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French fry and chipping quality of potato varieties during storage at elevated temperatures

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ABSTRACT

Five varieties were assessed for processing quality during storage at 10-12°C. Dry matter (DM) content increased during storage with Indian processing varieties recording significantly higher dry matter (>20%) than the exotic variety (Kennebec). Reducing sugar and sucrose contents recorded an increasing pattern during storage though Kufri Surya recorded the lowest contents. Free amino acids and total phenol contents also increased during storage. All the varieties maintained acceptable French fry colour upto six months, while their response differed with respect to chip colour. Lowest mean chip colour was recorded in Kufri Surya, which was at par with Kufri Chipsona-1. These potato varieties grown in North-western plains can profitably be used by the French fry industry upto 180 days of storage. Kufri Surya, maintaining acceptable chip colour for longer period during storage, can be the better choice for chip industry.

Key words: Potato storage, sugars, free amino acids, fry and chip colour.

INTRODUCTION

India is the world's second largest potato (*Solanum tuberosum* L.) producing nation, although its potato processing industry is still in its infancy. Per capita potato processing in India during 2007-08 was just 365 g (89.7% potato chips or crisps, 9.3% potato powder/flakes and 1.03% French fries) (Rana, 10). Potatoes meant for processing are stored at intermediate temperatures of 10-12°C with sprout suppressant (isopropyl N-3-chloro phenylcarbamate, CIPC) treatment, because low temperature storage leads to excessive accumulation of reducing sugars which react with free amino acids during high temperature frying resulting in brown coloured and bitter tasting products because of 'Maillard reaction' (Kumar *et al.*, 6). At these temperatures also, the maintenance of quality in terms of low accumulation of reducing sugars over the period of time is decided by many factors mainly by the genotype. The ability of cultivars to maintain low concentration of sugars during long-term storage is important for round the year profitable operations of the industry. Central Potato Research Institute has developed different varieties for making chips and French fries, but due to non-availability of quality raw material, these varieties are being used for both the purposes. Consolidated information on their performance during long term storage at 10-12°C is not available. Therefore, three recently released varieties were assessed for processing quality changes during storage at 10-12°C was undertaken.

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MATERIALS AND METHODS

Four Indian varieties, *viz.* Kufri Chipsona-1, Kufri Chipsona-3, Kufri Surya and Kufri Frysona and one exotic variety (Kennebec) were used for this study (2009 and 2010) conducted at CPRS, Jalandhar. Crop was raised by following recommended cultural practices in the field. Cutting of haulms was done at full maturity (100 days after planting) and crop was harvested after 20 days of skin curing in the soil. Twenty kilograms well-cured and graded tubers of each variety were stored in nylon bags in commercial cold store on 15th of March each year. The holding temperatures of storage varied between 10-12°C with relative humidity of 85 ± 5%. The treatment of sprout suppressant, *i.e.* 50% CIPC, was given as fog @ 35 ml/ tonne, twice during the storage period (Singh *et al.*, 12). Potato samples were drawn at monthly intervals after 60 days of storage (DOS) up to 180 days. Out of 25 tubers taken out on each date, fifteen tubers were used for chip and fry colour determination and rest 10 for biochemical estimations. For chips, potatoes were hand peeled and cut into slices of 1.4 mm thickness with a semi-automatic slicing machine. The slices were washed thoroughly in cold water, air-dried and immediately fried in cotton seed oil at 190°C till the bubbling on the chip surface stopped.

For the preparation of French fries, tubers were hand peeled and strips were cut into 1 × 1 cm^2 in cross section using a vegetable cutter. The cut strips were blanched, par fried, frozen and final fried as per the method described earlier (Mehta *et al.*, 8). The fries and chips were subjectively scored for colour and assigned a value according to 1-10 scale (1 being the lightest and 10 dark brown with a score up to and including 4 being acceptable) (Ezekiel *et al.*, 3). The biochemical estimations comprised quantification of dry matter percent (by hot-air oven drying) and reducing sugars, sucrose, total phenols and free amino acids as per the standard methods (Mehta and Singh, 7).

