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ASSESSMENT OF PROCESSING AND NUTRITIONAL QUALITY OF POTATO GENOTYPES IN PAKISTAN

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Thirty two genotypes including eight commercial varieties of potato were evaluated for yield processing quality traits. Significant differences in all the quality parameters were observed among the genotypes. The highest dry matter was found in NARC 1-2006/1 (25.65%) while NARC 1-2006/2 had the lowest dry matter (14.86%). Reducing sugars ranged from 0.57% in 396243-24 to 0.01% in NARC1-2006/1. Maximum starch was observed in NARC 1-2006/1 (20.01%) while it was minimum in Cardinal (9.00%). Protein value was found to be the highest (3.40%) in 9721 whereas the minimum value for protein was recorded in NARC 1-2006/2 variety (0.72%). The correlation analysis demonstrated that dry matter content of genotypes was positively correlated to starch (r = 0.9048), specific gravity (r = 0.5966) and negatively related to reducing sugars (r = -0.5515). The quality traits/characteristics represented by specific gravity, dry matter, sugars, starch, protein and ash are influenced by genotype.
Keywords: Potato, processing, quality, yield attributes

INTRODUCTION

The potato is one of the most important vegetable and a part of daily food utilization of almost all the world population (Mathur, 2003). It is a balanced food containing high energy, nutritional quality protein, essential vitamins and minerals (Mehdi *et al*., 2008). It produces more dry matter and protein (Ezeikal *et al*., 1999). Potato tuber contains 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). Moreover, it is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries (Brown, 2005). Currently the number of industries and potato products are increasing with enhancing demand of specific varieties.

Besides immediate consumption, potato is increasingly being used as a raw material by the processing industry (Iritani, 1981). The grower should take into account the fact that customers are concerned about quality. Now a day the most important features of potato production are tuber quality. Potato serving as raw material for the processing industry must meet a number of requirements including high dry matter content and good color.

At present no variety has been developed for processing purpose in Pakistan despite the fact that demand for potato varieties with acceptable yield and processing quality is gradually increasing. The yield and processing characteristics of available potato genotypes are largely unidentified. It is important to know the consumer requirements for its various uses and to identify varieties that possess traits to meet the domestic demand will provide growers the opportunity to meet the challenges of frequently changing market and production circumstances, and improving their economic condition (Connor *et al*., 2001). Therefore a study was designed to evaluate and select potato genotypes for yield traits and processing aspects for the well being of growers, food industrialists and the potato product consumers in Pakistan.

MATERIALS AND METHODS

The present study was conducted at National Agricultural Research Centre, Islamabad during 2007. The research material comprised of 32 potato genotypes including 24 advanced lines (Table 1) and 8 commercial varieties (Table 2) of potato obtained from different sources. The experiment was conducted following Randomized Complete Block Design with three replications. Each plot size was kept 15 m^2, consisting of five rows. Uniform cultural practices were adopted for all treatments. Estimation/ assessment of quality traits were made after harvest of the crop. Data were recorded for processing quality *viz.* specific gravity, dry matter, sugars and nutritional traits, i.e. starch, protein and ash content.

Table 1. Accession number and source of 24 advanced potato genotypes from different sources

S. No.	Advanced Genotypes (Anced genotypes nes)	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

Table 2. Name and source of 8 commercial varieties of potato

S. No.	Commercial Varieties as Control (Anced Genotypes Nes	Source
1	Paramont	Dutch
2	Bellini	Dutch
3	Kiran	Pakistani
4	Desiree	Dutch
5	Cardinal	Dutch
6	Kufri Badshah	India
7	Diamont	Dutch
8	Chipsona-111	India

***Tuber dry matter content*:** Dry matter content was determined by oven drying finely chopped tuber pieces first at 80°C for six hours and then at 65°C till constant weight.

***Specific gravity*:** Selected sample units (five kg each) were first weighed in air and then the same unit was re-weighed suspended in water. Specific gravity was calculated using the formula: Specific gravity = Weight in air (Weight in air -Weight in water).

