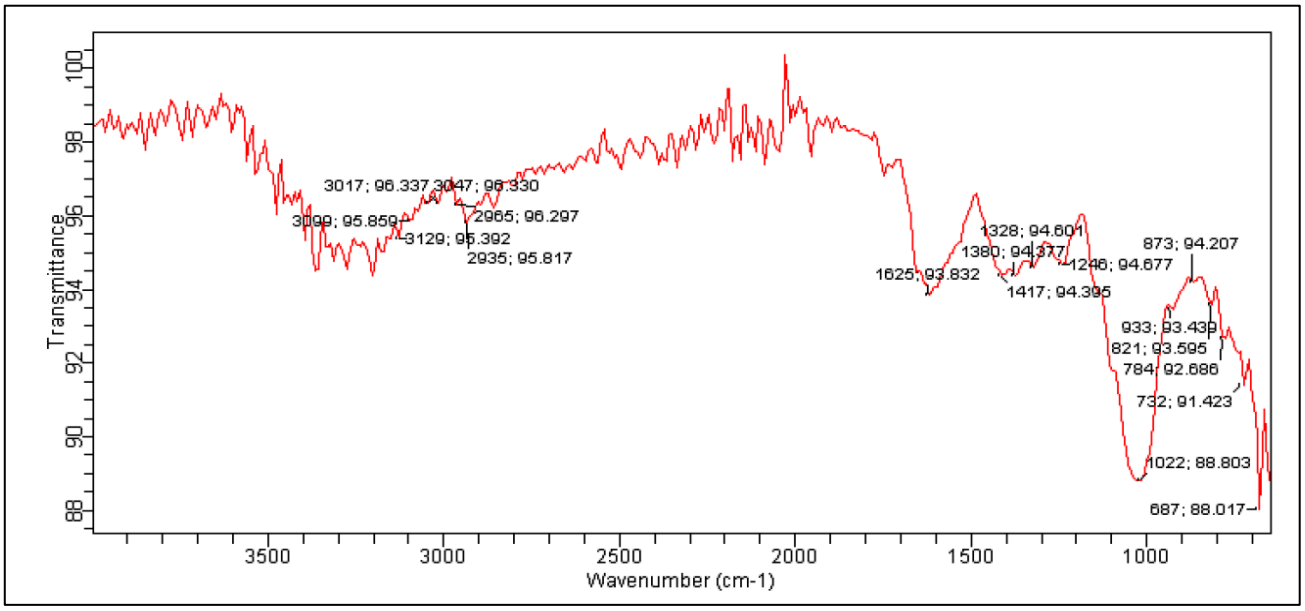
Table 3 shows the minerals content of the developed powder by mechanical cabinet air dryer Na, Ca, K, Mg, Cu, Fe, Mn and Zn, 0.16%, 1.26%, 2.82%, 1.00%, 25.40 mg/ 100 g, 88.30 mg/ 100 g, 43.70 mg/ 100 g and 57.40 mg/ 100 g respectively, and heavy metals were analysed by Inductive Coupled Plasma (ICP) that reviled *viz*., Cd, Co, Cr, Ni, Pb, 0.21 mg/ 100 g, 0.09 mg/ 100 g, 1.31 mg/ 100 g, ND, 58.40 mg/ 100 g, respectively.

Functional groups of okra powder

Functional properties of developed okra powder by mechanical cabinet air dryer and solar tunnel dryer were determined by the FT- IR (Fourier transmittance – Infrared Spectroscopy). Fourier Transform Infrared spectroscopy (FT-IR) is a spectral measurement method with long-wave infrared radiation that records absorbance in a time field and converts it to a frequency field using the Fourier transform algorithm (Baravkar *et al*., 2011). FTIR has been used to analyse a variety of samples due to its ability to identify functional groups of chemical compounds, such as carbohydrates, esters, as well as the chemical bonds between atoms.

