Development and quality characteristics of nutritionally enhanced potato legume based *wari*- an Indian traditional savoury

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Abstract The present study was carried out to develop *waris* from potato and legume blends and to analyze them for organoleptic, physicochemical, phytochemical and shelf life quality. *Wari* is a partially fermented legume based savoury, used as adjunct in vegetable curries. In this study, potato (boiled and dehydrated) was used to supplement black gram or urad dhal *waris*. Two processing cultivars (Kufri Chipsona-1, Kufri Chandramukhi) and one commonly grown cultivar (Kufri Pukhraj) were evaluated for processing into *waris*. Based on preliminary sensory trails, *waris* with potato (70 %) and urad dhal (30 %) level of supplementation were found to be most acceptable and these *waris* were subjected to nutritional evaluation. Storage stability of the *waris* was assessed by storing the product at room temperature for a

period of 12 months. Results were compared with dhal *waris* (control). Protein content was significantly higher in control *waris* compared to potato supplemented *waris*. Bioactive compounds including ascorbic acid, total phenolics and total antioxidant activity measured as DPPH radical scavenging activity increased significantly on incorporation of potato. Between the cultivars, *waris* enriched with Kufri Pukhraj, a table variety which is considered unfit for processing, displayed the highest phytochemical content and total antioxidant activity. Sensory evaluation indicated higher overall acceptability scores of potato enriched *waris* compared to control *waris*. Between the treatments i.e. boiled mash and dehydrated flour, *waris* supplemented with boiled potato mash showed a significantly higher content of phytochemicals and total antioxidant activity compared to potato flour *waris*. However no significant difference was observed in sensory quality of the product prepared either with fresh potato mash or potato flour. Storage studies showed that the potato *waris* can be stored safely for 12 months with its nutrient constituents intact.

Research Highlights

- Fresh potatoes are subject to post harvest losses during storage. These losses serve as a stimulus to response of processing this staple food into a product of longer shelf life. Development of value added potato products with enhanced nutrition may potentially boost consumption.
- In the present study, we developed nutritionally enriched *waris* (partially fermented legume-based savoury) utilizing both fresh as well as dehydrated potato. The developed product may provide beneficial health effects to the consumers economically as it contained significant amount of bioactive compounds including ascorbic acid, total phenolics and antioxidant activity and high acceptability ratings.
- This product can be successfully utilized throughout the year during the off season with its nutrient constituent intact.
- Minimizing of post harvest losses of potato through value addition with variety food products would provide economic security to the potato growers as well as food security to some extent in the world being the commonly used food article.

Keywords Antioxidant activity · Potato · Potato flour · Phytochemicals · Supplementation · *Wari*

Introduction

Potato (*Solanum tuberosum* L.) is a nutritious vegetable containing significant amount of carbohydrates, superior quality protein, dietary fibre, some minerals and negligible amount of fat (Kaur et al. 2012). Beyond these basic nutrients, potatoes contain several secondary metabolites (phytochemicals) with antioxidant activity, which contributes to the physiological defense against oxidative and free radical mediated reactions (Ezekiel et al. 2013). Polyphenols, ascorbic acid and

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carotenoids are the major bioactive compounds known in potato for their antioxidant properties (Lachman and Hamouz 2005; Hejtmankova et al. 2009; Gumul et al. 2011). The scavenging activity of these compounds is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors, and singlet oxygen quenchers (Kaur and Kapoor 2002; Babbar et al. 2011).

Potatoes are a major contributor to dietary phytochemical concentrations due to consumption levels. Al-Saikhan et al. (1995) determined total antioxidant activity in different genotypes of potato cultivars and found that total antioxidant capacity (Percent inhibition relative to control) ranged 65.20–88.12 %. Hesam et al. (2012) reported higher antioxidant activity of 92.89 % and 94.10 % in Iranian potato genotypes by DPPH radical scavenging method while moderate antioxidant activity of 80 % in Canadian potato genotype ‘Russet Burbank’ was reported by Velioglu et al. (1998). Kaur and Kapoor (2002) determined antioxidant activity in both aqueous and alcoholic (80 %) potato extracts by β -carotene bleaching method. The authors suggested moderate antioxidant activities of 62.5 % and 62.3 % in aqueous and alcoholic extracts, respectively. Kaur and Aggarwal (2014) determined total phenolics and antioxidant activity in sixteen Indian potato genotypes. The authors observed 31.30–68.20 mg/GAE phenolics and 28.0–67.3 % antioxidant activity in different genotypes and concluded that potatoes contain enough phytochemicals to be used as functional food for improving human health.

India became the second largest producer of potato in the world with bumper crop of 41.48 million tonnes in the year 2012–13 (FAO 2014). Potato is one of the commonly used vegetable and is staple diet for a large number of people in the world but main disadvantage of the crop is that it is seasonal and bulky production of crop has short life (Misra and Kulshrestha 2003). Lack of sufficient storage facilities result in crop deterioration as post harvest time advances. Dehydration of bumper perishable crop seems to be convenient alternative for long term storage and could serve as means to ensure availability of potatoes in different forms throughout the year.

