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POTATO PEEL: A WONDERFUL SOURCE OF POLYPHENOLS DUE TO HIGHER BIOACCESSIBILITY

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ABSTRACT: Type and concentration of various antioxidants present in potato peel is well reported. However, bioaccessibility of potato peels' antioxidants, particularly polyphenols has not been reported yet. Therefore, present study aimed at evaluation of bioaccessibility of polyphenols and carbohydrates from peel of Kufri Chipsona-1 (processing variety); Kufri Jyoti and Kufri Bahar (table varieties). *In-vitro* bioaccessibility of total polyphenols, chlorogenic acid, caffeic acid and rutin revealed that bioaccessibility of total and individual phenols is maximum in the gastric phase. On average, the release of chlorogenic acid, caffeic acid and rutin was 3, 18 and 1.1 folds higher in intestinal phase compared to their content in undigested peel, respectively. Starch decreased from oral to intestinal phase with concomitant increase in sugars. Though potato peel is known to contain high concentration of polyphenols, the bioaccessibility of chlorogenic acid and caffeic acid is many folds higher than the ranges reported through biochemical procedures in undigested peels. Potato peel has a huge potential to be used as a fortificant in development of various food products not only due to presence of high concentration of polyphenols but also because of their high bioaccessibility that can help to improve the health of consumers.

KEY WORDS: Potato peel, polyphenols, carbohydrates, *in vitro* bioaccessibility.

INTRODUCTION

Potato is one of the major cash crops in many provinces of India. Besides being a main source of carbohydrates, it is also a good source of vitamin C, polyphenols and minerals. Potato is used majorly as vegetable in cooked form either alone or in combination with the other vegetables. Conventionally, potato peel is removed before processing the potatoes into different products. Thus potato processing industries generates a lot of peel waste with no value. Depending on the peeling method, losses in form of potato peel waste can vary from 15 to 40% in processing industry (Arapoglou *et al.,* 2010). However, potato peels contain lot of nutritional and phytochemical components such as dietary fibre, antioxidants and polyphenols etc. Almost 50% of the potato polyphenols are located in potato peel and adjoining tissues and concentration of polyphenols decreases towards tuber pith (Al-Weshahy and Rao, 2009). Potato peel can be used as natural antioxidants in food system due to high polyphenol content, which was reported 10 times higher than their levels in potato flesh. Potato peel phenols show higher radical scavenging activity as compared to potato tuber (Nara *et al.,* 2006). Phenolic compounds present in human diet prevents degenerative diseases, render positive effects on certain types of cancer, cardiovascular diseases, various inflammatory disorders and thus, value added use of this by-product is

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of great interest to potato industry (Shahidi, 2000; Birt, 2006). Interestingly, chlorogenic acid is significantly high in potato peels as compared to potato flesh. Chlorogenic acid constitutes 90% of total phenolic compound in potato peel and is known to function as an antioxidant and insulin sensitizer and exhibit anti-inflammatory properties (Chaplick *et al.*, 2010). Caffeic acid also shows immunomodulatory and anti-inflammatory activity (Park *et al.*, 2004).

Potato peel is also good source of dietary fibre consisting of insoluble carbohydrates such as cellulose, hemicellulose, lignin, pectin and gums (Camire *et al.*, 1997). Oxidative deterioration of fats and oils causes rancid odours and flavors, decrease the nutritional quality and leads to formation of secondary toxic compounds which has adverse effects to human health. Therefore, addition of antioxidants in processing is an important step to preserve flavour and to prevent nutrient loss and thus, potato peel can be an alternate substitute for synthetic antioxidants and can be used as natural antioxidant without any harm to human health.

