ASSESSMENT OF POTATO VARIETIES FOR PROCESSING INDUSTRY IN BANGLADESH

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CERTIFICATE

*This is to certify that the thesis entitled "**ASSESSMENT OF POTATO VARIETIES FOR PROCESSING INDUSTRY IN BANGLADESH** " submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **MD. MAHFUZAR RAHMAN,** Registration. No. **08-02660** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

(Prof. Dr. Tuhin Suvra Roy)
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The Author

ASSESSMENT OF POTATO VARIETIES FOR PROCESSING INDUSTRY IN BANGLADESH

ABSTRACT

The experiment was conducted at Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during March to June 2013 to study the assessment of potato varieties for processing industry in Bangladesh. A total of forty potato varieties were analyzed for different physico-chemical attributes and processing quality. On the basis of morphological and physiological traits such as, tuber shape, size, average weight, eye depth, color and general appearance of tuber, 'Diamant', 'Lady Rosetta', 'Binella', 'Dheera', 'Elgar', 'Agila', 'Sagitta', 'Provento', 'Cardinal', 'Steffi', 'Felsina', 'Ailsa', 'Multa', 'Espirit', 'Meridian', 'Asterix', 'Rumba', 'Omega', 'Caruso', 'Amanda', 'Svenja', and 'Connect' varieties were found suitable for processing. The specific gravity, dry matter, starch, protein and sugar content were determined to clarify their processing quality. The specific gravity, dry matter, starch, reducing sugar, non-reducing sugar and total sugar contents of different potato varieties studied in this experiment were ranged from 1.053 to 1.123, 13.56 to 24.60%, 6.80 to 18.93%, 0.02 to 0.61%, 0.09 to 0.53% and 0.27 to 0.78%, respectively. Among the varieties, 'Lady Rosetta', 'Ailsa', 'Caruso', 'Forza', 'Amanda', 'Ludmila', and 'Tomensa', had specific gravity, dry matter and starch content more than 1.07, 20% and 17%, respectively and reducing sugar content less than 0.2%. The variety 'Lady Rosetta', 'Dheera', 'Cardinal', 'Ailsa', 'Tomensa', 'Caruso', 'Forza', 'Amanda', 'Ludmila' and 'Omega' were found to be optimum chips color (L^*, a^*, b^*, chroma, hue angle) and crispness compared to those of other varieties. Among the forty varieties, 'Lady Rosetta', 'Ailsa', 'Caruso', 'Forza', 'Amanda', 'Ludmila', and 'Tomensa', had optimum morphological and physiological traits; also contain maximum dry matter and starch and minimum reducing sugar which are suitable for processing industry. The information obtained in this study will inform Bangladeshi potato farmers and processors regarding the suitable potato varieties for processing industries.

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LIST OF ACCRONYMS AND ABBREVIATIONS

Abs	Absorbance
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
cm^2	Square centimeter
CRD	Completely Randomized Design
CV	Coefficient of Variance
Dev.	Development
df	Degrees of freedom
DMC	Dry Matter Content
DMRT	Duncan's Multiple Range Test
Environ.	Environmental
et al.	And others
Expt.	Experimental
FAO	Food and Agriculture Organization
g	Gram (s)
m^2	Meter squares
mg	Milligram
min	Minute
ml	Milliliter
mm	Millimeter
M.S	Master of Science
Sci.	Science
i.e.	*id est* (L), that is
Res.	Research
j.	Journal
Kg	Kilogram (s)
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
t ha^{-1}	Ton per hectare
TPOD	Total Potato Defects
TPS	True Potato Seed
TSS	Total Soluble Solids
UNDP	United Nations Development Programme
viz	Namely
%	Percentage

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as 'The king of vegetables', It is the fourth most important food crop in the world after rice, wheat and maize. Bangladesh is the 8th potato producing country in the world. In Bangladesh, it ranks second after rice in production (FAOSTAT, 2013). The total area under potato crop, national average yield and total production in Bangladesh are 444534.41 hectares, 19.35 t ha^{-1} and 8603000 metric tons, respectively (BBS, 2013). The total production is increasing day by day as such consumption also rapidly increasing in Bangladesh (BBS, 2013). Potato 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 and 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 day, 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 identified variety for processing purpose, despite the increasing demand of acceptable yield and processing quality. The yield and processing characteristics of available potato genotypes are largely unidentified. French fries and potato crisps are the most consumed industrially processed potato products in Bangladesh, especially in the major urban centers. Processors have, however, complained of inadequate supply and low quality of potatoes currently supplied in the market. 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 (>20%), high starch, high crispness, high firmness, high specific gravity (>1.07) content and good color to fulfill the requirement of processing. The processing characteristics of available potato varieties are largely unidentified. Keeping in view the consumers requirement, it is important to identify varieties that posses 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 by selling their export quality potato at good price to the processing industry both in Bangladesh and abroad.

