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Physico-chemical Properties of Potato Cultivars for their Processing Suitability

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ABSTRACT

Processed potatoes are an important nutritional component of our diets and the demand for processed potato products are increasing. To evaluate the variety suitable for processing, ten potato cultivars procured from Agricultural Research Station, Hassan, Karnataka were studied for their physical, biochemical and functional parameters. Significant differences in the physical parameters were observed. Sprouting and shrinkage were observed in some cultivars after storage for three months at 10-15°C. Kufri Chipsona-1 and Atlantic cultivar had the highest dry matter content, which is an important quality measure suitable for processing. Proximate composition of all the cultivars varied significantly. Phenol content ranged from 5.74 to 26.79 mg/100g, with the lowest in Frito Lay-1533 and Atlantic cultivar. TSS, water absorption index, bulk density, gelatinization and emulsion capacity vary significantly among the cultivars. Kufri Chipsona-3 contained the highest starch (81.1%) and total soluble solids (7.12°Brix). Based on the low phenol content, Atlantic and Frito Lay-1533 were processed and studied for their functional parameters. Water absorption and gelatinization capacity of Atlantic and Frito Lay-1533 were higher in the processed than in the unprocessed sample and differ significantly.

KEYWORDS

Potato, physicochemical properties, processing

INTRODUCTION

Potato (*Solanum tuberosum)*, a starchy tuber belonging to Solanaceae family is one of the most important food crops in developed as well as developing countries. Potato is the fourth most important food crop in the world after rice, wheat and Maize. It is staple food in many parts of the world grown contributing substantially in caloric intake. In India, it is grown over an area of 2.18 Mha with an average annual production of 52.2 MT. The country held second position in its production next to China (Global Potato Conclave, 2019). Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh and Punjab are top five potato producing states of India National Horticulture Board (2017-2018). Despite large production in India, its availability is much lower. Reduction in availability accounts for 10% of the produce used as seed and 10-15 % wasted during harvesting and post-harvest operations due to non-availability of sufficient cold storage facilities (Raj *et al.*, 2007). Fresh potatoes are high in water and are primarily composed of carbohydrates. They are rich in good quality proteins, carbohydrates, vitamin C and B_6, and with other micronutrients and fibre. Processes involving heat that breaks down the starch are performed prior to consumption of potatoes. Potato chips, french fries, baked, boiled, mashed and using flour to make a cake, pancake, etc. are some ways in which potato is consumed (Zaheer and Akhtar, 2016). Dry matter, reducing sugar, free amino acids and phenol content are some bio-chemical attributes which have a strong influence on processing quality (Gupta *et al.*, 2014). Variety, growing location as well as storage temperature affects the dry matter content and reducing sugars content of potatoes. The per capita processing of potato in India is 365g out of which potato powder or flakes contribute 9.28 % (Rana, 2011).

Potato flour is a highly versatile raw material that can be incorporated as an ingredient in various processed food products. Potato flour is used for its distinct characteristics, which differ significantly from those of flour from other plant sources (Singh *et al.*, 2003). The physico-chemical properties of potato flour vary with genotype and cultural practices. The starch present in the potato flour may significantly affect the physico-chemical properties. With this background, the research was undertaken to evaluate the physico-chemical properties of ten potato cultivars from Hassan, Karnataka.

MATERIALS AND METHODS

Potato sample

Ten potato cultivars namely: Atlantic, Frito Lay-1533, Kufri Ashoka, Kufri Bahar, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Jyoti, Kufri Pukraj and Kufri Surya used in this study were procured from Agricultural Research Station, Hassan, Karnataka. Potato samples harvested in September 2009 were immediately packed (30/43cm) in perforated (40 perforations) High Density Polyethylene (HDPE) pouches (400 gauge) of 43×30cm dimension, labelled and stored at 10-15°C for further processing.