***Reducing, non-reducing and total sugars*:** Sugars were extracted following the procedure for Determination of Food Carbohydrates by Southgate (1976) and determination was made following the method of Pearsons Composition and Analysis of Foods by Kirk and Sawyer (1991). Non reducing sugars were calculated by subtracting reducing sugars from total sugars.

***Starch*:** Starch content was determined by following the method of FAO Manual of Food Quality Control by Martin (1979).

***Protein*:** The AOAC (2005) No. 2001:11 method was used in the determination of the protein content with some modifications as

(i) Buchi digestion unit Model No. K- 435 and Auto kjeldhal unit Model No. K-370 was used instead of digestion unit and manual titration.

(ii) 32% NaOH and 0.25 N H_2SO_4 was used instead of 40% NaOH and HCl.

***Ash content*:** Ash content of tubers was determined by following AOAC (2005) No. 923.03.

Statistical analysis of the data was carried out in Randomized Complete Block Design (RCBD) in MSTAT-C package (MSTAT, 1991) and the means were compared by Duncan's Multiple range test at 5% level of significance (Gomez and Gomez, 1984). Correlations were worked between various processing and nutritional traits and the data was compared at $P< 0.05$.

RESULTS AND DISCUSSION

***Processing quality aspects*:** There exists huge scope for fast growth of processing industry due to increased demand for fast foods in Pakistan. The quality of processed products based on tubers is mainly influenced by quality characters like dry matter and reducing sugar content etc. Suitability of these parameters is essential for assessment of potato varieties for processing industries that are discussed as follows:

***Specific gravity*:** Processing aspects of the genotypes are given in Table 3. Genotypes varied with respect to specific gravity, which ranged from 1.0343 to 1.1443. It was observed that NARC 1-2006/1 had the highest specific gravity (1.14) followed by NARC 2002-1 (1.13) with non significant difference, while the minimum value for specific gravity (1.03) was noted for NARC 1-2006/2. The results in Table 5 showed the positive correlation of specific gravity with dry matter ($r = 0.5966$) and starch content ($r = 0.5309$) and negative correlation to reducing sugars ($r = -0.2310$). The characteristics represented by specific gravity are influenced by genotype. Specific gravity illustrated a positive relationship with starch content, dry matter and was negatively correlated with reducing sugars (Feltran *et al.*, 2004). Amoros *et al*. (2000) studied six clones of potato and found that specific gravity ranged between 1.121 and 1.141. Specific gravity and dry matter content reflect the amount of starch present and are used as basic indicators of the processing quality. A decrease in starch would be expected