Bioaccessibility can be defined as amount of compound released from the food matrics, solubilised in the small intestine and available for subsequent absorption (Tagliazucchi *et al.*, 2010). Studies regarding bioaccessibility of phytochemical compounds require *in-vivo* experiments with humans. However, *in-vitro* studies have proven to be useful in determining the behaviour changes and stability of phytochemicals under gastrointestinal (GI) conditions as it is cost effective, have no ethical issues, almost mimic the ideal human conditions by simulated GI models (Thakur *et al.*, 2020). Though various reports are present indicating potato peel as a good source of phytonutrients, but to the best of our knowledge, there are no studies reported, regarding bioaccessibility/ changes during *in-vitro* GI digestion of phytochemicals and other nutritional compound present in potato peel. Various reports have suggested utilization of potato peel as a fortificant due to high antioxidant concentration, however, information is lacking on the behaviour of potato peels' antioxidants and carbohydrates; and extent of their release during digestion. Thus, effect of *in-vitro* gastrointestinal digestion on potato peels' antioxidants (total polyphenols, chlorogenic acid, caffeic acid, rutin) and carbohydrates (starch, reducing sugars, sucrose) was evaluated to establish nutritional value of potato peel. In the present study, Indian potato cultivars viz. Kufri Jyoti, Kufri Bahar and Kufri Chipsona 1 were used. Among these, Kufri Jyoti and Kufri Bahar are quite popular and consumed at large scale in India. These two are the table purpose varieties and each of these has occupied almost 30% of the cultivated area under potato. Kufri Chipsona 1 being processing cultivar is used by both organized and unorganized sector for preparation of chips and other value added products. Because of more use of these varieties, there will be more wastage of peels.

MATERIALS AND METHODS

Reagents

HPLC grade methanol and HPLC grade acetic acid, Folin-Ciocalteau reagent, Bovine Serum Albumin Fraction V and glucose was purchased from Merck. Chlorogenic acid, caffeic acid, rutin, pepsin (675U/mg) from porcine, α-amylase (13U/mg) from porcine, bile salt, pancreatin was purchased from Sigma Aldrich. All the other reagents and chemicals of analytical grade were purchased from Himedia.

Sample collection and preparation

Freshly harvested tubers of potato variety Kufri Jyoti (used as both table and processing variety), Kufri Bahar (table variety) and Kufri Chipsona 1 (processing variety) were

procured from Central Potato Research Institute, Modipuram, Meerut, UP, India (29° 05'19'' N, 77° 41'50'' E, 237 m asl) during 2019. Tubers were washed with tap water to remove macroscopic impurities, surface dried and peeled manually. Fresh peel of all varieties was used for *in-vitro* digestion and biochemical estimations {total polyphenols, reducing sugars, sucrose, total starch and individual phenols (chlorogenic acid, caffeic acid and rutin)} in both digested (oral, gastric intestinal) and undigested samples. Results are reported on fresh weight basis.

Sample extraction and analysis

Extractions from undigested samples for reducing sugars, sucrose and total starch were carried out as mentioned by Raigond *et al.* (2014). For estimation of polyphenols, the method described by Thimmaiah (2000) was adopted.

Extraction of Individual phenols: Extraction of potato peel for individual phenols was carried out as per method described by Albishi *et al*. (2013) with some modifications. Fresh peel (1g) was ground in 5ml of methanol/ water/ glacial acetic acid (80:19.5:0.5 v/v/v) solution. Sample was sonicated for 15min and centrifuged at 9000 rpm for 10 min at 4°C. Supernatant was collected and residue was again extracted with 2ml of methanol/ water/ glacial acetic acid (80: 19.5:0.5 v/v/v) solution and centrifuged. Both supernatants were pooled together. Supernatants were freeze dried in lyophilizer (-56°C, 4.0 mbar, Christ, Germany). Residue was re-suspended in 1ml of water: methanol (90:10v/v) solution, vortexed and filtered through 0.2µm PVDF filter.

In-vitro digestion of polyphenols, individual phenols, reducing sugar and sucrose

The *in-vitro* GI digestion process was followed as per the method described by Miranda *et al*. (2013) with slight modifications. Potato peel (2g) was used for *in-vitro* digestion and digestions were performed in triplicate.

Oral Phase

Oral digestion was performed by adding 5ml of α-amylase from porcine pancreas (450U/g of potato peel) dissolved in 0.9% sodium chloride (pH 6.9 with 1N sodium hydroxide) in 2g of potato peel. Sample was ground in presence of α-amylase to mimic oral conditions. After 2 min of incubation at 37°C samples were centrifuged for 10min at 10,000 rpm and aliquot (approximately 1ml) was collected for further analysis.

Gastric Phase

Gastric phase was started by adding 9ml of pepsin (from porcine gastric mucosa) solution (pepsin 6500U/g of potato peel prepared in 0.9% sodium chloride solution) to the oral solution. Then the pH was decreased to 2 with 6M hydrochloric acid and mixture was incubated in incubator shaker at 37°C for 1 hr with continuous agitation. Sample was centrifuged for 10 minutes at 10,000 rpm. Aliquot (approximately 1ml) was collected for further analysis and remaining sample was used for intestinal phase.