Physical parameters

Samples in each variety were pooled, every tenth potato sample was picked at random and mean weight, size and colour were measured. Sprouting percentage of tubers having at least one sprout longer than 5mm was counted as sprouted tuber

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and sprouting percentage was calculated. Potato tubers showing any sign of shrinkage such as wrinkling and drying upon visual inspection was counted and the shrinkage percentage was calculated.

Biochemical composition

The potato samples were subjected to nutrient analysis in fresh and dehydrated samples. Total starch, total sugar, reducing sugar, phenol, moisture and vitamin C were analysed on fresh weight basis. Amylose, protein, fat and ash were analysed on dry weight basis. Moisture and fat content of the dehydrated potato samples were determined using National Institute of Nutrition (NIN) method by Raghuramulu *et al.* (2003). Protein and total ash content of the dehydrated potato samples were determined using AOAC method (1980). Ascorbic acid, total starch, amylose and amylopectin, total sugars, reducing sugars and phenol content of the samples were estimated using method by Sadasivam and Manickam (1991).

Functional properties

Water absorption capacity (WAC) was estimated by the method of Rosario and Flores (1981). Bulk density was estimated using the method of Singh *et al.* 2005. Emulsification and gelatinization capacity were estimated using the method given by Sathe and Salunkhe (1981). TSS of beverages, referred in °Brix was determined using a hand refractometer.

Statistical analysis

The mean, standard error and cumulative differences were applied wherever necessary. The data were subjected to Minitab statistical software (Minitab Inc., USA and SPSS 16.0 version, 2007).

RESULTS AND DISCUSSION

Physical parameters

The physical parameters of potato samples namely: weight, length and breadth is presented in Table 1. The mean values of the sample weight ranged from 37-111 g. Kufri Chipsona-1 had the lowest mean weight (37g) while Kufri Bahar weighed the highest (111g). The mean length ranged between 4.8-7.9 cm with Kufri Chipsona-2 measuring the shortest (4.9 cm) and Kufri Bahar measuring the longest (7.8 cm). The breadth of the samples varied between 3.5 cm for Kufri Chipsona-1 to 9.8 cm for Frito Lay-1533. Length and breadth of the potato tuber indicates the diameter or tuber size of the samples. Statistically significant difference ($p<0.05$) was observed between the physical parameters of the cultivars. Table 2 indicates the colour notation of the samples. According to Munssel colour chart all the potato cultivars possessing the same hue of 7.5 yellow red. The lightness value (v) ranged from 5.4 to 8.0 with the lowest value observed in Kufri Chipsona-1 and the highest value observed in Kufri Ashoka. The strength (departure from neutral) of the colour varied between 6.0 in Atlantic and 10.0 in Kufri Ashoka.

Table 1: Physical parameters of potato cultivars

Cultivars	Weight (g)/ tuber	Length (cm)/ tuber	Breadth (cm)/ tuber
Atlantic	104	5.7	5.3
Frito Lay-1533	100	6.9	9.8
Kufri Ashoka	99	7.5	5.0
Kufri Bahar	110	7.8	5.1
Kufri Chipsona-1	37	5.5	3.5
Kufri Chipsona-2	60	4.9	4.5
Kufri Chipsona-3	78	7.0	4.5
Kufri Jyoti	111	7.0	5.4
Kufri Pukhraj	91	6.8	5.2
Kufri Surya	94	7.3	4.8
F-value	*	*	*
SEm	1.26	0.04	0.052
CD	3.71	0.11	0.15

* Significant at $p<0.05$

Table 2: Varietal difference in colour of potato samples

Cultivars	Colour	(H v/c)
Atlantic	7.5 YR	5.9/6.0
Frito Lay-1533	7.5 YR	7.2/9.3
Kufri Ashoka	7.5 YR	8.0/10.0
Kufri Bahar	7.5 YR	7.8/9.2
Kufri Chipsona_1	7.5 YR	5.4/7.0
Kufri Chipsona-2	7.5 YR	6.4/7.1
Kufri Chipsona-3	7.5 YR	5.7/6.5
Kufri Jyoti	7.5 YR	5.9/8.2
Kufri Pukhraj	7.5 YR	7.3/9.5
Kufri Surya	7.5 YR	6.9/8.8

