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FRENCH FRY QUALITY OF POTATO VARIETIES: EFFECT OF TUBER MATURITY AND SKIN CURING

Ashiv Mehta[1], Priyamvada Charaya[1], BP Singh[2]

ABSTRACT: Four Indian processing and one exotic potato variety harvested directly at 10 day interval between 70 and 100 days after planting and at 120 days after 20 days of tuber skin curing in the soil following dehaulming, were evaluated for French fry quality. Tuber dry matter increased with maturity and was >20% at 90 days after planting in Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Frysona and at 100 days in Kufri Surya. Reducing sugar content was low (<100 mg/100g fresh weight), except in Kennebec (172 mg/100 g fresh weight) harvested at 100 days after planting. Sucrose content decreased significantly towards crop maturity and curing. Changes in free amino acid contents did not record any trend while total phenols increased with maturity and curing. All varieties made acceptable fries except Kennebec. Fry yield increased significantly with maturity up to 100 days and decreased during the curing period. Fry texture improved towards maturity and Kufri Frysona and Kufri Chipsona-3 produced fries with superior texture. Varieties differed significantly with respect to oil uptake and Kufri Frysona fries contained lowest oil content. Based on quality parameters, Kufri Frysona was rated as the best variety for French fries.

KEYWORDS: potato varieties, tuber maturity, French fry quality, sugars, free amino acids

INTRODUCTION

India produced 25 million t of potatoes during 2004-05 and is the third largest producer in the world after China (75 million t and Russian Federation (37 million t (Pandey and Sarkar, 2005). Increased potato production with inadequate, expensive and unevenly distributed refrigerated storage facilities in our country has resulted in frequent gluts in the market causing economic loss to the farmers and wastage of precious food. Diversification of potato utilization can solve this problem to some extent.

Fresh potatoes can be processed into several value added fried and non-fried products having long shelf life. The demand for processed potato products like chips and French fries is increasing continuously in the present day liberalized economy mainly due to improved living standards, urbanization growth, preference of new generation for fast foods, rise in per capita income, increase in the number of working women preferring ready-cooked food and expanding tourist trade. Consequently, potato processing is emerging as a fast growing industry with more entrepreneurs joining and existing ones increasing the capacity of processing units (Pandey *et al.*, 2009).

Frozen French fries are an important segment of potato processing industry. With an upsurge in the global consumption of French fries and an increasing demand in the big cities of India for internal consumption as well as for export in the recent years, there is a continuous need for potato processors to ensure optimum quality in the product. French fry quality is primarily measured by colour and texture. While light cream to golden brown is considered a good fry colour, a crisp outer crust and a soft mealy interior are desirable textural features (Agblor and Scanlon, 2000). Colour of the fries is mainly dependent upon the concentration of reducing

[1]Central Potato Research Station, Jalandhar-144 003, Punjab, India
E-mail: ashiv_mehta@yahoo.com
[2]Central Potato Research Institute-171 001, Shimla, Himachal Pradesh, India

sugars and free amino acids, while texture is controlled by the physical and biochemical changes in the structural components of potato tissue during processing. All these changes are influenced by the location, cultivar, date of harvest and tuber curing (Marwaha *et al*., 2005)). Presently, French fry industries are mainly using Kufri Chipsona-1 and are in the dire need for new varieties with better performance. With a view to prolong the availability of suitable raw material for the industries, tubers of five processing varieties grown at Jalandhar (Punjab) and harvested directly at different tuber maturity dates (70-100 days after planting) and then at 120 days after 20 days of skin curing in the soil following dehaulming of the crop were evaluated for quality of French fries

MATERIALS AND METHODS

Field trial was conducted with four Indian processing varieties *viz*. Kufri Chipsona-1, Kufri Chipsona-3, Kufri Surya, Kufri Frysona and one exotic variety Kennebec in sandy loam soil at farm of Central Potato Research Station, Jalandhar (Punjab) in northern plains of India during October to February (2008-09, 2009-10). The seed tubers (about 50 mm in size) were planted in a randomized split plot design, replicated four times with cultivars in main plots and dates of harvest in sub plots; directly at 70, 80, 90 and 100 days after planting, and plants defoliated at 100 days and harvested at 120 days after 20 days of skin curing in the soil. N, P and K were applied at 270, 100 and 150 kg/ ha, respectively and recommended cultural practices were followed. Varieties were evaluated for tuber dry matter, fry colour, yield of fries and different biochemical constituents *viz.* reducing sugars, sucrose, phenol and amino acids by the standard methods (Marwaha, 1999 and Marwaha *et al*., 2005).