Okra powder by cabinet air dryer

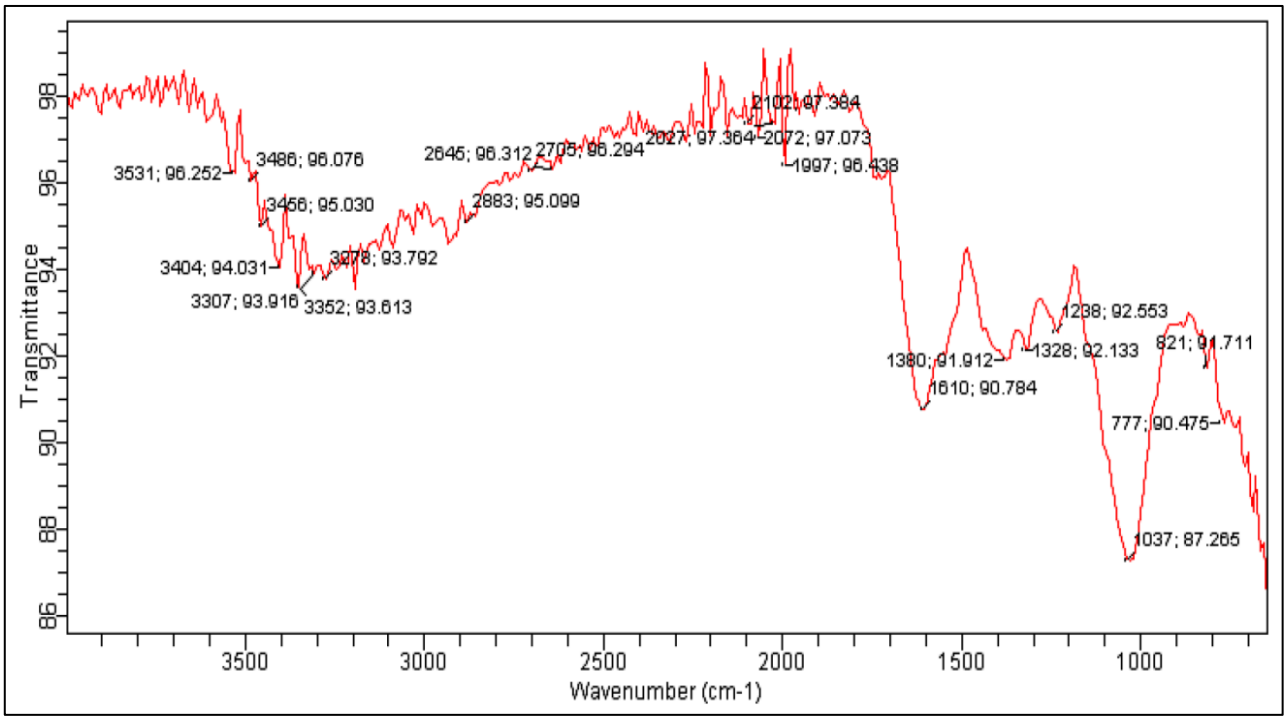
FT- IR spectrum was used to identify the active component present in the okra powder in Graph. 1 showed the wavenumber 2935cm^{-1}, 2965 cm^{-1}, cm^{-1}, 1625 cm^{-1}, 933 cm^{-1}, which represent methyl (CH3), methylene (CH2-), C=C, HC=CH are present in the powder which similar result shows in (Muchtaridi *et al*., 2019; Rohman *et al*., 2015) [18].



Graph 1: FT-IR analysis peak of okra powder by cabinet air dryer

Okra powder by solar tunnel dryer

The spectra of okra powder developed by the solar dryer was much clear peak that cabinet air dyer Graph. 2 represent the data where 1380^{-1} 1238^{-1} 1037^{-1} 777^{-1}, wavenumbers which shows CH3, C-O, C-OH, –HC=CH respectively functional groups were present in the powder and similarly data present in the (Muchtaridi *et al*., 2019; Rohman *et al*., 2017) [18].

