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RESEARCH PAPER

Functional, Morphological, Nutritional and Storage Evaluation of Developed Cauliflower Powder in Cabinet air Dryer and Solar Tunnel Dryer

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ABSTRACT

Cauliflower powder was developed using the PSBK-1 cultivar, which was dried in a mechanical cabinet air dryer and a solar tunnel dryer. Moisture, protein, carbohydrate, fibre, ash, fat, total polyphenolics, total carotenoids, and antioxidant activity were 7.52 per cent, 16.60 per cent, 46.43 per cent, 14.28 per cent, 4.08 per cent, 1.87 per cent, 122.35 mg GAE/ 100 g, 13.86 mg/ 100 g, 46.45 per cent, respectively, in cabinet air dried powder, while solar tunnel dried powder had 8.57 per cent, 15.87 per cent, 43.20 per cent, 13.44 per cent The cabinet air dryer and solar dryer took 11.75 and 22.99 hours to dry, respectively. Based on our findings, we discovered that cabinet air drying produced the best results. Further the dried powder analysed for minerals including Na, Ca, K, Zn, Cu, Fe, Mn, and Mg were also found in the dried powder, with levels of 0.43 per cent, 0.28 per cent, 0.38 per cent, 29.10 mg/ 100 g, 27 mg/ 100 g, 47 mg/ 100 g, 34.00 mg/ 100 g, and 0.71 per cent, respectively. Cd, Co, Cr, Ni, and Pb levels per 100 g powder were 0.11 mg, 0.02 mg, 1.23 mg, nil, and 16.61 mg, respectively, according to inductively coupled plasma (ICP) analysis. At 1200, 2000, and 3000 magnifications at 15 working distance, the morphology of the powder was examined using Scanning Electron Microscopy (SEM), which revealed particles with broken glass structure and rough surfaces. Overall, the cabinet dried powder was more visible in shape and size than solar dried powder. Moisture, fibre, ash, total polyphenolics, total carotenoids, and antioxidant activity of cabinet dried powder stored in polyethylene pouches for up to 6 months at refrigerated (4˚C) and ambient temperature were 7.52 per cent, 14.28 per cent, 4.08 percent, 122.35 mg GAE/ 100 g, 13.86 mg/ 100 g, and 57.00 per cent, respectively, with non-significant differences in most of the attributes after 6 months except moisture, total polyphenolics Overall, the powder quality was better when kept refrigerated (4°C) than when kept at room temperature (18-38 ˚C).

HIGHLIGHTS

- Mechanical cabinet air dryer and solar tunnel dryer were used for the development of cauliflower powder.
- Scanning electron microscopy (SEM) was used for the morphological quality evaluation of the developed powder by mechanical cabinet air dryer and solar tunnel dryer.
- Functional groups of the powder (developed by mechanical cabinet air dryer) was reviled by Fourier Transmittance Infrared Spectroscopy (FT-IR).
- Atomic Absorption Spectroscopy (AAS) and Inductive Coupled Plasma (ICP) were used for minerals and Heavy metals analysis respectively.

