Defence Life Science Journal, Vol. 8, No. 1, January 2023, pp. 71-82, DOI : 10.14429/dlsj.7.18208

Phenolic and Antioxidant Capacity Retention of Potato Peel Waste as a Function of Cultivar, Pretreatment and Drying Procedure

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ABSTRACT

Drying procedures employed for potato peels (both raw and boiled) may adversely affect the useful bioactive components present in them. This study envisaged the identification of a feasible drying procedure for handling bulk potato peel waste for maximising the retention of phytochemicals in the peel powder. The total phenols (TP), flavonoids (TF) and antioxidant capacity (TAC) were assessed in peels of three commercial and one newly developed anthocyanin rich Indian potato cultivars in response to boiling pretreatment and varying drying procedures. Microwave drying (600W) was best in terms of drying rate for both raw and boiled peels. It yielded the greatest amount of TP and TF in the dried raw peel, irrespective of cultivar. Dried raw peels of an thocyanin rich Kufri Neelkanth cultivar exhibited maximum TAC. Retention of TF, metal scavenging activity and reducing power followed almost a similar pattern as TP irrespective of cultivar, pretreatment and drying procedure. Our study shows that potato peel from Kufri Neelkanth (raw) and Kufri Frysona (both raw and boiled) are best source of phenolics and flavonoids and can serve as a suitable matrix for extraction of bioactive compounds which holds promise for use in the food industry.

Keywords: Potato peel; Boiling; Drying procedure; Phenolics; Antioxidant activity; Total flavonoids

1. INTRODUCTION

Phytochemicals, especially phenolics are the major bioactive compounds in fruits and vegetables that impart multiple health benefits including antioxidant activity. These plant phenolics can be found both in edible as well as non-edible parts of the plant. Residues obtained from food processing industry are a treasure trove of these phenolics. In potato processing industry, huge quantum of peel is generated annually (≥16 percent of potato handled). The potato peel obtained from processing industry usually contains about 80-90 % water that is reduced to about 40 % by use of mechanical presses before being discarded.

Drying is considered as a critical factor for the postharvest management of potato waste. Although potato peel is considered as zero value product and is used as a source of dietary fibre in animal feed, but it is also a rich source of pharmacologically active compounds including phenolics.[1] Potato peel can be utilised as a food additive for dietary fibre, natural antioxidants and antimicrobials benefits.[2-4] As an antioxidant, potato peel extract is non-mutagenic and non-carcinogenic compared to synthetic preservatives. Drying of peel is a mandatory step for reducing moisture content to a sufficiently low level that inhibits microbial spoilage and curbs the biochemical changes. In addition, the drying of waste reduces bulk and facilitates easy and safe storage.

Several drying techniques are in vogue to dry the waste generated such as sun drying, hot air drying, freeze drying, microwave drying etc. Sun drying is not an efficient method since it is climate dependent; takes long time for the quantum of waste generated to be dried and consequently may be accompanied by microbial infestation since the required moisture content may not be achieved. Freeze drying and microwave drying are efficient methods of drying but are costly and require special infrastructure to be operational which hampers their feasibility of scale-up. Hot air drying usually takes a long time and if temperature is not monitored properly may result in loss of bioactives present in waste. The degradation of thermally sensitive compounds maybe reduced by pretreatment such as boiling (blanching) or by management of drying temperature.[5] However, some studies have reported an increase in the bioactive molecules and antioxidant content owing to the release

Received : 28 May 2022, Revised : 22 December 2022
Accepted : 29 December 2022, Online published : 3 April 2023

of these compounds from bound food matrices even upon application of high temperatures in pears, pinto, black beans etc. 6-7 Shade drying is a time-honored, low-cost method that dries the matrix at room temperature and prevents the deterioration of the active ingredients. However, because it is slow, metabolic processes may continue for a longer period of time, which could result in quality loss. Since, in the processing industry, drying of peel can be accomplished by huge cabinet dryers, the objective of the present study was to compare different temperatures for the drying of potato peel to achieve a product having low moisture content as well as having high bioactives. Potato peel was subjected to four different drying temperatures viz., 40 °C, 50 °C, 60 °C, 70 °C and shade drying to evaluate the quality of dried waste in terms of total phenolic content and antioxidant capacity.

Sand roasting is a high temperature short time cooking process that results in faster dehydration through conduction. In case of cereals and legumes, sand roasting improves the sensory, nutritional and antioxidant profile. Starchy tubers such as potatoes, sweet potatoes, taro, tapioca and yams are also sand baked. 8 Cultivated potatoes, primitive forms and their wild counterparts are genetically variable, resulting in differences in tuber shapes, peel and flesh colours[9] and also the nutrient, antioxidant and flavonoids values.

In India, Kufri Chipsona 1 and Kufri Chipsona 4 are used for manufacturing chips while Kufri Frysona is used widely in the fries industry owing to the low reducing sugar and high dry matter content (≤125 mg/100 g and ≥20 %, respectively). Kufri Neelkanth is a recently released purple peel coloured cultivar by ICAR-Central Potato Research Institute, India that is rich in anthocyanins. Significant amount of peel is produced from processing industries using raw and boiled potatoes (chips and aloo mash, respectively). The amount of waste produced varies from 15 to 40 % 10 depending on the peeling procedure. Utilising this by-product can assist the potato industry's waste disposal issues. Additionally, it can also enable other food matrices to be enhanced with physiologically active substances.

To produce a product with high phytochemical retention, the utilisation methods must be supported by understanding of the effects of thermal processing of the potato peel. To the best of our knowledge, no report is available on the effect of different drying conditions on the stability of phytochemical constituents of both raw and boiled potato peel with respect to cultivar. This information will be of great value to the nutraceutical and functional food industries that usually searched low cost natural resources for physiological active compounds extraction.

2. METHODOLOGY

2.1 Procurement of Tubers and Chemicals

Tubers of four potato cultivars, namely, Kufri Chipsona 1 (KC1), Kufri Chipsona 4 (KC4), Kufri Frysona (KF) and Kufri Neelkanth (KN) were sampled during the harvest season February-March in 2020 from ICAR-Central Potato Research Institute, Modipuram Campus, Uttar Pradesh, India. Chemicals used for analysis of phytochemicals were procured from Sigma and Merck Pvt. Ltd.

2.2 Treatment of Tubers and Collection of Peel

The tubers of each cultivar were washed under running water to remove the adhered soil. The samples were divided into two lots. One lot of tubers was peeled using a stainless steel peeler to get raw peels. Tubers of each cultivar from the second set were boiled separately in a pressure cooker for 10 min as per the procedure reported by Azizi[3], *et al.* The boiled tubers were peeled manually and the peel was collected. Both the set of peels were subjected to drying as per the details of the drying experiment given in Table 1.