Potato can be processed into an indigenous dehydrated product called *wari*, which has a promising future due to its long shelf life and diverse uses. *Wari* is a partially fermented legume-based savoury which is manufactured on cottage scale in rural areas of Northern India and is used as adjunct in curries. Generally, *wari* is prepared from batter of split black gram or green gram dhal along with various spices and condiments like dried fenugreek leaves, coriander powder, cumin seeds, red chilli powder and black pepper (Kulkarni et al. 1997). Fermentation and drying of the batter takes place simultaneously and the drying cause case hardening which

result in a cavity or porous texture. Dehydrated *waris* are easy to prepare, require no costly machinery for manufacture and have a longer shelf life.

Several dehydrated value added potato products such as potato *papad* (Marwaha and Sandhu 2003), dehydrated chips (Marwaha and Pandey 2006) and potato cubes (Sandhu and Parhawk 2002) have been developed earlier. Still, there is a need to find diversified uses of potatoes and to develop new processed products with improved nutritional quality which can be available for consumption throughout the year. Also, data on phytochemical content and antioxidant activities of savoury snacks commonly consumed in India is scanty. Thus, the aim of this work was to develop *waris* enriched with different potato cultivars and to evaluate the quality characteristics of the developed product in order to assess its physicochemical, phytochemical and shelf life properties.

Materials and methods

Materials

Two potato cultivars known for better quality characteristics (Kufri Chipsona-1, Kufri Chandramukhi) and one commonly cultivated variety (Kufri Pukhraj) were procured from Vegetable Crops Department of the University and were used for production of *waris*. Split black gram dhal (*Phaseolus mungo* Roxb.) and whole spices (dried fenugreek leaves, coriander seeds, cumin, cinnamon, black pepper, red pepper, cloves, nutmeg, asafoetida) were purchased locally.

Preparation of raw materials

Waris were prepared by incorporating both fresh boiled potato mash as well as dehydrated potato flour. One part of the harvested tubers of each cultivar was used for preparation of boiled potato mash. The remaining part of tubers was used for the preparation of potato flour.

Boiled potato mash Fresh potato tubers (1 kg) of each cultivar were washed, peeled, cut into four quarters and cooked in an open pressure cooker (Model 2170, TTK Prestige Ltd., Mumbai, India) in water (1 L) for 10 min at 95 °C. The boiled potatoes were cooled for 5 min under running tap water until the tubers reached room temperature. The cooked boiled potatoes were then mashed.

Dehydrated potato flour The tubers of K. Chipsona-1, K. Chandramukhi and K. Pukhraj were peeled and cut into 2–3 mm thick slices with a rotary hand slicer. The slices were cooked in boiling water containing 0.25 % potassium metabisulphite for 10 min to prevent enzymatic darkening (Marwaha and Pandey 2006). Immediately after cooking,

potato slices were cooled under running tap water. The sulphited slices were drained, loaded in trays and dried in hot air cabinet drier (Model 1254, Pharma Tech International, Kolkata, India) at $60 \pm 5^\circ\text{C}$ for 5 to 6 h. The dried potato slices were ground in an electric grinder (Philips India Limited, Mumbai, India) and then powdered in a cyclotec mill (FOSS CT 193 cyclotec Mill, Denmark).

Wet pulse paste Black gram dhal or Urad dhal (450 g) was washed thoroughly and soaked in about 550 ml of water overnight. The drained pulses were then ground in an electric grinder (Philips India Limited, Mumbai, India) with small addition of water, till it became a thick paste.

Spice mix Whole spices were coarsely ground in a grinder and used for the preparation of *waris*.

Formulation of *waris*

Waris were formulated by incorporating potato in different proportions. Proportions of ingredients which were liked best sensorily were selected for the development of final product. *Waris* were prepared by the ‘traditional *wari*’ recipe as described by Kulkarni et al. (1997) with slight modifications. Potato (boiled and dehydrated) of each variety was incorporated in the traditional recipe to replace urad dhal at levels of 10, 30, 50, 70 and 90 % in preparation of *waris*. Based on preliminary sensory trials, substitution of up to 70 % of potato produced significant desirable changes in the sensory characteristics of *waris*. So, this level was used for the preparation of the final product.