Table 3. Processing quality traits of different potato varieties/genotypes

S. No	Genotypes	Specific gravity	Dry matter (%)	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)
1	NARC 2002-1	1.13 a	25.18 ab	0.02 p	0.20 g	0.23 q
2	NARC 1-2006/1	1.14 a	25.60 a	0.01 p	0.19 gh	0.21 rs
3	NARC 1-2006/2	1.03 e	14.86 k	0.40 g	0.11 q	0.51 g
4	NARC 1-2006/3	1.09 bcd	22.37 cd	0.19 l	0.16 k-p	0.35 no
5	NARC 2-2006/1	1.07 cde	18.29 efg	0.44 ef	0.13 p	0.58 f
6	NARC 2-2006/2	1.09 abc	24.25 abc	0.22 k	0.16 j-n	0.39 l
7	NARC 2-2006/3	1.06 cde	17.83 e-i	0.30 i	0.39 b	0.70 c
8	393574-6	1.07 cde	18.70 efg	0.31 hi	0.19 ghi	0.50 gh
9	9735 CIP	1.07 cde	18.53 efg	0.02 p	0.31 d	0.34 o
10	393574-61	1.08 bcd	22.21 d	0.10 n	0.14 nop	0.24 p
11	394021-120	1.12 ab	23.74 a-d	0.07 no	0.16 k-o	0.24 pq
12	396239-111	1.07 cde	18.14 e-h	0.19 l	0.17 ijk	0.36 m
13	VR 92-813	1.03 e	14.97 jk	0.53 c	0.15 m-p	0.68 d
14	396239-131	1.06 cde	17.80 e-i	0.57 b	0.14 op	0.71 b
15	393574-72	1.06 cde	18.41 efg	0.24 k	0.20 g	0.44 j
16	VR 90-217	1.07 cde	23.50 bcd	0.07 o	0.15 l-p	0.23 qr
17	9625	1.08 bcd	21.79 d	0.03 p	0.17 ijk	0.20 s
18	396206-72	1.06 cde	16.97 ghi	0.50 d	0.17 i-l	0.68 d
19	394055-40	1.07 b-e	19.73 e	0.02 p	0.31 d	0.34 o
20	392285-5	1.06 cde	16.90 g-j	0.13 m	0.34 c	0.47 i
21	396206-52	1.06 cde	17.72 f-i	0.43 f	0.15 k-p	0.59 f
22	396240-6	1.08 bcd	18.71 efg	0.23 k	0.18 g-j	0.42 k
23	9721	1.06 cde	16.26 h-k	0.29 ij	0.20 g	0.49 h
24	396243-24	1.06 cde	17.75 e-i	0.65 a	0.10 q	0.75 a
25	Paramont	1.04 de	15.86 ijk	0.50 d	0.17 h-k	0.67 d
26	Bellini	1.06 cde	17.46 ghi	0.12 m	0.23 f	0.35 mn
27	Kiran	1.08 bcd	22.18 d	0.29 ij	0.42 a	0.71 b
28	Desiree	1.06 cde	17.55 f-i	0.51 cd	0.17 j-m	0.69 cd
29	Cardinal	1.05 cde	15.86 ijk	0.27 j	0.38 b	0.65 e
30	Kufri Badshah	1.05 cde	15.99 ijk	0.46 e	0.28 e	0.74 a
31	Diamont	1.07 b-e	19.49 ef	0.30 i	0.38 b	0.69 c
32	Chipsona-111	1.08 bcd	23.70 a-d	0.33 h	0.14 op	0.47 i
LSD Value at 5%		0.0468	1.9891	0.0226	0.0219	0.0131

to decrease the specific gravity of the tuber (Rowe and Powelson, 2002). In general, tubers with high specific gravity are preferred for processing (Adams, 2004) and NARC 1-2006/1 was out standing for this character.

***Dry matter (%)*:** Dry matter ranged from 14.86% to 25.65% (Table 3). Maximum dry matter was found in NARC 1-2006/1 (25.65%) followed by NARC 2002-1 (25.18%), while NARC 1-2006/2 had minimum dry matter (14.86%). Uppal (1999) has reported that it ranged between 15% in Kufri Ashoka and 20.1% in Kufri Jawahar. Another study showed the highest values for dry matter content (24–26%) in La Molina (Amoros, 2000). For processing varieties dry matter should be more than 20% as described by the other workers. For chips, French fries and dehydrated products tuber dry matter needs to be more than 20% (Ezekiel *et al.,* 1999). Tuber dry matter content differs considerably between cultivars and is a strongly genetic based character (Toolangi, 1995). The present work revealed that the genotypes NARC 1-2006/1, NARC 2002-1, 394021-120, VR 90-217, 393574-61 and 9625 had higher dry matter over 20% and hence are suitable for processing.

Table 5 depicts that the dry matter is positively correlated with starch (r = 0.9048), specific gravity (r = 0.5966) but exhibited an inverse relationship with reducing sugars (r = -0.5515). High dry matter content has been reported to be positively correlated with a lower sugar concentration during storage (Watada and Kunkel, 1955; Iritani and Weller, 1976). A significant relationship between dry matter and specific gravity was found in earlier reports (Rastovski *et al.,* 1981).