Potato being a vegetable with 80% of moisture in its fresh form is also subjected to price fluctuation and causes lot of economical loss to the farmers during glut seasons. Further increased cost of cold storage and appreciable loss in storage is making the growers to go for potato processing. Among the processed products, chips are the most popular ready-to-eat snacks in Bangladesh. Potato consumption in different processed products needs to be enhanced to sustain the increase in production and to ensure remunerative prices to the farmers. Processing of the bulky perishable potatoes into various processed products is a viable option which can help to extend the shelf life, solve the problem of storage, cater to consumer preferences belonging to different age groups and social strata, serve as a means to maximize the supply in off-seasons thereby maximizing potato utilization. With specifications for morphological and biochemical traits, screening of potato cultivars suitable for either direct consumption or processing is a prerequisite for processors, industrialists and consumers in the food chain. Employing the common and feasible methods of processing, the present study on screening of potato cultivars for chemical composition and processing was formulated with the following objectives,

OBJECTIVES

Considering the above facts, the present study was undertaken with the following objectives:

1. To study the physical characteristics of different potato varieties.
2. To estimate the bio-chemical composition of different potato varieties.
3. To evaluate and select potato varieties for processing.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Potato *(Solanum tuberosum* L.), the most valuable tuber crop is produced in 150 countries. As a crop in developing world, it comes fourth in dollar value among major food crops. Potatoes currently have the highest rate of production growth in most developing countries and the main stay in the diet of people in many parts of the world. On an average, about 28% of total potato produced throughout the world is processed. The related literature pertaining to the study entitled "Assessment of potato varieties for processing industry in Bangladesh" has been reviewed under the following subtitles:

2.1 Physico-chemical characteristics of potato varieties.

2.2 Processing and screening of potato varieties.

2.1 Physico-chemical characteristics of potato varieties

Physico-chemical characteristics of potatoes are influenced by many factors such as season, soil type, agronomic practices, species and varieties.

Ganga and Kulkarni (2014) conducted an experiment where ten potato cultivars were used and their chemical analyses were done. The dry matter content ranged from 15.30 (J/99-242) to Kufri Khayti (20.93%). Starch was minimum in J/99-242 (52.55%) and maximum in Kufri Khayti (85.67%). The highest reducing sugars were found in Kufri Pushkar (210.33 mg 100 g^{-1}) and lowest in Kufri Pukhraj (55.13 mg 100 g^{-1}). Lowest level of total sugars was found in J/99-242 (216.10 mg 100 g^{-1}) and Kufri Khayti (216.67 mg 100 g^{-1}) the two being at par with each other and highest in Kufri jyoti (816.67 mg 100 g^{-1}). Minimum non-reducing sugars (104.43 mg 100 g^{-1}) were also found in J/99-242 and maximum (575.00 mg 100 g^{-1}) in Kufri Chipsona-2. The dry matter was positively correlated with flavour and taste of baked potatoes which could be due to high amount of starch that forms stable complex with flavour compounds during cooking.

Ganga *et al.* (2013) studied on ten varieties of potato tubers and revealed that tubers mean length varied significantly between the cultivars ranging from 5.9 cm in J/99-242 to 7.6 cm in Kufri Ashoka. Mean breadth of tubers ranged between 4.4 cm to 5.6 cm with shortest in Kufri Pushkar and longest in Kufri Ashoka. Kufri Ashoka showed significantly large mass (113 g), highest volume (106.9 cc) and longest diameter (5.8 cm) while Kufri Pushkar had significantly smallest mass, lowest volume whereas Kufri Surya recorded significantly shortest diameter. Majority of the cultivars were oval shaped with brown colored skin and cream flesh, number of eyes were less in most of the cultivars with shallow eye depth, without scars and green tint. Highest numbers of natural depressions were found in Kufri Chipsona-2. Kufri Khayti produced highest slices (84.00%) as well as chips (22.83%) and thus ranked first. Specific gravity increased yield of slices as well as yield of chips which was significant at 0.05 levels.

Abbas *et al.* (2012) conducted an experiment using 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).

Misra and Chand (1990) conducted an experiment to see the relationship between size of tuber and chemical composition of potato in Meerut. A negative linear relationship was observed between tuber size and total phenolic content (44.0 mg 100 g^{-1} for 1.5 cm and 4.8 mg 100 g^{-1} for 8.0 cm) as well as reducing sugar (150 mg 100 g^{-1} for 1.5 cm and 0.3 mg 100 g^{-1} for 8.0 cm).The tuber size did not affect dry matter, sucrose and ascorbic acid content of the

two varieties. Thus bigger the tuber, better the processing characteristics so far as reducing sugars and phenolics content are concerned.

Physical properties of different potato cultivars were studied by Tabatabaeefar (2002) in Iran. Among the four varieties studied, Draga and Agria had longer diameter and larger masses than other two varieties. Average specific gravity of the vital variety (1.3) was higher than other varieties. All the varieties exhibited ellipsoidal shape. The per cent spherecity for Draga, Ajacks and vital varieties was 81%. With minimum sphericity (71%) and highest length to width ratio (1.5), Agria variety was less spherical. As the diameter of tuber increased, volume of potato increased linearly.

Evaluation of potato cultivars for processing into crisps was carried out by Abong *et al.* (2010) in Kenya. Majority of the cultivars with exception of Roslin Tana, Desire, Roslin Ebura, Nyayo, Tigonilong and Kihora had acceptable physical characteristics suitable for processing. Tuber diameter varied significantly ($p<0.05$) among the cultivars ranging from 43 mm in Tigoni long to 56 mm in Kenya Sifa and Clone 392617.54. The specific gravity of the cultivars varied from 1.074 to 1.098 and dry matter contents from 19.50 to 24.20%. Majority of the cultivars were round in shape. Reducing sugar levels varied significantly ($p<0.05$) among the cultivars and ranged between 0.07% and 0.4%.

Changes in reducing sugars content and chip colour of tubers during storage at different temperatures was observed by Singh and Ezekiel (2008) in Jalandhar. Dry matter content varied with the cultivar and growing location. Processing cultivars Kufri Chipsona-1 and Kufri Chipsona-2 had higher dry matter content (24.4 and 25.8% respectively) as compared to other cultivars. Least dry matter content was observed in Kufri Pukhraj (15.6%). Reconditioning was effective in reducing the sugar content significantly ($p<0.05$), however was less effective in improving the chip color.