Processing method

Standardized recipe of *waris* had the ingredients: potato mash 315 g, pulse paste 135 g, dried fenugreek leaves 3.5 g, coriander and cumin seeds 7.5 g, cinnamon 1.5 g, black and red pepper 3.0 g, cloves 0.8 g, nutmeg 0.25 g, asafetida 0.1 g. For preparation of *waris*, the thick wet pulse paste was whisked continuously with hand till it became light and fluffy due to incorporation of air. To the wet pulse paste, standardized amount of potato (70 % of the mix) was added. The resultant paste was then mixed thoroughly with flavourings. The resultant fluffy batter was taken in hand and divided into small balls weighing 50–60 g. The prepared balls were spread on stainless steel trays smeared with oil, maintaining a distance of 1–2 in. between balls. The trays were then loaded in hot air cabinet drier and dried at $60 \pm 5^\circ\text{C}$ for 14–16 h. The control (without potato) *wari* samples were used for physico-chemical, phytochemical and sensorial comparisons.

Waris were also prepared by incorporating potato flour (instead of potato mash) into legume-spice mix by using the same method as mentioned above.

Chemicals

The following chemicals were used: 2, 4-Dichlorophenol-Indophenol dye, methanol, Folin-Ciocalteu’s reagent, sodium bicarbonate, 1, 1-diphenyl-2-picrylhydrazyl (DPPH), Tris-HCl buffer were obtained from S. D. Fine Chem. Ltd., Mumbai, India. All the chemicals were of analytical grade.

Analysis

Physicochemical and phytochemical composition of raw ingredients and fresh *waris*

The moisture, ash, acid insoluble ash, acidity and protein contents were determined by official methods (AOAC 2005).

The ascorbic acid content was determined by visual titration method using 2, 4-Dichlorophenol-Indophenol dye method (Ranganna 2004). The results were expressed as milligram of ascorbic acid/100 g dw.

Phenolic compounds were extracted from sample (5 g fresh tissue; 1 g dry ingredient) according to Velioglu et al. (1998) with 50 ml of 80 % (v/v) aqueous methanol for 3 h at 40°C with refluxing. The content of total phenolic compounds in extract was determined using the Folin-Ciocalteu’s colorimetric method (Velioglu et al. 1998). The absorbance at 765 nm was measured after 30 min and the results were expressed as gallic acid equivalents (mg GAE/100 g dw).

The ability of the prepared extracts to scavenge the stable free radical 1, 1-diphenyl-2-picrylhydrazyl (DPPH) was estimated using the method of Yamaguchi et al. (1998) with little modification. To 1 ml of methanolic extract of sample prepared as above, 1 ml Tris-HCl buffer (50 mM, pH 7.4) was added. Then 2 ml of 0.1 mM freshly prepared DPPH was added to the reaction mixture. The reaction mixture was shaken and incubated in the dark at room temperature for 30 min and the absorbance was read at 517 nm against blank (80 % methanol and Tris buffer). The free radical scavenging activity was evaluated by comparing the absorbance with control solution to which distilled water was added instead of sample with 2 ml of 0.1 mM DPPH and 1 ml 50 mM Tris-HCl buffer. BHT was taken as a standard at a fixed concentration of 5 mg/ml.

$$\text{Radical scavenging activity (\%)} = \frac{\text{Absorbance of control (0 minute)} - \text{Absorbance of sample (30 minute)}}{\text{Absorbance of control (0 minute)}} \times 100$$

Color attributes

The color of *waris* was measured using a Minolta Chroma colorimeter model CR 200 (Minolta Co., Osaka, Japan)

against a white reference standard. The measurements were displayed in L^* : lightness, a^* : redness and b^* : yellowness.

Sensory quality evaluation of *waris*

For sensory evaluation, *waris* (40 g) were shallow-fried for 30 s in a frying pan containing 60 ml of cooking oil maintained at 150 °C. Fried *waris* were divided into small pieces and cooked in a vegetable curry preparation. For curry preparation, 40 ml of cooking oil was heated in a pan and seasoned with cumin seeds (1 g). To this, paste containing ginger (5 g), garlic (3 g), onion (50 g), tomato (66 g) was added, along with salt (2 g), turmeric (0.2 g), coriander (1 g) and red chilli powder (0.2 g). Shallow fried *wari* pieces were added to the above cooked paste along with 250 ml of water and were pressure cooked for 3 min. The cooked hot *wari* samples were evaluated by a panel of 10 judges using 9-point Hedonic scale for their sensory characteristics like appearance, flavor, texture and overall acceptability. The scores were assigned from extremely liked (9) to disliked extremely (1).

Storage studies

Waris were packed in 200 gauge polythene bags and sealed in tight air containers. The packed *waris* were exposed to room temperature (26–38 °C/RH 35–87 %) for a period of 12 months. Storage stability of the product was assessed by determining the changes in moisture and bioactive composition. Sensorial analysis of the stored *waris* was done by a semi trained panel of 10 judges using 9-point Hedonic scale.

Statistical Analysis

All the experiments were carried out in triplicate. One-way analysis of variance was performed using the SPSS version 20.0 (Statistical Package for Social Sciences). Significant differences ($p < 0.05$) were determined by Tukey's.

