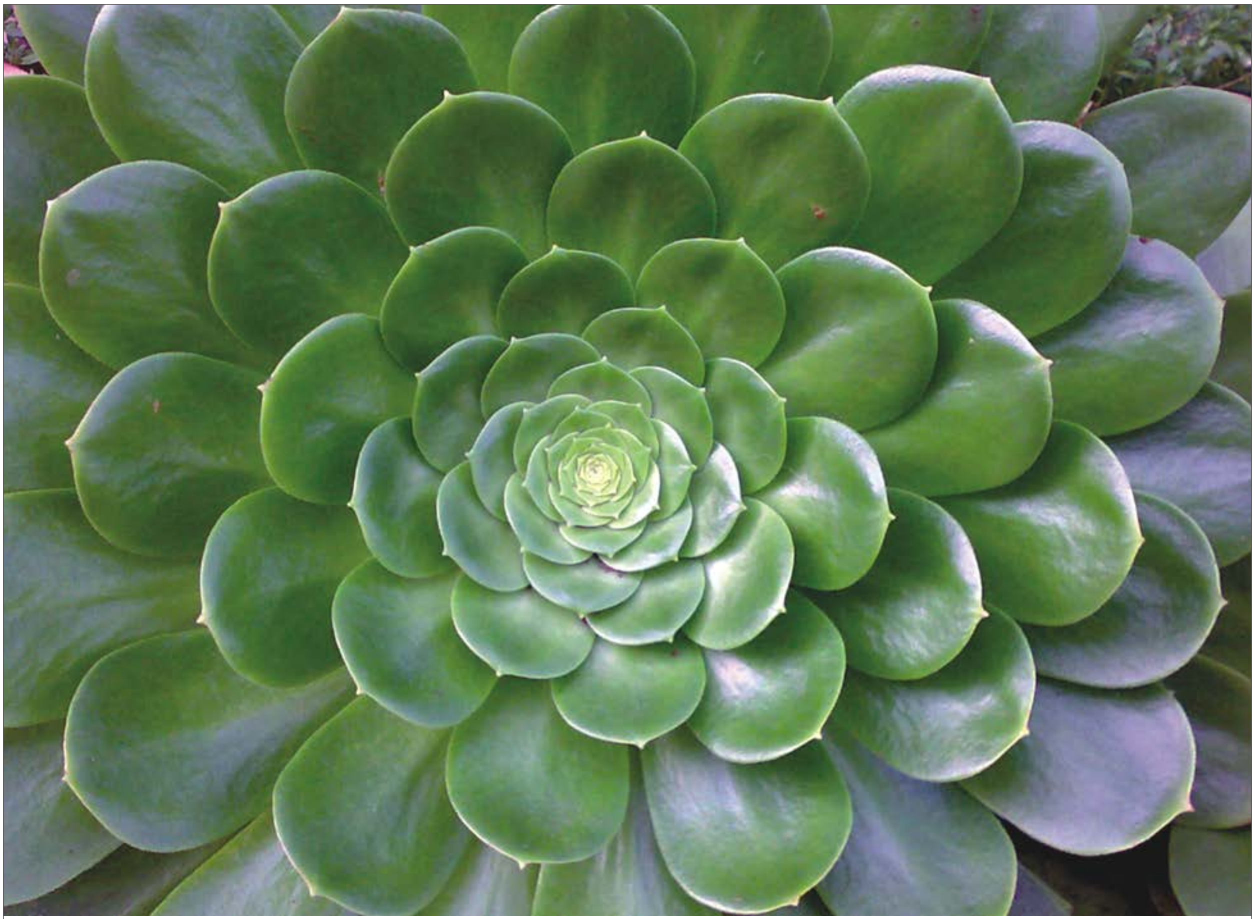

Journal of

Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 10 (3): 108-115, 2015
ISSN 1816-4951 / DOI: 10.3923/jps.2015.108.115