Intestinal Phase

The pH of solution was brought to 5.5 using 1M sodium bicarbonate and intestinal digestion was simulated by addition of bile extract (11mg/g of potato peel) and pancreatin (from porcine pancreas) (1.8mg/g of potato peel) for 2 hour at 37°C. Final digestion extract was centrifuged at 10,000 rpm for 10 min and aliquot was used for analysis.

In-vitro starch digestion

In-vitro starch digestion was carried out in the same manner as discussed above. In case of starch digestion, reaction was terminated

at the end of each phase i.e oral, gastric and intestinal phase. After centrifugation step, the residues were washed twice with 10ml of 80% ethanol to remove excess sugars and supernatant was drained carefully every time. Residue left after washing was extracted with 11.5ml of 52% perchloric acid and centrifuged at 10,000 rpm for 10 min. Supernatant was collected and volume was adjusted to 50ml with distilled water.

Analysis of oral, gastric and intestinal aliquots

Total polyphenols:

Total polyphenols were estimated as per the method described by Malik and Singh (1980). To 50µl of aliquot collected from three phases, 950 µl distilled water was added. To this, 0.5ml of phenol reagent (Folin-Ciocalteu) was added, vortexed and incubated for 3 minutes at room temperature. Further, 2ml of 20% sodium carbonate was mixed, incubated for 1 hr (room temp) and absorbance was recorded at 650nm (Spectrophotometer, Model-4001/A, ThermoSpectronic, USA). Standard curve was prepared using 1mg/ml chlorogenic acid as stock solution.

Individual phenols:

Aliquots (oral/ gastric/ intestinal) were filtered through PVDF membrane (0.2µm) before further analysis. Quantification of individual phenols was carried out as per the method of Albishi *et al*. (2013) using HPLC. A reverse phase column (125 × 4mm Purospher RP-18e, Merck, Germany) was used on the LaChrom HPLC system (Merck-Hitachi Darmstadt, Germany). Individual phenols were estimated at wavelengh of 324nm and injection volume of 20µl was used for analysis. Gradient was used where Mobile phase A contained 1% formic acid in water and mobile phase B consisted of methanol. Gradient composition of two mobile phases was as follows: 0 min-95% A; 2.5 min-84% A; 5 min-73% A; 7.5 min-62% A; 10 min-50% A; 12.5 min-40% A; 15 min-30% A, 17.5 min-25% A; 20 min-20% A; 22.5min-10% A and 25 min-95% A. Stock solution was prepared by using standard chlorogenic acid, rutin and caffeic acid at 1mg/ ml methanol concentration.

Reducing Sugars:

To 50µl of aliquot (oral/ gastric/ intestinal) 950µl of distilled water was added followed by addition of 1ml of Nelson reagent. Samples were boiled for 20 min (60-80°C) and then placed in cold water. After the samples were cooled, 1ml arsenomolybedate solution was added, vortexed and kept for 5 min at room temperature. Distilled water (7ml) was added to the above sample and absorbance was recorded at 620nm (Spectrophotometer, Model-4001/A, ThermoSpectronic, USA). Standard curve was prepared using 1mg/ml dextrose as stock solution.

Sucrose:

To 100µl of aliquot (oral/ gastric/ intestinal) 900µl of distilled water was added followed by addition of 100µl of 30% KOH. The above solution was boiled for 10 min (60-80°C) and placed in cold water. To the above solution, 3ml of 0.15% anthrone reagent (prepared in 76% sulphuric acid) was added. Samples were incubated for 15 min at 40°C and absorbance was recorded at 620 nm (Spectrophotometer, Model-4001/A, ThermoSpectronic, USA). Standard curve was prepared using 1mg/ml sucrose as stock solution.

Total Starch:

To 50µl of aliquot (oral/ gastric/ intestinal) 950µl of distilled water was added followed by addition of 2 ml of 0.2% anthrone reagent (prepared in 95% sulphuric acid). Samples were boiled for 8 min (60-80°C) and cooled to room temperature. Absorbance was recorded at 620nm (Spectrophotometer, Model-4001/A,

ThermoSpectronic, USA). Standard curve was prepared using 1mg/ml glucose as stock solution.