Results and discussion

Quality characteristics of fresh *waris*

Quality attributes i.e. physicochemical, phytochemical and color characteristics of control *waris* and potato incorporated *waris* are summarized in Table 2. The control and potato supplemented *waris* did not differ significantly ($p < 0.05$) in their moisture content. The ash content of control *waris* was 4.02 % and it ranged from 3.33 to 4.02 % in potato supplemented *waris* (Table 2). The ash content of *waris* conformed well to the

proposed standards (max. 4.50 %) for dhal *waris* (Kulkarni et al. 1997). Acid insoluble ash ranged 0.18–0.26 % and was within the prescribed limits (max. 0.40 %) (Kulkarni et al. 1997). The variations (1.31–1.41 %) in acidity (as oleic acid) of *waris* were within the proposed standards (max. 1.70 %) (Kulkarni et al. 1997). In control *waris*, protein content was 22.56 % that was found to be significantly ($p < 0.05$) higher than that of potato supplemented *waris* (14.58–16.82 %) (Table 2). The protein content of the control *waris* conformed to the proposed specifications (min. 16 %) (Kulkarni et al. 1997), while *waris* incorporated with potato showed significantly lower values.

Phytochemical attributes i.e. ascorbic acid and total phenolic content and radical scavenging activities of fresh *wari* samples significantly ($p < 0.05$) increased on supplementation with potato as compared to control *waris* (Table 2). It might be due to a larger amount of phytochemical content in potato in comparison to urad dhal (Table 1). Between the cultivars studied, *waris* supplemented with K. Pukhraj had the highest bioactive content and radical scavenging activity while lowest was observed in K. Chipsona-1 *waris* (Table 2). The higher concentration of these phytochemicals in K. Pukhraj at initial level (Table 1) might have contributed towards their higher retention in the prepared product.

Color characteristics (L^* , a^* and b^*) of control and potato supplemented *waris* were significantly ($p < 0.05$) different from each other (Table 2). K. Chipsona-1 supplemented *waris* had the maximum L^* (lightness) value while lowest was noticed for *waris* supplemented with K. Pukhraj. *Waris* incorporated with K. Pukhraj were darker in color (Fig. 1) which might be due to higher phenolic content in this cultivar. Besides providing antioxidant properties, phenolic compounds are also associated with enzymatic browning which occurs due to their oxidation by polyphenol oxidase enzyme (Marwaha and Pandey 2006; Marwaha et al. 2010; Mehta et al. 2011).

Sensory quality evaluation of fresh *waris*

It is clear from Table 3 that there was no difference ($p < 0.05$) in sensory quality between *waris* enriched with either fresh potato mash or potato flour. These results indicate that *waris* can be successfully prepared from both fresh potato mash as well as dehydrated flour. When fresh potatoes are not available, *waris* can be prepared from potato flour and can be used in off-season. Between the cultivars studied, highest preference was given to *waris* prepared from cultivar K. Chipsona-1, closely followed by K. Chandramukhi and K. Pukhraj (Table 3).

Table 1 Physicochemical and phytochemical traits of raw ingredients used in development of potato *waris*

Raw ingredients	Treatments	Moisture* (%)	Protein (%)	Ash (%)	Ascorbic acid (mg/100 g)	Total phenols (mg GAE/100 g)	Scavenging activity* (%)
Cultivars							
	K.Chipsona-1						
	Raw tubers	75.58 ± 0.12 ^b	21.42 ± 0.60 ^b	3.98 ± 0.12 ^d	82.31 ± 0.40 ^d	185.2 ± 0.22 ^f	40.80 ± 0.30 ^f
K.Chandramukhi	Boiled mash	75.69 ± 0.10 ^b	21.40 ± 0.62 ^d	4.03 ± 0.15 ^d	75.76 ± 0.30 ^f	165.4 ± 0.21 ^h	38.10 ± 0.25 ^g
	Dehydrated flour	6.02 ± 0.09 ^d	20.98 ± 0.54 ^e	3.86 ± 0.08 ^e	62.84 ± 0.21 ^h	132.3 ± 0.20 ^j	20.90 ± 0.28 ⁱ
	Raw tubers	75.60 ± 0.48 ^b	18.62 ± 0.48 ^b	4.85 ± 0.10 ^b	85.82 ± 0.50 ^c	240.8 ± 0.32 ^d	58.88 ± 0.48 ^d
K.Pukhraj	Boiled mash	75.70 ± 0.50 ^b	18.75 ± 0.55 ^f	4.92 ± 0.12 ^b	80.92 ± 0.30 ^e	224.2 ± 0.60 ^e	53.20 ± 0.50 ^e
	Dehydrated flour	6.05 ± 0.20 ^d	18.04 ± 0.40 ^g	4.62 ± 0.09 ^c	67.54 ± 0.22 ^g	167.8 ± 0.31 ^g	25.86 ± 0.50 ^h
	Raw tubers	84.50 ± 0.48 ^b	23.15 ± 0.58 ^b	6.90 ± 0.23 ^b	120.10 ± 0.58 ^a	440.8 ± 0.55 ^a	65.94 ± 0.28 ^b
Urad dhal	Boiled mash	84.69 ± 0.51 ^a	23.05 ± 0.60 ^b	6.85 ± 0.18 ^a	107.83 ± 0.55 ^b	419.9 ± 0.65 ^b	63.50 ± 0.30 ^c
	Dehydrated flour	6.15 ± 0.12 ^d	22.86 ± 0.52 ^c	6.92 ± 0.20 ^a	80.86 ± 0.21 ^e	318.6 ± 0.42 ^c	20.90 ± 0.25 ⁱ
	Fresh	9.80 ± 0.28 ^c	26.38 ± 0.70 ^a	3.63 ± 0.21 ^f	9.06 ± 0.10 ^j	155.2 ± 0.25 ⁱ	20.10 ± 0.30 ^j
Spice mix	Fresh	3.10 ± 0.18 ^e	0.21 ± 0.05 ^h	3.58 ± 0.18 ^f	nd	nd	98.10 ± 0.55 ^a