Yield, Dry Matter, Specific Gravity and Color of Three Bangladeshi Local Potato Cultivars as Influenced by Stage of Maturity

[1]Abul Hasnat Muhammad Solaiman, [2]Takashi Nishizawa, [3]Tuhin Suvra Roy, [3]Mahfuzar Rahman, [3]Rajesh Chakraborty, [3]Jannath Choudhury, [1]Md. Dulal Sarkar and [3]Mirza Hasanuzzaman

[1]Department of Horticulure, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-120, Bangladesh
[2]Faculty of Agriculture, Yamagata University, Tsuruoka, Japan
[3]Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, 1207, Bangladesh

Corresponding Author: Abul Hasnat Muhammad Solaiman, Department of Horticulure, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-120, Bangladesh

ABSTRACT

Stage of maturity often affects the yield, dry matter, specific gravity and color of potato tubers. Comparative account of some processing traits of three local varieties of potato (viz., 'Fata Pakri', 'Sada Pakri' and 'Rumana)' harvested at 80, 90, 100 and 110 days after planting with those of True Potato Seed variety 'BARI TPS-I' is given in this study tuber samples were harvested after 10 -days of tuber skin-curing in the soil. Yield increased significantly up to the last date of harvest. Mature tubers exhibited significantly higher dry matter and specific gravity compared to immature ones. Tuber color was also significantly affected by time of harvest irrespective of varieties. The 'BARI TPS-I' gave highest tuber yield. 'Fata pakri' exhibited highest specific gravity and dry matter content. On basis of flesh color, 'BARI TPS-I', 'Fata pakri' and 'Sadapakri' were found suitable for chips. Bangladeshi potato farmers and processors will get benefited from the information generated regarding the appropriate harvesting time of local potatoes for processing industries.

Key words: *Solanum tuberosum*, maturity time, tuber crop, yield, dry matter

INTRODUCTION

Bangladesh was the world's seventh largest producer of potatoes with a total production of about 8.8 million tons in 2012-2013 (FAOSTAT, 2012). Potato consumption as processed and fresh food is also increasing considerably in Bangladesh (Brown, 2005).

Abong *et al*. (2009) studied the storage and processing characteristics of red skinned, Kerr's pink, white skinned and Desiree potato varieties. Although, potato product manufacturers are using High Yielding Variety (HYV) consumers in some parts of northern region of Bangladesh also prefer the local potato cultivars, because of taste, flavor, color, ambient storage ability local cultivars of potato (Fig. 1).

Potato tuber quality is one of the most important quality attributes (Brown, 2005) for consumers and industrial demand. Potato having optimum dry matter, specific gravity, reducing sugars, starch, good color are preferred by processing industry. The specific gravity and dry matter of potato tubers is influenced by type and amount of fertilizers, dates of planting and harvesting etc., (Burton, 1966; Smith, 1968).