2.3 Peel Percentage and Peel Thickness

To find out the amount of per cent peel from raw tubers of each cultivar, the tubers were peeled with a stainless steel knife and peel weight was expressed as percentage. For boiled tubers, peel was removed manually and peel percent was calculated as before. Thickness of potato peel was measured using a vernier caliper (Mityoto, Japan) in triplicate for each cultivar.

2.4 Drying of Peel

The peel from raw and boiled potato was subdivided into seven equal lots. The peels were subjected to different drying procedures viz., shade drying (SD), cabinet drying (at 40 °C, 50 °C, 60 °C and 70 °C), microwave (MW) drying at 600W (Joshi et al. 2015) and drying by roasting (R) at 200 °C[11] upto moisture content of ~6 %. The time required for drying each set was noted. The dried potato peel of each cultivar from each treatment were ground and passed through a sieve (BSS 36) to achieve uniform particle size. The powders were stored in airtight bags in dark conditions under low temperature.

2.5 Preparation of Sample Extracts for Phytochemical Determination

Methanolic extracts were prepared by mixing dried peel with 95 % methanol and centrifuging the mixture for 15 min at 10,000 rpm. The supernatant was used to determine total phenolic content, flavonoids content and antioxidant activity as discussed below. For convenience and better comparison, all measured values for different attributes have been calculated at a constant moisture level of 6 %.

2.5.1 Total Phenolic Content

The total phenolic content of the dried peels was measured using the method of Sethi[12], *et al.* using the Folin-Ciocalteau Reagent (FCR). The phenols in the

sample extract react with the phosphomolybdic acids present in FCR under alkaline conditions to form a blue coloured complex. Absorbance of the developed colour was measured at wavelength of 765 nm by a spectrophotometer (Spectra Max M2, Molecular Devices, USA) and total phenolic content was calculated as mg gallic acid equivalents (GAE)/ 100 g peel dry weight.

2.5.2 Total Flavonoid Content

For determining the total flavonoid contents in the dried raw and boiled peel extracts, colorimetric assay using $AlCl_3$ reagent was followed as described by Sethi, *et al.*[12] using quercetin as standard. The aluminum chloride forms acid labile complexes upon reaction with the flavonoids in the peel extracts, the absorbance of which was measured at 510 nm wavelength using a Spectra Max M2 spectrophotometer (Molecular Devices, USA).

2.5.3 Total Antioxidant Activity

Total antioxidant activity of the dried peels was measured by three *in-vitro* methods, namely, FRAP (ferric reducing antioxidant power), DPPH (2, 2-diphenyl l-picrylhydrazyl) and ABTS (2, 2'-azinobis 3-ethylbenzothiazoline-6-sulfonic acid diammonium salt) scavenging assays as described by Sethi[12], *et al*. and Re[13], *et al*., respectively. The results thus obtained were expressed as µmol Trolox equivalent/ g (db).

FRAP assay: To determine total antioxidant activity by FRAP assay, peel extract (0.1 ml) was mixed with FRAP reagent (3 ml). The antioxidative compounds in the extract that have the ability to reduce ferric ion present in FRAP reagent to ferrous ion during incubation were measured by recording absorbance at 593 nm using a spectrophotometer (Spectra Max M2, Molecular Devices, USA).

ABTS assay: This assay is based on the inhibitory effect of peel antioxidants on the green colour development of ABTS radical. In the reaction, ABTS is oxidised by potassium persulphate to the intensely blue-green coloured $ABTS^+$. The scavenging ability of the potato peel antioxidants is measured as the reduction in the intensity of colour development as measured spectrophotometrically (Spectra Max M2, Molecular Devices, USA) at 600 nm.

DPPH assay: Percent radical scavenging activity (RSA) of peel extracts was quantified by reacting 0.1 ml extract with 3.9 mL DPPH reagent. The reduction of the purple coloured stable DPPH radical to yellow coloured diphenylpicrylhydrazine was measured by the decrease in the optical density of reaction mixture using Spectra Max M2 spectrophotometer (Molecular Devices, USA) at wavelength of 517 nm to determine the RSA of the peel extract and expressed in terms of µmole TE/g.

2.5.4 Metal Chelating Activity of Potato Peel Extracts

Metal chelating ability of potato peel extracts was determined according to the procedure reported by Dinis[14], *et al.*. The reaction medium included 0.25 ml ferrozine (5 mM), 0.05 ml ferrous chloride ($FeCl_2.4H_2O$, 2mM) and 0.2 ml of sample extract solution (at 100-1000 µg/ml concentrations). The volume was adjusted to 1ml with methanol and stirred vigorously. The mixture was incubated for 10 min at room temperature and its absorbance was measured at 562 nm. As control, solution prepared without potato peel extract was used. The ability of the sample to chelate ferrous ions at different concentrations was calculated with the following equation:

$$MCA(\%) = \left(\frac{Abs_{control562} - Abs_{sample562}}{Abs_{control562}}\right) x\ 100$$

where MCA is the metal chelating activity of the extract and Abs is the absorbance recorded at 562 nm.

2.5.5 Reducing Power Activity of Raw and Boiled Potato Peel

The method described by Oyetayo[15], *et al.* was used to determine the reducing power of potato peel extract. Extract was mixed with 2.5 ml of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 ml of 1 % (w/v) aqueous potassium ferricyanide. The reaction mixture was incubated for 20 min at 50 °C followed by addition of 2.5 ml of 10 % trichloroacetic acid. The mixture was centrifuged at 3000 rpm for 10 min. The supernatant (2.5 ml) was mixed with 2.5 ml deionised water and 0.5 ml of 0.1 % (w/v) ferric chloride and the absorbance of the resultant mixture was read at 700 nm. Higher absorbance of the reaction mixture depicts greater reducing power of the extract.

2.6 Moisture Content

Infrared moisture analyser (MS-70 A&D Co. Ltd., Japan) was used to estimate the moisture content of the dried potato peel with the resolution of 0.001 %.

2.7 Statistical Analysis

The results expressed as mean values of three replicates were analysed by three way analysis of variance (ANOVA). Data were subjected to analysis of variance using SAS package (9.3 SAS Institute, INC., USA) followed by Tukey's test.