Statistical Analysis

A completely randomised design was used for each biochemical parameter having three replications. The data were analysed using MSTAT 4.0C software and the procedure of Gomez and Gomez (1984). Differences between means were compared using Tukey's test ($P < 0.05$). Different letters have been used to indicate significant differences between the varieties and phases ($P < 0.05$).

RESULTS AND DISCUSSION

Bioaccessibility of polyphenols

Total polyphenols

Significantly higher concentration of total polyphenols was obtained in undigested peel of K. Jyoti (95 mg/100g) followed by K. Chipsona 1 (70 mg/100g) and K. Bahar (52 mg/100g) on fresh weight basis (Fig. 1). After *in-vitro* GI digestion significant decrease was observed in total polyphenolic content in oral, gastric and intestinal phases in peel of all varieties, however, polyphenols were highly bioaccessible in gastric phase followed by intestinal and oral phase (Fig. 1). The bioaccessible phenolic content in oral phase was 37 mg/100g, gastric phase was 43 mg/100g and intestinal phase was 38 mg/100g (average of three varieties).

Higher range of total phenols in peel of K. Chipsona 1 (148 mg/100g fresh weight (FW)) and K. Jyoti (148 mg/100g) was reported by Bandana *et al.* (2016). However, almost similar range was obtained for potato peel extract (70.82 mg of catechin equivalent/100 g) by Kanatt *et al.* (2005). Freeze dried potato peel extract was found to contain total polyphenols ranging from 1.5 to 3.3 mg of gallic acid equivalent/gram (Al-Weshahy and Rao, 2009). In another study, Albishi *et al.* 2013 reported that total phenolic content in freeze dried potato peel ranged from 4.54 to 13.85 (mg GAE/g) and in flesh varied from 1.36 to 2.09 mg GAE/g, respectively. Our results of *in-vitro* GI digestion are in accordance with those reported by Miranda *et al.* (2013), who reported more release of polyphenols from boiled potatoes in

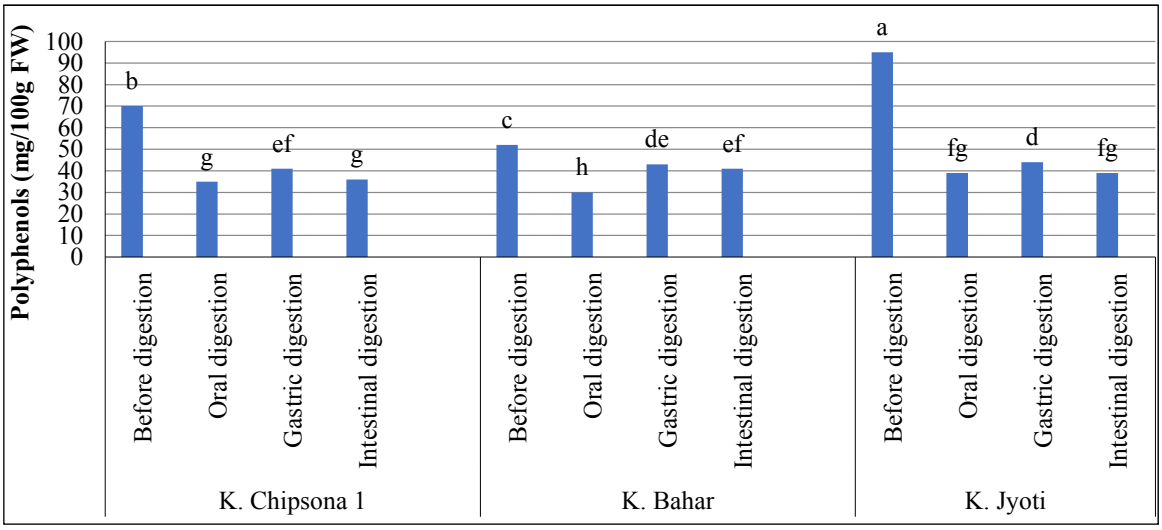


Fig. 1: *Changes in total polyphenols (mg/100g FW) during in-vitro gastrointestinal digestion of potato peel. Different letters indicate significant differences between varieties and phases (p< 0.05).*