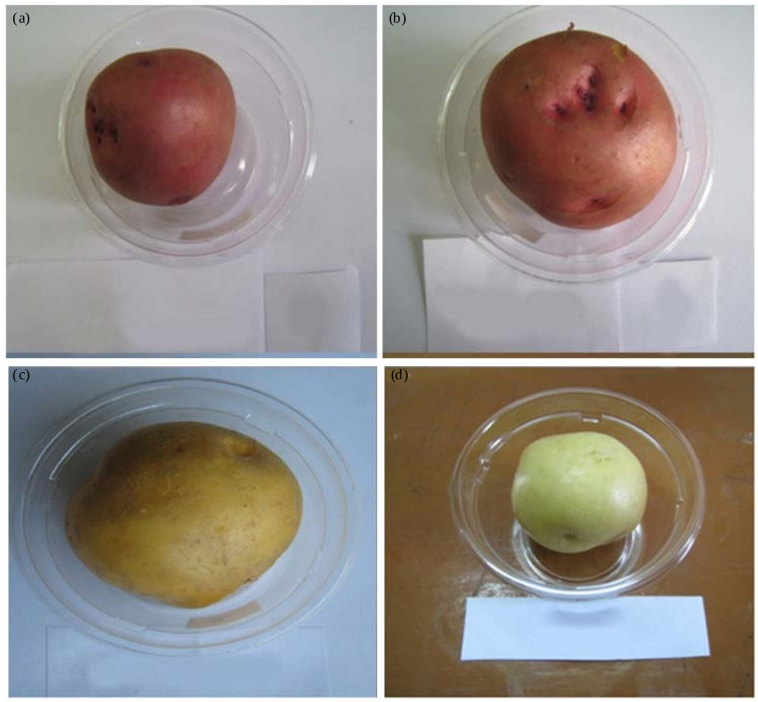

Fig. 1(a-d): Different potato varieties of Bangladesh used in the experiments, (a) FATA Pakri-7, (b) ROMANA, (c) SADA Parki and (d) BARI TPS-1

Harvesting time can influence the biomass accumulation in potato tuber. The location, cultivar, date of harvest and tuber curing influences the, physical and biochemical changes in the structural components of potato tissue during processing are influenced by Marwaha *et al.* (2005). Early harvesting of tuber gives economic support to the farmers but it affects the quality. Tuber harvested at full maturity stage contain maximum dry matter and protein content and have higher specific gravities than immature ones (Misra *et al.*, 1993). Specific gravity is an important factor for maintaining quality tuber and is directly associated with the dry matter content. High specific gravity potatoes are better suited for baking, frying, mashing and chipping (Haase, 2003; Pedreschi and Moyano, 2005). Potato product manufacturers prefer tubers of higher specific gravity than potatoes with lower specific gravity to get more chips (Haase, 2003). Color is also an important quality attribute which influences the acceptability of fried products (Nourian *et al.*, 2003). Golden yellow color is considered to be the best for high quality potato chips (De Freitas *et al.*, 2012). Specific gravity is positively correlated to dry matter and starch content in several researches.

In Bangladesh, local potato farmers has been lacking information on appropriate potato harvesting time and quality aspects. Hardly any study has been conducted in Bangladesh to determine the optimum harvesting time and correlating with dry matter accumulation, color and specific gravity of local potato cultivars.

Keeping in view the increasing demand for quality local potatoes by processing industry, effect of harvesting time on yield, specific gravity, dry matter content and color of different local and TPS potato varieties as has been evaluated.

MATERIALS AND METHODS

The study was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh situated at 23°77'N latitude and 90°37' E longitude at an altitude of 8.6 m above the sea level, during November, 2013 to April, 2014. Tubers (45-55 mm size) of three local potato varieties viz. 'Fata pakri', 'Sadapakri', 'Rumana' along with one True Potato Seed (TPS) cultivar 'BARI TPS-1' were planted at 50×25 cm spacing in plots 4.0×3.0 m in a split-plot design, replicated three times. Cultivars were taken in the main plots and time of harvest (80, 90, 100 and 110 days after planting) in the sub-plots. A basal dose of 60 kg N as urea 80 kg P_2O_5 as triple superphosphate and 150 kg K_2O ha^{-1} as muriate of potash was applied at planting time and an additional 60 kg was top dressed as urea three weeks after planting (Roy *et al*., 2009). The planting was done on November 15, 2013 and the crops were dehaulmed as per treatments and tuber samples were kept 10-days for tuber skin-curing in the soil. Finally, tubers were harvested at 80, 90, 100 and 110 DAP, respectively. The crops were grown as per recommendation of Roy *et al*. (2009).

Determination of yield: Matured tubers were harvested from randomly selected 1 m^2 area of each plot and weighed immediately. The following formula was used for determining tuber yield.

$$\text{Tuber yield (t ha}^{-1}) = \frac{\text{Yield (kg m}^{-2})\times 10000\text{ m}^2}{1000\text{ kg}}$$

Determination of specific gravity: Specific gravity was determined in the raw tubers according to weight under water method as described by Ludwig (1972).