Values within a column with different letters are significantly ($p < 0.05$) differentMean values ± SD ($n = 3$)

*g/100 g wet basis; nd – not detected

Table 2 Quality characteristics of fresh *waris**

Products	Moisture (%)	Ash (%)	Acid insoluble ash (%)	Acidity (%)	Protein (%)	Ascorbic acid (mg/100 g)	Total phenols (mg GAE/100 g)	Scavenging activity (%) Color attributes		
								L^*	a^*	b^*
Control (without potato)	5.82 ± 0.20 ^a	4.02 ± 0.15 ^a	0.26 ± 0.05 ^a	1.33 ± 0.02 ^a	22.56 ± 0.50 ^a	23.48 ± 0.21 ^g	360.7 ± 1.40 ^g	52.48 ± 0.23 ^c	3.76 ± 0.22 ^a	13.11 ± 0.11 ^b
<i>Waris</i> supplemented with boiled potato mash										
K.Chipsona-1	5.78 ± 0.22 ^a	4.02 ± 0.12 ^a	0.21 ± 0.01 ^a	1.33 ± 0.02 ^a	16.82 ± 0.19 ^a	30.42 ± 0.12 ^a	476.6 ± 1.20 ^e	56.89 ± 0.21 ^a	2.95 ± 0.23 ^c	15.78 ± 0.02 ^a
K. Chandramukhi	5.97 ± 0.25 ^a	3.33 ± 0.10 ^b	0.19 ± 0.01 ^a	1.41 ± 0.03 ^b	14.60 ± 0.15 ^c	33.86 ± 0.21 ^c	550.6 ± 1.80 ^c	56.28 ± 0.20 ^h	3.25 ± 0.22 ^{bc}	15.58 ± 0.28 ^a
K.Pukhraj	5.85 ± 0.18 ^a	3.87 ± 0.15 ^a	0.21 ± 0.02 ^a	1.33 ± 0.01 ^a	16.82 ± 0.20 ^b	37.24 ± 0.15 ^a	820.9 ± 2.00 ^a	54.32 ± 0.25 ^b	3.27 ± 0.07 ^b	13.79 ± 0.20 ^b
<i>Waris</i> supplemented with dehydrated potato flour										
K.Chipsona-1	5.98 ± 0.20 ^a	4.00 ± 0.20 ^a	0.20 ± 0.01 ^a	1.31 ± 0.01 ^a	16.74 ± 0.12 ^b	28.78 ± 0.10 ^f	387.0 ± 1.80 ^f	49.89 ± 0.19 ^d	3.85 ± 0.05 ^a	10.52 ± 0.25 ^c
K. Chandramukhi	5.63 ± 0.18 ^a	3.36 ± 0.10 ^b	0.18 ± 0.01 ^a	1.41 ± 0.03 ^b	14.58 ± 0.80 ^c	31.54 ± 0.30 ^d	509.4 ± 1.48 ^d	49.86 ± 0.28 ^e	3.44 ± 0.09 ^b	10.60 ± 0.15 ^c
K.Pukhraj	5.81 ± 0.20 ^a	3.80 ± 0.21 ^a	0.21 ± 0.02 ^a	1.33 ± 0.01 ^a	16.77 ± 0.054 ^b	35.55 ± 0.25 ^b	763.5 ± 0.30 ^b	47.60 ± 0.20 ^f	3.24 ± 0.14 ^{bc}	10.41 ± 0.12 ^c

Values within a column with different letters are significantly ($p < 0.05$) differentMean values ± SD ($n = 3$)

*Results expressed on dry weight basis

Fig. 1 *Waris* enriched with different potato cultivars (a) K.Chipsona-1 (b) K. Chandramukhi (c) K.Pukhraj (d) control (without potato)