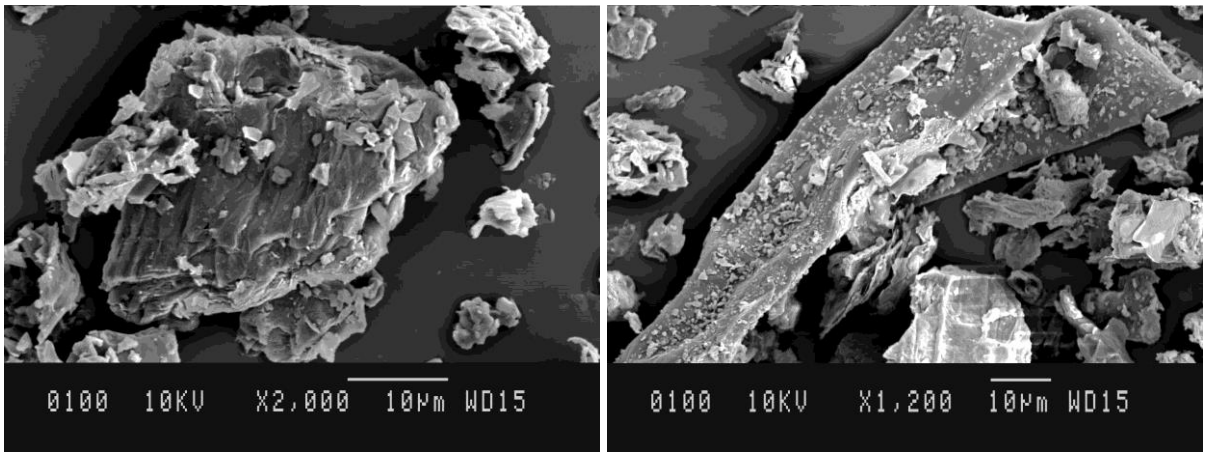


Graph 2: FT-IR analysis peak of okra powder by solar tunnel dryer

Morphological analysis of developed okra by Scanning Electron Microscopy (SEM)

SEM analysis of developed okra powder by Cabinet air dryer

The SEM image shows the uniform distribution of the pores which appeared to be heterogeneous in nature gives a well-defined appearance of the mesh (Figure. 2 A and B). Morphological analysis revealed that all particles had a broken glass structure and rough surfaces. In Figure.2 A shows the 2000 time magnified structure of the particle on the15 working distance (WD in the SEM is the distance at which the beam is focused, normally the distance from the final pole piece of the lens to the sample when the image is in focus) and Figure. 2 B shows 1200 time magnify structure on same working distance.

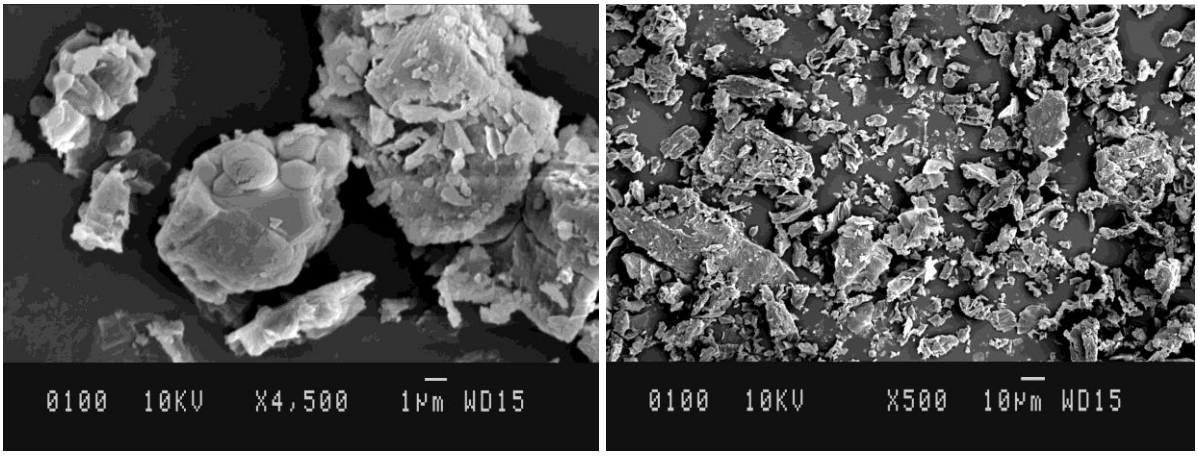


A B

Fig 2: A and B Micrograph of okra powder by mechanical cabinet air dryer

SEM analysis of developed okra powder by solar tunnel dryer

Figure. 2 C shows that the 4500 time magnifies structure of powder on 15 working distance and Figure, 2 D shows the 500 times magnifies structure of powder on the same working distance in the present picture the visible difference in the shape and size apart from these samples have a very similar microstructure to cabinet tunnel dryer.