3. RESULTS AND DISCUSSION

3.1 Peel Percentage and Peel Thickness

Among the raw tubers, peel per cent was greatest for Kufri Frysona (15.88 %). Raw tubers of the other three cultivars showed almost similar peel percent recovery (11.54-11.76 %). A drastic reduction in the peel per cent recovery was observed for the boiled counterparts that ranged between 1.52-2.73 %.

For processing industry, minimum peel percent is desirable to yield maximum edible portion from unit weight of tubers. Previously, Raj[16], *et al.* have reported peeling and trimming losses to be in the range of 11.60 (Kufri Chipsona 1) – 16.00 % (Kufri Jyoti).

A linear regression model (Eqn 1) has been established keeping tuber dimensions and peel thickness as the major contributors towards per cent peel loss. The model was significant with F value 171.22 and $p \leq 0.0058$.

$$\% \text{ pee loss} = 2.237 + 0.099X + 0.029Y - 0.144Z + 7.34T \ldots\ldots R^2 = 0.098 \quad (1)$$

where, X (breadth), Y (length) and Z (width) represent the three axis/ dimension of potato tuber and T denotes the peel thickness.

Variation in peel thickness of raw tubers may be due to the genetic variability of the cultivars studied as also the pressure applied during manual peeling. In the potato processing industry, peel thickness should be as low as possible to prevent the extent of loss incurred during peeling. Oval/ elongated large sised potato tubers with less number of eyes (vegetative buds) are preferred for processing to avoid peeling losses. Manual peeling using a knife may result in adhesion of certain pulp fraction thus, increasing the waste. A drastic reduction in thickness of peel recovered from boiled tubers was observed as it was totally devoid of any adhered starchy pulp.

3.2 Drying Studies of Potato Peel

Table 1 shows the variation in drying rate and the final moisture content of the dried peel. Highest drying rate was observed during roasting of boiled potato peels irrespective of cultivars. However, as expected due to lowest temperature gradient as well as air movement shade drying exerted lowest rate of water removal in both the raw and boiled peels. As far the performance of cabinet dryer is considered, the drying rate was the highest at 70 °C, followed by 6 °C, 50 °C and 40 °C, due to subsequent reduction in temperature gradient. Moisture evaporation rate through microwaving was almost 100 times higher than cabinet dryer. However, final moisture content in resulting products were found maximum after roasting (in raw peel) and in microwaved peel (in boiled peel). It may be due to prominent shrinkage defect caused by high rate of drying in microwaving and roasting treatment as well. Joshi[17], *et al.* had previously reported shrinkage defect in potato flesh upon microwaving due to maximum drying rate at 450 W.

3.3 Total Phenolic Content (TPC)

As depicted in (Fig 1), total phenolic content varied significantly in the varieties studied. Raw peel obtained from anthocyanin rich Kufri Neelkanth cultivar showed maximum phenolics (326.70 mg GAE/ 100g dw). The TPC of peel from shade dried raw tubers ranged from 194.86-326.70 mgGAE/100g dw. Variation in pattern of total phenolic content largely suggests that cultivar as well as drying temperature affects the phenolics retention differentially. Shade drying of the potato peel retained slightly higher phenolics in comparison to those dried under 40 °C and 50 °C. Activation of oxidative enzymes such as polyphenoloxidase and peroxidase under 40-50 °C drying temperatures might have led to the decrease in phenolic compounds. Further, an upsurge in the total phenolic content was observed upon drying of the potato peel beyond this temperature irrespective of the cultivar. This might be due to the release of bound phenolics attached to the tissue cell wall as well as the inactivation of enzymes. Microwave drying yielded the greatest amount of phenolics in the dried raw peel, irrespective of cultivar.

Vu[18], *et al.* also observed microwave drying of banana peels retained maximum total phenolics. Roasting, on the other hand was detrimental to the phenolic retention in the dried raw potato peel as evident from data given in Figure 1. An average decrease of 52.44 % in total phenolic compounds was observed in all variants of potato peels after roasting with maximum reduction in raw peel of Kufri Chipsona 4 (63.98 %). Since drying of peel by roasting in sand took less than 5 min to dry the peels, the release of bound phenolics was not attained hence, resulting in low total phenolic content. Previously, Zhou[19], *et al.* have also showed significant decline in TPC in black soybean roasted at 210 °C for 30 min.

Boiling showed a negative effect on the retention of total phenolics in general. Greatest loss of phenolics was observed from the peel of Kufri Neelkanth cultivar that is rich in water soluble anthocyanin pigment. Boiling clubbed with high temperature drying (>60 °C) resulted in maximum loss of phenolics from the peel matrix. Earlier, Azizi, *et al*.[3] have also reported a reduction in the phenolic content of potato peel upon boiling of

Table 1. Drying temperature, time and final moisture content of potato peel

S.No.	Drying method	Temperature (°C/W)	Time (min)		Drying rate (kg H_2O/ kg dwb/h)		Final moisture content (%)	
			Raw	Boiled	Raw	Boiled	Raw	Boiled
1	Shade drying (SD)	25-30	2880	300	5.21×10^{-5}	8.10×10^{-4}	7.9	6.9
2	Cabinet Drying	40	330	60	4.64×10^{-4}	4.12×10^{-3}	6.5	5.5
		50	330	60	4.65×10^{-4}	4.16×10^{-3}	6.4	4.8
		60	210	60	7.29×10^{-4}	4.21×10^{-3}	6.5	4.0
		70	210	60	7.31×10^{-4}	4.17×10^{-3}	6.4	4.6
3	Microwave drying (MW)	600W	7	2	2.13×10^{-2}	1.21×10^{-1}	8.2	7.0
4	Roasting (R)	200	5	<1	2.95×10^{-2}	4.03×10^{-1}	9.0	4.0

time exposure coupled with oxidation. Previously, Heras-Ramirez, *et al*.[20] have also reported significant reduction in polyphenol concentration in blanched apple pomace. Also, Azizi[3], *et al*. reported total phenols in the raw peel dried at 70 °C to be in the range of 245.00-393.95 mg GAE/ 100g dw. Sun et al.[21] indicated that bound phenolic compounds get released as the drying temperature increases, therefore achieving maximal values. Hayat[22] et al. have reported a 4 % reduction in TPC of microwaved Kinnow pomace while a 2.6-7.5 % reduction was observed by Sun[21], *et al*. after hot air drying at 60-120 °C. Similar to our findings, Sun[21], *et al.* have also reported maximum phenolic retention at 60 °C cabinet drying. Therefore, proper drying temperature identification can help to extract maximum phenolics from dried potato peel matrix.