Storage studies

Moisture content

Moisture is perhaps the most important factor, determining the shelf life of *waris* and has to be maintained within 11 % to preserve them from fungal attack (Kulkarni et al. 1997). *Waris* supplemented with potato mash and potato flour did not show any significant ($p < 0.05$) difference in moisture content (Table 4). However, there was a gradual increase ($p < 0.05$) in the moisture content of *waris*, irrespective of treatments (boiled potato mash and dehydrated flour). As seen in Table 4, the average moisture content of *waris* increased from 5.15 to 8.56 % during 12 months of storage. This might be due to variation in atmospheric relative

humidity, which ranged from 35 to 85 % during the storage period. Similar behaviour was also observed in Mung Bean *waris* stored at room temperature (12–37 °C) for 12 months (Singh et al. 2013) and in dehydrated jackfruit *papads* stored for 180 days (Jagadeesh et al. 2007). During storage, none of the *waris* exceeded the prescribed limits (Max. 11 %) for moisture content and all the samples were free from insect infestation up to 12 months.

Phytochemical content and antioxidant properties

The plant foods are known for their phytochemical content and antioxidant characteristics; therefore, it is essential to investigate the influence of storage and processing on these bioactive food components.

Table 3 Sensory evaluation of fresh *waris* supplemented with boiled potato mash and dehydrated flour

Product	Appearance	Flavor	Texture	Overall acceptability
<i>Waris</i> supplemented with boiled potato mash				
K.Chipsona-1	8.83 ± 0.01 ^{aA}	8.54 ± 0.03 ^{abA}	8.50 ± 0.04 ^{aA}	8.80 ± 0.02 ^{aA}
K. Chandramukhi	8.80 ± 0.01 ^{aA}	8.00 ± 0.04 ^{dA}	8.10 ± 0.02 ^{cA}	8.52 ± 0.04 ^{cA}
K.Pukhraj	8.32 ± 0.02 ^{CA}	8.20 ± 0.03 ^{CA}	8.24 ± 0.06 ^{bA}	8.30 ± 0.03 ^{eA}
<i>Waris</i> supplemented with dehydrated potato flour				
K.Chipsona-1	8.80 ± 0.01 ^{aA}	8.42 ± 0.03 ^{bA}	8.42 ± 0.05 ^{aA}	8.63 ± 0.01 ^{bA}
K. Chandramukhi	8.84 ± 0.02 ^{aA}	8.48 ± 0.05 ^{bA}	8.23 ± 0.04 ^{bA}	8.42 ± 0.02 ^{cdA}
K.Pukhraj	8.56 ± 0.02 ^{bA}	8.63 ± 0.04 ^{aA}	8.42 ± 0.03 ^{aA}	8.38 ± 0.02 ^{deA}

Values within a column with different superscript lower case letters are significantly ($p < 0.05$) different between cultivars

Values within a column with different superscript capital letters are significantly ($p < 0.05$) different between treatments. Mean values ± SD ($n = 3$)

Table 4 Quality characteristics of stored *waris**

Duration of storage (months)	Product	
	<i>Waris</i> supplemented with boiled potato mash	<i>Waris</i> supplemented with dehydrated potato flour
Moisture (%)		
0	5.22 ± 0.20 ^d	5.16 ± 0.18 ^c
3	5.68 ± 0.22 ^d	5.81 ± 0.16 ^d
6	6.65 ± 0.25 ^c	6.52 ± 0.20 ^c
9	7.12 ± 0.18 ^b	7.51 ± 0.22 ^b
12	8.41 ± 0.20 ^a	8.72 ± 0.21 ^a
Ascorbic acid (mg/100 g)		
0	32.03 ± 0.21 ^a	29.48 ± 0.11 ^a
3	31.49 ± 0.15 ^b	28.87 ± 0.21 ^b
6	29.52 ± 0.20 ^c	27.81 ± 0.18 ^c
9	27.11 ± 0.18 ^d	25.18 ± 0.20 ^d
12	25.14 ± 0.21 ^e	23.42 ± 0.30 ^e
Total phenols (mg GAE/100 g)		
0	582.2 ± 0.30 ^a	522.9 ± 0.22 ^a
3	578.1 ± 0.28 ^b	519.14 ± 0.30 ^b
6	574.1 ± 0.25 ^c	513.16 ± 0.20 ^c
9	573.1 ± 0.17 ^d	510.82 ± 0.31 ^d
12	573.2 ± 0.20 ^d	511.0 ± 0.28 ^d
Scavenging activity (%)		
0	88.86 ± 0.48 ^a	87.31 ± 0.54 ^a
3	87.61 ± 0.54 ^a	86.00 ± 0.44 ^b
6	86.12 ± 0.40 ^c	85.66 ± 0.50 ^c
9	85.12 ± 0.60 ^d	82.82 ± 0.45 ^d
12	85.24 ± 0.48 ^d	82.48 ± 0.48 ^d
Color attributes		
<i>L</i> *		
0	54.99 ± 0.20 ^a	49.95 ± 0.18 ^a
3	54.92 ± 0.25 ^a	49.87 ± 0.20 ^a
6	53.75 ± 0.30 ^b	48.63 ± 0.22 ^b
9	52.26 ± 0.28 ^c	47.75 ± 0.20 ^c
12	51.10 ± 0.20 ^d	45.92 ± 0.30 ^d
<i>a</i> *		
0	3.31 ± 0.22 ^a	3.57 ± 0.14 ^a
3	3.03 ± 0.20 ^a	3.56 ± 0.22 ^a
6	2.93 ± 0.16 ^a	2.98 ± 0.20 ^a
9	2.60 ± 0.18 ^b	2.76 ± 0.16 ^b
12	2.62 ± 0.09 ^b	2.58 ± 0.22 ^b
<i>b</i> *		
0	14.56 ± 0.15 ^a	11.16 ± 0.13 ^a
3	14.31 ± 0.17 ^a	10.95 ± 0.15 ^b
6	13.42 ± 0.15 ^b	10.10 ± 0.17 ^b
9	12.31 ± 0.20 ^c	9.99 ± 0.18 ^c
12	11.82 ± 0.11 ^d	9.95 ± 0.15 ^c