gastric phase. Simulated *in-vitro* digestion of orange peel treated with pulse electric field and high voltage electrical discharge decreased the concentration of total phenols compared to non-digested sample. Decrease was non-significant in gastric phase, whereas significant decrease in phenol concentration was observed in intestinal phase and non-dialysed sample as compared to undigested sample (Buniowska *et al.*, 2015). After *in-vitro* GI digestion of pomegranate peel flour, the total polyphenols decreased in oral, gastric and intestinal phase as compared to the test sample before digestion. The recovery percent of total polyphenols in pomegranate peel flour was maximum in oral phase (69%) followed by gastric phase (65%) and intestinal phase (43%) indicating that maximum degradation occurred during intestinal phase. Bioaccessibility of phenolic and flavonoid compounds in pomegranate peel flour at the end of intestinal digestion was found to be 35.90 and 64.02% respectively (Gullon *et al.*, 2015). Argyri *et al.* (2006) reported that solubility and availability of phenolic compounds are greatly influenced by pH conditions and interaction with dietary constituents, such as iron, fibre or proteins. Results suggested that several changes in phenolic compounds such as modification in chemical structure, increased or reduced solubility or interaction with other compounds might have happened during the GI digestion of potato peel which influenced the phenol bioaccessibility in different phases.

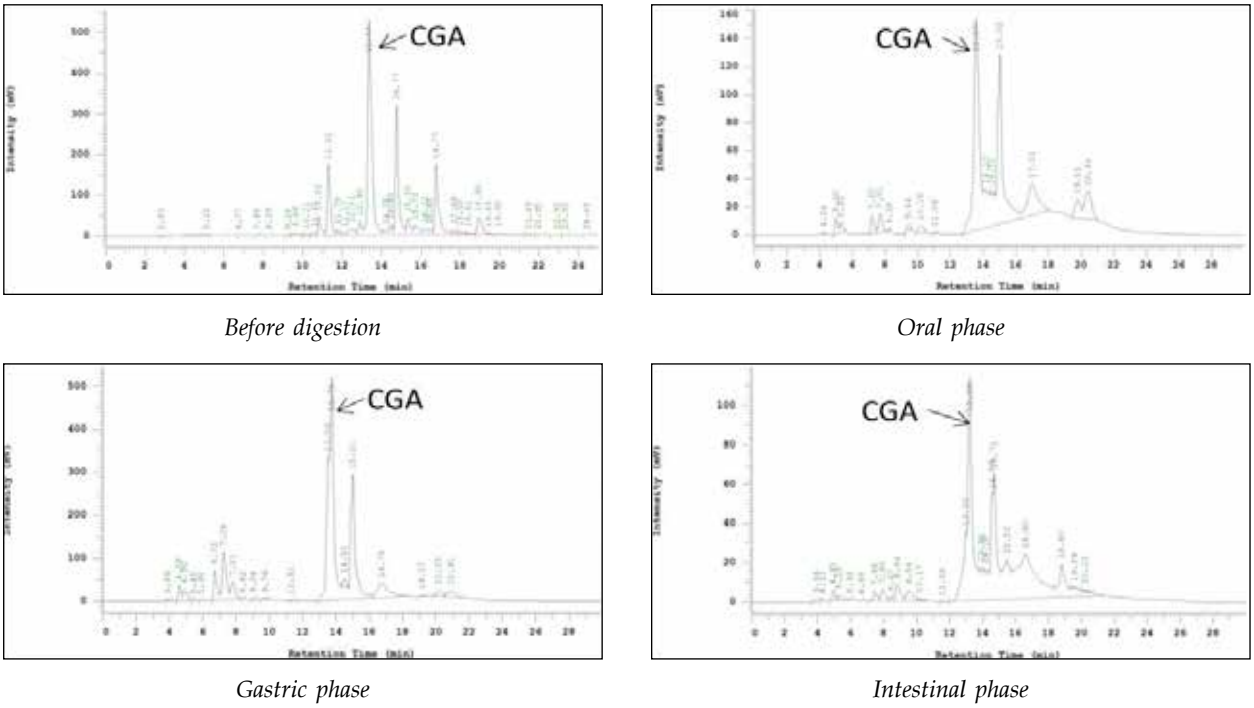
Chlorogenic acid, caffeic acid and rutin