Determination of dry matter content: For determination of dry matter, five whole tubers were randomly selected from each treatment and cut into small slices (1-2 mm) and mixed thoroughly. Dry weight of samples was then determined by drying at 70°C for 72 h in a forced air oven. The following formula was used for determining DM content:

$$\text{DM (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}}\times 100$$

Determination of total soluble solids (TSS, °brix): TSS was measured by portable hand refractometer (ERMA, Tokyo, Japan) at room temperature. Every single tuber was blend and juice was collected to measure (°brix). Mean was collected for each treatment.

Color measurements: Color was measured with a color spectrophotometer NF333 (Nippon Denshoku, Japan) using the CIE Lab L*, a* and b* color scale. The 'L*'value is the lightness parameter indicating degree of lightness of the sample; it varies from 0 = black (dark) to 100 = white (light). The 'a*' which is the chromatic redness parameter, whose value means tending to red color when positive (+) and green color when negative (–). The 'b*' is yellowness chromatic parameter corresponding to yellow color when it is positive (+) and blue color when it is negative (–). Each sample consisted of 10 slices, each of which was measured thrice. Hue Angle= arctgand chroma= were calculated. Higher numbers of chromaticity indicate a more vivid color, whereas lower numbers correspond to dull colors. Color measurement was done just after cutting tubers.

Data analysis: Analysis of variance (ANOVA) and least significant difference test for the variables at 5% level of probability were conducted using the MSTAT-C Program.

RESULTS AND DISCUSSION

Yield of tuber (t ha^{-1}): Different cultivars as well as harvesting time significantly affected the tuber yield (Table 1). The 'BARI TPS-1' produced significantly maximum yield (24.5 t ha^{-1}) compared to those of local cultivars while minimum was in 'Rumana' (14.6 t ha^{-1}). The mean tuber yield of all cultivars significantly increased with maturity. Harvesting at 100 and 110 DAP showed similar yield (Table 1). The maximum increase in yield was noticed between 90 and 100 DAP. All cultivars attained maturity on 100 DAP. Treatment combinations had also significant effect on tuber yield (Table 2). Among the sixteen treatment combinations, the cultivar, 'BARI TPS-1' harvested at 110 DAP attained the highest tuber yield (27.0 t ha^{-1}) and same variety harvested at 100 DAP produced similar yield, whereas the lowest yield (14.3 t ha^{-1}) was recorded in 'Rumana' at same harvest time. All cultivars produced minimum yield at early harvest (70 DAP). The yield of 'BARI TPS-1' was highest compared to those of other local cultivars irrespective of harvesting time may be due to its varietal characteristics. Among the local cultivars, 'Fata pakri' showed the best performance (20.5 t ha^{-1}) when harvested at 110 DAP. All the local cultivars gave low yields may be due to their genetically low yield potential. 'BARI TPS-1' attained higher yield due to its hybrid vigor in its first clonal generation (Pandey *et al*., 2002).

Table 1: Single effect of variety or stage of maturity on tuber yield, specific gravity and dry matter content and TSS of tuber

Parameters	Tuber yield (t ha^{-1})	Specific gravity	Dry matter content (%)	TSS (°brix)
Variety				
Fata Pakri	17.99^{b}	1.068^{b}	19.58^{b}	7.38^{a}
Sada Pakri	16.86^{b}	1.084^{a}	19.66^{b}	7.35^{a}
Romana	14.61^{c}	1.072^{b}	20.28^{a}	6.34^{b}
BARI TPS-1	24.47^{a}	1.053^{c}	17.90^{c}	6.18^{b}
Level of Significance	**	**	**	*
Harvesting at				
80 DAP	15.35^{d}	1.050^{c}	16.94^{d}	6.38^{a}
90 DAP	17.57^{c}	1.061^{b}	18.48^{c}	7.22^{a}
100 DAP	19.86^{ab}	1.085^{a}	20.28^{b}	6.93^{a}
110 DAP	21.02^{a}	1.082^{a}	21.72^{a}	6.73^{a}
Level of significance	*	**	**	ns

ns: Non-significant, **: Significant at $p \leq 0.01$ and *: Significant at $p \leq 0.05$, Different lowercase letters beside the mean values are significant at $p \leq 0.05$ or $p \leq 0.01$