All the estimations were done in three replicates and the data was statistically analyzed using completely randomized design through MSTAT C software (Gomez and Gomez, 4). Since free amino acids and reducing sugars both are involved in Maillard's reaction responsible for the colour of fried potato products, either component may be expected to exert an influence on the final colour of the product, while combination of both is likely to improve the prediction of colour. Therefore, mean data at six sampling dates was used for both simple and multiple regression analysis between chip and fry colour and determining factors as sugars and amino acids to derive prediction equations for the fry and chip colour.

RESULTS AND DISCUSSION

Dry matter content (DM) increased up to 120 DOS in 2009 and 90 DOS in 2010 (Table 1). An apparent increase in DM during storage occurs mainly because of water loss from the tuber. Varieties differed significantly in DM content with Indian processing varieties recording higher contents (>20%) than the exotic variety (Kennebec). Kufri Chipsona-3 (23.4%) and Kufri Frysona (23.2%) recorded mean maximum DM contents during 2009 and 2010, respectively. Tuber dry matter content has more influence on the quality of the finished fried product than any other single quality factor in the raw material and potatoes with >20% dry matter produce crispy fried product (Pavlista and Ojala, 9).

At the time of storage, reducing sugar content (RS) in potato varieties was low (62.3- 69.6 mg/100 g fr. wt.) (Table 1). RS contents decreased up to 60 days of storage in 2009 and increased, thereafter, while in 2010 the contents recorded a steady increase up to 180 days**.** The commercial cold stores of the region keep filling the stores till the first week of April resulting in fluctuations in holding temperatures, which could be the possible reason for differential changes in RS contents during the two years. Kufri Surya recorded significantly lower

Table 1. Chemical characteristics of potato varieties stored at 10-12°C.

Variety	Storage period (days) - 2009							Storage period (days) - 2010						
	0	60	90	120	150	180	Mean	0	60	90	120	150	180	Mean
							Dry matter (%)							
K. Chipsona-1	21.8	21.2	23.2	23.5	22.5	20.4	22.1	20.7	21.1	22.8	22.0	20.6	21.3	21.4
K. Chipsona-3	20.7	23.7	23.3	25.5	23.3	23.8	23.4	21.7	22.4	23.3	23.7	21.5	22.1	22.4
K. Surya	19.6	19.2	22.1	22.1	19.8	19.5	20.4	18.8	20.4	20.5	21.0	20.5	20.1	20.2
K. Frysona	21.8	22.6	23.7	23.2	23.3	24.6	23.2	22.8	23.6	24.3	23.3	23.6	21.9	23.2
Kennebec	18.8	18.4	19.9	19.4	20.9	21.6	19.8	19.4	19.1	19.8	19.3	17.7	17.4	18.8
Mean	20.6	21.0	22.4	22.8	22.0	22.0		20.7	21.3	22.1	21.9	20.8	20.6	
CD at 5%	Variety = 0.35, Storage = 0.37, Variety x Storage = 0.84							Variety = 0.17, Storage = 0.20, Variety x Storage = 0.43						
							Reducing sugars (mg/100 g fresh weight)							
K. Chipsona-1	35.0	41.5	42.8	125.0	69.1	140.0	75.6	64.5	65.9	201.8	116.8	155.9	73.6	113.1
K. Chipsona-3	67.8	39.7	78.7	98.2	125.5	190.9	100.1	80.5	60.9	74.5	100.5	91.8	93.2	83.6
K. Surya	59.6	52.3	34.1	84.6	66.9	123.7	70.2	62.3	120.5	13.6	32.3	58.6	57.7	57.5

