Pak. J. Bot., 44(1): 201-208, 2012.

DETERMINATION OF PROCESSING AND NUTRITIONAL QUALITY ATRIBUTES OF POTATO GENOTYPES IN PAKISTAN

GHULAM ABBAS, I. A. HAFIZ*, N.A. ABBASI AND AZHAR HUSSAIN

Department of Horticulture, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan
**Corresponding author's E-mail Address: decenthafiz60@yahoo.com*

Abstract

The acceptability of potatoes for processing as french fries is largely dependent on the quality of the end products. Processing industry is totally dependent on the quality parameters of tuber to satisfy the increasing demand of customers. Thirty two potato genotypes for processing and yield quality traits were assessed for screening. Significant differences in all the quality parameters and various characteristics were found, while the genotypes; 394021-120, 9625, Kiran, NARC 2002-1, NARC 1-2006/1 and VR 90-217 gave the highest results regarding yield and quality of potato tubers except kiran, which has a high yield but low quality characters. The tuber sizes and weight was also significantly different among genotypes except weight of big size tubers. Variations existed among genotypes in tuber characteristics (skin color, tuber shape, eye depth, flesh color and general appearance). The results regarding correlation studies indicated that french fry color exhibited negative correlation with reducing sugar ($r = -0.7046$), total sugars ($r = -0.6659$) and positive correlation with dry matter ($r = 0.5013$).This screening is helpful to the ongoing efforts to select the best genotype for the emerging processing industry of Pakistan.

Introduction

Potato (*Solanum Tuberosum L.*) is one of the most important vegetable crops and having a balanced food containing about 75 to 80% water, 16 to 20% carbohydrates, 2.5 to 3.2% crude protein, 1.2 to 2.2% true protein, 0.8 to 1.2% mineral matter, 0.1 to 0.2% crude fats, 0.6% crude fiber and some vitamins (Schoenemann, 1977). It is a staple diet in European countries and its utilization both in processed & fresh food form is increasing considerably in Asian countries (Brown, 2005). Moreover, number of processing industries and potato products are increasing with the demand of specific varieties.

Besides culinary consumption, the use of potato has progressively increased as a raw material by the processing industry (Iritani, 1981). Now a days, the most important features of potato production is tuber quality (Brown, 2005). So quality attributes should take into account to fulfill the customers and industry demand. Potato must meet a number of requirements including high dry matter content and good color to fulfill the requirement of processing.

Presently there is no variety for processing purpose, developed locally, despite the increasing demand of acceptable yield and processing quality. The yield and processing characteristics of available potato genotypes are largely unidentified. Keeping in view the consumers requirement, it is important to identify varieties that possess traits to meet the domestic demand and provide growers the opportunity to meet the challenges of frequently changing market, production circumstances and improving their economic condition (Connor *et al*., 2001).

The objective of the present study was to evaluate and select potato genotypes for yield traits and processing aspects, for growers, food industrialists and the potato product consumers in Pakistan.

Materials and Methods

Potato genotypes including 8 commercial varieties and 24 advanced lines obtained from different sources as mentioned in the Table 1 were planted at National Agriculture Research Center, Islamabad, Pakistan, for their evaluation and screening. The potato planting was done according to Randomized Complete Block Design in plots having size 15m^2 consisting of 5 rows, with three replications. Uniform cultural practices were adopted for all treatments. At crop maturity, dehaulming was done and tubers were harvested after 15 days of dehaulming allowing tuber skin to firm up.

Table 1. Advanced genotypes including commercial cultivars from different national and international sources.

S. No.	Advanced genotypes	Source
1.	NARC 2002-1	NARC
2.	NARC 1-2006/1	NARC
3.	NARC 1-2006/2	NARC
4.	NARC 1-2006/3	NARC
5.	NARC 2-2006/1	NARC
6.	NARC 2-2006/2	NARC
7.	NARC 2-2006/3	NARC
8.	393574-6	CIP
9.	9735 CIP	CIP
10.	393574-61	CIP
11.	394021-120	CIP
12.	396239-111	CIP
13.	VR 92-813	Dutch
14.	396239-131	CIP
15.	393574-72	CIP
16.	VR 90-217	Dutch
17.	9625	Dutch
18.	396206-72	CIP
19.	394055-40	CIP
20.	392285-5	CIP
21.	396206-52	CIP
22.	396240-6	CIP
23.	9721	Dutch
24.	396243-24	CIP
	Commercial varieties as control	
25.	Paramont	Dutch
26.	Bellini	Dutch
27.	Kiran	Pakistani
28.	Desiree	Dutch
29.	Cardinal	Dutch
30.	KufriBadshah	India
31.	Diamont	Dutch
32.	Chipsona-111	India

Yield parameters: Data was recorded for yield parameters ; tuber size, weight, large & medium size tubers and processing quality *viz*., tuber skin color, tuber shape, eye depth, general appearance and french-fries, for the assessment of quality traits after harvest of the crop

Number and weight (g) of tubers: Observation was noted at the time of harvesting. Tubers were counted and weighed from plot.

Tuber sizes and weight: Yield sample was graded into three groups considering size of tubers viz. <35mm, 35-55mm and >55mm. Grading was done by using grids made for the purpose, and tubers in each grade were counted and weighed.

Marketable yield: All the marketable tubers (>35mm in diameter) obtained from the plot and were weighed.

Non marketable yield: The tubers with diameter less than 35mm (non-marketable) were weighed and data were tabulated.

Salient features of tuber for processing

Color of skin and flesh: Tuber skin color i.e., white or red were noted by visual observation immediately after harvesting.