Table 2: Combined effects of variety and stage of maturity on tuber yield, specific gravity dry matter content and TSS of tuber

Treatment combination (variety and harvesting)	Tuber yield (t ha^{-1})	Specific gravity	Dry matter content (%)	TSS (%)
Fata Pakri				
80 DAP	14.97^{g}	1.056^{gh}	17.26^{j}	7.20^{a-c}
90 DAP	17.09^{f}	1.060^{f-h}	18.73^{fg}	6.97^{a-d}
100 DAP	19.40^{d}	1.074^{b-f}	20.47^{d}	7.73^{ab}
110 DAP	20.50^{cd}	1.081^{b-d}	21.86^{bc}	7.63^{a-d}
Sada Pakri				
80 DAP	13.27^{h}	1.055^{gh}	17.26^{j}	6.97^{a-d}
90 DAP	15.73^{g}	1.070^{c-g}	18.32^{gh}	7.13^{a-c}
100 DAP	18.69^{e}	1.089^{b}	20.62^{d}	8.07^{a}
110 DAP	19.75^{c-e}	1.124^{a}	22.78^{a}	7.23^{a-c}
Romana				
80 DAP	12.19^{h}	1.056^{gh}	17.86^{hi}	5.97^{c-e}
90 DAP	13.41^{h}	1.069^{d-g}	19.07^{f}	7.27^{a-c}
100 DAP	15.47^{g}	1.079^{b-e}	21.42^{c}	6.53^{a-e}
110 DAP	17.38^{f}	1.086^{bc}	22.36^{ab}	5.60^{de}
BARI TPS-1				
80 DAP	20.98^{c}	1.032^{i}	15.37^{k}	5.40^{e}
90 DAP	24.07^{b}	1.047^{hi}	17.75^{ij}	7.53^{a-d}
100 DAP	25.87^{a}	1.063^{e-h}	18.62^{fg}	5.37^{e}
110 DAP	26.95^{a}	1.071^{c-g}	19.86^{e}	6.43^{b-e}
Level of significance	**	**	*	**

ns: Non-significant, **: Significant at $p \leq 0.01$ and *: Significant at $p \leq 0.05$, Different lowercase letters beside the mean values are significant at $p \leq 0.05$ or $p \leq 0.01$

Specific gravity and dry matter content of tubers: Differences in specific gravity among the four varieties were consistent irrespective of harvesting time (Table 1 and 2). 'Sada pakri' tubers showed the highest specific gravity (1.084) than those from the other three varieties, whereas, the lowest value was recorded in 'BARI TPS-I'. It was revealed that all local varieties exhibited maximum specific gravity compared to those of 'BARI TPS-I'. The specific gravity of tubers significantly increased from 1.050 to 1.085 with increasing harvesting time i.e from 80 to 110 DAP (Table 1). Marwaha (1998) also observed an increase in the specific gravity of tubers with the increase in harvesting time. Tuber Dry Matter (DM) content was significantly affected by variety and harvesting time (Table 1 and 2). Among four varieties, 'Sada pakri' showed maximum (20.28%) DM content while BARI-TPS-1 recorded minimum DM content. DM content gradually increased from 16.94% at 80 DAP to 21.72% at 110 DAP irrespective of variety (Table 1). However, both the specific gravity and DM content increased with increase in harvesting time . Among the fourteen treatment combinations, Sadapakri' tubers exhibited highest (1.079) specific gravity and maximum (22.78%) DM content at 110 DAP, while 'BARI TPS-1' showed the lowest specific gravity and minimum DM content (Table 2). Tubers that have a longer time to accumulate carbohydrates will generally have higher specific gravity and DM content than those with shorter growth periods. This result is in agreement with (Misra *et al*., 1993; Marwaha, 1998; Ali *et al*., 2003; Elfnesh *et al*., 2011; Mehta *et al*., 2011). who reported that specific gravity and DM content increased with the maturity of tuber and crops grown usually have more time to mature those produce tubers with high specific gravity and DM content A positive correlation between specific gravity and dry matter of tubers was observed earlier (Walter *et al*., 1997).