Chlorogenic acid was found to be the most dominant individual phenol in potato peel. Peel contained significantly higher concentration of chlorogenic acid (87 µg/g FW) followed by rutin (24 µg/g FW) and caffeic acid (6 µg/g FW) (average of varieties) (Fig. 2, Table 1). *In-vitro* digestion significantly increased the release of chlorogenic acid, caffeic acid and rutin with maximum bioaccessibility observed in gastric phase (Table 1). Irrespective of the varieties, chlorogenic acid and rutin showed maximum bioaccessibility and trend was gastric phase> oral phase > intestinal phase. However, in case of caffeic acid trend in K. Chipsona 1 and K. Jyoti was gastric phase> intestinal phase > oral phase. Overall average significant increase in chlorogenic acid was 3 folds in intestinal phase (262 µg/g FW) after *in-vitro* digestion. Caffeic acid on an average increased to 18 folds (102 µg/g FW) in intestinal phase. Rutin increased significantly

Table 1: *In-vitro* gastro intestinal digestion of potato peel individual phenols (µg/g FW)

Individual Phenols	Treatment	Before Digestion	Oral Phase	Gastric Phase	Intestinal Phase
Chlorogenic acid	K. Chipsona 1	85 $^{(j)}$	333 $^{(d)}$	484 $^{(a)}$	211$^{(h)}$
	K. Bahar	76 $^{(j)}$	321 $^{(e)}$	362 $^{(c)}$	264 $^{(g)}$
	K. Jyoti	101$^{(i)}$	327 $^{(de)}$	383 $^{(b)}$	310 $^{(f)}$
Caffeic acid	K. Chipsona 1	3.08 $^{(i)}$	82 $^{(f)}$	162 $^{(a)}$	141$^{(b)}$
	K. Bahar	0.43 $^{(i)}$	78 $^{(f)}$	66 $^{(g)}$	55 $^{(h)}$
	K. Jyoti	2.20 $^{(i)}$	103 $^{(e)}$	125 $^{(c)}$	110 $^{(d)}$
Rutin	K. Chipsona 1	45.0 $^{(h)}$	202 $^{(d)}$	290 $^{(a)}$	24 $^{(j)}$
	K. Bahar	5.9$^{(k)}$	172 $^{(f)}$	252 $^{(b)}$	33 $^{(i)}$
	K. Jyoti	21.0$^{(j)}$	143 $^{(g)}$	180 $^{(e)}$	25 $^{(j)}$

Different letters indicate significant differences between varieties and phases ($P < 0.05$). Statistical analysis of chlorogenic acid, caffeic acid and rutin was carried out separately.



Before digestion *Oral phase*

Gastric phase *Intestinal phase*

Fig. 2: *HPLC Chromatograms of polyphenolics obtained from raw potato peel and during various phases of digestion of raw peel (CGA-Chlorogenic acid)*

to 1.1 folds (27 µg/g FW) in intestinal phase. Miranda *et al*. (2013) reported 5 folds increase in chlorogenic acid in variety Vitelotte and 2.3 folds increase in variety Nicola from boiled potatoes to gastric filtrate. Caffeic acid was reported more in intestinal phase in variety Nicola and in case of variety Vitelotte the content was more in gastric phase followed by intestinal and oral phase. Peel from two of our varieties i.e K. Chipsona-1 and K. Jyoti showed similar trend for caffeic acid as reported by Miranda *et al*. (2013).

Sukrasno *et al*. (2014) reported that fresh potato peel contained approximately 1.0 mg/g (0.1 %) of chlorogenic acid, whereas Kanatt *et al*. (2005) reported chlorogenic acid to be 25mg/100g. Wu *et al*. (2012) quantified phenolic compounds from potato peel and flesh for two consecutive years and reported that chlorogenic acid content was 3.87 and 1.26 mg/g dry powder in potato peel and 1.0 and 0.60 mg/g dry powder in potato flesh during both years. Caffeic acid content was 2.23 and 0.72 mg/g dry powder in potato peel during both years, however, caffeic acid was not detected in potato flesh indicating that potato peel contained higher amount of phenolic compounds than flesh. Chlorogenic acid and caffeic acid content in freeze dried potato peel ranged from 16 to 307 mg /100g and 23 to 66 mg /100g as reported by Albishi *et al*. (2013). In a study conducted by Rowayshed *et al*. (2015) chlorogenic acid was found to be 21 mg/100g DW and caffeic acid was 12 mg/100g DW in potato peel extract.