For flesh color ten tubers from each treatment were cut into two halves and the assessment of the sample for flesh color was done as described by (Wooster & Farooq, 1995).

1 = White	2 = Cream	3 = Yellow

Tuber shape: The tuber sample was scored for shape according to the following key (Wooster & Farooq, 1995).

1 = Round	2 = Round to short oval	3 = Short oval
4 = Short oval to oval	5 = Oval	6 = Oval to long oval
7 = Long oval	8 = Long oval to very long oval	9 = Very long oval

Eye depth: The evaluation of the sample, pertaining to tuber eye depth was made as mentioned by Wooster & Farooq (1995).

1 = Very deep	2 = Very deep to deep	3 = Deep
4 = Deep to medium	5 = Medium	6 = Medium to shallow
7 = Shallow	8 = Shallow to very shallow	9 = Very shallow

Processing aspects

Sensory evaluation of French fries: Sensory evaluation was done by a panel of five judges for French fries. Rating was done for the following as per model of Holm *et al*., (1994).

- Color
- Texture
- Flavor

Slices of 1.75 mm were fried at 180^{o}C till bubbling stopped or for 100 seconds. A score of 6 was considered acceptable for each.

Statistical analysis: Data analysis was done using MSTAT-C package (MSTAT, 1991) through RCBD in and comparison was made utilization Duncan's Multiple range test at 5percent probability level (Gomez and Gomez, 1984).

Results and Discussion

Yield and processing quality

Large size tubers and average tuber weight: Data regarding number of large size tubers (Table 2) depicted a significant difference among genotypes. Number of large size tubers were 125 in 394021-120 followed by 118 (Kiran), 115 (NARC 1-2006/1), 112 (9625), 110 (396239-131, 393574-61 and Kufri Badshah) and minimal number of tubers (74) were obtained in 9735 CIP and Bellini. The variation may be attributed to inheritability of genotypes. Varieties and lines also differ for different traits (Kumar *et al*., 2004). Moreover, a higher proportion of large size tubers may be due to rapid plant emergence and better plant growth (Patel *et al*., 2008).

Non-significant results regarding average weight of tubers, ranging from 121.39g (396239-131) to 100.55g (VR 90-217) were observed in different genotypes as shown in Table 2. Similar findings were reported earlier (Sharma & Singh, 2009) who found non-significant difference for average weight of large size tubers. Singh & Ahmad (2008) also reported similar trend in case of tuber weight among tested cultivars.

Medium size tubers and average tuber weight: The potato variety Kiran produced significantly more number of medium size tubers (435), followed by 9625 (425), 394021-120 (421), 396239-111 (401) and NARC 2002-1 (397). However, potato genotypes Bellini produced least number of medium size tubers (252). Number of factors viz., vegetative growth, genotypes, and plant growth rate and emergence time might be responsible for this variation in number of medium sized tubers. The present findings were also supported by the results reported by previous workers. Kufri Jyoti produced statistically higher number of tubers 222.6 than Kufri Chandra Mukhi 215.8 and in the same way significant variation was also reported by Desai & Jaimini (1997). Kumar and Ezekiel (2006) and Patel *et al*., (2008) described that rapid plant emergence and better plant growth results in higher number of medium size tubers. Luthra *et. al.* (2005) noted the more genotypic effects for tuber number. Sufficient growth (stem number and plant height) had positive contribution to tuber number.

Table 2. Data regarding tuber size and weight of potato genotypes

S. No.	Genotypes	No. of large tubers	Average weight (g)	No. of medium tubers	Average weight	No. of small tubers	Average weight
1.	NARC 2002-1	109 a-e	116.50 a	397 a-d	54.57 a-e	254 a-e	16.43 a-e
2.	NARC 1-2006/1	115 abc	120.64 a	388 a-e	52.02 a-i	248 a-f	14.43 e-j
3.	NARC 1-2006/2	78 ij	114.88 a	277 mn	50.29 a-i	200 hij	13.76 f-j
4.	NARC 1-2006/3	84 g-j	101.28 a	302 i-n	48.56 c-i	240 b-h	12.96 hij
5.	NARC 2-2006/1	80 hij	109.12 a	332 f-l	53.65 a-i	203 g-j	13.10 g-j
6.	NARC 2-2006/2	79 ij	106.39 a	346 d-j	48.10 d-i	223 c-j	12.99 g-j
7.	NARC 2-2006/3	76 ij	116.10 a	295 j-n	48.75 b-i	193 ij	16.50 a-e
8.	393574-6	77 ij	101.75 a	284 lmn	53.18 a-i	239 b-h	12.30 j
9.	9735 CIP	74 j	119.15 a	261 n	49.91 b-i	291 a	12.79 hij
10.	393574-61	110 a-e	109.99 a	359 c-h	55.65 a-d	290 a	15.35 c-h
11.	394021-120	125 a	117.33 a	421 ab	55.97 abc	213 e-j	17.22 abc
12.	396239-111	105 a-f	112.87 a	401 abc	53.76 a-h	254 a-e	15.83 a-f
13.	VR 92-813	80 hij	115.04 a	318 h-m	46.59 ghi	206 f-j	13.73 f-j
14.	396239-131	110 a-e	121.39 a	381 b-f	51.98 a-i	219 d-j	14.73 c-j
15.	393574-72	86 f-j	100.91 a	287 k-n	49.50 b-i	211 e-j	12.66 ij
16.	VR 90-217	100 b-h	100.55 a	384 a-f	56.35 ab	240 b-h	17.20 abc
17.	9625	112 a-d	120.07 a	425 ab	57.77 a	182 j	16.80 a-e
18.	396206-72	82 g-j	102.11 a	338 e-k	48.40 c-i	260 a-d	12.36 j
19.	394055-40	93 d-j	108.31 a	343 d-j	45.91 i	280 ab	17.10 a-d
20.	392285-5	84 g-j	102.55 a	318 h-m	45.91 i	242 b-h	14.60 d-j
21.	396206-52	90 e-j	107.52 a	354 c-i	55.01 a-e	242 b-h	15.58 b-g
22.	396240-6	96 c-i	107.86 a	363 c-h	53.79 a-g	254 a-e	18.20 a
23.	9721	86 f-j	101.35 a	295 j-n	49.82 b-i	204 f-j	13.00 g-j
24.	396243-24	92 d-j	105.22 a	350 c-i	47.45 e-i	243 b-h	16.41 a-e
25.	Paramont	78 ij	112.00 a	362 c-h	47.91 d-i	239 b-h	13.50 f-j
26.	Bellini	74 j	114.75 a	252 n	50.13 a-i	264 abc	13.66 f-j
27.	Kiran	118 ab	117.40 a	435 a	54.36 a-f	185 j	18.09 ab
28.	Desiree	102 b-g	111.16 a	353 c-i	46.80 f-i	254 a-e	14.34 e-j
29.	Cardinal	78 ij	118.38 a	315 h-m	46.02 hi	193 ij	15.17 c-i
30.	KufriBadshah	110 a-e	116.34 a	376 b-g	47.34 e-i	237 b-i	13.65 f-j
31.	Diamont	84 g-j	105.21 a	323 g-m	46.78 f-i	245 b-g	12.72 ij
32.	Chipsona-111	90 e-j	100.58 a	342 e-j	47.80 e-i	248 a-f	14.32 e-j
LSD value at 0.05%		**20.294**	**20.859**	**53.873**	**7.7505**	**44.427**	**2.6020**