Total soluble solid (°brix): Total soluble solid was measured in potato juice and local varieties showed significantly higher range of 7.5-8.1% TSS effects with the same DAP. The local varieties consisted thick juice than HYV varieties like TPS which can be an indication of using the local varieties for ready to drink juice along with other materials like malt and flavours (Islam and Jalaluddin, 2004; Sohail *et al*., 2013).

Color of skin and flesh: The statistical analysis revealed significant differences ($p<0.05$) for lightness (L^*), green-red chromaticity (a^*), blue-yellow chromaticity (b^*), chroma and hue angle of potato skin and fresh in different varieties but not for harvest dates (Table 3). Among four varieties, the skin of BARI TPS-I had the highest L^* value compared to those of others whereas the lowest

Table 3: Single effect of variety or stage of maturity on skin and flesh color of tuber

	Skin color					Flesh color				
Treatment	L^*	a^*	b^*	Chroma	Hue angle	L^*	a^*	b^*	Chroma	Hue angle
Variety										
Fata Pakri	49.47^{c}	16.46^{b}	17.76^{b}	24.24^{d}	0.82^{c}	70.97^{a-d}	2.03^{a}	36.33^{a}	36.36^{a}	1.52^{c}
Sada Pakri	59.86^{b}	10.69^{c}	30.88^{a}	32.69^{b}	1.23^{b}	72.72^{a}	1.69^{a}	34.77^{a}	34.80^{b}	1.52^{c}
Romana	47.36^{d}	19.03^{a}	16.47^{b}	25.50^{c}	0.72^{d}	68.54^{c}	0.85^{b}	29.47^{b}	29.48^{c}	1.54^{b}
BARI TPS-1	62.76^{a}	7.917^{d}	34.38^{a}	35.28^{a}	1.35^{a}	69.76^{bc}	0.35^{b}	27.27^{b}	27.69^{d}	1.56^{a}
Significance	**	**	**	**	**	**	**	**	**	**
Harvesting										
80 DAP	54.742	14.43	24.15	29.58	0.99^{b}	71.32	1.167	31.93	32.35^{a}	1.54^{a}
90 DAP	54.467	13.44	25.18	29.36	1.04^{a}	70.04	1.567	32.53	32.56^{a}	1.53^{b}
100 DAP	55.042	13.33	24.41	29.04	1.04^{a}	70.27	1.058	31.41	31.43^{b}	1.54^{a}
110 DAP	55.200	12.90	25.74	29.73	1.05^{a}	70.37	1.150	31.97	31.99^{a-d}	1.54^{a}
Significance	ns	ns	ns	ns	**	ns	ns	ns	*	**

ns: Non-significant, **: Significant at $p\leq 0.01$ and *: Significant at $p\leq 0.05$, Different lowercase letters beside the mean values are significant at $p\leq 0.05$ or $p\leq 0.01$

Table 4: Combined effects of variety and stage of maturity on skin and flesh color of tuber