Our results of chlorogenic acid, caffeic acid and rutin behaviour during *in-vitro* GI are similar to those reported by Miranda *et al.* (2013). However, in a study carried out by Colantuono *et al.* (2016) *in-vitro* bioaccessibility of phenols from pomegranate peel (PPe) and pomegranate peel cookies (PPeC) showed different trend than the

present study. During simulated *in-vitro* digestion of PPe, maximum bioaccessible amount of total polyphenols was found in oral phase (3278 mg/100g) followed by gastric phase (2502 mg/100g) and intestinal phase (1483 mg/100g). Pomegranate peel cookies have maximum amount of polyphenols in oral phase (223 mg/100g) followed by intestinal phase (154mg/100g) and gastric phase (62 mg/100g). The concentration of the polyphenols at each digestion step was associated with the total antioxidant capacity of the potentially bioaccessible compounds. The difference in phenol release trend could be due to difference in the food matrix.

The study indicated that the concentration of polyphenols being estimated from tubers (peel and flesh) is far low than the concentration of polyphenols that is released during digestion and is actually available/ bioaccessible for body. Digestion of proteins during gastric step may be responsible for more release of polyphenols that are available for body to be absorbed. This study has shown that the intake of polyphenols from potato peel might be quite high compared to the quantified concentrations reported from potato peel.

Bioaccessibility of carbohydrates

Total starch

Total starch in potato peel ranged from 12 to 15% (FW) before digestion and decreased significantly during *in-vitro* digestion (Fig. 3). Concentration of total starch was the maximum before digestion, and decreased from oral to intestinal phase. Average decrease in the total starch during *in-vitro* GI digestion was 92%, 94% and 96% in oral, gastric and intestinal phase, respectively. Bandana *et al.* (2016) reported 12.6 and 13% (FW) total starch in raw peel of K. Chipsona 1 and K. Jyoti, respectively. In another study, Arapoglou *et al.* (2009) reported total starch content to be 7.8% in raw potato peel. The decrease in starch content in gastric and intestinal phase is due to presence of digestive enzymes that lead to starch breakdown and release of sugars. Our results of starch hydrolysis are in accordance with those reported by Singh *et al*. (2020) and Tian *et al.* (2018), who reported more starch hydrolysis in intestinal phase compared to gastric phase.

Sugars

Reducing sugars ranged from 199 to 223 mg/100g FW in peel of three varieties (Fig. 4).

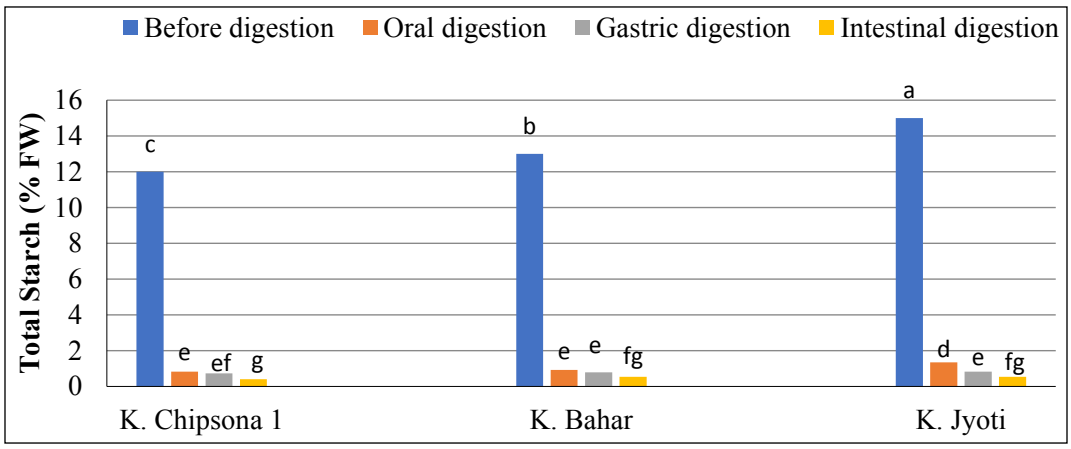


Fig. 3: *Total starch during in-vitro gastrointestinal digestion of potato peel. Different letters indicate significant differences between varieties and phases (p< 0.05).*

Significant increase was observed in reducing sugar after *in-vitro* digestion and maximum amount of reducing sugars was obtained in intestinal phase compared to gastric and oral phase. Varieties K. Chipsona 1 and K. Jyoti showed similar trend for reducing sugars as intestinal phase> gastric phase> oral phase, however, in K. Jyoti, the order of release of reducing sugar was oral phase> intestinal phase> gastric phase. Overall 7 folds (intestinal phase) increase in reducing sugars was noticed in potato peel during *in-vitro* digestion compared to undigested samples.