Average weight of medium size tubers exhibited significant differences among genotypes and was highest in 9625 (57.77 g) followed by VR 90-217 (56.35 g) and 394021-120 (55.97 g), while minimum average weight was observed in 392285-5 and 394055-40 (45.91g). Plant growth, heredity and emergence might be the reason for differences among potato varieties. More weight of medium size tubers may be owing to effect of growth characteristics (Patel *et al*., 2008 & Arsenault and Christie, 2004). The effect of heredity is also significant with respect to grade wise tuber weight (Muthuraj *et al*., 2005) which is proved by number of findings. Average weight of medium size tubers varied significantly among genotypes (Patel *et al*., 2007).

Small size tubers and average tuber weight: Results revealed significant differences among different potato varieties for number of small size tubers as presented in Table 3. Genotypes 9735 CIP, 393574-61, 394055-40, Bellini and 396206-72 yielded significantly higher number of small tubers having 291, 290, 280, 264 and 260 tubers respectively. On the other hand, Kiran, NARC 2-2006/3, Cardinal, NARC 1-2006/2 and NARC 2-2006/1 had significantly lower number of small size tubers viz., 185, 193, 193, 200 and 203 tubers respectively. Foliage growth as well as variety development and performance might be the causes for variation of small size tubers among different genotypes. The findings reported by other workers are in close agreements with the results found in the present study.

The difference in tuber number might be due to varietal character, affected by better performance of the variety (Kumar *et al.*, 2007). The effect of heredity was significant with regard to tuber grades (Muthuraj *et al.*, 2005). One of the essential factors which affect the percentage of different tuber sizes is vegetative growth and stem numbers as its influence on different varieties is different (Azad *et al.*, 1997). More number of under size tubers may be due to the higher vigor of plants coupled with delayed maturity (Sharma & Singh, 2009). The results indicated that average weight of small size tubers differ significantly among genotypes and was found to be the highest in 396240-6 (18.20 g) followed by Kiran (18.09 g), 394021-120 (17.22g), VR 90-217 (17.20 g), and 394055-40 (17.10 g) as given in Table 2. Significantly lowest value was observed in 393574-6 (12.30 g), 396206-72 (12.36 g), 393574-72 (12.66 g) and Diamant (12.72 g). The factors like crop growth and variety might cause the variation in average weight of small size tubers among genotypes (Ereifej *et al*., 1997 & Singh and Bhat, 2005). In addition, it may be due to the excessive vegetative growth of plants coupled with delayed maturity (Sharma & Singh, 2009).

Table 3. Yield Parameters of the genotypes Yield (t/hac.).