Treatment combination (variety and harvesting)	Skin color					Flesh color				
	L^*	a^*	b^*	Chroma	Hue angle	L^*	a^*	b^*	Chroma	Hue angle
Fata Pakri										
80 DAP	50.60^{c}	15.07^{b}	17.13^{de}	22.81^{f}	0.85^{de}	73.00^{ab}	2.03^{ab}	39.33^{a}	39.31^{a}	1.52^{ef}
90 DAP	50.40^{c}	16.43^{b}	18.67^{d}	24.87^{ef}	0.85^{be}	70.97^{a-c}	1.63^{a-c}	33.37^{b-d}	33.40^{e}	1.52^{ef}
100 DAP	46.83^{cd}	18.63^{b}	16.87^{de}	25.13^{e}	0.74^{f}	70.03^{a-c}	2.30^{a}	36.83^{ab}	36.90^{b}	1.51^{f}
110 DAP	50.07^{c}	15.70^{b}	18.37^{de}	24.16^{ef}	0.87^{d}	69.90^{a-c}	2.16^{a}	35.77^{a-d}	35.83^{bc}	1.51^{f}
Sada Pakri										
80 DAP	60.77^{a-d}	10.90^{c}	30.27^{c}	32.17^{c}	1.22^{c}	71.73^{a-c}	1.63^{a-c}	34.03^{b-d}	34.06^{de}	1.52^{ef}
90 DAP	58.10^{b}	11.23^{c}	29.10^{c}	31.19^{c}	1.20^{c}	72.03^{a-c}	1.93^{a-d}	35.33^{a-c}	35.38^{c}	1.52^{ef}
100 DAP	60.10^{a-d}	10.57^{cd}	31.10^{bc}	32.85^{bc}	1.24^{c}	74.17^{a}	1.63^{a-c}	34.67^{a-c}	34.70^{cd}	1.52^{ef}
110 DAP	60.47^{a-d}	10.07^{cd}	33.03^{a-c}	34.53^{a-d}	1.27^{bc}	72.93^{a-d}	1.56^{a-c}	35.03^{a-c}	35.06^{cd}	1.53^{de}
Romana										
80 DAP	44.53 d	23.57^{a}	14.47^{e}	27.67^{b}	0.55^{g}	68.97^{bc}	1.00^{a-d}	30.27^{c-f}	30.28^{g}	1.54^{cd}
90 DAP	47.57^{cd}	17.77^{b}	17.47^{de}	24.92^{ef}	0.78^{ef}	68.63^{bc}	1.93^{a-d}	31.90^{b-e}	31.95^{f}	1.51^{f}
100 DAP	49.60^{c}	17.20^{b}	17.67^{de}	25.46^{de}	0.80^{d-f}	68.37^{c}	0.16^{d}	27.60^{e-g}	27.60^{jk}	1.56^{a-d}
110 DAP	47.73^{cd}	17.60^{b}	16.27^{de}	23.97^{ef}	0.75^{f}	68.20^{c}	0.33^{cd}	28.10^{e-g}	28.10^{ij}	1.56^{a-d}
BARI TPS-1										
80 DAP	63.07^{a}	8.17^{cd}	34.73^{ab}	35.67^{a}	1.34^{a-d}	71.57^{a-c}	0.12^{d}	24.10^{g}	25.77^{l}	1.57^{a}
90 DAP	61.80^{a-d}	8.33^{cd}	35.50^{a}	36.46^{a}	1.34^{a-d}	68.53^{bc}	0.76^{b-d}	29.50^{d-f}	29.50^{gh}	1.55^{bc}
100 DAP	63.63^{a}	6.93^{d}	32.00^{a-c}	32.74^{bc}	1.36^{a}	68.50^{bc}	0.13^{d}	26.53^{fg}	26.52^{kl}	1.57^{a}
110 DAP	62.53^{a}	8.23^{cd}	35.30^{a}	36.25^{a}	1.34^{a-d}	70.43^{a-c}	0.53^{cd}	28.97^{d-g}	28.97^{hi}	1.55^{bc}
Significance	**	**	**	**	**	**	**	**	*	**

ns: non-significant, **: Significant at $p \leq 0.01$ and *: Significant at $p \leq 0.05$, Different lowercase letters beside the mean values are significant at $p \leq 0.05$ or $p \leq 0.01$