Yaghbani *et al*. (2006) investigated composition and characterization of starch extracted from various potato cultivars in Golestan province of Iran. The diameter of potato starch granule were shown to range from 34.2 to 42.1μm with a mean of 38.7+3.3μm , indicating that the granule size had no significant differences among potato varieties. The yield of potato starch varied from 9 to 12.6% on fresh weight basis. The highest and lowest yield of starch was observed in Concord and Draga respectively. The starch yield was directly correlated to the dry matter content of the tubers, which ranged between 17.2 and 22%. Among the six potato cultivars, the average value of the amylase content was lowest in Sante (24.4%) and highest in Draga (27.1%).

Study on distribution of dry matter and sugars of potato cultivars namely: Kufri Chipsona-1, Kufri Chipsona-2, Kufri Jyoti, Kufri Lauvkar and Atlantic were undertaken by Kumar and Ezekiel (2004) in Himachal Pradesh. The highest values of dry matter were obtained in stem end cortical tissue of Kufri Chipsona-2 (27.5%) and lowest in pith region of Kufri Lauvkar (14.8%). The dry matter distribution pattern was more or less similar when compared within the individual varieties. The highest mean values for reducing sugar were obtained in stem and cortical tissue (260 mg 100 g^{-1}). Sucrose content has also been found to vary significantly within the tuber.

Physico-chemical properties of dry matter and starch from potatoes grown in Canada were estimated by Liu *et al*. (2007). Per cent total starch, dietary fiber, protein, free sugar and apparent amylase content of AC Stampede Russet, Russet Burbank and Karnico potato dry matter ranged between 70.5 to 72.4%, 5.2 to 5.6%, 7.1 to 9.7%, 3.3 to 6% and 29.7 to 33.3% respectively.

Comparison of the specific gravity of four different cultivars of potato in Iran indicated that Herta and Cosima had the highest values of specific gravity (1.088 and 1.086 respectively) and Picaso had the lowest (1.068) specific gravity. The solid content of different cultivars differed significantly. The starch content of Picaso (55.3 g 100 g^{-1}) was significantly lower than other

varieties. Picaso (2.4 g 100 g^{-1}) contained the highest level of reducing sugar and Agria cultivar content lowest 1.2 g 100 g^{-1} (Ramezani and Aminlari 2004).

Sood *et al*. (2008) in Hissar conducted a biochemical evaluation of potato tubers and peels of Kufri Chipsona-1, Kufri Chipsona-2, Kufri Ashoka, Kufri Sutlej, Kufri Pukhraj and Kufri Jawahar. The energy value exhibited a range of 314 to 375 in tubers and 278 to 349 kcal 100 g^{-1} in peels. Starch is the major constituent of potato tubers and it varied from Kufri Sutlej (68.49%) to Kufri Chipsona-1 (79.65%) and average to 75.03%. The highest amylose content was recorded in Kufri Chipsona-1(31.84%) and the lowest in Kufri Jawahar (19.28%) and the mean observed was 26.49% whereas amylopectin averaged to 48.54% ranging from 45.93 to 52.71%.

Study on suitability of potato varieties grown in North-eastern Indian plains for processing was undertaken by Singh *et al.* (2009) in West Bengal. The dry matter content of popular variety Kufri Jyoti, from different districts of West Bengal, ranged from 17 to 19.6%. Processing varieties 'Lady Rosetta', Kufri Chipsona-3, Kufri Chipsona-1 and Atlantic showed a dry matter content of 23.3, 22.8, 19.5 and 20.1% respectively, while all the other varieties, except Kufri Chandramukhi (19.2%), had dry matter content of 18.1%. The reducing sugars content of processing varieties, Atlantic and Kufri Chipsona-1 was very low (45.0-57.7 mg 100 g^{-1} fresh wt), while all other varieties contained higher levels of reducing sugars (96.3-240.7 mg 100 g^{-1} fresh wt). Kufri Jyoti contained higher levels of total phenols (74.6-110.4 mg 100 g^{-1} fresh wt); while processing varieties, Atlantic and Kufri Chipsona-1 had lower levels (43.3-58.9 mg 100 g^{-1} fresh wt). 'Lady Rosetta' contained lowest total phenols (23.6 mg 100 g^{-1} fresh wt), whereas, Kufri Jyoti contained very high levels of phenols (55.1-92.4 mg 100 g^{-1} fresh wt).

Uppal (1995) experimented in Punjab and found that there was a significant varietal difference in sugar content and invertase activity at the time of storage and during storage. During storage, reducing sugar content increased about 37% and invertase activities coincided with the accumulation of sugars.

Sucrose content decreased during storage. Both basal and total invertase activities increased during storage, however basal activity was about 50 per cent of the total. Tubers of Kufri Sherpa contained minimum level of free sugars and invertase activity.

Marwaha (1999) in Punjab studied the chipping quality and related processing characteristics of Indian potato varieties grown under short day and showed that dry matter contents of the varieties ranged from 16.7-20.7% with lowest in Kufri Bahar and highest in Kufri Chandramukhi, while the reducing sugar contents varied between 92-332 mg 100 g^{-1} fresh weight basis with the lowest in Kufri Sherpa and highest in Kufri Lalima. Glucose constituted the major fraction of reducing sugars in all the varieties. 'Kufri Jyoti' had maximum content of total phenols with 49.7 mg 100 g^{-1} fresh weight basis, while free amino acids were maximum in 'Kufri Bahar' with 105.2 mg 100 g^{-1}.