3.4 Total Flavonoid Content (TFC)

The TFC of the dried potato peels produced at different drying temperatures are given in (Fig. 2). It is noted that TFC of peel was significantly affected by the cultivar, treatment and drying temperature. The reduction in TFC is related to the temperature of drying and duration of exposure. The total flavonoids (TF) of the shade dried raw potato peels varied from 123.79 to 172.56 mg quercetin equivalents/ 100 g dw (Fig. 2). Maximal total flavonoid content could not be achieved from raw peels dried at lower temperatures (upto 50 °C). Low temperature long time drying enhances the degradation of the phytochemicals possessing antioxidant activity due to prolonged exposure to oxygen[5]. Raw peels from Kufri Chipsona 1 and Kufri Chipsona 4 showed an increase in the total flavanoid content as temperature of drying was enhanced to 60 °C, thereafter, the values declined. For the raw peels obtained from Kufri Frysona and Kufri Neelkanth, the increase was observed in elevated temperature of 70 °C. The tendency to increase in flavonoids content at higher temperature can be attributed to the shorter drying time which may reduce the chances of phenol degradation. Microwaving of the raw peels was successful in extracting highest TFC with maximum values recorded for Kufri Neelkanth (1050.51 mg QE/ 100g dw) followed by Kufri Frysona (460.67 mg QE/ 100g dw). This increase can be explained by the breakdown of the cellular matrix and release of sequestered flavonoids.

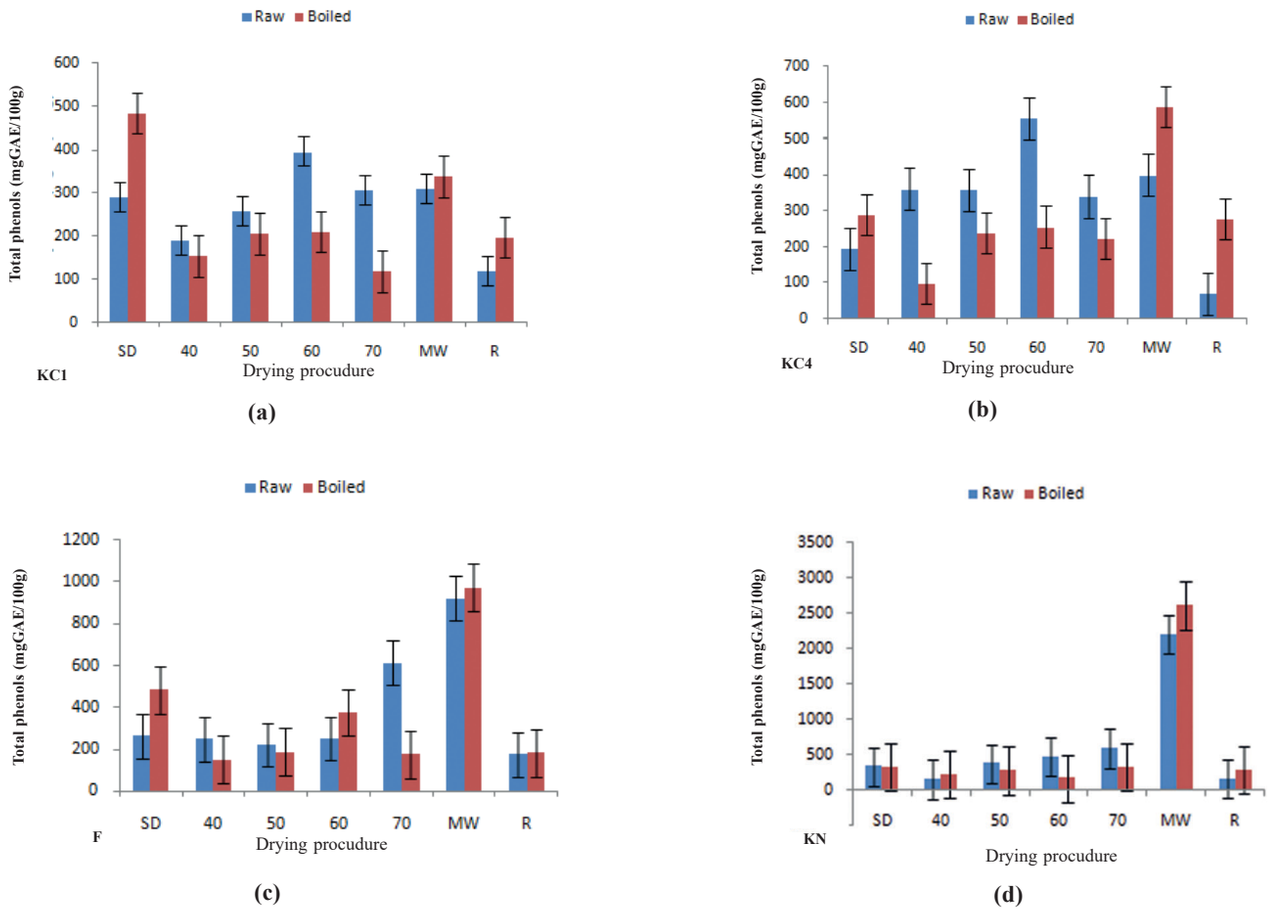


Figure 1 (a-d). Total phenolic content of potato peel extracts.

(SD: Shade drying; KC1: Kufri Chipsona; KC4: Kufri Chipsona 4; KF: Kufri Frysona; KN: Kufri Neelkanth; MW: Microwaved; R: Roasted; 40, 50, 60, 70: Cabinet drying temperatures, °C). Values are means ±standard error (n=3).

tubers. They reported a 71.2 % and 55.89 % reduction in total phenols in boiled peels of Kufri Chipsona 1 and Kufri Frysona upon drying at 70 °C. Such depletion in phenolics might have resulted due to the water solubility and leaching of the phenolics into the boiling water. However, reverse trend for boiled peel was observed due to elevated temperature exposure upon microwaving and roasting.

Phenolic acids may exist in both free and bound forms in plants, the latter conjugated to various components either in glycosylated or ester-bound forms. The phenolic acids maybe released from their bound form as the temperature increases. Conversely, few phenolic acids may get destroyed as the temperature elevates. Potato peel samples dried at 60-70 °C yielded maximum phenolics across cultivars (Fig. 1). Lower temperature of drying promotes greater degradation of phenolics due to long

Flavonoids are water soluble subclass of phenolic compounds. In general, the peels exhibited a reduction in TFC upon boiling. Our observations are in contrast to the report of Heras-Ramirez[20], *et al*. who observed an increase in TFC in blanched apple pomace. However, similar trend was observed upon shade drying of boiled peels which showed higher TFC in comparison to the raw counterparts of all the four potato cultivars studied. Further, boiling of peels clubbed with the high temperature short time microwave and roasting treatment showed higher retention of TFC than the raw counterparts. Drying of peels by sand roasting proved to be the most detrimental treatment, both for raw as well as boiled potato peels, maybe due to the breakdown of compounds at elevated temperature of 200 °C.