S. No.	Genotypes/varieties	Total tubers in 15m^2	Average weight (g)	Marketable yield (%)	Non marketable yield (%)	Yield t/hac.
1.	NARC 2002-1	760 a	50.71 a-d	89.17 a-e	10.82 g-j	25.69 abc
2.	NARC 1-2006/1	751 ab	50.12 b-e	90.49 a-d	9.50 klm	25.09 a-d
3.	NARC 1-2006/2	555 g	46.20 d-i	89.29 a-e	10.73 hij	17.09 kl
4.	NARC 1-2006/3	626 c-g	42.00 ghi	88.17 c-f	11.83 def	17.52 jkl
5.	NARC 2-2006/1	615 c-g	47.48 d-i	90.92 a-d	9.11 lm	19.46 h-l
6.	NARC 2-2006/2	648 b-g	43.17 f-i	89.58 a-e	10.36 ij	18.64 i-l
7.	NARC 2-2006/3	564 g	46.79 d-i	87.97 c-f	12.06 def	17.59 jkl
8.	393574-6	600 efg	43.14 f-i	88.64 b-f	11.36 fgh	17.25 kl
9.	9735 CIP	626 c-g	40.85 i	85.46 fg	14.56 b	17.04 kl
10.	393574-61	759 a	48.12 d-g	87.83 c-g	12.19 de	24.34 b-e
11.	394021-120	759 a	55.20 abc	91.25 abc	8.75 mn	27.93 a
12.	396239-111	760 a	49.26 b-f	89.26 a-e	10.74 hij	24.95 a-d
13.	VR 92-813	604 d-g	44.45 d-i	89.50 a-e	10.53 Ij	17.89 jkl
14.	396239-131	710 a-d	51.24 a-d	91.15 a-d	8.87 lmn	24.25 b-e
15.	393574-72	584 fg	43.75 e-i	89.58 a-e	10.45 Ij	17.03 kl
16.	VR 90-217	724 abc	49.48 b-f	88.47 b-f	11.52 d-h	23.88 b-f
17.	9625	719 abc	57.11 a	92.55 a	7.44 o	27.37 ab
18.	396206-72	680 a-f	41.10 hi	88.50 b-f	11.49 d-h	18.63 i-l
19.	394055-40	716 abc	42.75 f-i	84.41 g	15.64 a	20.40 f-k
20.	392285-5	644 b-g	41.53 ghi	86.79 efg	13.21 c	17.83 jkl
21.	396206-52	686 a-f	47.99 d-h	88.62 b-f	11.45 e-h	21.94 d-i
22.	396240-6	713 a-d	48.40 c-g	86.60 efg	13.39 c	23.00 c-g
23.	9721	585 fg	44.54 d-i	89.89 a-e	10.17 jk	17.37 kl
24.	396243-24	685 a-f	44.33 d-i	86.88 efg	13.13 c	20.24 g-k
25.	Paramont	679 a-f	43.16 f-i	89.02 b-e	11.01 ghi	19.53 g-l
26.	Bellini	590 fg	41.90 ghi	85.45 fg	14.58 b	16.48 l
27.	Kiran	738 ab	55.36 ab	91.81 ab	8.19 no	27.23 ab
28.	Desiree	709 a-e	44.44 d-i	88.44 b-f	11.56 d-g	21.00 e-j
29.	Cardinal	586 fg	45.49 d-i	89.02 b-e	10.98 ghi	17.77 jkl
30.	KufriBadshah	723 abc	46.80 d-i	90.45 a-d	9.56 kl	22.55 c-h
31.	Diamont	652 a-g	41.52 ghi	88.49 b-f	11.51 d-h	18.04 jkl
32.	Chipsona-111	680 a-f	43.59 e-i	87.73 d-g	12.26 d	19.30 h-l
LSD value at 0.05%		**109.33**	**6.9360**	**3.5179**	**0.8018**	**3.5295**

Total number of tubers: The results pertaining to total number of tubers per plot (15m^2) statistically displayed significant results among potato genotypes (Table 3). Total tubers were significantly higher in NARC 2002-1, 396239-111, 393574-61, 394021-120 and NARC 1-2006/1 having 760, 760, 759, 759, 751 tubers respectively, while minimum number of total tubers was 555 in NARC 1-2006/2. The reasons for variation in total tuber number might be genetic makeup and number of stems. Restricted vegetative growth helps in onset of tuberisation while excessive development of foliage retards formation of tubers (Ravikant & Chandha, 2009). Our results are also in line with Luthra *et al*., (2005) who also reported variation in different genotypes due to sufficient growth (stem number and plant height)

Average weight of total tuber: Average weight of tubers varied significantly among genotypes as shown in Table 3. Heavy tubers were found in 9625, Kiran, 394021-120 and NARC 2002-1 having weight 57.11, 55.36, 55.20 and 50.71 g. Low average tuber weight 40.85, 41.10, 41.52 , 41.53 g was recorded in 9735 CIP, 396206-72, Diamont, and 392285-5. The difference may be attributed to genotypes, adequate and vegetative growth. Some other researchers also reported variation among potato genotypes for average weight. Significant genotypic and phenotypic differences for average tuber weight were also found by Desai and Jaimini (1997) & Mehdi *et al*., (2008). Higher average tuber weight may be due to sufficient vegetative growth for tuberisation (Ravikant and Chandha, 2009). More average tubers weight, (more than 51g) may be due to rapid plant emergence and better plant growth (Patel *et al*., 2008).

Marketable yield (%): The statistical results indicated that potato genotypes differed significantly for marketable yield. Significantly higher percent of processing grade yield shown by 9625 followed by Kiran and 394021-120 having values 92.55, 91.81 and 91.25 percent respectively, while the minimum by 394055-40 having values 84.41 percent. The variation in the marketable yield of potato genotypes may be due to response of genotype/variety factor. According to Pandey *et al*. (2004), Marwaha *et al*., (2007) and Kumar *et al*., (2007) different varieties had significant influence on marketable yield.

Non-marketable yield (%): The results indicated that varieties differed significantly for non-marketable yield percentage. Higher percentage of non-marketable yield was shown by 394055-40, Bellini and 9735 CIP i.e. 15.64, 14.58 and 14.56 percent respectively while lower percentage of non-marketable yield was 7.44, 8.19 and 8.75 percent produced by 9625, Kiran and 394021-120 respectively. The variation in non-marketable yield percent of the genotypes may be due to crop maturity, inherent ability of potato genotypes and number of tubers per plant. The results for non-marketable yield of potato varieties in present work are in lines with the findings reported by Muthuraj *et al*., (2005), Kumar *et al*., (2004), Minhas *et al*., (2006) and Kumar and Ezekiel (2006).