Uppal (1999) studied the effect of storage environments on chip color and sugar levels in tubers of potato cultivars were studied in Punjab. The contents of reducing sugars ranged between 188 mg and 325 mg 100 g^{-1} fresh weight basis at the initial stage with lowest in 'Kufri Sherpa' and highest in 'Kufri Jawahar'. However sucrose was maximum in tubers of 'Kufri Sherpa' with 312 mg 100 g^{-1} fresh weight basis and maximum in 'Kufri Chandramukhi' (198 mg 100 g^{-1}) fresh weight basis. Maximum reduction (44 %) in reducing sugars was found in tubers of 'Kufri Jawahar' and minimum (6 %) in 'Kufri Lauvkar', when stored at evaporative cool storage.

Ezekiel and Dahiya (2004) assessed the storage losses of potatoes stored in heaps and pits in the Malwa region (Madhya Pradesh) and found that at harvest, tuber had relatively higher dry matter content of 22.3% and lower reducing sugar content of 25.1 mg 100 g^{-1} fresh weight basis. The chip color score was 3.3, which was good. After storage in heaps and pits, the dry matter content improved by 2-3% due to weight loss with higher in heap storage method (25.2%) and the reducing sugar content remained within the acceptable limit (36.7 mg 100 g^{-1}) on fresh weight basis.

Peschin (2000) studied the influence of storage temperature and reconditioning on the biochemical composition of potato tubers in Himachal. There was no significant varietal difference among genotypes in their biochemical constituents at the time of storage and during storage. Among these Kufri Kuber, Kufri Chandramukhi and Kufri Lauvkar contained low reducing sugars of 1.8, 5.8 and 5.0 mg/100 g fresh weight basis respectively. On storage at 5-7° C, all the cultivars showed accumulation of large quantities of reducing sugars and phenols and produced dark brown colored chips. All the genotypes reflected an accumulation of phenols, which was more predominant after 90 days of storage. Post harvest reconditioning of tubers for 10 days at ambient temperature (20±2° C) caused decline in reducing sugar in all the cultivars. However, it was ineffective as a means of lowering free amino acids content and there was no significant improvement in chip color.

A study was undertaken to determine the cooking quality characteristics of advanced clones and potato cultivars by Hassanpanah *et al.* (2011) in Iran under invitro conditions. There were significant differences between cultivars and clones for tuber dry matter, starch percent, specific gravity, chips color, quality and amount of reducing sugars. Dry matter (22.52%), specific gravity (1.91) and starch (16.62%) content were highest in Savalan variety among the three cultivars whereas 396156-6 clones had the highest dry matter (24.4%). Specific gravity (1.100) and starch (17.69%) were highest in 396156-6 among the clones.

Uppal (2000) documented chip color and processing parameters of potatoes grown during spring and autumn in north-western plains in Punjab. The reducing sugar content of both Kufri Chandramukhi and Kufri Jyoti varieties were much low, 67 to 89 mg 100 g^{-1} fresh weight basis in spring as against 289 to 304 mg 100 g^{-1} in autumn. But Kufri Chandramukhi contained high amount of reducing sugars and total sugar, in both the seasons.

Effect of location, season and cultivar on the processing quality of potatoes was investigated by Kumar *et al.* (2003) in Uttar Pradesh. An average dry matter

content of 20% and above was observed for tubers grown at Deesa, Dhali, Jorhat, Kota, Chindwara and Taizabad. Among several locations, reducing sugar content was highest in Kufri Sutlej ranging from 74.7 to 338.6% mg 100 g^{-1} fresh weight basis. The sucrose content was below 200 mg 100 g^{-1} tuber fresh weight at Jorhat, Kota and Chindwara.

Evaluation of potato cultivars for processing into potato crisps was carried out by Abong *et al.* (2010) in Kenya. Most cultivars with exception of six of them including Roslin Tana, Desire, Roslin Ebura, Nyayo, Tigonilong and Kihora had acceptable physical characteristics suitable for processing. Tuber diameter varied significantly ($p<0.05$) among the cultivars ranging from 43 mm in Tigoni long to 56 mm in Kenya Sifa and Clone 392617.54. The specific gravity of the cultivars varied from 1.074 to 1.098 and dry matter contents from 19.50 to 24.20%. With exception of Roslin Tana, Desire, Roslin Eburu, Nyayo and Tigoni Long which had long or pointed oval shapes, majority of the cultivars were round in shape. Reducing sugar levels significantly ($p<0.05$) varied among the cultivars and ranged between 0.07% and 0.4%.

With an effort to develop a processing potato variety suitable for growing in high lands, a study was conducted in Himachal Pradesh by Pandey *et al.* (2008b). The round oval tubers had high dry matter (22.4%), low reducing sugar (<100 mg 100 g^{-1} fresh weight basis) with less than 250 mg 100 g^{-1} of sucrose on fresh weight basis.

Marwaha *et al*. (2008) undertook the effect of blanching of slices of potato varieties on chipping quality in Punjab. Dry matter content ranged from Kufri Pukhraj (15%) to Kufri Chipsona-2 (23.4%). Kufri Chipsona-1 and Kufri Chipsona-2 contained high tuber dry matter i.e. >21%, while Kufri Pukhraj contained minimum dry matter (15%).

Starch content, yield and quality of dehydrated chips were investigated in Patna. Varieties Kufri Chipsona-1 and Kufri Chipsona-2 had higher dry matter content of 21.2% and 22.0% respectively. There was no significant difference

in the moisture content of dehydrated chips. The peeling loss was also low in both Kufri Chipsona-1 (11.3%) and Kufri Chipsona-2 (11.9%) respectively (Das *et al.*, 2001).

Marwaha *et al.* (2009) researched on Indian and exotic potato processing varieties for storage behaviour and changes in nutritional compounds under different condition. Indian and American processing varieties having high dry matter content viz. Kufri Chipsona-1, Kufri Chipsona-2, Atlantic and Frito Lay produced high chip yield 30.4 to 32.1% with low oil content (<35%). Both Indian and American processing varieties contained (>22%) dry matter, while Kufri Jyoti showed lowest dry matter content before 17.2% and after storage 19.6% and 18.4% under both storage condition.