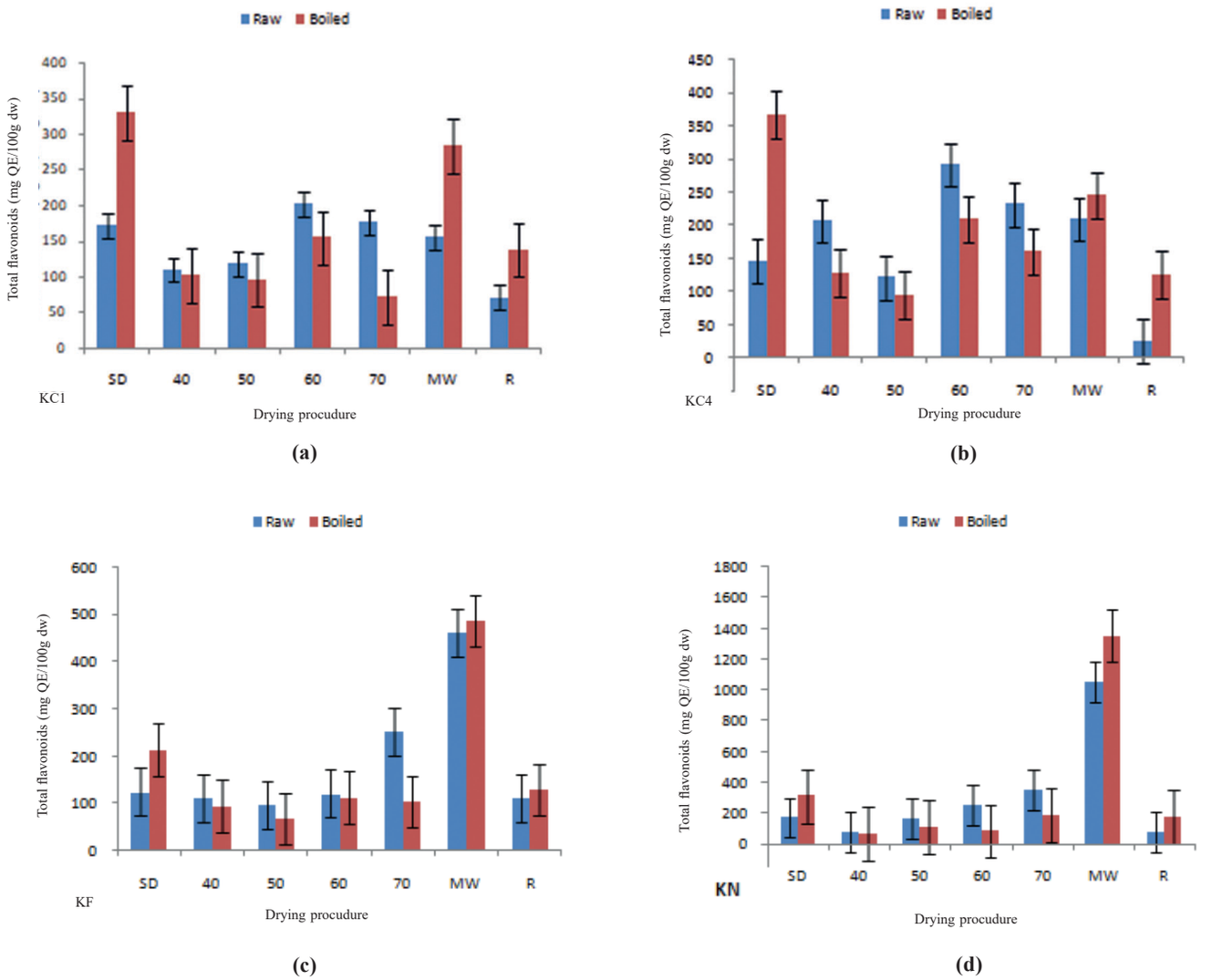


Figure 2 (a-d). Total flavonoid content of potato peel extracts.

(SD: Shade drying; KC1: Kufri Chipsona; KC4: Kufri Chipsona 4; KF: Kufri Frysona; KN: Kufri Neelkanth; MW: Microwaved; R: Roasted; 40, 50, 60, 70: Cabinet drying temperatures, °C). Values are means±standard error (n =3).

3.5 Total Antioxidant Capacity (TAC)

TAC of the potato peels was evaluated with three assays, namely, FRAP, ABTS and DPPH. It is evident that drying temperature has an obvious influence on the TAC. The antioxidant capacity of foods depends on various factors, including phenolic content, ascorbic acid and substrate properties. Differences in antioxidant capacity of foods might result from the production of alternate compounds possessing antioxidant capacity (e.g., phenolic acid, γ-tocopherol) or from the breakdown under elevated temperature and time[23]. TAC values measured using the FRAP, ABTS, and DPPH methods are dependent on individual phenolic compounds in potatoes. For example, some antioxidants may be detected in greater amounts by the ABTS method compared to FRAP, so it is advisable not to use a single method when measuring TAC.[12,24]

3.5.1 FRAP Assay

The results showed high variability of TAC in terms of FRAP values among the samples. Out of the four potato cultivars, maximum FRAP values (12.35 µmole TE/ g) were shown by peels of raw Kufri Frysona dried at 60 °C. Interestingly, among all the drying procedures employed, boiled peels exhibited higher FRAP values irrespective of cultivar. Analysis of TAC of peels by FRAP assay revealed that cabinet drying of raw peels under 60 °C yielded maximum values while shade drying was best for boiled counterparts.

3.5.2 ABTS Assay

Kufri Frysona recorded the maximum average ABTS values (24.45 µmole TE/ g) in raw peel upon drying at different temperatures (Table 2). Upon boiling, an increase in the ABTS values was observed across the temperatures/ drying treatment applied with Kufri Frysona peel exhibiting maximum average ABTS values (47.12 µmole TE/g). Similar increase in ABTS values has been previously reported by Heras-Ramirez[20], *et al.* for blanched apple pomace after drying. Interestingly, in our study least percent increase in ABTS value (27.46%) was observed in boiled peel of Kufri Neelkanth. This may be attributed to the water solubility of anthocyanins present in the peels which is a major contributor to the TAC.