Keywords: Cauliflower, FT-IR, SEM, Solar dryer, ICP

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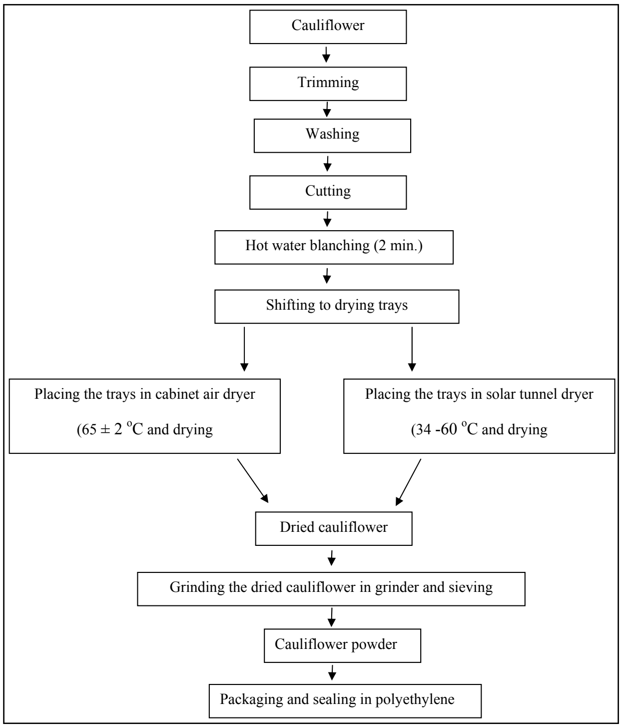
Vegetables are a good source of vitamins and minerals, and they hold a special place among all food crops since they contain enough other bioactive substances for humans. They're also high in carotene, ascorbic acid, riboflavin, and folic acid, as well as minerals like calcium, iron, and phosphorus (Fasuyi, 2006). The Cruciferous family includes cauliflower (*Brassica oleracea* L.). The waste index of cauliflower is very high (Kulkarni *et al.* 2001), and it is also an excellent source of protein (16.1%), cellulose (16%), and hemicellulose (8%). (Wadhwa *et al*. 2006). Brassica foods, according to Jahangir (2008), are high in nutrients and health-promoting bioactives such as vitamins, carotenoids, fibre, soluble sugars, minerals, glucosinolates, and polyphenolics. Cauliflower leaves are inexpensive and accessible to the average person, according to Gopalon *et al.* (2004), but they are only available for a limited period because they are a very perishable crop with a moisture content of approximately 90%. According to the National Institute of Nutrition (NIN) in Hyderabad, India, 100 grammes of fresh cauliflower leaves include 5.9 grammes of protein, 1.3 grammes of fat, 7.6 grammes of carbohydrate, 2 grammes of crude fibre, and 66 calories. Fennema 1996 discovered that cauliflower has therapeutic characteristics, and that eating it can help protect you from certain types of cancer. According to FAOSTAT, cauliflower has an area of 8.88 million hectares and a global production of 16.40 million tonnes. Carotenoids (carotenes and xanthophylls) are lipid-soluble antioxidants present in low concentrations in cauliflower. They are both radical scavengers and singlet oxygen quenchers because of their conjugated double bonds (Krinsky, 1998). Variations in cauliflower phytochemical levels can be produced by a variety of reasons, including genotypic variances, growing circumstances, and agricultural techniques (Lisiewska and Kmiecik, 1996; Lo Scalzo *et al*. 2007). In cauliflower many of the bioactive compounds are present but we found that polyphenols are recognised as powerful antioxidants (Rice-Evans *et al*. 1997). Sulphoraphane, indole-3-carbinol, and 2-propenyl isothiocyanates, which are the breakdown products of glucoraphanin, glucobrassicin, and sinigrin, respectively, are abundant in cauliflower (Agerbirk *et al*. 2009). The head (the white curd) of aborted floral meristems is consumed most of the time in cauliflower, while the stalk and surrounding thick, green leaves are discarded. While its leaves are typically discarded as garbage, they are a rich source of iron and -carotene and can thus be used in a variety of value-added products (Kowsalya and Sangeetha, 1999). Vegetables can be preserved in a variety of ways, but the most common method is drying. The secret to extending the shelf life of veggies is to remove some of the water from them (Somogyi and Luh, 1986). As noted by, the essential objective of the drying process is to reduce the moisture content of the product to prevent degradation within a particular time frame, commonly referred to as the "safe storage period" (Ekechukwa and Norton, 1998). The removal of the bulk of water present in the veggies by mechanical cabinet air drying or dehydration is the main stage in the manufacturing of dehydrated fruits and vegetables. Commercially available drying processes are available, and the best method is chosen by quality criteria, raw material qualities, and cost considerations. (Lussier, 2010). The current study's goal was to improve the drying and storage conditions for the developed powder in order to extend its shelf-life, as well as to assess its nutritional makeup.

MATERIALS AND METHODS

Raw cauliflower was obtained from a Solan market, and the current investigation was carried out in the Department of Food Science and Technology, with minerals analysis carried out in the HP-HDP lab of the Department of Soil Science. Inductively coupled plasma (ICP) was used to analyse heavy metals in the Department of Environmental Science, College of Forestry, Dr. YSPUHF, Solan HP, India. In the Department of Pharmacy, Shoolini University, Solan HP, India, functional groups of the produced powder were investigated using Fourier transform-infrared spectroscopy (FT-IR). The Sophisticated Analytical Instrumentation Facility (SAIF), Punjab University, Chandigarh, utilised scanning electron microscopy (SEM) for their microstructural examination of the developed cauliflower powder.