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Variety	Storage period (days) - 2009							Storage period (days) - 2010						
	0	60	90	120	150	180	Mean	0	60	90	120	150	180	Mean
K. Frysona	81.8	32.9	68.2	134.6	214.1	245.9	129.6	51.8	80.5	74.1	89.1	255.9	236.8	131.4
Kennebec	67.3	36.6	58.7	68.2	25.5	31.8	48.0	89.1	120.0	115.0	157.7	182.3	230.9	149.2
Mean	62.3	40.6	56.5	102.1	100.2	146.5		69.6	89.5	95.8	99.3	148.9	138.5	
CD at 5%	Variety =10.04, Storage = 11.00, Variety x Storage = 24.60							Variety = 5.30, Storage = 5.80, Variety x Storage = 1.30						
	Sucrose (mg/100g fr. wt.)													
K. Chipsona-1	194.7	127.7	113.1	115.4	91.6	118.5	133.5	88.5	118.5	479.2	201.5	221.5	169.2	213.1
K. Chipsona-3	180.8	118.5	120.8	364.7	230.8	348.5	227.3	85.4	117.7	245.4	138.5	168.5	263.9	169.9
K. Surya	183.9	123.1	116.2	177.7	174.6	221.6	166.2	96.9	147.7	186.9	136.2	185.4	335.4	181.4
K. Frysona	174.6	120.8	141.6	220.8	148.5	329.2	185.9	99.2	111.5	179.2	143.1	215.4	360.9	184.9
Kennebec	172.3	123.9	97.7	160.8	128.5	194.6	146.3	96.9	125.4	141.5	197.7	226.2	263.9	175.3
Mean	181.2	122.8	117.9	215.9	154.8	238.5		93.4	124.2	246.5	163.4	203.4	278.6	
CD at 5%	Variety = 10.8, Storage = 11.8, Variety x Storage = 26.3							Variety = 12.4, Storage = 13.6, Variety x Storage = 30.35						
	Free amino acids (mg/100g fresh weight)													
K. Chipsona-1	528	385	534	773	566	552	556	462	601	704	718	518	717	620
K. Chipsona-3	407	356	602	821	662	670	586	498	516	563	585	705	681	591
K. Surya	568	438	698	870	701	779	676	771	514	812	803	688	1115	784
K. Frysona	520	331	532	759	598	482	537	501	561	701	639	442	913	626
Kennebec	615	490	673	999	855	866	749	768	690	767	788	827	1431	878
Mean	528	400	607	845	676	670		600	576	709	707	636	971	
CD at 5%	Variety = 33.7, Storage = 16.9, Variety x Storage = 82.5							Variety = 32.88, Storage = 36.00, Variety x Storage =80.50						
	Total phenols (mg/100g fresh weight)													
K. Chipsona-1	28.9	41.4	43.8	59.2	47.1	44.6	44.1	38.9	40.0	43.4	44.3	49.4	52.9	44.8
K. Chipsona-3	37.2	39.7	46.3	73.5	57.4	58.9	52.1	43.4	43.7	51.7	60.6	64.3	75.4	56.5
K. Surya	51.5	52.3	55.2	80.0	74.9	61.2	62.5	52.6	50.9	60.6	60.6	70.6	84.3	63.2
K. Frysona	32.3	32.9	42.6	60.0	44.3	51.4	43.9	44.0	42.0	45.4	44.0	54.0	57.1	47.8
Kennebec	22.9	36.6	60.3	66.6	55.2	52.6	49.0	50.3	50.9	63.4	47.4	66.6	62.0	56.8
Mean	34.5	40.5	49.6	67.8	55.8	53.7		45.8	45.5	52.9	51.4	61.0	66.3	
CD at 5%	Variety = 1.9, Storage = 2.1, Variety x Storage = 4.7							Variety = 2.88, Storage = 3.17, Variety x Storage = 7.10						

mean sugar contents in both the years though it was statistically at par with Kufri Chipsona-1 in 2009, thus, highlighting the importance of the genotype. Maximum mean RS contents (significantly higher than the rest of the varieties) during storage were recorded in Kufri Frysona in 2009 and in Kennebec in 2010. The genetic component has a strong influence upon initial reducing sugar levels in a mature tuber as well as during storage (Es and Hartmans, 2). Also the quantitative relationships between cultivar and reducing sugars are reported to vary with year (Kumar *et al.*, 6).

Though role of sucrose in browning reaction is not clear, it plays an important role in determining the quality of potatoes after storage. Although sucrose does not participate in non-enzymatic browning of processed products directly, it serves as a substrate for reducing sugar production *via* the storage activated invertase enzyme (Kumar *et al.*, 6). Tubers with low sucrose levels prior to harvest are known as chemically mature, but in this case, the data did not discern much difference among the varieties and recorded more or less uniform initial sucrose values (Table 1). Sucrose content in potatoes was low (93.4 mg/100 g fresh weight) at the time of storage in 2010, may be due to delayed harvesting of the experiment by more than one week (beyond the curing period of 20 days) because of heavy rain (24.32 mm) in the second week of February. In 2009, sucrose concentration decreased up to 90 DOS and increased thereafter, whereas the contents recorded an increasing trend during storage in 2010. Es and Hartmans (2) also reported that CIPC treatment greatly increase the sucrose content of potatoes late in the storage as sugars could no longer be translocated to the sprouts. Varieties differed significantly with respect to sucrose accumulation during storage and maximum mean sucrose contents were recorded in Kufri Chipsona-3 in 2009 and in Kufri Chipsona-1 in 2010.