Average 114 mg/100g FW sucrose was reported in undigested potato peel (Fig. 4). Sucrose was found to be significantly increased after *in-vitro* GI digestion. Maximum amount of sucrose was bioaccessible in intestinal phase followed by gastric and oral phase. Similar trend was noticed in all the three varieties and average increase during digestion was 4.9 folds (555mg/100g) in intestinal phase.

Bandana *et al.* (2016) reported 35 and 26 mg/100 FW of reducing sugars in peel of K. Chipsona 1 and K. Jyoti and similar range of sucrose in peel of K. Chipsona 1 (98 mg/100FW) and K. Jyoti (73 mg/100g FW). The study indicated that the starch content decreased from oral to intestinal phase with concomitant increase in sugars. Starch hydrolysis starts from oral phase itself due to presence of α amylase in salivary solution. Further hydrolysis in gastric phase occurred due to acidic conditions of gastric phase. In intestinal phase, presence of pancreatin further leads to breakdown of starch. During each phase enzymatic/acidic hydrolysis of starch resulted in release of sugars. Singh *et al.* (2020) reported similar trend for reducing sugars as reported in the present study.

CONCLUSION

Results showed that potato peels contain significantly higher levels of antioxidants such as total polyphenols, chlorogenic acid, caffeic acid and rutin. The present study indicated that these antioxidants are highly bioaccessible from potato peel. Due to high bioaccessibility of antioxidants from potato peel, it can be used as fortificant in many

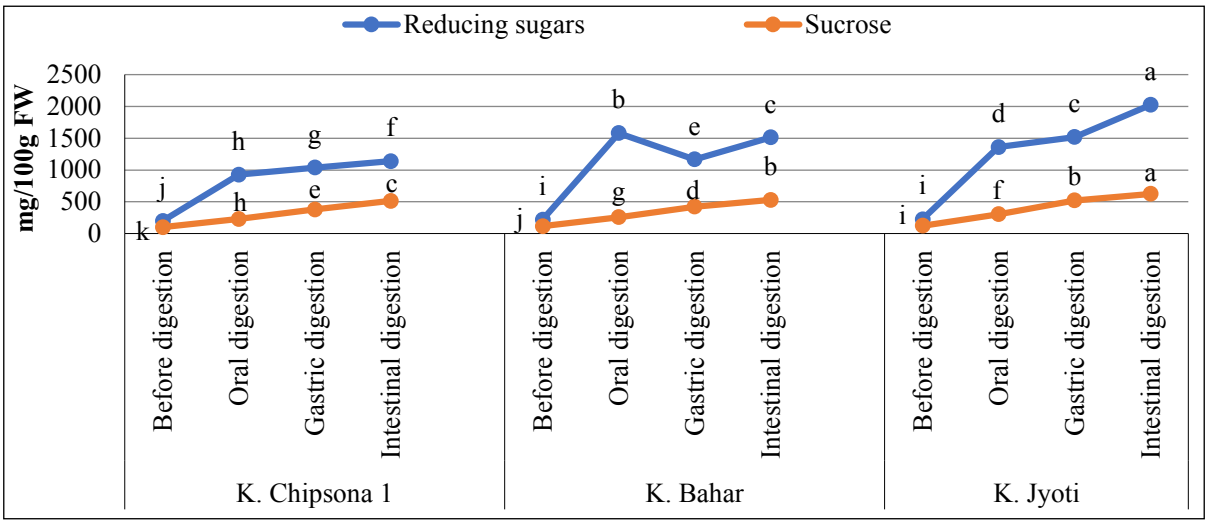


Fig. 4: *Reducing sugar and sucrose during in-vitro gastrointestinal digestion in potato peel. Different letters indicate significant differences between varieties and phases (p< 0.05).*

food preparations. Incorporation of potato peels to other foods may not only enhance nutritional quality due to high polyphenolics bioaccessibility but may also help to enhance iron bioavailability due to high concentration of ascorbic acid from potato peel. Because of high chlorogenic acid bioaccessibility in potato peels, they can be utilized for development of health foods for diabetics and health conscious consumers by mixing potato peels with other ingredients. Thus, potato processing wastes may be used in food formulations and their extracts could potentially be employed as an effective source of natural antioxidants in food systems.

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CONFLICTS OF INTEREST

The authors confirm that this manuscript has no conflicts of interest

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