The raw cauliflowers were weighed and undesired parts including green leaves, broken bits, and stems were removed. They were rinsed in tape water then sliced into uniform-sized pieces with a knife. For enzymatic inactivation, the cauliflower pieces were blanched in boiling water for 2 minutes after cutting.

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



The blanched pieces were drained and spread out on trays to dry in a cabinet air dryer at 65°C and a solar tunnel dryer (34-60°C) for 11.75 and 22.99 hours, respectively, until they reached a consistent moisture content. To make a fine and consistent powder, the dry slices were ground in a mixer cum grinder (Havells, Model MX-1155) and passed through a 36 grit screen.

Fig. **1 (A)** Raw cauliflower B. Cutting of cauliflower C. Blanching in hot water D. Powder developed by cabinet air dryer E. powder by solar dryer.

In the Fig. 1 A shows fresh raw cauliflower, 1 B shows cutting of cauliflower in uniform size for drying 1 C. Blanching of cauliflower for inactivation of enzymes 1 D. Developed powder by cabinet air dryer 1 E. shows the developed cauliflower powder by solar tunnel dryer, we observe that the solar tunnel dryer powder color was more dark than cabinet air dryer because there was ununiformed heating during drying as well as it also takes long time for drying and were observe that after drying there is much chance for of 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). Total phenolic content (mg GAE/ 100 g) was determined by Bray and Thorpe (1954), Antioxidant activity (DPPH free radical scavenging activity) was investigated by Williams *et al.* (1995) procedures. FT-IR analysis guidelines given by Stuart (2005) and scanning electron microscopy (SEM) given by (Palmerini *et al.* 2018). Minerals analysis of the powder were analysed by the standard procedure given by Rajsekaran *et al.* (2005). For heavy metals analysis followed by the standard guidelines given by Saison *et al.* (2004).

RESULTS AND DISCUSSION

The research was carried out in the Department of Food Science and Technology College of Horticulture, Dr. YS. Parmar University of Horticulture and Forestry in Solan, HP, India.

Table 1: Physico-chemical analysis of raw cauliflower

Parameter	Mean ± Standard Error
Physical	
(a) Length (mm)	94.94 ± 1.63
(b) Diameter (mm)	111.83 ± 1.86
(c) Weight (g)	262.06 ± 1.53
Biochemical	
Moisture (%)	93.87 ± 0.91
Protein (%)	1.82 ± 0.04
Fibre (%)	1.77 ± 0.10
Ash (%)	0.69 ± 0.02
Carbohydrate (%)	4.33 ± 0.17

Total polyphenolics (mg GAE/100 g)	136.32 ± 0.92
Total carotenoids (mg / 100 g)	19.64 ± 0.68
Antioxidant activity (%)	55.99 ± 0.59

Table 1 shows the average length of cauliflower, 94.94 ± 1.63 (mm), Diameter and Weight, 111.83 ± 1.86 (mm) and 262.06 ± 1.53 (g) respectively and chemical composition of raw cauliflower. Moisture, protein, fibre, ash, carbohydrate, total polyphenolics, total carotenoids, and antioxidants were found to be 93.87 ± 0.91 per cent, 1.82 ± 0.04 per cent, 1.77 ± 0.10 per cent, 0.69 ± 0.02 per cent, 4.33 ± 0.17 per cent, 136.32 ± 0.92 mg GAE/100 g, 19.64 ± 0.68 mg / 100 g, and 55.99 ± 0.59 per cent respectively.