3.5.3 DPPH assay

The DPPH assay is employed to assess the free RSA of naturally occurring antioxidants. Potato peel subjected to different drying procedures showed variation in the DPPH inhibition (Table 2). The extracts were able to reduce the purple DPPH radical to yellow diphenyl-picrylhydrazine indicating their potential to scavenge DPPH radical. Maximum average DPPH values (2.82 µmole TE/ g) were observed in raw peel of Kufri Neelkanth followed by Kufri Frysona (1.70 µmole TE/ g). An increase in the DPPH values was observed with a corresponding increase in the cabinet drying temperature upto 60 °C. This maybe owing to the release of bound antioxidative compounds as well as generation of partially oxidised polyphenols that possess greater antioxidant activity in comparison to non-oxidised polyphenols as suggested earlier by Nora[25], *et al.* Roasted peel of all four cultivars showed a loss in DPPH values. This might be due to the dissipation of antioxidative compounds under elevated temperatures (200 °C) due to thermal or chemical decomposition. For boiled peels, shade drying resulted in an increase in DPPH values for Kufri Chipsona 4 (73.36 %), Kufri Chipsona 1 (51.91 %) and Kufri Frysona (63.92%). Interestingly, boiling of Kufri Neelkanth peels caused a 41.09% loss in average DPPH values from the raw counterparts. Recently, Azizi et al.[3] reported 4.38 to 34.26% reduction in CUPRAC values of potato peel upon boiling in four potato cultivars studied (Kufri Chipsona 1, Kufri Chipsona 4, Kufri Bahar and Kufri Jyoti). Increase in DPPH levels of citrus waste have been reported by Esparza-Martinez[26], *et al*. upon drying at higher temperature (120°C). Deng[27], *et al*. observed highest DPPH and FRAP values in orange peels dried at 65 °C in comparison to lower and higher temperatures. Ho and Lin[28] also reported an increase in the radical scavenging activity with drying time.

Drying at low temperature (i.e. shade drying, 40 and 50 °C) obtained lower antioxidant activity values when compared to higher temperature (60-70 °C) or microwaving. Lower drying temperature implies longer time of exposure of the food matrix to the particular temperature to attain the desired moisture level resulting in greater loss of antioxidants by oxidation. Similar observations were noted by Kuljarachanan et al.29 in citrus waste. The data shown in Table 2 clearly indicates that TAC in terms of FRAP, ABTS and DPPH enhanced upon boiling. Such a trend depicts presence of compounds other than phenolics in the potato peel that may contribute to the antioxidative property of peels. Overall, in our study, greatest retention of antioxidant activity was observed for potato peels dried using microwaves. This might be due to the high vapour pressure developed in the peel tissue due to the intense, instant and uniform heat generated by the microwaves resulting in disruption of polymer matrix and release of bound bioactives. Previously, Vu et al.18 observed that banana peels dried using microwave retained highest antioxidant capacity in terms of DPPH scavenging ability, ABTS and FRAP values.

3.5.4 Metal Chelation and Reducing Power

The total antioxidant activities of potato peel developed using different drying conditions were also evaluated using metal chelation and reducing power as shown in (Figs 3 and 4). The human body needs a steady supply of antioxidants to combat oxidative stress caused by the formation of free radicals. Several radical reactions may commence as a result of presence of ferrous (Fe^{2+}) ion. Therefore, chelation of iron is a probable approach to reduce the oxidative stress. Of the four potato cultivars studied, microwave dried peels of raw Kufri Neelkanth yielded the highest (434.55%) average metal chelating ability. Peels from all cultivars demonstrated a reduction in their metal chelating ability after boiling.

Table 2 Total antioxidant activity of dried potato peel extracts

Cultivar/ Drying procedure	FRAP (µmole TE/g)		ABTS (µmole TE/g)		DPPH (µmole TE/g)	
	Raw	Boiled	Raw	Boiled	Raw	Boiled
KC1-SD	7.72^{opqr}	20.90^{d}	12.82^{cd}	41.76f^{fg}	1.71^{sr}	3.56^{ed}
KC1-40	5.10^{uvw}	16.79e	11.97^{ed}	40.21^{g}	1.75^{r}	3.25^{gf}
KC1-50	6.00 ^{stuvw}	11.84^{hij}	18.47^{xyz}	60.25^{c}	1.66^{rst}	2.70^{jkl}
KC1-60	10.63^{ijkl}	10.84^{hijk}	17.39^{xyz}	25.05^{nopq}	1.18^{vwxyz}	2.62^{jkl}
KC1-70	4.94^{vw}	5.72 ^{stuvw}	13.03^{cd}	21.89^{stur}	1.01^{wxyza}	1.15 ^{vwxyz}
KC1-MW	9.44 ^{klmn}	11.73^{hij}	14.71^{abc}	32.26^{i}	1.39^{tuv}	3.22^{fg}
KC1-R	7.04^{pqrs}	8.69^{o}	13.40^{cd}	28.58^{lk}	0.92^{za}	2.12^{mnop}
KC4-SD	6.61^{ustr}	20.16^{d}	14.46^{cb}	70.97^{a}	1.57^{rstu}	5.91^{b}
KC4-40	11.40^{hij}	16.82^{e}	30.93^{ij}	31.99^{i}	0.95^{za}	1.85 ^{vwxyz}
KC4-50	5.20^{tuvw}	8.54^{nop}	16.76^{yz}	21.39^{stu}	2.09^{mnopq}	2.97^{ghi}
KC4-60	10.70^{ijk}	13.92^{g}	22.96^{rst}	31.24^{ij}	2.48^{kl}	3.01^{gh}
KC4-70	6.69^{qrst}	8.98^{mno}	16.10^{zab}	25.72^{mnop}	1.33^{uvw}	1.82^{pqr}
KC4-MW	4.87^{vw}	11.42^{hij}	16.87^{yz}	29.73^{jk}	0.52^{c}	2.57^{jkl}
KC4-R	2.68^{x}	8.31^{opn}	12.30^{ed}	21.07^{tuv}	0.41^{c}	1.79^{rq}
KF-SD	6.32^{sturv}	22.91^{c}	19.01^{wx}	52.00^{d}	1.71^{sr}	4.74^{c}
KF -40	10.51^{jklm}	14.83^{fg}	22.08^{rstu}	52.98^{d}	1.40^{tuv}	1.84^{opqr}
KF -50	9.12l^{mno}	15.36^{efg}	21.82^{stur}	42.72^{f}	1.45^{stuv}	2.12^{mno}
KF -60	12.35^{h}	16.89^{e}	16.67^{zya}	39.92^{g}	1.72^{sr}	3.33^{ef}
KF -70	6.38^{sturv}	16.29^{ef}	30.39^{ijk}	48.49^{e}	1.27^{vwx}	3.66^{d}
KF -MW	6.05^{stuvw}	8.71^{o}	35.40^{h}	67.69^{b}	3.77^{d}	4.85^{c}
KF-R	0.24^{y}	4.99^{vw}	25.82^{mno}	26.07^{mn}	0.58^{bc}	1.13^{vwxyz}
KN-SD	11.80^{hij}	16.44^{e}	23.13^{rst}	33.7^{l}	2.10^{mnop}	1.74^{rs}
KN-40	4.89^{vw}	8.63^{on}	11.75^{ed}	27.68l^{m}	0.92^{za}	1.25^{vwxy}
KN-50	9.74^{klmn}	10.62^{ijkl}	23.40^{qsr}	30.63^{ij}	2.36^{lm}	1.30^{uvw}
KN-60	11.37^{hij}	12.13^{ih}	31.16^{ij}	37.52^{gh}	2.83^{ijh}	1.18^{nopqr}
KN-70	8.21^{nopq}	8.77^{o}	21.68^{stur}	29.76^{jk}	1.76^{r}	2.15^{nm}
KN-MW	30.29^{b}	36.47^{a}	44.20^{ef}	45.90^{e}	8.81^{a}	3.19^{gf}
KN-R	1.93^{x}	4.60^{w}	14.23^{bc}	20.90^{tuv}	0.97^{xyz}	0.83^{ab}