Maximum yield of small size tubers may be due to higher number of tubers as well as varietal character and adaptability or establishment effect of other growth attributes (Patel *et al*., 2008 & Kumar *et al*., 2007). However higher percentage of under or small size tubers may be due to the higher vigor of plants coupled with delayed maturity (Sharma & Singh, 2009). Stem number and plant height can strongly influence non-marketable yield of many potato cultivars (Arsenault & Christie, 2004).

Yield (t/hac): The results regarding yield of different potato varieties presented in Table 3 differed significantly. Higher yield was recorded in 394021-120, 9625, Kiran, NARC 2002-1, NARC 1-2006/1 and 396239-111 resulting 27.93, 27.23 , 25.69, 25.08, and 24.95 t/hac yield respectively, while least in Bellini with 16.48 t/hac.

Patel *et al*., (2008), Ravikant & Chandha (2009) documented that higher tuber yield which may be due to higher number of tubers per plant as well as combined effect of all other growth and yield attributes. Struik *et al*., (1998), Luthra *et al*., (2005), Patel *et al*., (2008), Pandey (2004), Gupta *et al*., (2009) and Singh & Ahmad (2008) evaluated potato yield influenced by the genotypic and phenotypic characters. The increase in yield was mainly on account of higher number of tubers/plant and tuber size (Mehdi *et al*., 2008).

Salient features of tuber for processing: Tuber characteristics include tuber skin color, tuber shape, eye depth, flesh color and general appearance. These are also called quality characteristics which are important for marketing as well as for processing. The genotypes varied for these characteristics (Table 4). More importance was given to eye depth, tuber shape and general appearance. Consumers like potatoes of attractive look, suitable shape, size and shallow to medium eyes to avoid peeling losses.

Table 4. Salient tuber characteristics of 32 potato genotypes.

S. No.	Genotypes/ varieties	Tuber skin color	Tuber shape	Eye depth	Flesh color	General appearance
1.	NARC 2002-1	Red	oval	Shallow	Yellow cream	8
2.	NARC 1-2006/1	Red	Oval round	Shallow- m. deep	Cream	7
3.	NARC 1-2006/2	Red	Oval round	Deep	cream	6
4.	NARC 1-2006/3	red	oval	Medium deep	cream	6
5.	NARC 2-2006/1	white	oval	Deep	Cream	7
6.	NARC 2-2006/2	white	oval	Medium deep	cream	8
7.	NARC 2-2006/3	white	oval	Medium deep	cream	7
8.	393574-6	Red	oval	Shallow	Yellow	8
9.	9735 CIP	Red	oval	Shallow	Yellow	7
10.	393574-61	Red	oval	Shallow	Yellow	7
11.	394021-120	White	oval	shallow	white	7
12.	396239-111	White	Oval round	shallow	cream	7
13.	VR 92-813	white	oval	Medium deep	cream	7
14.	396239-131	White	oval	shallow	white	7
15.	393574-72	Red	oval	Shallow	Yellow	6
16.	VR 90-217	red	round	shallow	cream	7
17.	9625	White	Oval round	shallow	cream	7
18.	396206-72	White	oval	shallow	cream	7
19.	394055-40	White	oval	shallow	white	7
20.	392285-5	White	oval	shallow	cream	7
21.	396206-52	White	oval	shallow	cream	7
22.	396240-6	White	oval	shallow	cream	6
23.	9721	Red	oval	Shallow	Yellow	7
24.	396243-24	White	oval	shallow	cream	6
25.	Paramont	Red	oval	Shallow	cream	8
26.	Bellini	White	oval	shallow	cream	8
27.	Kiran	white	Oval round	Shallow- m. deep	yellow	6
28.	Desiree	Red	oval	Shallow	cream	7
29.	Cardinal	Red	oval	Shallow	cream	7
30.	KufriBadshah	White	oval	Medium deep	white	7
31.	Diamont	White	oval	shallow	cream	7
32.	Chipsona-111	White	Oval	shallow	cream	7

Color of skin and flesh: Similarly color of skin and flesh is controlled by genetic factors. Depth of eyes and tuber shape may be affected both by genetic and environmental factors while skin and flesh color is controlled purely by genetic factor (Anwar, 1982). In Bangladesh, Bhutan, Nepal, Pakistan and Philippines red skin potatoes are traditionally preferred. Thus characters such as tuber appearance, size, shape, color, skin finish etc. which influence consumer choice, are considered as quality attributes in potato (Pandey *et al*., 2000).

Tuber shape: Oval shape tubers are preferred for making chips and French. The Shape of tubers is also controlled by the genetic factors and environment may also affect it to some extent. Most of the genotypes had oval shaped tubers except five genotypes *viz.* NARC 1-2006/1, NARC 1-2006/2, 396239-111, 9625 and Kiran that had oval round tubers. General appearance was scored by giving number 9 for excellent to 1for disliking. Out of 32, six genotypes got minimum score of 6 (fairy liking) while other genotypes got higher.

Eye depth: In the present trial only two genotypes NARC 1-2006/2 and NARC 2-2006/1 had deep eyes whereas other genotypes had shallow to medium deep eyes which were liked by consumers. The characteristic eye depth is controlled by particular gene and less affected by environment. During evaluation all genotypes had either shallow or medium eye depths, which are suitable to reduce losses during trimming and peeling (Kabira & Lemaga, 2006).

Processing aspects

French fries sensory evaluation: Sensory evaluation is an essential criteria for quality judgment in product development and to congregate the consumer requirements. Any product must give pleasure and satisfaction to the consumers if it has to be a part of their eating behavior. Potato is an important vegetable and has potential for use in the processing industry in Pakistan. Consequently french fries prepared from potato were appraised for various characters.