***Reducing sugars (%)*:** Significant difference was recorded among the genotypes with respect to the reducing sugar

Table 4. Nutritional traits of potato genotypes

S.No	Genotypes	Starch (%)	Protein (%)	Ash (%)
1	NARC 2002-1	19.09 ab	3.10 bc	1.13 ij
2	NARC 1-2006/1	20.01 a	3.38 a	1.44 b
3	NARC 1-2006/2	10.75 lm	0.72 q	0.85 r
4	NARC 1-2006/3	17.32 cd	2.55 h	0.96 pq
5	NARC 2-2006/1	13.01 ghi	1.98 k	0.78 s
6	NARC 2-2006/2	18.70 abc	2.77 f	1.03 lm
7	NARC 2-2006/3	14.10 efg	1.84 l	1.21 ef
8	393574-6	12.58 g-j	3.15 b	1.27 cd
9	9735 CIP	14.80 ef	0.96 n	1.20 fg
10	393574-61	16.98 d	1.89 l	1.01 mno
11	394021-120	19.20 ab	3.01 d	1.25 cd
12	396239-111	14.00 efg	2.31 ij	1.24 de
13	VR 92-813	11.00 klm	2.58 h	1.05 kl
14	396239-131	11.76 i-l	2.88 e	0.84 r
15	393574-72	13.71 fgh	0.94 n	1.14 hij
16	VR 90-217	19.30 ab	1.88 l	0.99 nop
17	9625	17.42 cd	2.36 i	1.51 a
18	396206-72	11.00 klm	0.84 o	1.27 cd
19	394055-40	15.33 e	2.30 ij	0.71 t
20	392285-5	12.00 i-l	0.89 no	1.17 gh
21	396206-52	12.40 h-k	1.66 m	0.94 q
22	396240-6	14.03 efg	2.22 j	0.87 r
23	9721	9.50 mn	3.40 a	1.03 lm
24	396243-24	13.00 ghi	0.81 op	1.07 k
25	Paramont	10.45 lmn	0.73 pq	0.96 pq
26	Bellini	12.99 ghi	2.98 d	1.12 j
27	Kiran	16.92 d	1.64 m	1.28 c
28	Desiree	11.02 j-m	2.89 e	1.16 ghi
29	Cardinal	9.00 n	1.98 k	0.98 opq
30	Kufri Badshah	11.89 i-l	1.82 l	0.99 op
31	Diamont	14.00 efg	2.68 g	1.03 lmn
32	Chipsona-111	18.21 bcd	3.04 cd	0.99 nop
LSD 5%		1.5613	0.0841	0.0367

Table 5. Correlation coefficients of potato processing quality characteristics

	A	DM	NRS	P	RS	SG	S
DM	0.3025						
NRS	NS	NS					
P	NS	0.4345	NS				
RS	-0.2649	-0.5515	-0.2530	-0.2481			
SG	0.3769	0.5966	NS	0.3251	-0.2310		
S	0.3181	0.9048	NS	0.3387	-0.6039	0.5309	
TS	NS	-0.5930	0.2316	-0.2928	0.8826	-0.2176	-0.6451

A Ash, DM Dry matter, NRS Non reducing sugar, P Protein, RS reducing sugar, SG Specific gravity, S Starch, TS Total sugar, NS non significant

percentage (Table 3). Maximum reducing sugar (0.65%) was recorded in 396243-24 followed by 396239-131 having 0.57% reducing sugars. The reducing sugar was least (0.01%) in NARC1-2006/1. It is evident from Table 5 that the reducing sugars content of varieties had negative correlation with dry matter (r = -0.5515) and specific gravity (r = -0.2310). Reducing sugars were negatively correlated with specific gravity (Feltran *et al.*, 2004). A significant decrease in the reducing sugar content was mentioned previously with an increasing specific gravity and dry matter (Wilde *et al.,* 2004).