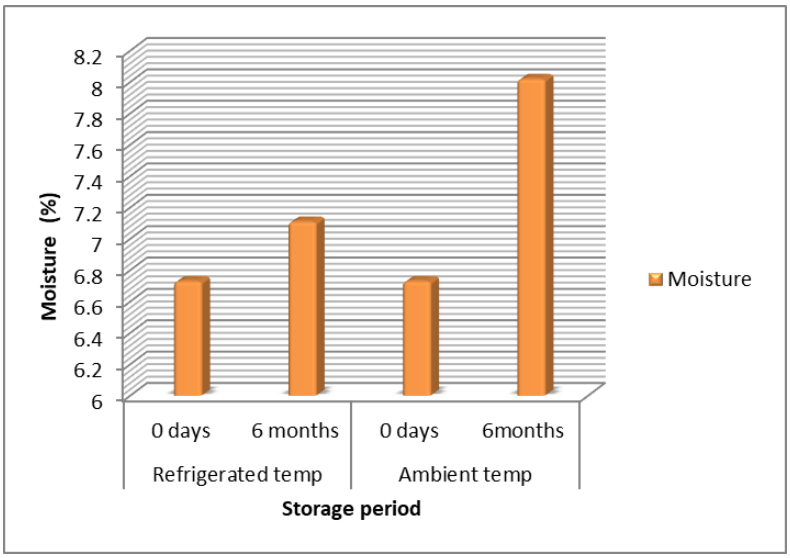


C D

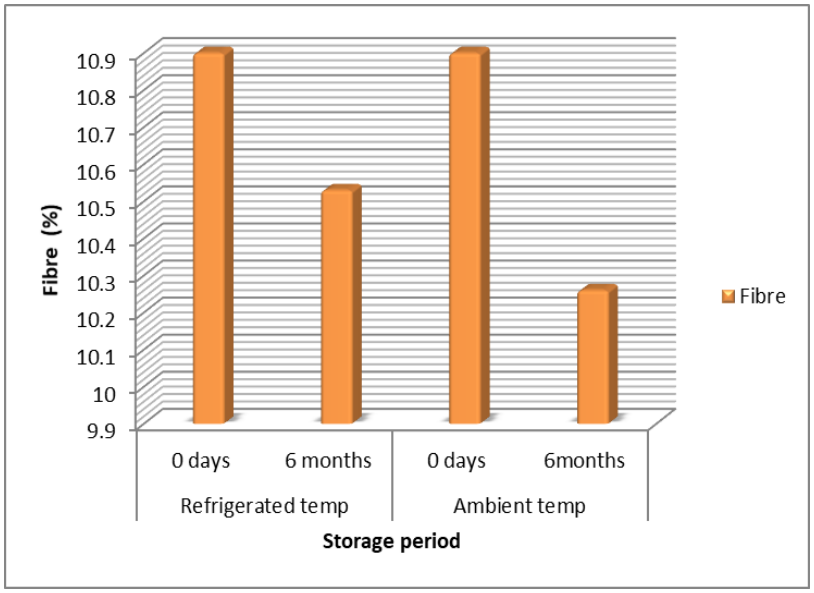
Fig 2: C, D Micrograph of okra powder by Solar tunnel dryer

Storage analysis of okra powder at ambient temperature (18-38 ºC) **and refrigerated temperature** (4 ºC).

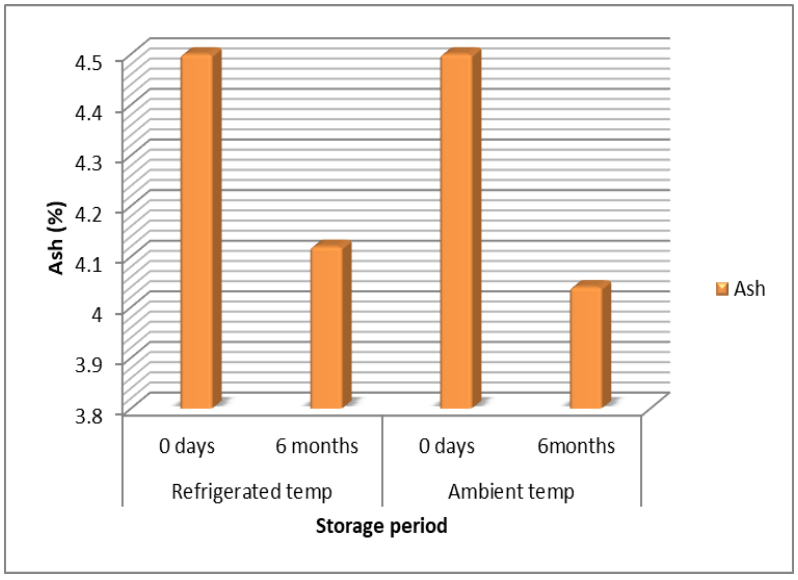
The developed okra powder was packed in polyethylene pouches and stored for 6 months at refrigerated and ambient temperature for the evaluation of nutritional quality, observation was recorded initial and after 6 months.