was observed in 'Rumana'. In case of flesh, 'Fata pakri' and 'Sada pakri' had L^*values that were significantly higher than the values of others. 'Rumana' was characterized by a higher a^* value and also showed the lowest b^* value. Harvest date had no effect on lightness (L^*), degree of yellowness (b^*) and redness (a^*) both for skin and flesh (Table 3). The combination effect on variety and harvest date had significant effect on skin and flesh colour (Table 4). The treatment combinations of variety and harvest date had significant effect on L^*, a^* and b value. Among sixteen combinations, the skin of 'BARI TPS-I' and 'Sadapakri' exhibited maximum L^* values (63.63-59.10) irrespective of all harvest time. The variety, 'Sadapakri' also showed the highest L^* value (74.14) for flesh when harvested at 90 DAP, whereas, the lowest was recorded in 'Rumana' irrespective of harvest dates (Table 4). A higher L^* value indicates a lighter color, which is desirable in potato chips (Garayo and Moreira, 2002). 'BARI TPS-1', 'Fata pakri' and 'Sada pakri' were observed suitable for flesh color. The values of 'a^*' were significant for varieties but not for harvest date. The skin of 'Rumana' was characterized by the highest a^* value (23.57) at 80 DAP, while the lowest was exhibited in 'BARI TPS-1' (6.93) at 100 DAP (Table 4). In case of flesh, 'Fata pakri' and 'Sada pakri' demonstrated higher a^*values irrespective of all harvested dates and 'Rumana' showed similar results at earlier harvesting time whereas, 'BARI TPS-1' was characterized by lower a^* values (<0.8) irrespective of all harvesting times (Table 4). Th e findings provided evidence of slightly less redness color of 'BARI TPS-1' compared with other varieties. Among the four varieties, 'Fata pakri' and 'Sada pakri' demonstrated maximum b^* values and harvesting date had no effect on this parameter.

Again, chroma and hue angle were significantly affected by variety. Among the treatment combinations, 'Fata pakri' and 'Sadapakri' exhibited dark yellow color flesh and 'Rumana' and 'BARI TPS-1' displayed light yellow color flesh irrespective of all harvesting dates. The variation of color can be explained by differences in composition within varieties, particularly in antioxidant content and enzyme activity.

'Sada pakri' and 'BARI TPS-1' varieties produced light colored skin and all other varieties produced light colored flesh (L^*>50), which indicates that there was no excessive darkening. This can be attributed to low reducing sugars levels exhibited by the varieties. All the varieties tended towards the positive values of redness parameter (a*) of skin and flesh color indicating that there was less or no excess browning of the products during frying. Lack of excess browning can be attributed to low and acceptable levels of sugars, major causes of browning during frying of potato products. Also all the potato varieties tended towards yellow as indicated by positive values of yellowness (b*) parameter (Table 3 and 4). Abong and Kabira (2011) also found significant varietal differences in color and textural properties of crisps and French fries with the product and variety. This might be attributed due to genetical, environmental or inter cultural factors. This colour parameter could be used as an objective color index for preparing chips. Moreira *et al*. (1999) reported that low reducing sugar content (below 0.25% and preferably below 0.1% is desired for the production of potato chips.

CONCLUSION

Harvesting time had potential effect on tuber maturation and finally on specific gravity, dry matter content and tuber color . The findings revealed that though 'Sadapakri', 'Fata pakri' and 'Rumana' produced lower yields than 'BARI TPS-1' but these local cultivars may be good for processing industry because of their more than 1.07 and 20% specific gravity and dry matter content respectively. These also displayed acceptable flesh color when harvested at 100-110 DAP.

ACKNOWLEDGMENT

The author would like to acknowledge the Japan Society for Promotion of Science and University Grants Commission of Bangladesh for supporting financially in conducting this experiment (UGC-11311).

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