Table 3 revealed that reducing sugars ranged from 0.65% in 396243-24 to 0.01% in NARC1-2006/1, while the other genotypes were between these two limits. The results of the present trial are in close agreement with earlier findings. The reducing sugar content in the hybrid HT/92-621 was far lower (19.21-61.56%) than the upper limit of acceptable values for chips or French fries (Kumar *et al.,* 2006). The upper acceptable limit of reducing sugar content is 150 mg/100g fresh weight (Pandey *et al.,* 2005). A reducing sugar level of <100 mg per 100 g on fresh tuber weight is generally considered acceptable for producing light colored chips stated by Pandey *et al.* (2008a). The tubers of Kufri Himsona had low levels of reducing sugars. The reducing sugar in variety Kufri Jyoti was higher 206.7mg/100g on fresh weight (Pandey *et al*., 2008b). Average reducing sugar content was higher in Kufri Lauvkar (43.74 mg/100g on fresh weight) than Atlantic (14.68 mg/100g on fresh weight) (Kumar and Ezekiel, 2006). Therefore, due to the growing demand of the processed potato products, important parameter for the selection of raw material is reducing sugar content below 150 mg /100 g fresh tuber weight (Mathur, 2003). There were different statements regarding sugar limits for processing. Uppal (1999) mentioned that the acceptable limit was 0.25% but can be acceptable up to 0.5%. Marwaha (1998) stated that generally 0.33% tuber sugar content is suitable for product making. The acceptable limits was 150-250 mg/100g on fresh weight (Ezekiel *et al*., 1999; Ezekiel *et al*., 2003). Singh *et al.* (1999) reported below 150 mg/100g on fresh weight basis. The reducing sugar content, measured right after harvesting met the standard requirements (0.15%-0.31% on fresh weight basis) for all cultivars, except cv. Belousovsky (Zeiruk *et al.,* 2007). Reducing sugar ranged from 13.2 mg/100 g fresh weight in cv. Atlantic to 35.7 mg/ 100g fresh weight in heat tolerant hybrid HT/92-621 in early autumn crop (Pandey *et al*., 2004). Potato tubers contain 0.01-0.6% reducing sugars on fresh weight basis (Storey, 2007).

Accumulation of reducing sugar is a heritable character, but is also affected by a number of environmental factors. The reducing sugars are influenced by genotype or cultivar (Feltran *et al.,* 2004). The commonly cultivated potato variety Kufri Jyoti showed high levels of reducing sugars while processing varieties Kufri Chipsona-1, Kufri Chipsona-3, Atlantic and Lady Roseta, contained lower content of reducing sugars on fresh weight basis (Singh and Kaur, 2009). Varieties used for the processing purpose are generally low in reducing sugars (Wilde *et al.,* 2004). In the present work suitable genotypes NARC 1-2006/1 (0.01), NARC 2002-1 (0.02) and 9625 (0.03%) had far low content of reducing sugar compared to processing variety Chipsona-111 (0.33%) and other commercial cultivars Desire (0.51), Cardinal (0.27) and Diamont (0.30%).

Non reducing sugars (%)**:** It is evident from Table 3 that all the genotypes were significantly different in terms of non reducing sugars. Kiran was found to have the highest non reducing sugars percentage (0.42%), while lowest value (0.10%) was recorded in genotype 396243-24.

Sugar level in potato during tuberization and at harvest is largely dependent on cultivar (Sinha *et al.,* 1992). Low sugar content is a desirable character for processing purpose. Some varieties have been developed for low sugars (Wilde *et al.*, 2004). Amount and kind of sugars in particular cultivars are inherited characteristics (Lauer and Shaw, 1970). Sucrose content at the time of harvest is an indicator of chemical maturity of the tuber. Lower sucrose content is desirable for long term storage at intermediate temperatures (Shallenberger *et al*., 1959). The higher values of sucrose in potato tuber at the time of harvest indicate its immaturity. The sucrose content at harvest is very important because when hydrolyzed by invertase it results in accumulation of reducing sugars making the potatoes unfit for processing (Uppal, 1999).