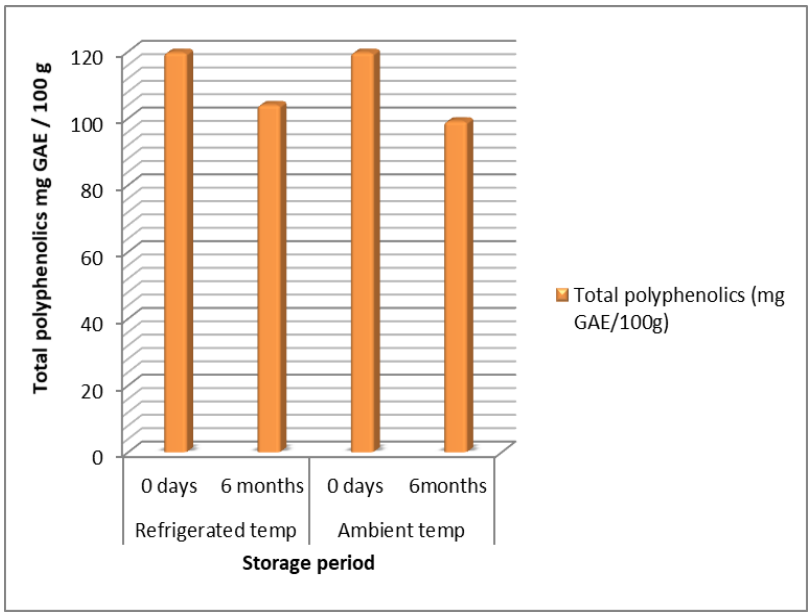
Graph 1: Moisture (%)



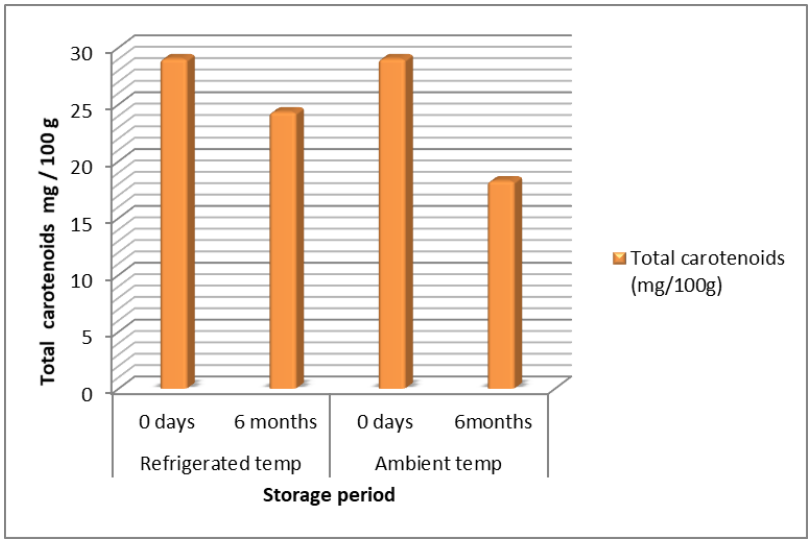
Graph 2: Fibre (%)



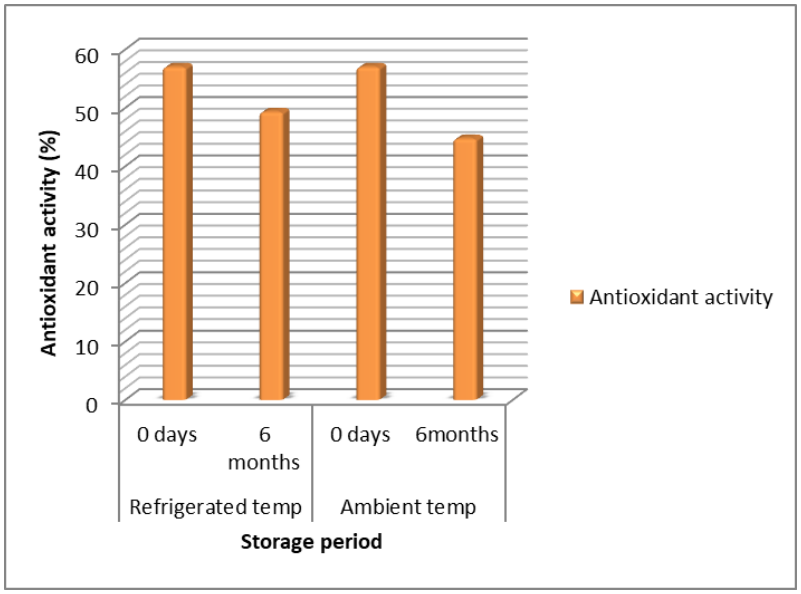
Graph 3: Ash (%)