Investigation on impact and future priorities of potato processing varieties was carried out by Pandey *et al.* (2009) in Himachal Pradesh. Processing varieties Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3 produced dry matter content of 21 to 24% and reducing sugars of <0.1%.

A study conducted on low and high sugar potato cultivars for processing quality as influenced by storage temperature by Marwaha (2000) in Punjab. The dry matter content of exotic cultivars was higher than the Indian cultivars and free amino acids and total phenols were significantly lower in the exotic cultivars than the Indian cultivars at the time of storage. The reducing sugar content of the exotic cultivars was very low (64 to 80 mg 100 g^{-1} fresh wt basis) as compared to the Indian cultivars (158 to 285 mg 100 g^{-1} fresh wt basis).

Abong *et al.* (2009) experimented on Kenyan cultivars to observe the influence of potato cultivar and stage of maturity on chips and French fries. Dry matter content ranged from 19.50 to 24.07% and 20.56 to 24.66% in clone 393385.39 and variety Dutch Robyjn for tubers harvested 90 and 120 days after planting, respectively.

A study on potato varieties grown at different locations for chipping was done by Uppal and Khurana (2001) in Punjab. The chip quality and contents of dry matter and free sugars varied among varieties and locations. Potatoes grown at Bhubeneswar, Chhindwara, Deesa, Kota and Patna had low concentration of reducing sugar ranging from 0.13% to 0.24 % on fresh weight basis. The amount of reducing sugars was much more than the permissible limits (0.29% to 0.4%) for processing at Faizabad, Muzaffarbad, Hisar, Jalandhar and Udham Singth Nagar.

A study was carried out on the effect of chemical composition of potato on crisps by Kita (2002) in Poland. The contents of dry matter, starch and protein nitrogen ranged from 19.92 to 23.28%, 15.2 to 18.4% and 0.136 to 0.0180% respectively.

A study was conducted to determine the chemical composition of six potato varieties by Basuny *et al*. (2009) in Egypt. Among the varieties, 'Valour' had the highest moisture (83.27%) and lowest in 'Osina' (75.53%) whereas protein (2.73%), ash (0.97%) and carbohydrate (18.70%) were highest in 'Osina' variety.

A study was undertaken on MP/97-644: A promising hybrid for making potato chips and dehydrated products in Uttar Pradesh. The hybrid MP/97-644 gave significant higher dry matter, low reducing sugars and showed round shape with shallow eyes making it suitable for chips preparation (Singh *et al*., 2005).

Tuber with large size is better for processing as well as for export as it contains low reducing sugar and phenols. Compared to peel, tuber posse's greater values of energy and total carbohydrates whereas peels considerably rich in crude protein, crude fibre, minerals matter, insoluble minerals, reducing sugar, total fructose, non reducing sugar and free amino acid. The contents of biochemical metabolites in tubers differ with the cultivars and growing location. Among the Indian cultivars Kufri Chipsona-1 and Kufri Chipsona-2 were rich in dry matter and suitable for processing with low content of reducing sugar.

2.2 Processing and screening of potato varieties

The potato processing industry is primarily concerned with the quality and yield of processed products. The processing quality, in turn, is a function of physical and chemical factors. Screening of potato varieties help the processing industries to pick appropriate tubers with low reducing sugar and moisture, high dry matter as well as impart acceptable color and flavour to the processed products.

Singh *et al*. (2005) in Uttar Pradesh carried out a study on MP/97-644: A promising hybrid to assess the processing quality parameters of tubers during storage at 10-120° C with Isopropyl N-(3-chlorophenyl) carbamate (CIPC) application in a commercial cold store for six months. The hybrid MP/97-644 gave significant acceptable chip color (grade<3) over the control at all locations and better than the exotic variety Atlantic, thereby assuming higher economic returns to the farmers as well as the processors.

Joshi and Nath (2002) investigated the effect of pre-treatment on quality and shelf life of fried chips from sprouted tubers of potato variety 'Kufri Chandramukhi' in Pantnagar. Sensory evaluation of 1.5 to 2.0 mm thick slices from unpeeled sprouted tubers treated with citric acid, sodium chloride and calcium chloride and conditioning (195° C) for 17 seconds yielded best quality chips. Chips from peeled potatoes and unpeeled potatoes did not differ significantly.

Yield and quality of dehydrated chips and starch content was investigated by Das *et al.* (2001) in Patna. Varieties Kufri Chipsona-1 and Kufri Chipsona-2 produced higher chip yield of 14.3% and 15.3% respectively. There was no significant difference in the moisture content of dehydrated chips. The quality of dehydrated chips prepared from Kufri Jyoti and Kufri Sindhuri were also comparable to other two varieties.

Suitability of potato varieties grown in North-eastern Indian plains for processing was assessed. Varieties Kufri Chipsona-1 and Atlantic produced

chips of excellent color quality with color score between 1.75 to 2.75 in both 2006 and 2007 year, while 'Lady Rosetta' collected during 2007, also produced chips of very good quality. Chip yield varied between 27.4 to 28% in Kufri Chipsona-1 and Atlantic during 2006, while it ranged from 28.1 to 32% in Kufri Chipsona-1, Kufri Chipsona-3, Atlantic and Lady Rosseta (Singh *et al.*, 2009).

Raj and Lal (2008) studied the effect of cultivars, cold storage and frying media on yield and processing qualities of potatoes in Solan. Cultivars with high dry matter and low moisture produced chips with low moisture levels. The color and texture of the chips of Kufri Chipsona-1 and Kufri Chipsona-2 were the best.