For the preparation of fries, 8-10 tubers were hand peeled and strips were cut into 1 x 1 cm^2 in cross section using a vegetable cutter. The cut strips were washed in cold water, blanched twice, first at 82 ^oC for 3 min, washed in cold water and then at 72^oC for 8 min, air dried and fried in cotton seed oil at 180 ^oC for 1.5 min. These were immediately frozen and stored at -20 ^oC and then finish fried at 180 ^oC for 3.0 min. The fries 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 4 being acceptable). Texture of fries was determined by the Texture Analyzer, Micro Stable Systems, UK using multiple chip rig probe. Oil content of fries was determined by the method described by Marwaha *et. al.* (2005). For each estimation, observations were recorded for four replicates and the data was pooled and statistically analyzed (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Morphological characters such as shape and eye depth of the tubers showed that varieties Kufri Surya and Kufri Frysona had oblong tubers and Kufri Chipsona-1 and Kufri Chipsona-3 had oval to long oval tubers which are suitable for French fries, while Kennebec had round tubers. All the varieties were white skinned and had shallow to medium-deep eyes. Varieties with perfect oblong to oval tubers with shallow eyes result in minimum losses on peeling and trimming.

Dry matter content of tubers increased towards maturity and after skin curing **(Table 1)**. Tuber dry matter content has more influence on the quality of the finished French fries than any other single quality factor in the raw material (Pavlista and Ojala, 1997). Potatoes with >20% dry matter produce crispy French fries (Smith, 1987)). Raw material with high dry matter content requires relatively less frying time to remove moisture from French fries. Therefore, there is less opportunity for oil

Table 1. Influence of harvest date and skin curing on dry matter content (%) of potatoes.

Variety (V)	Days after planting (DAP)					Mean
	70	80	90	100	100 days + cured[1]	
K. Chipsona-1	19.8	19.4	20.7	21.5	21.3	20.5
K. Chipsona-3	19.2	21.0	22.2	21.3	22.8	21.3
K. Surya	18.1	18.9	19.6	20.1	20.1	19.4
K. Frysona	19.6	21.2	22.2	23.2	23.4	21.9
Kennebec	16.7	17.2	16.4	17.4	19.6	17.5
Mean	18.7	19.5	20.2	20.7	21.3	
SEm±	V =0.10, DAP =0.10, V x DAP =0.20					
CD (0.05)	V =0.29, DAP =0.29, V x DAP = 0.58					

[1]Plants defoliated on 100 days, but tubers harvested at 120 days after 20 days of skin curing in the soil

Table 2. Influence of harvest date and skin curing on colour[1] of French fries.

Variety (V)	Days after planting (DAP)					Mean
	70	80	90	100	100 days + cured[2]	
K. Chipsona-1	2.00	2.00	2.00	2.00	2.66	2.13
K. Chipsona-3	2.00	2.33	2.33	2.00	2.49	2.23
K. Surya	2.00	3.65	3.32	2.66	3.33	2.99
K. Frysona	2.33	3.83	3.65	2.33	2.32	2.89
Kennebec	2.00	2.00	4.66	3.83	2.99	3.10
Mean	2.07	2.76	3.19	2.56	2.76	
SEm±	V =0.08, DAP =0.08, V x DAP =0.19					
CD (0.05)	V =0.23, DAP =0.23, V x DAP = 0.55					

[1]On a 1-10 scale of increasing dark colour, fry colour score up to 4 was acceptable
[2]Plants defoliated on 100 days, but tubers harvested at 120 days after 20 days of skin curing in the soil

absorption and discoloration during cooking. In the present study, cv Kennebec had low dry matter of less than 20% on all harvesting dates, while Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Frysona had dry matter more than 20% after 90 days after planting and Kufri Surya at 100 days after planting.