Color: Higher color score values were given to french fries prepared from potatoes of genotypes NARC 1-2006/1, VR 90-217, 9625, 394055-40 and NARC 2002-1 having values 7.42, 7.33, 7.29, 7.22 and 6.94 respectively. The lowest score for color was given to french fires prepared from genotype 396243-24 (4.47). The results regarding correlation studies (Table 6) indicated that French fry color exhibited negative correlation with reducing sugar (r = -0.7046), total sugars (r = -0.6659) and positive correlation with dry matter (r = 0.5013). The findings of other researchers support our results.

French fries color is based on reducing sugar content of the potato tuber. Potatoes with high reducing sugar levels make dark fries (Anon., 2010), which is not liked by the consumers. Pritchard and Adam (1994) and Rodriguez *et al*., (1997) found low relationship between non-reducing sugars and fries color in potato tubers. Sugar percentage affects color of fries in potato (Coffin *et al*., 1989; Cipar *et al*., 1990; Reeves *et al*., 1990). Pandey *et al.*, (2004) and Marwaha (1998) also found that the color of fries is influenced by dry matter and reducing sugar content of potato. Genetic character might be another reason for variation of color among genotypes in this work. Abong *et al*., (2009) reported that different cultivars showed significant differences for french fries.

Flavor: Data regarding flavor score in Table 5, showed significance differences. Results revealed that the judges assigned highest score to flavor of VR 90-217 which was followed by NARC 1-2006/1, 394055-40, 9625 and 393574-61 with score values 8.33 followed by 7.30, 7.19, 7.14 and 6.94 respectively. The results further demonstrated that the judges assigned significantly lower score to flavor of genotypes VR 92-813, 396239-131, 396206-72, NARC 2-2006/3 and 396239-111 with score values 5.11, 5.19, 5.36, 5.53 and 5.80 respectively. Zaehringer *et al*., (1967) reported that potatoes having more starch usually rated superior in flavor. Sayre *et al.*, (1975) stated that the processed products were influenced by quantity of reducing sugars and percent dry matter.

Pardo *et al*., (2000), Jansky (2008) and Abong *et al*., (2009) also showed that values obtained for each of the varietal sensory characteristics of flavor (fried) significantly differed among cultivars due to their genetic makeup.

Texture: Results showed that sensory score of fries texture prepared from different potato varieties were found to be highly significant (Table 5). Texture scores was higher 7.89, 7.36, 7.30, 7.17 and 7.14 in VR 90-217, 394055-40, NARC 1 2006/1, 394021-120 and NARC 2002-1 respectively. The lowest score obtained were 4.75 by VR 92-813. The correlation analysis (Table 6) showed that the variable of French fry texture was found to be positively associated with starch (r = 0.5884), dry matter (r = 0.5827) and specific gravity (0.2947) while exhibited an inverse relationship with reducing sugar (-0.5642) and total sugar (-0.4798), Starch provides the more important contribution to the texture of processed potatoes. Cultivar affects starch concentration and thus texture. Potatoes high in sugar have a poor/soft texture after cooking (Adams, 2004). A mealy potato is dry and granular while a waxy potato is moist gummy. Texture is influenced by starch content (Van Marle *et al*., 1997). Pandey *et al*., (2004) and Marwaha (1998) evaluated that texture of fries were affected by dry matter and reducing sugar content. The higher dry matter contents are recommended for french fries processing. However, if the range is large it could lead to different scores in different sensory attributes in french fries. Potatoes having more dry matter show mealiness when processed (Mehdi, *et al.,* 2008).

Table 5. French fries evaluation of potato varieties/genotypes.

S. No.	Treatment	Color	Flavor	Texture
1.	NARC 2002-1	6.94 ab	6.55 b-f	7.14 abc
2.	NARC 1-2006/1	7.42 a	7.30 b	7.30 ab
3.	NARC 1-2006/2	5.78 d-j	6.00 e-k	5.53 i-l
4.	NARC 1-2006/3	6.08 c-g	6.44 b-g	6.05 d-j
5.	NARC 2-2006/1	5.19 j	5.64 f-k	5.64 h-k
6.	NARC 2-2006/2	5.92 c-i	6.05 d-j	6.22 d-i
7.	NARC 2-2006/3	6.00 c-i	5.53 g-k	6.44 c-g
8.	393574-6	6.28 cd	6.00 e-k	6.28 d-i
9.	9735 CIP	6.19 c-f	6.05 d-j	6.29 d-i
10.	393574-61	6.44 bc	6.94 bcd	6.50 c-f
11.	394021-120	7.19 a	6.83 b-e	7.17 abc
12.	396239-111	6.44 bc	5.80 f-k	4.94 klm
13.	VR 92-813	5.42 hij	5.11 k	4.75 m
14.	396239-131	5.39 ij	5.19 jk	4.80 lm
15.	393574-72	5.55 g-j	5.44 h-k	5.44 j-m
16.	VR 90-217	7.33 a	8.33 a	7.89 a
17.	9625	7.29 a	7.14 bc	6.80 bcd
18.	396206-72	5.61 f-j	5.36 ijk	5.44 j-m
19.	394055-40	7.22 a	7.19 bc	7.36 ab
20.	392285-5	5.86 c-i	5.86 f-k	6.28 d-i
21.	396206-52	5.64 e-j	5.83 f-k	5.69 g-k
22.	396240-6	6.14 c-g	5.97 e-k	5.67 h-k
23.	9721	6.18 c-g	6.34 c-h	5.79 f-j
24.	396243-24	4.47 k	6.00 e-k	5.92 f-j
25.	Paramont	6.17 c-g	6.28 c-i	6.03 e-j
26.	Bellini	6.24 cde	6.28 c-i	5.95 f-j
27.	Kiran	6.19 c-f	6.47 b-f	6.44 c-g
28.	Desiree	6.03 c-h	5.94 e-k	6.22 d-i
29.	Cardinal	6.19 c-f	6.35 c-h	6.08 d-j
30.	KufriBadshah	6.03 c-h	6.11 d-j	6.08 d-j
31.	Diamont	5.67 d-j	6.14 d-i	6.33 d-h
32.	Chipsona-111	6.43 bc	6.30 c-h	6.75 b-e
	LSD value at 0.05%	**0.6325**	**0.9371**	**0.7605**

Table 6. Correlation coefficients of potato French fries parameters.