Indian and exotic potato processing varieties were evaluated for storage behaviour, processing quality and changes in nutritional and antioxidant compounds under different condition by Marwaha *et al.* (2009). Indian and American processing varieties having high dry matter content *viz.*, Kufri Chipsona-1, Kufri Chipsona-2, Atlantic and Frito Lay produced high chip yield 30.4 per cent - 32.1 per cent with low oil content (<35%). Compared to peeling losses before storage, the peeling losses of tubers after storage were 4.3% and 2.8% higher in farm and evaporative cold stores respectively. Chip color produced by Atlantic variety was most acceptable (3.5) compared to other varieties.

Gaur *et al.* (1998) screened Kufri Chipsona-1 variety for processing. Kufri Chipsona-1 had 2 to 4% higher tuber dry matter than Kufri Jyoti. It also produced acceptable light color chips of grade 1-3. In contrast, Kufri Jyoti produced unacceptable brown color chips of grade 5-6. But chip yield from Kufri Chipsona-1 as well as Kufri Jyoti were 331.7% and 306.0% respectively.

Ezekiel and Rani (2006) investigated the shelf life of potato chips during storage. The dry matter content of tubers of thirty three potato genotypes varied

from 16.3 to 26.2%. Oil content showed a highly significant negative relationship with tuber dry matter content and starch content.

A study was undertaken on effect of frying oil temperature on quality and yield of potato chips. Frying at 170° C for 6 min gave potato chips of most acceptable qualities, which had 1.1% moisture and 38.5% oil content. Decrease in yield when temperature was raised from 160° C to 170° C was more than decrease in yield when temperature was raised from 170° C to 180° C at any given frying time (Nema and Prasad, 2004).

Pandey *et al.* (2009) investigated the impact and future priorities of potato processing varieties in Himachal Pradesh and concluded that all the processing varieties Kufri Chipsona- 1, Kufri Chipsona-2, Kufri Chipsona-3 produced imparted < 5% per cent undesirable color and <15 % total defects in chips when grown at different locations in India.

A study was done on processing quality of low and high sugar potato cultivars as influenced by storage temperature by Marwaha (2000) in Punjab. Before storage, fresh fried chips prepared from exotic cultivars were for superior in color i.e. 1, 1, 2, 1, 1 in Atlantic, FL 1291, FL 1533, FL 1584, FL 1625 respectively in comparison to Indian varieties with 5, 5, 3 color score for Kufri Chandramukhi, Kufri Jyoti and Kufri Lauvkar respectively. High temperature storage up to 75 days was found to be suitable for producing chips of acceptable light color from all the exotic cultivars, while only one Indian variety, Kufri Lauvkar, performed well that grown under short day condition.

Pokharkar and Mahale (2001) studied the optimization of processing variables for preparation of fresh fried chips by developing regression equation. The loss of reducing sugars have an average diffusivity of 5-01X10-9 m^2s^{-1} in case of blanching of 1.5 and 2.0 millimeter thick slices in boiling water. For good quality potato chips, the optimum parameters including frying time; 219-221 seconds, oil temperature ;145-146° C and thickness of slices ; 2.0 mm by linear programming technique. The color score of chips from 7 to 9 were acceptable

by consumers. Chips with scores less than 7 and more than 9 were unacceptable.

A study was carried out on chipping quality and related processing characteristics of Indian potato varieties grown under short day conditions by Marwaha (1999) in Punjab. Fresh fried chips prepared from two varieties *viz.*, Kufri Sherpa, Kufri Lauvkar were light in color with color score 2 and 3 respectively and were acceptable, whereas other eight varieties gave a unacceptable color score ranging from 6 to 8. However, when morphological characters such as tuber size and shape were taken into consideration, only Kufri Lauvkar was found most suitable for chipping.

Barry-Ryan *et al.* (2010) investigated differences in the physicochemical and sensory properties of organic and conventional potatoes (cv. Orla) in Ireland. The conventional potatoes had a lower dry matter content ($P < 0.05$) and a slightly softer texture ($P < 0.05$) than the organic potatoes. The conventional baked potato was slightly softer, less adhesive and wetter than the organic baked potato ($P < 0.05$). There was no significant difference between the organic and conventional baked potato samples for the sensory attributes of appearance, aroma, texture, taste and acceptability.

The influence of potato cultivar and stage of maturity on chips and French fries was experimented using eight Kenyan cultivars in Kenya including five varieties and three promising potato. The sensory attributes for each separate harvest indicated that there were significant ($P<0.05$) differences in scores for color, texture, flavour, and overall acceptability in chips made from different cultivars in both harvests (Abong *et al.,* 2009).

With an effort to develop a processing potato variety suitable for growing in highlands, a study was conducted in Himachal Pradesh by Pandey *et al.* (2008b). The variety Kufri Himsona produced high yield and good processing grade tubers. The color of the chips produced from Kufri Himsona was light and acceptable (<3.0). None of the varieties produced acceptable color chips.

Uppal and Khurana (2001) researched on chipping performance of potato varieties grown at different locations in Punjab. Potatoes grown at Bhubeneswar, Chhindwara, Deesa, Kota and Patna produced acceptable chips of golden yellow color with color score 4.7, 4.0, 4.2, 3.6 and 4.3 respectively. The tubers grown at Faizabad, Muzaffarbad, Hisar, Jalandhar and Udham Singth Nagar were unfit for making chips and produced chips of darker color ranging from 6.3 to 9.7 color score.