Yr→ Yellowish Yellow-red
(H v/c) → Hue value/chroma

Sprouting and Shrinkage percentage

The earliest sprouting and shrinkage were observed after 3 months of storage at 10-15^{0}C. Normally potato tuber remains dormant for 2-3 months. After which buds in the eyes of potato tubers begin to grow and form sprouts (Muthoni *et al.* 2014). Sprouting and shrinkage of potato tuber indicates the breakage of dormancy and loss of moisture in the tuber. Fig. 1 shows percent sprouting and shrinkage in the potato cultivars. The sprouting

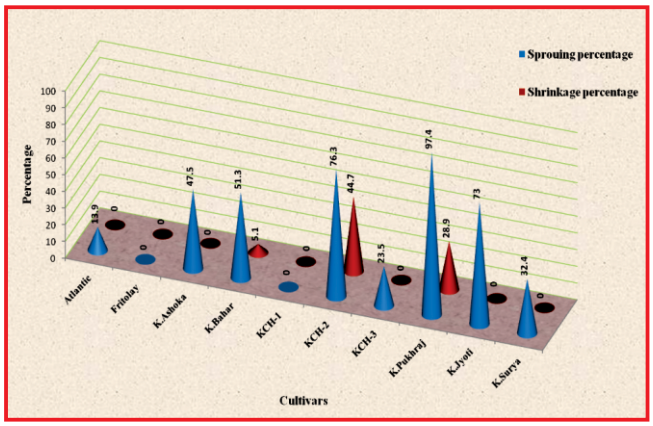

Fig. 1: Percent sprouting and shrinkage in potato cultivars

percentage of the cultivars ranged from 13.9 (Atlantic) to 97.4 percent (Kufri Pukhraj) with no sprouting being observed in Frito Lay-1533 and Kufri Chipsona-1 cultivars. Shrinkage was observed in only three cultivars, highest being in Kufri Chipsona-2 (44.7%), followed by Kufri Pukhraj (28.9%) and Kufri Bahar (5.1%).

Biochemical composition

The proximate composition of the potato cultivars is presented in Table 3. Moisture content of the potato cultivars ranged from 75.10 percent in Kufri Chipsona-2 to 83.22 percent in Kufri Pukhraj. Dry matter content of potato tubers is an important measure of quality. It is used to assess suitability of tubers for processing efficiency, product yield and oil absorption. Potatoes meant for making fried or dehydrated products should have a dry matter content of 20 percent or more (Marwaha *et al*. 2005). Dry matter content of the cultivars ranged from 16.69 to 24.91 percent. Kufri Bahar contained the least dry matter while the highest dry matter was found in Kufri Chipsona-1 (24.91%) followed by Atlantic (24.16%). Joseph *et al*. (2004) reported similar dry matter content of 23.7 percent in Kufri Chipsona-1 and 22.6 percent in Kufri Chipsona-2, and lower dry matter content of 15.7-17.0 percent in Kufri Jyoti and Frito Lay-1533. The present study showed higher dry matter content of 22.54 and 19.25 percent in Frito Lay-1533 and Kufri Jyoti respectively. Joseph *et al*. (2004) attributed the lower dry matter content in the exotic variety to susceptibility to late blight as the same varieties grown in the plains where late blight was not a problem, recorded over 20 percent tuber dry matter.