Among the drying temperatures applied, cabinet drying at 60-70 °C were most effective to get maximum chelation ability of the raw peel extracts (Fig. 3). Due to presence of an electron pair, phenolic molecules are more favoured by electrophiles (Fe^{2+}). A loss in phenolics therefore, results in a reduction in metal chelating activity. Therefore, across drying procedures similar trend was observed for metal chelation ability

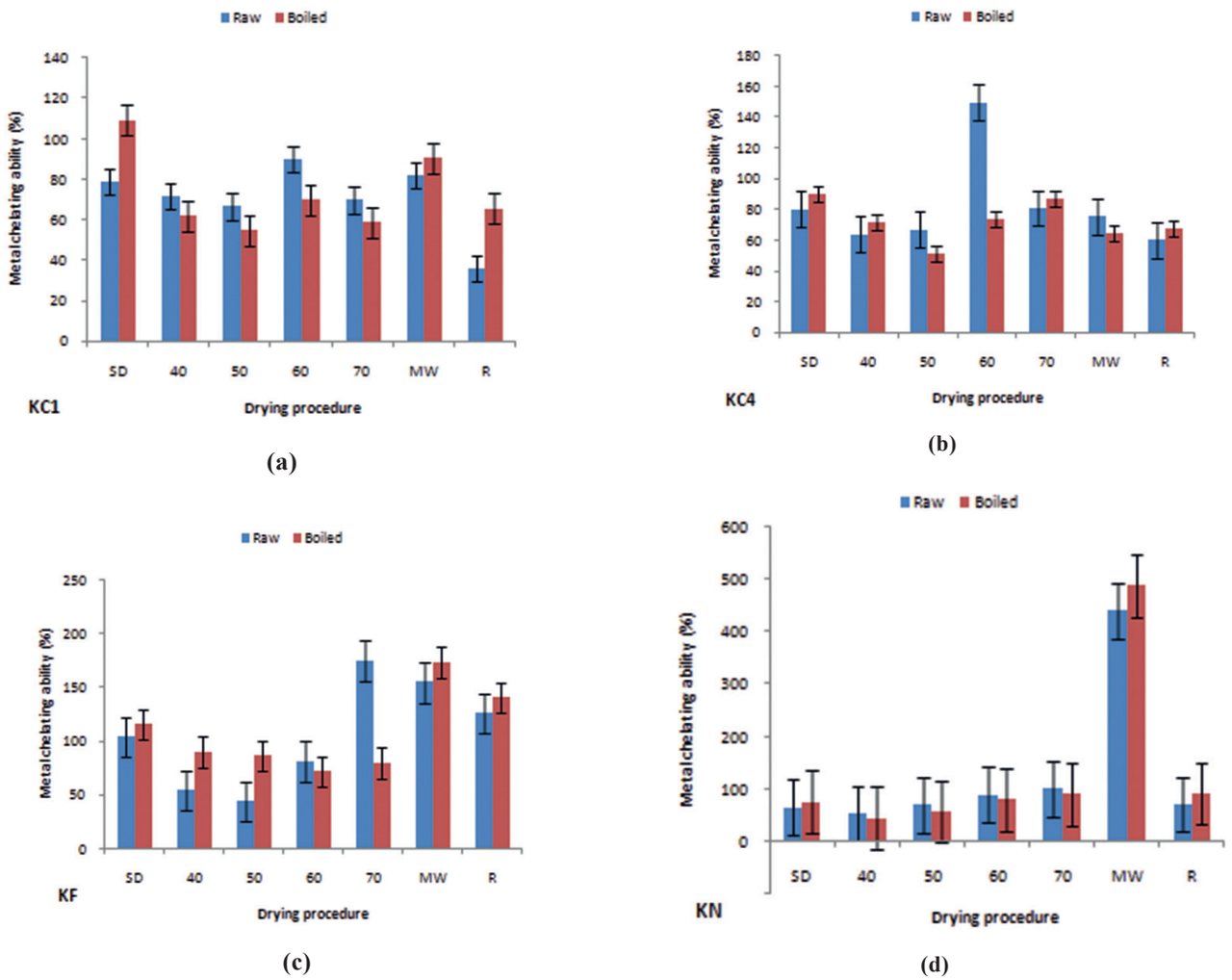
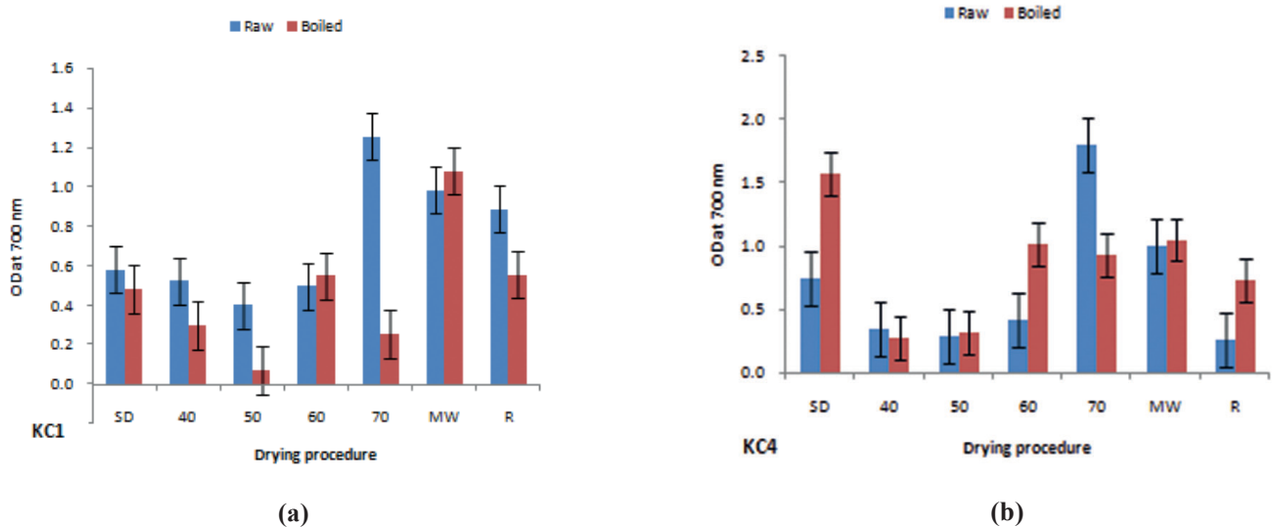