	C	DR	F	NR	RS	SP	S	TX
DR	0.5013							
F	0.6443	0.4783						
NR	NS	NS	NS					
RS	-0.7046	-0.5515	-0.5272	-0.2530				
SP	0.2848	0.5966	NS	NS	-0.2310			
S	0.5093	0.9048	0.4788	NS	-0.6039	0.5309		
TX	0.6149	0.5827	0.6539	NS	-0.5642	0.2947	0.5884	
T	-0.6659	-0.5930	-0.5278	0.2316	0.8826	-0.2176	-0.6451	-0.4798

C= Color, DR= Dry matter, F= Flavor, NR= Non-reducing sugar, RS= Reducing sugar, F= Flavor, Tx= Texture, SP= Specific gravity, S= Starch, TS= Total sugar , NS= Non-significant

References

Abong, G.O., M.W. Okoth, E.G. Karuri, J.N. Kabira and F.M. Mathocko. 2009. Influence of potato cultivar and stage of maturity on oil content of French fries (chips) made from eight Kenian potato cultivars. *African J. Food Agric. Nutrition*, 9(8).

Adams, J.B. 2004. Raw materials quality and the texture of processed vegetables. In: *Texture in Foods, Solid Foods*. (Ed.): D. Kilcast, Woodhead Publ. Ltd.: Cambridge, 2: 342-363.

Anonymous, 2010. Commercial Potato Production - Botany of the Potato Plant Western Potato Council, 2003. Manitoba Agriculture, Food and Rural Initiatives. (Searched on 4.2.10). http://www.gov.mb.ca/agriculture/index.html.

Anwar, J. 1982. Screening of new exotic potato germplasm under Faisalabad conditions. M.Sc. (hons). Thesis, Department of Horticulture, University of Agriculture, Faisalabad.

Arsenault, W.J. and B.R. Christie. 2004. Effect of whole seed tuber size and pre plant storage conditions on yield tuber size distribution of reset Burbank. *Amer. J. Potato Res*., 81: 371-376.

Azad, S., B.K. Nehra, S.C. Khurana and N. Singh. 1997. Influence of plant density and geometry on growth and yield in seed crop of potato. *Indian Potato Assoc*., 24(1-2): 17-23.

Brown, C.R. 2005. Antioxidant in potato. *Am. J. Potato Res*., 82:163-72.

Cipar, M.S., D. Hunter, P. Porter and G. Henderson. 1990. Norwis: a new potato variety combining chipping quality, wide adaptation, disease resistance and high yield. *Am. Potato J*., 67: 371-379.

Coffin, R., R. Chase, N. Thompson, G.R. Johnston, A. McKeown, M.K. Keenan, D. Craven, R. Kitohen, J. Wilson and R.Y. Yada. 1989. Saginaw Gold: A yellow-fleshed potato cultivar with medium high specific gravity and excellent chip and french fry quality after storage. *Am. Potato J*., 66: 303-313.

Connor, C.J., K.J. Fisk, B.J. Smith and L.D. Melton. 2001. Fat uptake in French fries as affected by different potato varieties and processing. *J. Food Sci*., 66: 903-908.

Desai and S.N. Jaimini. 1997. Genetic variability, heritability and Genetic advance for yield in potato. *J. Indian Potato Assoc*., 24(1-2): 52-58.

Ereifej, K.I., R.A. Shibli, M.M. Ajlouni and A. Hussein. 1997. Chemical composition variations of tissues and processing characteristics in 10 potato cultivars grown in Jordan. *Am. Potato J*., 74: 23-30.

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. New York; John Viley. 680 p.

Gupta, V.K., B.K. Das and S.K. Pandey. 2009. Performance of local potato varieties in Meghalaya hills. *Potato J*., 36(1-2): 65-67.

Iritani, W.M. 1981. Growth and pre-harvest stress and processing quality of potatoes. *Am. Potato J*., 58: 71-80.

Jansky, S. H. 2008. Genotypic and environmental conditions to baked potato flavor. *Am. J. Potato Res*., 85: 455-465.

Kabira, J.N. and B. Lemaga. 2006. Potato Processing: Quality Evaluation procedures for research and food industries applications in East and Central Africa. Kenya Agricultural Research Publication, Nairobi, Kenya. 10 p.

Kumar, D., B. Singh and P. Kumar. 2004. An overview of the factors affecting sugar content of potatoes. *Ann. Appl. Biol.* 145: 247-256.

Kumar, D. and R. Ezekiel. 2006. Effect of physiological and biochemical attributes of potato cultivars Kufri Lauvkar and Atlantic on their chipping quality. *Potato J*., 33(1-2): 50-55.

Kumar, P., S.K. Pandey, S.V. Singh and D. Kumar. 2007. Irrigation requirement of chipping potato cultivars under west-central indian plains. *Potato J*., 34(3-4): 193-198.