Total sugars**:** Significant difference was found in terms of total sugar in potato varieties (Table 3). The genotype 396243-24 had the maximum total sugar (0.75%) followed by Kufri Badshah (0.74%), both being at par. The genotype 9625 had the lowest value of total sugar (0.20%). Increase in total sugars or a particular sugar and dry matter is a heritable character, but is also affected by a number of environmental factors (Ezekiel *et al*., 1999). Sugar level in potatoes during tuberization and at harvest is largely dependent on cultivar (Sinha *et al.,* 1992). Quantity and kind of sugars in particular cultivar are inherited characteristics (Lauer and Shaw, 1970). Potato tuber sugar content may be affected by cultivar, maturity, production site, and season as well as storage temperature (Gray and Hughes, 1978).

Starch content (%)**:** Starch comprises 65-80% of the dry weight of tubers (Kadam *et al.,* 1991). Maximum starch was depicted in NARC 1-2006/1 (20.01%) followed by VR 90-217 (19.30%). The minimum starch was noted in Cardinal (9.0%) as shown in Table 4. Starch content is influenced by genotypes and it was found to be positively correlated to dry matter ($r = 0.9048$) and specific gravity ($r = 0.5309$) (Table 5). Its percentage varied both with variety and environment (Gall *et al.,* 1965); however, several other factors, including environmental conditions, and cultural practices during growth are also important (Kumar *et al*., 2004). Specific gravity showed a positive correlation with starch content (Feltran *et al*., 2004). Starch content was proportional to the dry matter (Uppal, 1999). Since the dry matter content of potato tuber is mostly dependent on starch (Dean and Thornton, 1992). The results of the present study revealed that starch content in new genotypes NARC 1-2006/1 (20.01%) and VR 90-217 (19.30%) was higher in contrast to variety Chipsona -111 (18.21%).

***Protein content (%)*:** The statistical analysis for protein content of different potato genotypes showed significant variation (Table 4). The highest value for protein content was found in 9721 (3.40%) followed by NARC 1-2006/1 (3.38%) with non significant difference. The minimum value for protein was observed in varieties NARC 1-2006/2 (0.72%). The average protein percentage in potato is 2% and range is 0.7 to 4.6% (Singh and Kaur, 2009).

The difference in protein content may be due to genotype (Ereifej *et al*., 1997). In a previous report, protein content of Kufri Jyoti and Kufri Sinduri was 1.82 and 2.12%, respectively (Sandhu and Parhawk, 2002). In general, potato cultivars vary for protein content (Jansen *et al.,* 2001). The results also showed more protein in genotype NARC 1-2006/1 (3.38%) than variety Chipsona-111 (3.04%).

***Ash content (%)*:** The results regarding ash content of different potato varieties are given in Table 4, which showed that the ash content of genotypes differed significantly. The ash content was found the highest (1.51%) in potato genotypes 9625, followed by NARC 1-2006/1 (1.44%). The potato genotype 394055-40 showed the least ash content (0.71%). The average ash content in potato is 1% and range for ash percent is 0.44 to 1.9 (Singh and Kaur, 2009). Variation in ash may be a varietal character as mentioned by earlier researchers (Ereifej *et al*., 1997; Sandhu and Parhawk, 2002).

CONCLUSIONS

The Pakistan potato processing industry is in developing phase. The increased demand of fast foods by consumers exerts pressure on scientists for identifying suitable potato genotypes for processing. The present investigation lead to conclude that genotypes *viz.* NARC 1-2006/1, NARC 2002-1, 394021-120, 393574-61, VR 90-217 and 9625 possessed high dry matter, low reducing sugar could be considered the highly suitable for processing. The above mentioned lines may be included in the national zonal trials. Farmers can get maximum return by cultivating such genotypes that will ultimately improve their socio economic conditions. Moreover, it will help in establishment and growth of processing industry by providing raw material.

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