Total free amino acids (FAA) content is also taken into account in determining the processing quality, being another reactant of Maillard's reaction responsible for browning in fried potato products. Though reducing sugars are the major and limiting components, FAA can also influence colour under certain situations (Kumar *et al.*, 6). The FAA contents decreased on 60 DOS and recorded an increasing pattern during storage in both the years (Table 1) because of upturn of proteinase activity on the break of dormancy (Brierley *et al.*, 1), even though the sprouting was checked with CIPC. Kufri Surya and Kennebec recorded significantly higher FAA contents than the rest of three varieties in both the years.

Phenols are associated with enzymatic browning in cut potatoes exposed to air. This parameter is important when potato is processed in cottage industry and in making dehydrated products. Some of the constituents like tyrosine and ortho-dihydric phenols present in the tubers react with oxygen in the presence of polyphenoloxidase enzyme and tuber flesh turns brown (Schaller and Amberger, 11). This type of discoloration can be prevented if potatoes are immediately immersed in water and are not exposed to air. Total phenol contents recorded increasing trend with significantly higher contents recorded in variety Kufri Surya during both the years (Table 1). Kufri Chipsona-1 recorded significantly lower total phenols content than rest of the varieties. Phenolic compounds are potent antioxidant compounds which play important role in reducing oxidative damage to cellular membranes and reducing low temperature sweetening in potato (Kumar, 5). In this study also, cv. Kufri Surya with higher phenol contents maintained lowest reducing sugar levels during storage.

It is desirable that French fries should be of light golden colour without any brown over-colouring or black spots or traces. Excessive darkening and development of off-flavour due to high reducing sugars are unacceptable for processed potato products. All the varieties maintained acceptable French fry colour (4.0 and below) up to six months of storage in both the years (Table 2). The fries made from cv. Kufri Surya were uniformly golden yellow possibly because of relatively yellow tuber flesh as compared to other cultivars.

The mean value of chip colour increased gradually after 60 and 90 days of storage in 2009 and 2010 and further deteriorated at 180 days (Table 2). Chip colour during storage was better in 2010, may be due to low sucrose contents at harvest. Potatoes with low sucrose levels prior to harvest are reported to demonstrate superior processing quality for chipping when stored at 11.7°C (Kumar *et al.*, 6). Kufri Surya recorded the lowest value for chip colour in both the years though it was statistically at par with Kufri Chipsona-1 in 2009. When interaction between genotype and duration was observed, the varietal performance differed in the two years. All varieties except Kennebec and Kufri Chipsona-1, could make acceptable chips at most storage dates up to 150 days in 2010. While in 2009, Kufri Chipsona-1 could make acceptable colour chips up to 90 days, Kufri Chipsona-3 up to 120 days and Kufri Surya up to 150 days with slight deterioration on 60 and 120 days. Chip colour of Kufri Frysona and Kennebec was however, unacceptable on most dates of storage. The

Table 2. Colour of French fries and chips prepared from potatoes stored at 10-12°C.