The contents of reducing sugars in potatoes were affected by harvest date and response of varieties differed. Reducing sugar concentration decreased towards maturity up to 90 days and then increased after 100 days and during the curing period in all the varieties except Kufri Surya where it started increasing after 90 days **(Fig. 1a)**. Kufri Frysona also showed erratic behaviour and recorded an increase in reducing sugar concentration at 80 days after planting. Physiological maturity of tubers is reported to occur when a peak of dry matter is attained which usually coincides with a minimum sugar content (Iritani and Weller, 1981), but in this study increase in reducing sugar contents at 100 days after planting may be due to increased activity of invertase associated with low soil temperatures (<10^{o}C) in the month of January-February under short day conditions (Marwaha, 1999). Tubers of Kufri Surya and Kufri Chipsona-1 contained lowest mean reducing sugars. The reducing

Table 3. Influence of harvest date and skin curing on yield (%) of French fries

Variety (V)	Days after planting (DAP)					Mean
	70	80	90	100	100 days + cured [1]	
K. Chipsona-1	48.5	46.8	44.1	50.3	42.2	46.4
K. Chipsona-3	42.9	46.4	46.0	45.3	41.2	44.4
K. Surya	49.5	49.0	47.2	47.1	39.7	46.5
K. Frysona	47.3	42.1	44.3	47.0	45.3	45.2
Kennebec	46.8	43.1	45.4	45.3	43.5	44.8
Mean	47.0	45.5	45.4	47.0	42.4	
SEm±	V =0.40, DAP =0.40, V x DAP =0.89					
CD (0.05)	V =1.16, DAP =1.16, V x DAP = 2.59					

[1]Plants defoliated on 100 days, but tubers harvested at 120 days after 20 days of skin curing in the soil

Table 4. Influence of harvest date and skin curing on texture (g force) of French fries.

Variety (V)	Days after planting (DAP)					Mean
	70	80	90	100	100 days + cured [1]	
K. Chipsona-1	804.8	958.1	1052.8	1050.0	1169.1	1007.0
K. Chipsona-3	1052.9	1462.8	1583.1	1958.2	1584.1	1528.4
K. Surya	1095.1	1071.1	1234.8	1125.5	1164.3	1158.1
K. Frysona	1256.6	1570.8	1714.6	1609.7	1690.1	1568.3
Kennebec	1493.2	1387.7	1473.7	1469.2	1384.9	1439.7
Mean	1140.5	1310.1	1411.8	1440.5	1398.6	
SEm±	V =32.73, DAP =32.73, V x DAP =73.19					
CD (0.05)	V =91.65, DAP =91.65, V x DAP =205.0					

[1]Plants defoliated on 100 days, but tubers harvested at 120 days after 20 days of skin curing in the soil

Table 5. Influence of harvest date and skin curing on oil content (%) of French fries.

Variety (V)	Days after planting (DAP)					Mean
	70	80	90	100	100 days + cured [1]	
K. Chipsona-1	14.1	13.6	14.6	13.4	12.8	13.7
K. Chipsona-3	17.5	11.8	14.5	13.6	13.0	14.1
K. Surya	11.6	10.2	13.2	14.4	14.3	12.8
K. Frysona	11.9	12.5	10.9	11.7	11.0	11.6
Kennebec	12.8	14.9	15.1	12.9	12.6	13.7
Mean	13.6	12.6	13.7	13.2	12.8	
SEm±	V =0.41, DAP =0.41, V x DAP =0.92					
CD (0.05)	V =1.19, DAP =NS, V x DAP = 2.67					

[1]Plants defoliated on 100 days, but tubers harvested at 120 days after 20 days of skin curing in the soil

sugar content of all the varieties was low (<100 mg/100g fresh weight) on all maturity dates except in Kennebec (172 mg/100 g fresh weight) harvested 100 days after planting. The genetic component has a strong influence upon initial reducing sugar levels in a mature tuber