Figure 3 (a-d). Metal chelation ability of potato peel subjected to different drying treatments.

(SD: Shade drying; KC1: Kufri Chipsona; KC4: Kufri Chipsona 4; KF: Kufri Frysona; KN: Kufri Neelkanth; MW: Microwaved; R: Roasted; 40, 50, 60, 70: Cabinet drying temperatures, °C). Values are means±standard error (n =3).



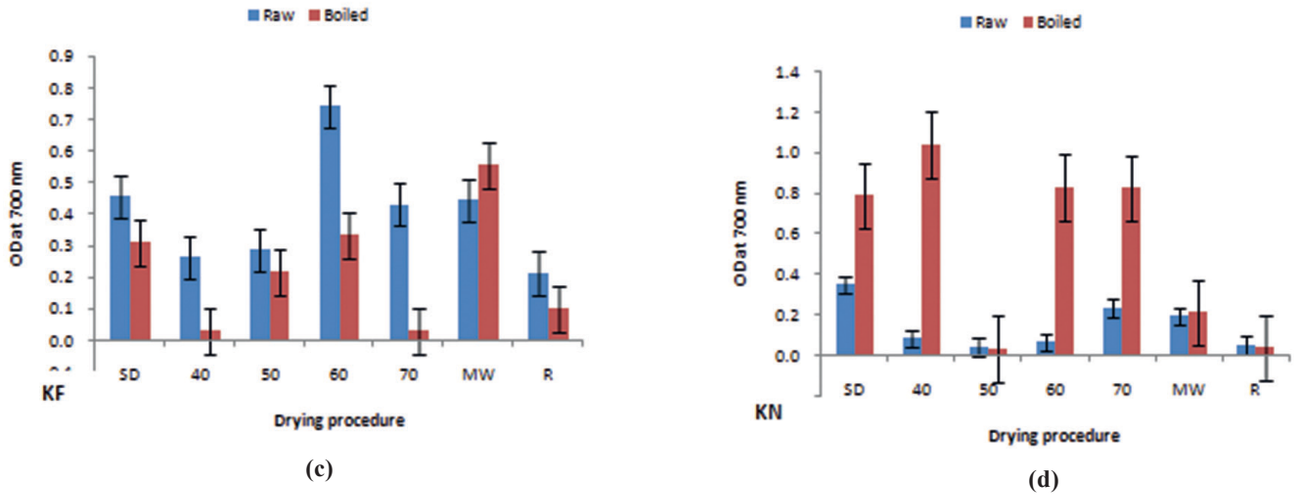


Figure 4 (a-d). Reducing power of potato peel subjected to different drying treatments.

(SD: Shade drying; KC1: Kufri Chipsona; KC4: Kufri Chipsona 4; KF: Kufri Frysona; KN: Kufri Neelkanth; MW: Microwaved; R: Roasted; 40, 50, 60, 70: Cabinet drying temperatures, °C) Values are means ± standard error (n =3).

and extractable phenolics.

Several studies have reported an association of reducing power of bioactive molecules with the antioxidant activity.[30-31] The reducing power of a compound is related to the electron donating ability of the compound that plays a crucial role in the interruption of the free radical reaction. Greater the absorbance, greater is the reduction potential of the compound. In case of reducing power also, drying of raw peels at higher temperatures of 60-70 °C proved beneficial for maximum retention (Fig 4). In general, boiling had a negative influence on the reducing ability of the peel extracts irrespective of the drying method employed except Kufri Neelkanth.

Maximum average reducing power was found in Kufri Chipsona 1 raw peels (0.73) while minimum values were observed for boiled Kufri Frysona (0.22) peels. Being electron donors, phenolics majorly govern the reducing power of the potato peel. The loss of phenolics upon boiling has thus led to a reduction in the reducing ability of the peel extracts.

4. CONCLUSIONS

Potato peel is a zero value resource composed of phytochemicals, hence, focus needs to be shifted towards extraction of these compounds. To the best of our knowledge, this is the first report that deals with identification of feasible drying procedure of potato peel for the purpose of retention of bioactives. We report here the potato peel to be a source of phenolics, flavonoids and antioxidants which showed high variability among cultivars. All the peel extracts studied showed antioxidant potential, although in different capacities. Boiling as a pretreatment was useful for retention of antioxidant activity in Kufri Chipsona 1, Kufri Chipsona 4 and Kufri Frysona, but not for cultivar Kufri Neelkanth. Significant effects of drying methods on phenolic content and antioxidant capacity of the dried potato peel were observed. It is worth mentioning that among the drying procedures studied, microwave drying is the best for utilization of potato peel as a source of phenolics, flavonoids and antioxidants. High temperature speeds up the drying process and prevents the oxidative deterioration of phytochemicals. Although, shade drying also proved to be a suitable method for better retention of phytoceuticals, but its adoption on a commercial scale may not be feasible due to additional space and time requirement. Our study shows that potato peel from Kufri Neelkanth (raw) and Kufri Frysona (both raw and boiled) are best source of phenolics and flavonoids and can serve as a suitable matrix for extraction of bioactive compounds which holds promise for use in the food industry.

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