Luthra, S.K., J. Gopal, S.K. Pandy and B.P. Singh. 2005. Genetic parameters and characters associated in tuberosum potatoes. *Potato J*., 32(3-4): 234.

Marwaha, R.S. 1998. Processing of potatoes: Current status, need, future potential and suitability of Indian varieties - A critical appraisal. *J. of Food Sci. and Technol*, 34(6): p. 14.

Marwaha, R., S. K. Pandey, S.V. Singh and D. Kumar. 2007. Yield, chapping and nutritive qualities of spring grown potatoes in north-western plains. *Potato J*., 34(1-2): 61-62.

Holm, E.T., P.H. Orr and R.H. Johansen. 1994. Sensory evaluation as a tool in breeding potatoes for French fries and flakes. *Am. Potato J*., 71: 1-14.

Mehdi, M., T. Saleem, H.K. Rai, M.S. Mir and G. Rai. 2008. Effect of nitrogen and FYM interaction on yield and yield traits of potato genotypes under Ladakh condition. *Potato J*., 35(3&4): pp. 126-129.

Minhas, J.S., D. Kumar, T.A. Joseph, B.T. Raj, S.M.P. Khurana, S.K. Pandey, S.V. Sindh, B.P. Singh and P.S. Naik. 2006. Kufri Surya: A new heat-tolerant potato variety suitable for early planting in North-western plains, peninsular India and processing into French fries and chips. *Potato J*., 33(1-2): 35-43.

MSTAT. 1991. Users manual for MSTAT-C. Michigan State university. East Lansing, Michigan, pp. 450.

Muthuraj, R., G. Ravichandran, K.S. Krishna and S. Singh. 2005. Effect of planting date on seed size tuber yield of potato in Nilgiris. *Potato J*., 32(3-4): 239.

Pandey, S.K., G.S. Shekhwat and D. Sarkar. 2000. Quality attributes of Indian Potatoes for export: Priorities and Possibilities. *J. Indian Potato Assoc*., 27(3-4): pp. 103-111.

Pandey, S. K., S.V.D. Sing, P. Kumar and P. Manivel. 2004. Sustaining potato chipping Industry from western and central Uttar Pardesh: Adoption of suitable varieties. *Potato J*., 31(3-4): 119-127.

Pardo, J.E., A. alvarruz, J.I. Perez, R. Gomez and R. Varon. 2000. .Physical, chemical and sensory quality evaluation of potato varieties (*Solanum tuborosum* L.). *Journal of Food Quality*, 23: 149-160.

Patel, C.K., P.T. Patel and S.M. Chaudhari. 2008. Effect of physiological age and seed size on seed production of potato in North Gujarat, 35(1&2): 85-87.

Patel, N.H., R.N. Patel, S.V. Singh, S.K. Pandey, J.M. Patel and S.B. Patel. 2007. Performance of exotic and Indian potato varieties in Gujarat for processing into french fries. *Potato J*., 34(1-2): 51-52.

Pritchard, M.K. and L.R. Adam. 1994. Relationships between fry color and sugar concentration in stored Russet Burbank and Shepody potatoes. *Am. Potato J*., 71: 59-68.

Ravikant and S.Chandha. 2009. Effect of planting season and fertility regimes on different potato cultivars. *Potato J*., 36 (1-2): 68-71.

Reeves, A.F., R.V. Akeley, H.J. Murphy, E.A. Porter, R.H. Cole, J. Watts, B.J. Christ, F.E. Manzer and R.H. True. 1990. Somerset: a new chipping potato variety. *American Potato J*., 66: 153-161.

Rodriguez, L.E., Wrolstad, R.E. Pereira and C. Modeling. 1997. The contribution of sugars, ascorbic acid, chlorogenic acid and amino acids to non-enzymatic browning of potato chips. *J. Food Sci*., 62: 1001-1005.

Sayre, R.N., M. Nonaka and M.L. Weaver. 1975. French fry quality related to specific gravity and solids content, variation among potato strips within the same tuber. *Am. Potato J*., 52: 73-82.

Schoenemann, J.A. 1977. Grading, packaging and Marketing potatoes, In: *Potatoes production, storing processing*, (Ed.) O. Smith. 2nd Edition. The AVI publishing company Inc., West port, pp. 470-505.

Sharma, A.K. and S. Singh. 2009. Effect of seed tuber desprouting on potato production in kufri Griraj. *Potato J*., 36(1-2): 51-56.

Singh, B.P. and M.N. Bhat. 2005. Development issues and strategies for the management of potato late blight. *Potato J*., 32(3-4): 105-117.

Singh, N and Z. Ahmad. 2008. Effect of mulching on potato production in high altitude cold arid zone of Ladakh. *Potato J*., 35(3-4): 118-121.

Struik, H.W.P.C., J. Wang and X. Zhang. 1998. Potential and actual yields of potato at different elevations and in different seasons in subtropical southwest China. *J. Agron. Crop Sci*., 180: 93-99.

Van Marle, J.T., T.S.Smits., J. Donkers, C.V. Dijk, A.G.J. Voragen and K. Recourt. 1997. Chemical and microscopic characterization of potato (*Solanum tuberosum* L.) cell walls during cooking. *J. Agric. Food Chem*., 45: 50-58.

Wooster, P. and K. Farooq. 1995. National program of germplasm screening, general instructions for trial and guide to data collection. Pak Swiss Potato Development Project, PARC Islamabad, Pakistan. p. 24.

Zaehringer, M.V., R.M. Reeves, E. Talley, D. Dinkel and R. Hyde. 1967. Specific gravity and composition of potatoes for various processing and cooking purposes. Potato Handbook, 1: 5. Academic Press, New York.

(Received for publication 8 January 2011)