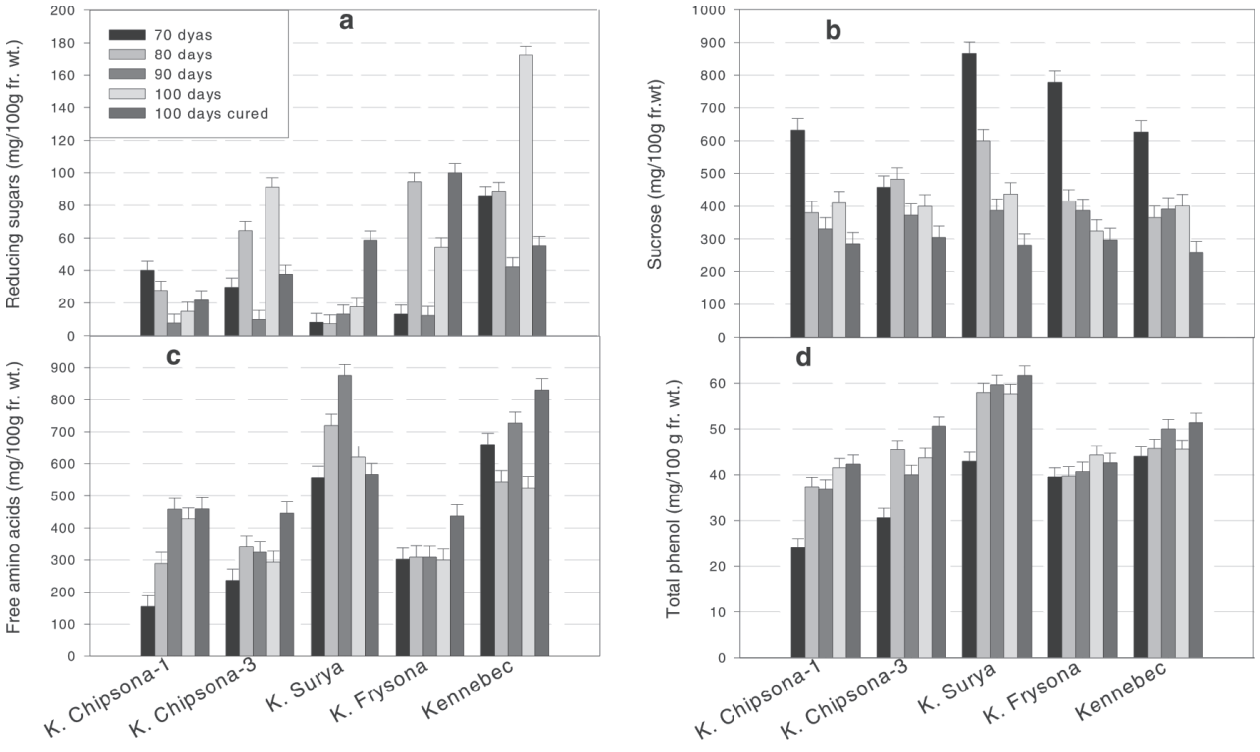

Fig. 1. Biochemical constituents in potato tubers as influenced by harvest date and skin curing. CD (P=0.05) a: V=7.22, DAP=7.22, VxDAP=16.14, b: V=45.5, DAP=45.5, VxDAP=101.7, c: V=44.9, VxDAP=100.5, d: V=2.65, DAP=2.65, VxDAP=5.91
(error bars represent SEm± values of variety and days after planting interaction, fr. wt. means fresh weight)

(Stevenson *et al*., 1964).

Sucrose content decreased towards maturity and after dehaulming of the crop and there were large variations among the cultivars **(Fig. 1b)**. Mature and cured tubers contained only 42.4% sucrose as compared to 70 day old ones. A decrease in sucrose over subsequent harvests was also reported under long day conditions (Leszkowait *et al.*, 1989). Although sucrose does not participate in non enzymatic browning of processed products directly, it serves as a substrate for reducing sugar production via the enzyme invertase and low sucrose concentration in tubers ensures acceptable processing for long-term storage at intermediate temperatures (Sowokinos, 1978). Kufri Surya contained significantly higher mean sucrose concentration which was mainly due to higher levels in immature tubers (70 and 80 days harvest) than other varieties, but the levels were at par in mature and cured potatoes.