Protein content of the cultivars was found to be lowest 9.06% in Kufri Ashoka and highest 14.07% in Kufri Bahar followed by Kufri Surya 13.12% on dry weight basis. Protein content reported by Jansen *et al*. (2001) in wild potatoes (9.7% on dry weight) and potato cultivars (8.1% on dry weight) were on par with the values observed in the present study. Sood *et al*. (2008) reported similar protein content of potato tubers ranging from 9.80 to 15.05 percent. Fat content of the potato cultivars ranged from 0.005 to 0.264g/100g. The lowest fat content was observed in Atlantic and the highest in Kufri Jyoti. The fat content as observed in the present study was lower than the value reported by Gopalan *et al*. (2004), which was 0.1g/ 100g of fresh edible portion of potato tuber attributing to varietal difference and the location of cultivation. Ash content of the cultivar varied between 3.80 and 5.18g/ 100g. Kufri Jyoti contained the least total ash content of 3.80% and Kufri Pukhraj with the highest content of 5.18%. Singh *et al*. (2005) reported similar ash content of 4.08% for Kufri Jyoti. Ramezani and Aminlari (2004) reported ash content of four potato cultivars ranging from 3.8 to 5.4 g/ 100g of dry matter which is on par with the values observed in the present study. The differences in ash content of potato flours may also be attributed to genetic variation (Singh *et al*., 2003).

Since a certain amount of vitamin C remains in the tubers even after cooking, they could be responsible for the uptake of a significant percentage of the recommended dietary allowance (RDA) for vitamin C (40mg/day for adults) (Gonnella *et al*. 2009). Ascorbic acid content ranged from 9.12 to 15.95mg/100g in the cultivars. The lowest ascorbic acid content was observed in Kufri Pukhraj and Kufri Surya (9.12mg/100g each) while Kufri Chipsona-3 and Kufri Jyoti (15.95mg/100g each) were observed to contain higher ascorbic acid. Statistically significant difference ($p<0.05$) were observed between the nutrient compositions of the cultivars. The processing quality of potato depends on biochemical composition of its variety, particularly its content of dry matter, reducing sugars, protein and nitrogenous and phenolic compounds (Ramezani and Aminlari, 2004). Table 4 indicates phenol content of the potato cultivars. Phenol values ranged from 5.74 to 26.79mg/ 100g. The lowest phenol content was observed in Frito Lay-1533(5.74mg/ 100g), followed by Atlantic (5.85mg/ 100g) and Kufri Ashoka (5.92mg/ 100g) and the highest phenol content was seen in Kufri Bahar followed by Kufri Surya (17.16mg/ 100g). Statistical significant

Table 3: Proximate composition of potato cultivars

Cultivars	Moisture (%)	Dry matter (%)	Protein (g/100g)	Fat (g/ 100g)	Ash (g/ 100g)
Atlantic	75.84	24.16	9.88	0.005	5.85
Frito Lay-1533	77.54	22.54	9.99	0.022	5.74
Kufri Ashoka	82.14	17.83	9.06	0.018	5.92
Kufri Bahar	83.00	16.69	14.07	0.087	26.79
Kufri Chipsona_1	79.33	20.13	11.89	0.024	8.91
Kufri Chipsona-2	75.10	24.91	10.32	0.257	15.25
Kufri Chipsona_3	79.38	20.46	10.04	0.184	9.19
Kufri Jyoti	80.71	19.25	10.62	0.264	10.18
Kufri Pukhraj	83.22	16.71	10.65	0.016	8.83
Kufri Surya	81.02	18.82	13.12	0.052	17.16
F-value	*	*	*	*	*
SEm	0.17	0.02	0.02	0.001	0.03
CD	0.51	0.06	0.05	0.004	0.08

*Significant at $p<0.05$

Table 4: Ascorbic acid and Phenol content of different potato cultivars

Cultivars	Ascorbic acid (mg/ 100g)	Phenols (mg/ 100g)
Atlantic	11.60	5.85
Frito Lay-1533	11.60	5.74
Kufri Ashoka	15.93	5.92
Kufri Bahar	13.40	26.79
Kufri Chipsona-1	15.91	8.91
Kufri Chipsona-2	9.19	15.25
Kufri Chipsona-3	15.95	9.19
Kufri Jyoti	15.95	10.18
Kufri Pukhraj	9.12	8.83
Kufri Surya	9.12	17.16
F-value	*	*
SEm	0.12	0.05
CD	0.35	0.14

*Significant at $p<0.05$

difference ($p<0.05$) was observed in phenol content of the cultivars.