Values within a column with different superscript lower case letters are significantly ($p < 0.05$) different within the storage duration. Mean values ± SD ($n = 3$)

*Results expressed on dry weight basis

Ascorbic acid and Total phenolic content

During storage, the mean ascorbic acid content of *waris* was found to be decreased from original value, regardless of the treatments (i.e. boiled potato mash and dehydrated potato flour) (Table 4). The initial mean ascorbic acid content of potato supplemented *waris* was 30.75 mg/100 g dw, which decreased ($p < 0.05$) consistently to 24.28 mg/100 g dw, after 12 months of storage. This might be due to oxidation of the thermolabile ascorbic acid into dehydroascorbic acid upon storage (Kaur et al. 2012; Selvamuthukumaran and Khanum 2014). The ascorbic acid loss accounted to 21.0 % after 12 months of storage period. Wills and Silalahi (1990) and Abong et al. (2011) observed similar losses in ascorbic acid content during storage of potato crisps.

The initial mean phenolic content of the potato added *waris* was 552.50 mg GAE/100 g dw storage period, irrespective of the treatments. The decrease in total phenolic content was slow and gradual up to 9 months of storage (Table 4) and after 9 months, the decrease was found to be non-significant ($p < 0.05$) up to 12 months of storage. This might be due to the sensitivity of phenolic components to oxidation at above stored conditions. The change in mean total phenolics content of *waris* during the entire storage period from the initial values was very less i.e. 1.90 %. Selvamuthukumaran and Khanum (2014) reported 36 % losses in total phenolics of buckwheat jam stored at 37 °C for 8 months. Oliveira et al. (2012) also noticed higher reductions in total phenolics in pasteurized peach stored at 22 °C for 90 days. It has been reported that genetics, environment, growing conditions, processing methods and storage influence the level of phenols present in fruits and vegetables (Gitanjali et al. 2004; Nayak et al. 2011).

As to the treatments, higher mean ascorbic acid and total phenolics were observed for *waris* supplemented with boiled potato mash in comparison to potato flour *waris* (Table 4). This might be due to presence of higher amount of phytochemicals in the fresh boiled potato mash compared to dehydrated potato flour (Table 1) as a result of losses caused by leaching into water and degradation from the effect of heat during processing. Bioactive compounds are soluble in water but susceptible to thermal processes. They are lost by washing out of potato and undergoing thermal degradation (Ezekiel et al. 2013; Nems et al. 2015).

DPPH radical scavenging activity

There was slight but significant ($p < 0.05$) decrease in the mean radical scavenging activities of potato enriched *waris* during storage, regardless of treatments (Table 4).

The mean radical scavenging activities of *waris* extracts was estimated to be 88.08 % initially and this was found to decline significantly to 83.86 % after 9 months of storage. However, after 9 months non-significant ($p < 0.05$) changes were observed up to 12 months of storage (Table 4). The decrease in the total antioxidant activity may be linked to decrease in the content of phytonutrients such as total phenolics and ascorbic acid. The correlation between bioactive concentration and antioxidant activity of plant foods is well established (Reyes et al. 2005; Ah-Hen et al. 2012; Ezekiel et al. 2013). Kapoor and Aggarwal (2014) reported significant losses (43.40 %) of total antioxidant activity in carrot juice stored at room temperature for 6 months. However in our study, the loss in total antioxidant capacity as radical scavenging activity accounted for only 4.80 % after 12 months of storage.