A comparative study of physical and sensory properties of pre-treated potato slices during vacuum and atmospheric frying was conducted by Troncoso *et al.* (2009) in Chile. Vacuum frying increased significantly ($p<0.05$) oil content and decreased instrumental color and textural parameters. Potato slices fried under vacuum had better color readings significantly higher compare to the slices fried under atmospheric conditions. Sensory attributes, flavour quality and overall quality, were significantly improved using vacuum frying. The higher frying temperature (140 °C) increased color, breaking force, hardness and crispness. A great improvement on color parameters was obtained using sulphited potato slices instead of the other pre-treatments. Although, the better flavour was obtained for control potato chips, no significant differences were found for overall quality between control and sulphited potato chips. Significant correlations ($p<0.01$) between sensory and instrumental responses were found.

Study on effect of pre-drying on texture and oil uptake of potato chips was undertaken in Chile by Pedreschi and Moyano (2004). Texture analysis revealed that final maximum force was significantly higher ($p>0.05$) for blanched and dried potato chips than for only blanched potato chips. Both frying temperature and pre-drying temperature had a significant effect ($p>0.05$) over the final texture and oil content of the fried potato chips. When fried at 120° C, potato chips containing moisture <10g $100g^{-1}$ were crispier and contained more oil than potato chips fried at 180° C. Pre-drying dramatically

decreased the oil absorption and significantly increased ($p>0.05$) the crispness of the blanched potato slices after frying.

With an aim to develop a reference color chart for potato chips from fresh and stored potatoes, a study was conducted by Ezekiel *et al.* (2003) in Himachal Pradesh. Increasing color scores showed a significant positive correlation (r= 0.77**) with reducing sugar content of tubers. Tubers with reducing sugar content ranging from 30 to 54 mg 100 g^{-1} fresh weight produced chips of color score 1, whereas tubers with reducing sugar content of 44 to 239 mg 100 g^{-1} fresh weight produced chips of color score 5.

Research on chip color and processing parameters of potatoes grown during spring and autumn in north-western plains was conducted by Uppal (2000) in Punjab. Chips made from tubers of spring crops were of light yellow color (2 to 3 scores), superior in taste and highly acceptable, whereas autumn crop potatoes produced unacceptable chips having dark brown color (6 to 7 scores).

Kumar *et al.* (2003) investigated the effect of location, season and cultivar on the processing quality of potatoes was investigated in Uttar Pradesh. An average chip color score of less than 4 was observed from the potatoes procured from Deesa, Dhali, Jorhat and Kota. Potatoes from Jorhat gave most consistent results.

A study was conducted in Peradeniya on eleven locally available potato varieties to investigate their suitability for chipping. The total sugar content increased and the dry matter content decreased during storage of the tubers. The chip lightness 'L' value showed a negative relationship with total sugars. The color of the chips made from 'Asteric', 'Atlantic', 'Desiree' and 'Red Star' was acceptable and was not affected by three months storage. Whereas 'Escort, ''Granola'', 'Monolize', 'Prelude', 'Sita', 'Vivald' and 'Aranka' did not produce chips of acceptable color. Hot water blanching at 90-100° C for 1 minute with 200 ppm KMS improved the chip color of 'Escort', 'Prelude', 'Sita' and 'Vivaldi' varieties. The residual sulphur dioxide content of these

chips was 45 ppm. Chip color of ‘Monoliza’, ‘‘Granola’’ and ‘Aranka’, varieties was not improved even by the KMS treatment (Illeperuma and Wickramasinghe, 2000).

The effects of various preparation technologies on the proximate composition and energy content of potato products were investigated by Ramaswamy *et al*. (1999) in Mauritius. Result shows that various preparation technologies viz., boiling, baking, frying of chips and frying of battered cakes have a significant effect ($P < 0.01$) on the proximate composition and energy content of potato products. A general decrease in moisture, fiber, carbohydrate and protein was noted for most of the preparation technologies. The ash content of processed products increased @ 5, 4.7, 9.5 g 100 g^{-1} dry weight basis for boiled potato, baked potato and chips respectively compared to raw potato (4.4 g 100 g^{-1} dry weight basis) with the exception of battered cakes. In frying chips and battered cakes, the fat as well as energy contents were significantly higher ($P < 0.01$) compared to boiling and baking. Compared to raw potato, drastic increase in fat contents of 9795% and 9321% were observed during frying of chips and battered cakes respectively.

Basuny *et al*. (2009) conducted the study to determine the relationship between the sensory evaluation of potato chips and chemical composition of six potato varieties in Egypt. Organoleptic evaluation for fried potato chips in sunflower oil indicated that Osina, Sponta and Glactica potato varieties are suitable for frying process as judged by the taste panelists. The highest oil uptake by chips from varieties *viz.,* Valour, Ledy valour and Hana potato was evident. Chips produced from Osina, Sponta and Glactica potato varieties had lowest oil uptake.

Hassanpanah *et al*. (2011) studied the cooking quality characteristics of advanced clones and potato cultivars in Iran under invitro conditions. These cultivars were suited for C type cooking and thus 396156-6 clone and Savalan cultivars were appropriate for chips production whereas 397009-3 clone for French fry, chips and starch production. The Marfona cultivar with lower dry

matter content 19.67% and B cooking type was suitable for consumption of boiled and mashed tuber.

A study was carried out by Jansky (2008) in USA to determine the relative contributions of genotype and environment to baked potato flavor variation in standard potato cultivars. In addition, relationships between individual flavor components and overall quality perception scores were determined. Differences among cultivars and production environments were found. Stored potatoes received higher quality perception scores than fresh potatoes. Mealiness was the most variable flavour attribute and was influenced by both genotype and environment. Sweetness and flavour intensity were positively associated with quality perception. A strong negative association between off flavour and quality perception was also detected.