Total and reducing sugars content of the potato cultivars are presented in Table 5. Total sugar content ranged from 412.4 to 882.9mg/ 100g. Frito Lay-1533 contained the least total sugars whereas Kufri Ashoka contained the highest total sugars followed by Kufri Jyoti (849.1mg/100g), Kufri Chipsona-3 (781.8mg/100g) and Kufri Chipsona-2 (754.7mg/100g). Kumar and Ezekiel (2006) reported the mean values of sucrose and reducing sugars content of Atlantic variety to be 400.7 and 75.1mg/100g of fresh weight which was found to be lower those reported in the present study. The higher values in the present study could be attributed to the difference in maturity of tubers, time and temperature of storage.

The reducing sugars ranged from 3.0 to 341.0mg/100g where the least reducing sugar was observed in Kufri Chipsona-1 and the highest was observed in Atlantic closely followed by Frito Lay-1533 (331.0mg/100g). Statistically significant difference ($p<0.05$) was observed in total and reducing sugars of the cultivars. Joseph *et al.* (2004) reported reducing sugars ranging from 79.1 to 354.3 mg/100g of fresh tuber weight where all the cultivars, except Kufri Jyoti, had reducing sugars content in acceptable range. Similarly, Misra and Chand (1990) showed a great variation of reducing sugars content in two potato varieties in relation to tuber size with the values ranging from 30.6 to 733.0 mg/ 100g. The values of the present study fall within the values reported earlier except for Kufri Chipsona-1 which was found to be much lower. The variation in the reducing sugars content could be attributed to difference in maturity at harvest, time and temperature of storage.

Total starch content and its fractions- amylose and amylopectin is shown in Fig. 2. The starch content varied with the cultivars ranging from 49.5 to 81.0 percent. The starch content was highest in the processing cultivar Kufri Chipsona-3 (81.1%) followed by Kufri Surya (72.3%) and Frito Lay-1533 (70.2%), whereas its least value was observed in Kufri Bahar followed by Kufri Chipsona-2 (52.5%) and Atlantic (56.4%). Amylose content ranged from 15.3 to 24.6 percent, where the lowest was seen in Kufri Pukhraj and the highest amylose content in Kufri Chipsona-2 closely followed by Kufri Chipsona-3 and Frito Lay-1533 (24.2% each). The amylopectin content ranged from 27.5 to 57.2 percent, where the lowest amylopectin was observed in Kufri Bahar and in Kufri Chipsona-3**.** Statistically significant difference ($p<0.05$) was observed in the starch, amylose and amylopectin content of the cultivars.

Table 5: Total and reducing sugar content in potato cultivars

Cultivars	Total sugars mg/100g)	Reducing sugars (mg/ 100g)
Atlantic	426.8	341.0
Frito Lay-1533	412.4	331.0
Kufri Ashoka	882.9	64.7
Kufri Bahar	647.2	291.0
Kufri Chipsona-1	661.0	3.0
Kufri Chipsona-2	755.3	97.7
Kufri Chipsona-3	782.6	74.3
Kufri Jyoti	848.5	290.3
Kufri Pukhraj	555.9	57.7
Kufri Surya	667.1	270.3
F-value	*	*
SEm	0.85	0.45
CD	2.52	0.60