Table 2: Drying time and nutritional evaluation of developed cauliflower powder by mechanical cabinet air dryer and solar tunnel dryer

Parameter	Mean ± Standard Error	
	Cabinet air drying	**Solar drying**
Drying time (h)	11.75 ± 0.14	22.99 ± 0.26
Moisture (%)	7.52 ± 0.20	8.57 ± 0.17
Protein (%)	16.60 ± 0.19	15.87 ± 0.48
Carbohydrate (%)	46.43 ± 0.62	43.20 ± 0.08
Fibre (%)	14.28 ± 0.16	13.44 ± 0.27
Ash (%)	4.08 ± 0.07	4.04 ± 0.04
Fat (%)	1.87 ± 0.05	1.76 ± 0.04
Total polyphenolics (mg GAE/ 100 g)	122.35 ± 0.58	105.12 ± 2.93
Total carotenoids (mg/ 100 g)	13.86 ± 0.10	10.31 ± 0.05
Antioxidant activity (%)	46.45 ± 0.58	43.39 ± 0.99

Table 2 depicts that in the present research investigation the chemical composition of developed powder by mechanical cabinet air dryer and solar tunnel dryer, drying time, moisture, protein, carbohydrate, fibre, ash, fat, total polyphenolics, total carotenoids and antioxidant activity, 11.75 ± 0.14 h, 7.52 ± 0.20 per cent, 16.60 ± 0.19 per cent, 46.43 ± 0.62 per cent, 14.28 ± 0.16 per cent, 4.08 ± 0.07 per cent, 1.87 ± 0.05 per cent, 122.35 ± 0.58 mg GAE/ 100 g, 13.86 ± 0.10 mg/ 100 g, 46.45 ± 0.58 per cent and 22.99 ± 0.26 h, 8.57 ± 0.17 per cent, 15.87 ± 0.48 per cent, 43.20 ± 0.08 per cent, 13.44 ± 0.27 per cent, 4.04 ± 0.04 per cent, 1.76 ± 0.04 per cent, 105.12 ± 2.93 mg GAE/ 100 g, 10.31 ± 0.05 mg/ 100 g and 43.39 ± 0.99 per cent respectively.

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

Minerals	Amount (mg/100 g)	Heavy metals	Amount (mg/100 g)
Na (%)	0.43	Cd	0.11
Ca (%)	0.28	Co	0.02
K (%)	0.38	Cr	1.23
Mg (%)	0.71	Ni	ND
Cu	27.00	Pb	16.61
Fe	47.00		
Mn	34.40		
Zn	29.10		

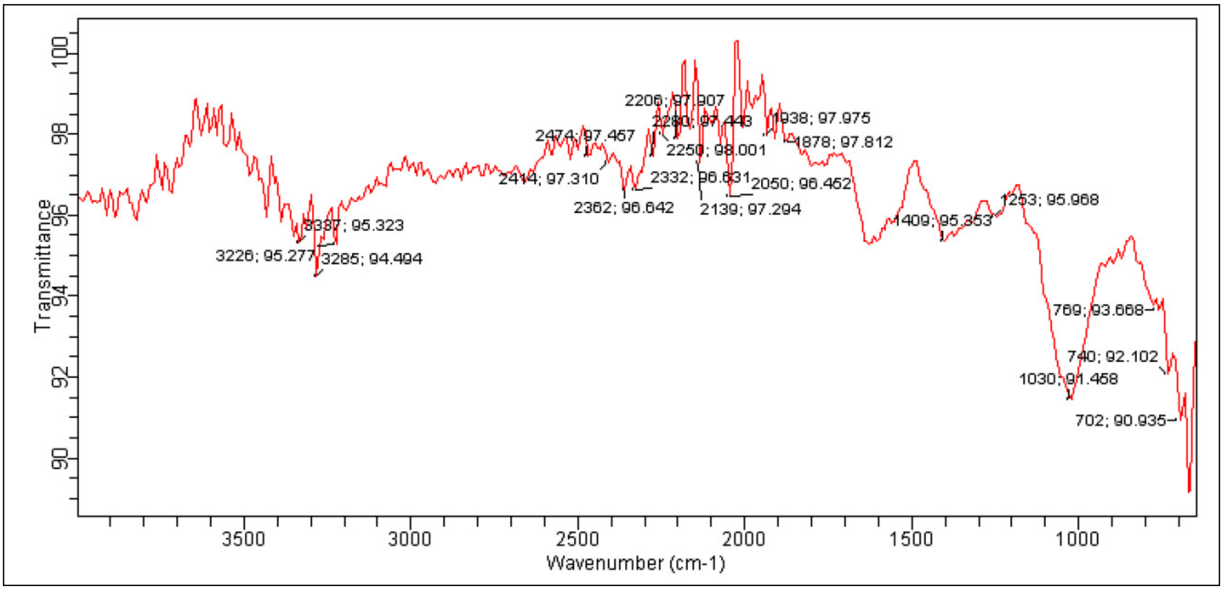
Minerals were analysed of the developed cauliflower powder by mechanical cabinet air dryer and reviled that, Na, Ca, K, Mg, Cu, Fe, Mn and Zn, 0.43 per cent, 0.28 per cent, 0.38 per cent, 0.71 per cent, 27.00 mg/100 g, 47.00 mg/100 g, 34.40 mg/100 g and 29.10 mg/100 g respectively and heavy metals were analysed by the Inductive Coupled Plasma (ICP), *viz*., Cd, Co, Cr, Ni and Pb, 0.11 mg/100 g, 0.02 mg/100 g, 1.23 mg/100 g, ND and 16.61 mg/100 g respectively which shows in the Table 3.