Variety	Storage period (days) - 2009							Storage period (days) - 2010						
	0	60	90	120	150	180	Mean	0	60	90	120	150	180	Mean
Fry colour (on a 1-10 scale of increasing dark colour, score up to 4 was acceptable)														
K. Chipsona-1	2.00	2.00	2.75	2.00	2.25	2.75	2.29	1.50	2.00	2.13	2.00	3.25	2.50	2.23
K. Chipsona-3	3.28	2.75	2.75	2.50	2.00	2.00	2.55	1.63	1.50	2.38	2.38	3.00	3.25	2.35
K. Surya	2.72	3.25	3.25	3.75	2.25	3.00	3.04	1.75	2.75	2.50	2.25	2.63	2.25	2.52
K. Frysona	2.35	3.25	2.00	2.00	2.75	3.00	2.56	1.50	1.50	1.63	1.50	2.25	2.88	1.88
Kennebec	2.75	2.00	2.75	2.00	3.50	2.00	2.50	2.25	1.63	1.88	1.50	3.25	2.00	2.08
Mean	2.62	2.65	2.70	2.45	2.55	2.55		1.73	1.88	2.10	2.13	2.88	2.58	
CD at 5%	Variety = 0.29, Storage = NS, Variety x Storage = 0.69							Variety = 0.17, Storage = 0.17, Variety x Storage = 0.40						
Chip colour (On a 1-10 scale of increasing dark colour, score up to 4 was acceptable)														
K. Chipsona-1	2.35	4.00	4.00	4.25	4.50	6.75	4.31	3.00	2.50	5.25	4.38	4.25	4.63	4.00
K. Chipsona-3	4.75	3.00	4.50	3.75	5.75	6.75	4.75	3.00	2.75	4.00	2.00	3.50	5.50	3.46
K. Surya	3.00	4.25	3.75	4.50	3.50	7.00	4.33	2.50	3.38	2.75	2.00	2.88	4.25	2.96
K. Frysona	5.25	5.50	5.50	6.25	6.25	6.75	5.92	2.00	3.75	4.00	2.88	4.50	6.00	3.85
Kennebec	4.50	6.50	2.75	4.25	3.50	6.50	4.67	5.00	4.50	5.50	4.75	4.75	6.75	5.21
Mean	3.97	4.65	4.10	4.60	4.70	6.75	3.10	3.38	4.30	3.20	3.97	5.43		
CD at 5%	Variety = 0.31, Storage = 0.35, Variety x Storage = 0.78							Variety = 0.17, Storage = 0.20, Variety x Storage = 0.43						

quantitative relationship between colour of processed products and reducing sugar content during storage is reported to vary among the cultivars (Kumar *et al.*, 6).

Maintenance of acceptable chip colour for longer period of time is essential for processors to run the industry for most part of the year, since fresh potatoes are available for limited period. This feature has been observed in cv. Kufri Surya in both the years of the study and only Kufri Chipsona-1 only in 2009. Differential behaviour of varieties during storage in the two years may be due to differences in initial holding temperatures of cold stores as indicated earlier.

Stepwise regression analysis carried out to quantify the role of determining factors showed that fry colour was not related to any factor, reducing sugars, sucrose and FAA alone and in combination possibly because, all these potato constituents (even if in higher quantity), were reduced to acceptable levels by leaching out during washing and blanching process of French fries. Chip colour however, correlated with different parameters. Reducing sugars, sucrose and FAA contents accounted for 50, 36 and 28% variation in chip colour, respectively (Table 3). Prediction of chip colour was further improved up to 65% by combining reducing sugars, sucrose and free amino acids. Mehta and Singh (7) also showed that reducing sugar and glucose contents accounted for 67-71% of variation in chip colour.

The selection of a suitable variety for any potato operation is essential for long-term success. Several table or ware purpose varieties are available to Indian farmers, but only few varieties are ruling the fields. For processing variety also, quality at harvest alone does not complete the story; the maintenance of quality during long-term storage is equally important. On the basis of this study, it can be concluded that all the five varieties grown in North Western plains when harvested at right chemical maturity and stored at right time with proper management of storage at 10-12°C, can provide potatoes to the French fry industry up to 180 days. For the chip industry, Kufri Surya can be the better choice up to 150 days, while Kufri Chipsona-1 and Kufri Chipsona-3 can be used up to 90 and 120 days of storage, respectively

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Table 3. Coefficient of determination: chip colour (CC) versus sugars/amino acids.

Sl. No.	Regression line	R^2	Significance of factors
1	CC vs Reducing sugars (RS) CC = 2.364 + 0.0143 RS	0.497	p < 0.01
2	CC vs sucrose (Su) CC = 2.342 + 0.0084 Su	0.358	p < 0.01
3	CC vs Free amino acids (FAA) CC = 1.586 + 0.0033 FAA	0.284	p < 0.01
4	CC vs RS, Su CC = 1.952 + 0.0109 RS + 0.00419 Su	0.558	RS p < 0.01 Su = NS
5	CC vs. RS, FAA CC = 0.917 + 0.0124 RS+ 0.00236 FAA	0.633	RS p < 0.01 FAA p < 0.01
6	CC vs RS, Su, FAA CC = 0.886 + 0.0109 RS + 0.00221 Su + 0.00206 FAA	0.648	RS p < 0.01 Su NS FAA p < 0.05

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