Free amino acids were estimated because in the Maillard reaction (responsible for browning in fried potato products) besides reducing sugars these are also reactant. Though reducing sugars are the major and limiting components, free amino acids can also influence colour under certain situations (Roe *et al.*, 1990). The contents of free amino acids increased up to 90 days with a significant drop at 100 days in Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Surya **(Fig. 1c)** however no increase was recorded in Kufri Frysona. No fixed trend in changes in free amino acid contents with maturity was observed in Kennebec. With the exception of Kufri Surya, free amino acid contents increased during the curing period as

reported earlier also (Marwaha *et al.*, 2005).

The phenols are associated with enzymatic browning in cut potatoes exposed to air. This parameter is very important when potato is processed in cottage industries 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 polyphenol oxidase enzyme and tuber flesh turns brown (Schaller and Amberger, 1974). This type of discoloration can be prevented if potatoes are not exposed to air and are immersed in water. However, this is not a major problem in our country as almost all the cultivated varieties are free from this defect (Pandey *et al.*, 2000). Total phenols increased uniformly with maturity and curing (**Fig. 1d)**. Tubers of Kufri Surya and Kennebec contained significantly high contents of free amino acids and total phenols. Varieties with low total phenols are generally preferred for processing (Marwaha, 1999)

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 (Lisinska and Leszeczynski, 1989). All the varieties contained lower contents of reducing sugars than the prescribed limit for French fries (0.2% on fresh weight) and made acceptable fries with colour score of 4.0 or below except in Kennebec harvested after 90 days where the colour was unacceptable and on the border line of acceptance in potatoes harvested after 100 days **(Table 2)**. The quantitative relationship between colour and reducing sugars vary among the cultivars (Singh *et al.*, 2005).

Evaluation of fry quality and important processing traits revealed that mean fry yield was significantly higher in immature tubers (70 day harvest) mainly due to low peeling losses because of immature skin **(Table 3)**. Total losses (peeling + trimming) during processing into fries were taken into account for fry yield evaluation (Marwaha *et al.*, 2005). Fry yield increased significantly with maturity up to 100 days in positive relationship to increasing dry matter content and decreased during the curing period probably due to increased peeling losses because of well formed cured skin. Mean fry yield ranged between 44.4 and 46.5% with Kufri Chipsona-1 and Kufri Surya giving significantly higher fry yield. Fry texture improved towards maturity and Kufri Frysona and Kufri Chipsona-3 with higher dry matter content produced most firm fries **(Table 4)**. Varieties differed significantly with respect to oil uptake of French fries with Kufri Frysona fries recorded lowest oil content **(Table 5)**. French fries prepared from Kufri Frysona would provide less calories which is preferred by calorie conscious consumers. Absorption of more oil by the French fries increases fry limpness producing a soggy interior texture (Weaver *et al.*, 1975). Though the oil content of fries decreased with maturity and curing but the differences were non-significant.

CONCLUSIONS

Both tuber dry matter and reducing sugars are strongly influenced by the location. In general, potatoes grown in cooler north-western region contain relatively less tuber dry matter and more reducing sugars. With farther away towards the warmer regions of eastern and central plains and peninsular India, the percent tuber dry matter increases and the reducing sugar content decreases. Therefore, acceptable quality potatoes having high dry matter and low reducing sugars suitable for processing are expected to be produced only in a few regions, *viz.* Indore and Ujjain districts in Madhya Pradesh, Nagrota in the foothills of Himachal Pradesh, a part of central Uttar Pradesh (*rabi* crop), Hassan, Belgaum and Dharwar districts in Karnataka (*kharif* crop) (Pandey and Sarkar, 2005). The study

established that four potato cultivars *viz.* Kufri Chipsona-1, Kufri Chipsona-3, Kufri Surya and Kufri Frysona can be successfully grown for producing potatoes for making good quality French fries even in cooler northern plains, an area previously presumed to be unsuitable for producing potatoes for processing. Potatoes of the four varieties harvested on different dates can prolong the availability of processing potatoes and provide an uninterrupted supply to the French fry industry for more than 50 days starting from 20th December. The variety Kennebec having lower dry matter content (<20%) was not found suitable for French fries.

Further, based on oblong shape of tubers, high dry matter, good colour, superior texture and low oil content of fries, Kufri Frysona was rated as the best variety for French fries.

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