Functional groups of cauliflower powder by mechanical cabinet air dryer

FT-IR (Fourier transform – Infrared Spectroscopy) was used to determine the functional parameters of cauliflower powder generated by a mechanical cabinet air dryer. FTIR (Fourier Transform Infrared Spectroscopy) is a long-wave infrared spectral measurement method that records absorbance in a time field and converts it to a frequency field using the Fourier transform algorithm (Baravkar *et al*., 2011). Because of its capacity to identify functional groups of chemical compounds such as carbohydrates and esters, as well as chemical bonds between atoms, FT-IR has been used to analyse a wide range of samples.

Cauliflower powder by mechanical cabinet air dryer

FT- IR spectrum was used to identify the active component present in the cauliflower powder in Graph 1 showed the wavenumber 3337 cm^{-1}, 1409 cm^{-1}, 1030 cm^{-1}, which represent O-H, C=C and C-O respectively in the powder which similar result shows in (Muchtaridi *et al*. 2019; Rohman *et al*. 2015).



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

Morphological analysis of developed cauliflower powder in mechanical cabinet air dryer and solar tunnel by scanning electron microscopy (SEM)

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 (Fig. 2 A and B). Morphological analysis revealed that all particles had a broken glass structure and rough surfaces. In Fig. 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 Fig. 2 B shows 1200 time magnify structure on same working distance.

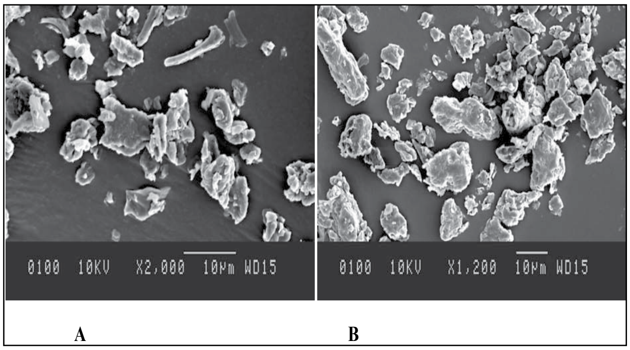


Fig. 2: A and **B** Micrograph of cauliflower powder by mechanical cabinet air dryer

SEM analysis of developed cauliflower powder by solar tunnel dryer

Fig. 2 C shows that the 3000 time magnifies structure of powder on 15 working distance and Fig. 2 D shows the 2000 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.