*Significant at $p<0.05$ level

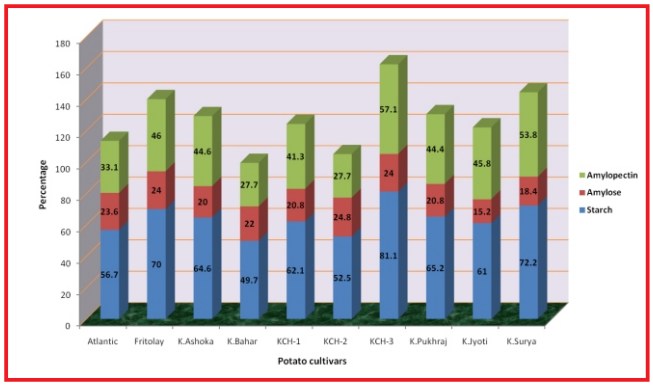

Fig. 2: Starch, amylose and amylopectin content of potato cultivars

Functional properties of unprocessed samples

Total soluble solids and the functional properties of unprocessed potato samples are presented in Table 6. Total soluble solids (TSS) content of the cultivars ranged from 5.42 to 7.12 °Brix, where the lowest TSS was observed in Kufri Ashoka followed by Kufri Chipsona-2 (5.50 °Brix), Frito Lay-1533 (5.60 °Brix), and Kufri Bahar (5.60 °Brix) and the highest TSS was observed in Kufri Chipsona-3 (7.12 °Brix) followed by Atlantic (6.78 °Brix) and Kufri Surya (6.65 °Brix) as presented in Table 6. Statistically significant difference ($p<0.05$) was observed in total soluble solids of the cultivars.

The functional properties were found to vary among the cultivars. The water absorption capacity ranged from 1.11 to 1.64 ml/ g. The lowest water absorption capacity was observed in Kufri Jyoti and the highest was observed in Kufri Bahar. An important functional characteristic of any flour is its WAC. Starch granules when heated in water undergo gelatinization accompanied with a disruption of molecular order, which losses crystallinity and an increase in the ability to bind water (Njintang and Mbofung 2006). The bulk density of the potato cultivars ranged from 0.94 to 1.00 g/ ml. Kufri Jyoti and Kufri Pukhraj had the lowest bulk density of 0.94g/ml each and Kufri Chipsona-1 had the highest bulk density of 1.00g/ml. High bulk density may be desirable in some products as in infant formulas (Shalaby and El-Shourbagy, 2016). Singh et al. (2005) reported slightly lower bulk density of potato flour of Kufri Jyoti (0.92g/ml) and that of other varieties ranging from 0.77 to 0.91g/ml.

When starch is heated in presence of excess water, starch gelatinization occurs. Gelatinization capacity of the cultivars was found to range from 10.14 to 37.30 g/ ml. The lowest being in Frito Lay-1533 and the highest in Atlantic variety. Foaming and emulsifying characteristics and the stability of dispersions depend on the properties of the surface-active

Table 6: Total soluble solids and Functional properties of unprocessed** potato cultivars

Sl. No.	Cultivars	Total soluble solids (°Brix)	Water absorption capacity (ml/g)	Bulk density (g/ml)	Gelatinization capacity (g/ml)	Emulsification Capacity (ml/g)
1.	Atlantic	6.78	1.14	0.98	37.30	1.03
2.	Frito Lay-1533	5.66	1.57	0.98	10.14	0.83
3.	Kufri Ashoka	5.42	1.14	0.96	21.47	0.84
4.	Kufri Bahar	5.60	1.64	0.98	13.40	1.40
5.	Kufri Chipsona-1	6.93	1.37	1.00	12.60	0.87
6.	Kufri Chipsona-1	5.59	1.50	0.98	14.77	1.03
7.	Kufri Chipsona-1	7.12	1.60	0.96	12.17	0.65
8.	Kufri Jyoti	5.64	1.11	0.94	16.53	1.27
9.	Kufri Pukhraj	5.75	1.30	0.94	16.70	1.05
10.	Kufri Surya	6.65	1.47	0.96	16.67	1.37
	F-value	*	*	*	*	*
	SEm	0.03	0.02	0.01	0.06	0.03
	CD	0.09	0.06	0.02	0.18	0.03