Regarding treatments, extracts of *waris* supplemented with boiled potato mash showed a significantly ($p < 0.05$) higher content of radical scavenging capacity compared to potato flour *waris* extracts (Table 4). This might be due to differences in the profiles of antioxidants contained in boiled potato mash and in the dehydrated flour (Table 1). According to Nems et al. (2015), thermal stages of food processing are one of most important factors affecting the changes in the bioactive components naturally present in raw material and therefore change the antioxidant capacity of the processed food. Similar findings were observed by Hes et al. (2014) who found that raw barley and buckwheat groats extracts showed higher DPPH scavenging ability compared to boiled barley and buckwheat groats extracts. In another study, Singla et al. (2010) compared the total antioxidant activities of extracts obtained from osmotically dehydrated and spiced mushroom snack food with raw unprocessed mushrooms; they reported 76 and 72 % scavenging activity of free extracts of raw and dry snack mushrooms, respectively on DPPH radical.

Color attributes

Color is one of the important physical parameters often used by the manufacturers and consumers to qualitatively assess the characteristics quality of food products. The color attributes (lightness, redness and yellowness) of *waris* enriched with boiled potato mash and potato flour as influenced by treatments and storage is shown in Table 4. Mean L^* (lightness) value for *waris* enriched with boiled potato mash and flour was 52.40 and 48.42, respectively (Table 4). Compared with potato mash *waris*, *waris* enriched with flour were slightly less bright which might be due to degradation of color pigments of potato during drying process used in preparation of potato flour. a^* and b^* values which depict the intensity of red and yellow in the sample followed a similar pattern as that of L^* value (Table 4).

Table 5 Effect of storage on overall acceptability of control and potato supplemented *waris*

Product	Duration of storage (months)				
	0	3	6	9	12
Control (without potato)	7.20 ± 0.05 ^{dA}	7.20 ± 0.03 ^{cA}	7.00 ± 0.06 ^{dB}	6.80 ± 0.04 ^{dC}	6.52 ± 0.02 ^{dD}
<i>Waris</i> supplemented with boiled potato mash					
K.Chipsona-1	8.80 ± 0.02 ^{aA}	8.54 ± 0.02 ^{aB}	8.23 ± 0.03 ^{aC}	8.00 ± 0.05 ^{aD}	7.80 ± 0.04 ^{aE}
K. Chandramukhi	8.52 ± 0.04 ^{bA}	8.30 ± 0.05 ^{bB}	8.10 ± 0.05 ^{bC}	7.90 ± 0.03 ^{bD}	7.50 ± 0.01 ^{bE}
K.Pukhraj	8.30 ± 0.04 ^{cA}	8.26 ± 0.05 ^{bA}	7.94 ± 0.05 ^{CB}	7.42 ± 0.05 ^{cC}	7.04 ± 0.03 ^{cD}

Values within a column with different superscript lower case letters are significantly ($p < 0.05$) different between treatments

Value within a row with different superscript capital letters are significantly ($p < 0.05$) different within the storage duration. Mean values ± SD ($n = 3$)

Storage exerted a significant ($p < 0.05$) effect on the color changes in *waris*, regardless of treatment. The L^* , a^* and b^* values decreased ($p < 0.05$) consistently during storage of the *waris* for 12 months (Table 4). The change in color might be due to increase in moisture content and temperature during storage (Hamed et al. 1973). Changes in color values are reported to be influenced by the method of processing, extent of exposure to light, storage temperature and interaction of ingredients (Pawar et al. 2012). A similar trend was also observed by Topuz et al. (2009) during storage of dried paprika powder. In the present study, visual color appearance of the *waris* enriched with both boiled potato mash as well as dehydrated flour was highly acceptable even after 12 months storage despite changes in color characteristics (L^* , a^* and b^* values).

Sensory quality

The effect of storage on the overall acceptability of *waris* stored at room temperature (26–38 °C/RH 35–87 %) is represented in Table 5. Potato supplemented *waris* had better acceptability scores as compared to control (without potato) *waris*. Both control and potato incorporated *waris* were free from fungal infestation and were found to be highly desirable up to 12 months of storage. Also, *waris* supplemented with K.Pukhraj, an unmarketable cultivar, displayed excellent keeping quality during the entire storage period (Table 5). Incorporation of such potato cultivars into low-cost value added products such as *waris* could serve as an excellent vehicle for enhancing the utilization of this resourceful food crop.

Conclusions

It can be concluded that nutritionally enriched *waris* can be developed from both fresh potato mash as well as dehydrated potato flour which provides significantly more bioactive compounds including ascorbic acid, total phenolics and

antioxidant activity and high acceptability ratings than traditional dhal *wari*. Interestingly, this study also demonstrated that manufacturing of highly acceptable *waris* from varieties of potato generally not in demand is feasible. Potato *waris* can be successfully utilized throughout the year during the off season with its nutrient constituent intact. Such products may prove beneficial to the health of consumer in large and would go a long way in containing malnourishment. Minimizing of post harvest losses of potato through value addition with variety food products would provide economic security to the potato growers as well as food security to some extent in the world being the commonly used food article.

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