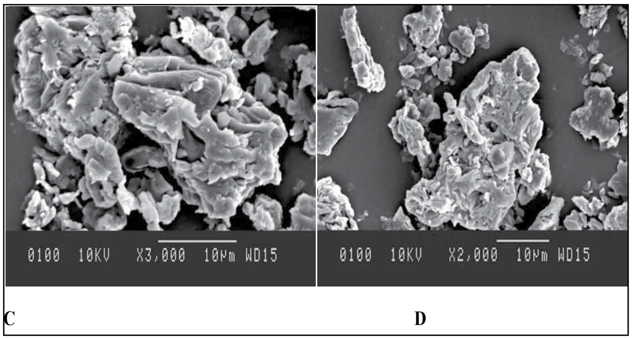


Fig. 2: C and **D** Micrograph of cauliflower powder by solar tunnel dryer

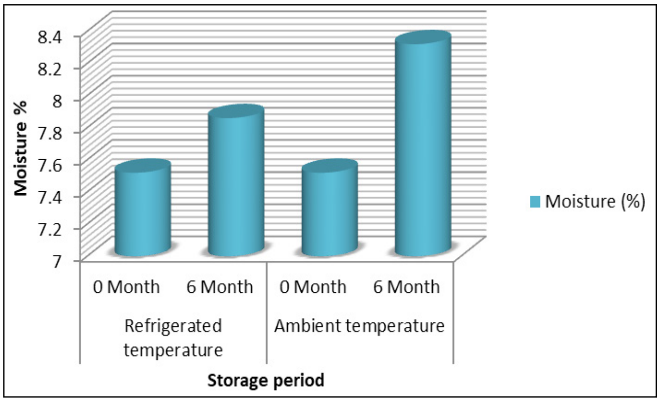
Effect of storage on various chemical characteristics of cauliflower powder at ambient temperature (18-38 °C) and refrigerated temperature (4 °C).

For the evaluation of nutritional quality, the generated cauliflower powder by cabinet air dryer was packed in polyethylene pouches and stored for 6 months at refrigerated and ambient temperatures. Initial and 6-month observations were recorded.

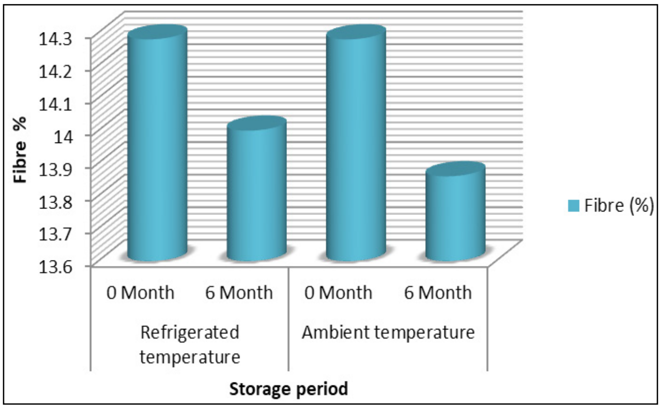
Moisture (%) the Graph 3 depicts the initial moisture in developed cauliflower powder was 7.52 per cent after 6 months refrigerated condition and ambient temperature, 7.86 per cent, 8.32 per cent respectively there is not much increasing moisture at refrigerated temperature but we observe that there is moisture content is increasing day by day at ambient temperature from 7.52 per cent to 8.32 per cent.

Fibre (%) In the present investigation we were found that initial fibre content 14.28 % and it was stored at refrigerated condition and ambient temperature for 6 months, and after observe that 14.00 per cent, 13.86 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 14.28 per cent to 13.86 per cent which shows in Graph 4.

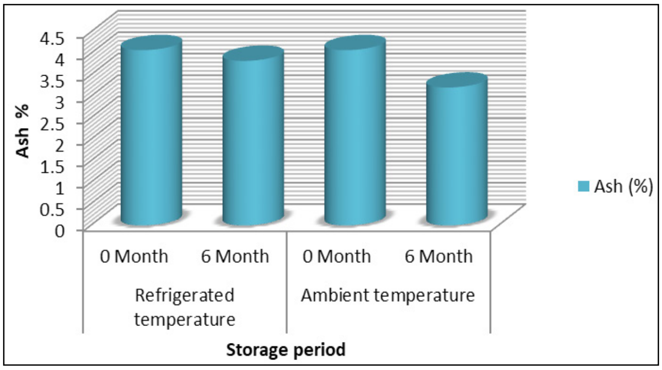
Ash (%) Graph 5 represents the changing of ash content of powder during storage period, initial ash content 4.08 per cent, after 6 months we find changing in ash at refrigerated condition and ambient temperature, 3.83 per cent, 3.21 per cent respectively there is not much decreasing ash content at refrigerated temperature but we observe that there is changing in ash at ambient temperature from to 4.08 to 3.21 per cent.