*Significant at p<0.05 level **Uncooked samples

components in the system. The most important surface-active components in foods are proteins and low-molecular weight emulsifiers viz. lipids, phospholipids and surfactants etc. (Sanchez and Patino, 2005). Emulsification capacity ranged from 0.65 to 1.40 ml/ g, with the lowest value in Kufri Chipsona-3 and the highest in Kufri Surya. Statistically significant difference (p<0.05) was observed in the functional properties of the cultivars.

Most of the carbohydrate in the cooked potato flour are gelatinized starch and in rather soluble form. The starch present in the potato flour may significantly affect its physico-chemical properties (Singh *et al.*, 2005). Table 7 indicates the functional properties of two potato cultivars- Atlantic and Frito Lay-1533 with lowest phenol content and the comparison of the functional properties between the processed and the unprocessed samples. Here processed samples referred to pre-gelatinized or cooked potato after dehydration, whereas unprocessed samples referred to potato with reduced moisture. Pre-gelatinized starches were cooked and dried giving products readily dispersed in cold water for stable suspensions. Pre-gelatinized starch dispersions have some characteristics of the untreated starch leading to its wider application in the preparation of products like instant puddings, soup mixes, salad dressings, etc. An increase in the water absorption capacity (1.14 to 3.64ml/g in Atlantic and 1.60 to 2.15ml/g in Frito Lay-1533) and gelatinization capacity (37.37 to 68.87g/ml in Atlantic and 10.17 to 38.37g/ml in Frito Lay-1533) were observed in the processed samples in both the varieties whereas bulk density (0.97 to 0.95g/ml in Frito Lay-1533) and emulsification capacity (0.93 to 0.87ml/g in Atlantic and 0.89 to 0.83ml/g in Frito Lay-1533) decreased in the processed samples except for the bulk density in Atlantic which remained unchanged. Statistically significant difference (p<0.05) was observed for water absorption capacity and gelatinization capacity between the unprocessed and processed samples (Table 7) and also between the cultivars and the bulk density between the cultivars in the unprocessed samples. Considering the water absorption capacity, the processing method adopted in the study is suitable as it increases the WAC which is a desirable character in product development.

Table 7: Functional properties of Atlantic and Frito Lay-1533

	Variety	WAC (ml/g)	BD (g/ml)	GC (g/ ml)	EC (ml/g)
Unprocessed	Atlantic	1.14	0.97	37.37	0.93
	Frito Lay-1533	1.60	0.97	10.17	0.89
Processed	Atlantic	3.64	0.97	68.87	0.87
	Frito Lay-1533	2.15	0.95	38.37	0.83
Unprocessed	F-value	*	*	*	NS
	Sem	0.005	0.005	0.12	0.04
	CD	0.02	0.02	0.40	0.13
Processed	F-value	*	NS	*	NS
	Sem	0.005	0.005	0.12	0.04
	CD	0.02	0.02	0.40	0.13

*Significant at p<0.05 NS= Not significant

WAC: Water absorption capacity, BD: Bulk density, GC: Gelatinization capacity and EC: Emulsification capacity

CONCLUSION

Potatoes are low in fat, nutritious and wholesome food which supplies many important nutrients to the diet. Besides other nutrient content potato starch is in many ways a superior starch and its many interesting properties make it attractive

for both food and industrial applications. An improvised storage system in which potatoes stored for processing maintain a firm and healthy appearance with minimum storage losses and accumulate low reducing sugars needed to obtain acceptable products with good yield. The physico-chemical properties of potato starch or flours vary with genotypes and cultural practices. Its functional properties have an important role in the processing and the quality of the processed products. The properties of starch such as amylose content, mean diameter, size distribution of granules and other functional properties may become more important in the future.

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