Graph 4: Total polyphenolics (mg GAE/ 100 g)



Graph 5: Total carotenoids (mg/100 g)



Graph 6: Antioxidant activity (%)

Moisture (%) the data presented in the Graph. 3 shows initial moisture content 6.73% after 6 months refrigerated condition and ambient temperature, 7.11%, 8.02 per cent respectively there is not much increasing moisture at refrigerated temperature but we observe that there is increasing moisture at ambient temperature from 6.73% to 8.02 per cent.

Fibre (%) In the present investigation we were found that initial fibre content 10.90% and it was stored at refrigerated condition and ambient temperature for 6 months, 10.53%, 10. 26 per cent respectively, we were observed that there is not much decreasing fibre at refrigerated temperature but there is decreasing fibre at ambient temperature from 10.90% to 10.26 per cent which shows in Graph 4.

Ash (%) Graph 5 dipicts the changing of ash content of powder during storage period, initial ash content 4.50 per cent, after 6 months were observe that changing in ash at refrigerated condition and ambient temperature, 4.12%, 4.04 per cent respectively there is not much decreasing ash content at refrigerated temperature but we observe that there is changing in ash at ambient temperature from to 4.50 to 4.04 per cent.

Total polyphenolics (mg GAE/100g) initial total polyphenolics content 119.67 mg GAE/100g after 6 months refrigerated condition and ambient temperature, 104 mg GAE/100g, 99.10 mg GAE/100g respectively there is not much decreasing total polyphenolics at refrigerated temperature but we observe that there is decreasing total polyphenolics at ambient temperature from to 119.67 mg GAE/100g to 99.10 mg GAE/100g which is shown by Graph 6.

Total carotenoids (mg/100g) the data presented in the Graph. 7 shows initial Total carotenoids 29.00 mg/100g after 6 months refrigerated condition and ambient temperature, 24.32 mg /100g and 18.26 mg/100g respectively there is not much decreasing total carotenoids at refrigerated temperature but we observe that there is decreasing total carotenoids at ambient temperature from to 29.00 mg/100g to 18.26 mg/100g.

Antioxidant activity (%) in the present investigation initial antioxidant activity 57.00% present in the developed powder and it stored for 6 months at refrigerated condition and ambient temperature were observe that 49.32% and 44.74 per cent respectively there is not much changing in antioxidant activity at refrigerated temperature but we observe that there is decreasing total antioxidant activity at ambient temperature from to 57.00% to 44.74.

Conclusion

In the present investigation okra powder was prepared in mechanical cabinet air dryer and solar tunnel dryer and cabinet air dryer rated better in terms of many attributes *viz*., total phenolic content, carotenoids content, antioxidant activity these all are not disturb much after drying and we were used the scanning electron microscopy (SEM) for the morphological characteristics of the developed powder and Atomic Absorption Spectroscopy (AAS) were used for the minerals content of the dried okra powder, Fourier transmittance- Infrared spectroscopy (FTIR) for checking the chemical groups which are present in the powder, as well as Inductively coupled plasma (ICP) was perform for detection of the heavy metals (Cd, Co, Cr, Ni and Pb). Developed powder was stored in the refrigerated and ambient temperature for 6 month during storage were analysed initial and 6 months on the basis of moisture, fibre, ash, total phenolic content, total carotenoid content and antioxidant activity, then we were observed that refrigerated condition is given better result to ambient temperature where polyphenols, carotenoids and antioxidant activity were decrease and the moisture were consistently increase day by day so in this research we conclude that the cabinet air drying method is better than solar tunnel drying and in the terms of storage study the refrigerated condition given better result than ambient temperature.

Acknowledgement

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