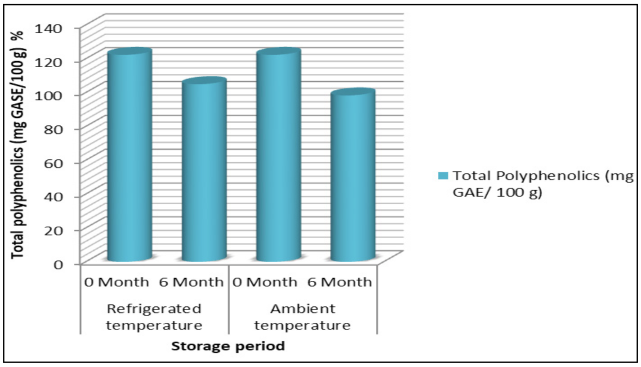
Graph 3: Moisture (%)



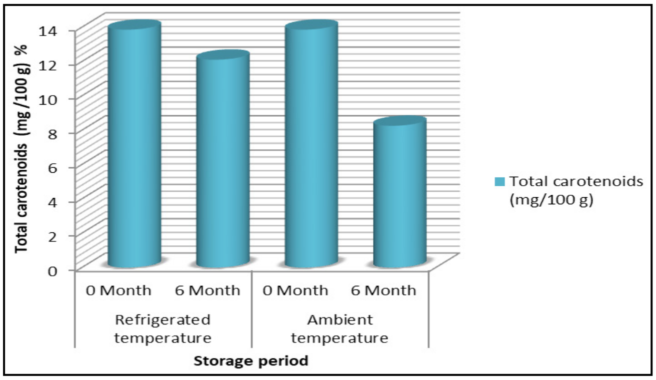
Graph 4: Fibre (%)



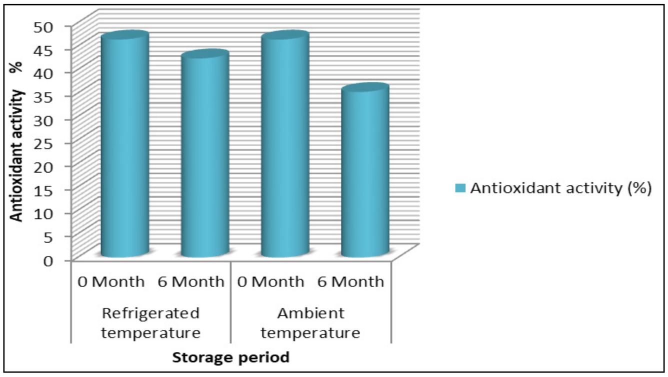
Graph 5: Ash (%)



Graph 6: Total polyphenolics (mg GAE/ 100 g)



Graph 5: Total carotenoids (mg/100 g)



Graph 6: Antioxidant activity (mg GAE/ 100 g)

Total polyphenolics (mg GAE/ 100 g) initial total polyphenolics content 122.35 mg GAE/100g after 6 months refrigerated condition and ambient temperature, 105.02 mg GAE/100g , 98.36 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 122.35 mg GAE/100 g to 98.36 mg GAE/100g which is shown by Graph 6.

Total carotenoids (mg/100 g) the data presented in the Graph. 7 shows initial Total carotenoids 13.86 mg/100g after 6 months refrigerated condition and ambient temperature, 12.11 mg /100g , 8.26 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 13.86 mg/100g to 8.26 mg/100g.

Antioxidant activity (%) in the present research initial antioxidant activity 46.45 per cent present in the developed powder and stored for after 6 months refrigerated condition and ambient temperature, 42.43 per cent and 35.28 per cent respectively there is not much decreasing antioxidant activity at refrigerated temperature but we observe that there is decreasing total antioxidant activity at ambient temperature from to 46.45 per cent to 35.28.

CONCLUSION

In this study, cauliflower powder was dried in a mechanical cabinet air dryer, a solar tunnel dryer, and a cabinet air dryer. The mechanical cabinet air dryer outperformed the solar tunnel dryer in terms of total phenolic content, carotenoids content, and antioxidant activity. SEM was used to check the morphological quality of the powder, and Atomic Absorption Spectroscopy (AAS) was used to check the minerals content of the dried cauliflower powder, Fourier Transform-Infrared Spectroscopy (FT-IR) was used to check the chemical groups present in the powder, and Inductively coupled plasma (ICP) was used to detect heavy metals (Cd, Co, Cr, Ni and Pb). For 6 months, the developed powder was kept refrigerated (4^{o}C) and at room temperature (18-38^{o}C). We found that refrigerated conditions produced superior results than ambient temperatures in terms of nutritional quality.

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