Kita (2002) investigated the effect of chemical composition of potato on chips in Poland. The chips made of Aster, Karlena, Saturna and Panda varieties were characterized by an appropriate golden-yellow color, typical flavour and odour, a slightly darker color produced from Ania potato variety. The Ania variety with more reducing sugar (0.13%) produced darker color chips. The highest fat content was in crisps made of the Aster potato variety-39.44%, while those produced from the Panda variety had 35.77% of fat. The highest score was given to texture of crisps made from the Panda and Saturna potato varieties. Worse textures were produced from the Aster and Karlena tubers and the worst from the Ania potato variety. Apart from starch and protein nitrogen, the crisp texture was also influenced by non-starch polysaccharides which contributed to the extent of (9-21%) towards crispness in the model.

Mestdagh *et al.* (2008) in Belgium documented the impact of chemical pre-treatment on the acrylamide formation as well as sensorial quality of potato chips. The oil content was highest in chips which were blanched in water alone (40%) whereas least when chips were blanched along with the component Ca100 and Ca200 @ 23%. The addition of calcium provoked a more crispy texture i.e. CaCl2 (snap, 9.1; crispness, 9.1), Ca100 (snap, 9.1; crispness, 8.9)

and Ca200 (snap, 8.7; crispness, 9.0) compared to the control chips (snap, 6.7; crispness, 6.8). A significant correlation was found between both textural descriptors, snaps and crispness, as well as between the taste and general appraisal.

Effect of oils and frying temperature on the texture and fat content of potato chips was investigated by Kita *et al.* (2007). The chips fried in rapeseed oil absorbed the smallest amount of fat (36.8%) irrespective of frying temperature, whereas the crisps fried in olive oil and modified oil II (hydrogenated with mixture of rape seed oil and palm oil) absorbed the highest quantity of fat (41%). Significant differences in fat content of potato chips fried in rapeseed and olive oils were observed at frying temperatures of 150° C, 170° C and 190° C. Crisps fried at 150° C in rapeseed and peanut oils exhibited harder and less crispy textures. Most variable texture was in crisps fried in olive oil i.e. hardest at lower (30.26 N) and crispy at highest (15.43 N) frying temperature. Except for olive oil there was no significant difference between textures of crisps fried at 190° C and 170° C. Type of oils used and frying temperature markedly affected fat content and texture of potato chips.

Abong *et al.* (2010) evaluated the potato cultivars for processing into potato chips in Kenya. The sensory attributes of potato chips that were evaluated differed significantly ($p<0.05$) among the cultivars. Variety Roslin Eburu had the highest color score (5.68) while Cangi had the lowest score (2.73). The highest score for texture was exhibited by Roslin Eburu (5.41) and lowest by Cangi (3.32).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from March to June 2013 to study the "Assessment of potato varieties for processing industry in Bangladesh". The materials and methods describes a short description of the experimental site, climate condition of the storage room, experimental materials, experimental treatments and design, methods of the study, data collection procedure and procedure of data analysis. The detailed materials and methods that were used to conduct the study are presented below under the following headings:

3.1 Location of the experimental site

The experiment was conducted at the Agronomy Laboratory, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. It was located in 24.09^0 N latitude and 90.26^0 E longitudes.

3.2 Conditions of storage room

The temperature and relative humidity of the storage room were recorded daily basis during the study period with a digital thermo hygrometer (TERMO, TFA, Germany). The minimum and maximum temperature during the study period of the storage room was 26.2^0 C to 33.4^0 C, respectively. The minimum and maximum relative humidity was 56% and 84%, respectively.

3.3 Experimental materials

The forty varieties of potato tubers namely- 'Granola', 'Diamant', 'Raja', 'Lady Rosetta', 'Binella', 'Jerla', 'Dheera', 'Elgar', 'Agila', 'Dura', 'Sagitta', 'Saikat', 'Patrones', 'Provento', 'Cardinal', 'Steffi', 'Felsina', 'Laura', 'Ailsa', 'Multa', 'Espirit', 'Quincy', 'Meridian', 'Asterix', 'Almerah', 'Cumbica', 'Rumba', 'Omega', 'Endeavour', 'Caruso', 'Forza', 'Belarossa', 'Amanda',

‘Ludmila’, ‘Connect’, ‘Svenja’, ‘Tomensa’, ‘BARI TPS-1’, ‘Bat Pakri’ and ‘Jam alu’ were collected from Bangladesh Agricultural Research Institute (BARI) and Agriconcern Limited. The collected tubers were free of any visible defects, disease symptoms and insect infestations and transported to the Laboratory of the Department of Agronomy, SAU, Dhaka with careful handling to avoid disease and injury.

3.4 Experimental treatments and design

Tubers were randomly selected and placed on the floor of the Laboratory at natural condition to find out the better variety/genotypes under quality observation. The potatoes were harvested as per the experimental requirements.

Treatment: Potato variety (40 varieties) as

1.‘Granola’, 2.‘Diamant’, 3.‘Raja’, 4.‘Lady Rosetta’, 5.‘Binella’, 6.‘Jerla’, 7.‘Dheera’, 8.‘Elgar’, 9.‘Agila’, 10.‘Dura’, 11.‘Sagitta’, 12.‘Saikat’, 13.‘Patrones’, 14.‘Provento’, 15.‘Cardinal’, 16.‘Steffi’, 17.‘Felsina’, 18.‘Laura’, 19.‘Ailsa’, 20.‘Multa’, 21.‘Espirit’, 22.‘Quincy’, 23.‘Meridian’, 24.‘Asterix’, 25.‘Almerah’, 26.‘Cumbica’, 27.‘Rumba’, 28.‘Omega’, 29.‘Endeavour’, 30.‘Caruso’, 31.‘Forza’, 32.‘Belarossa’, 33.‘Amanda’, 34.‘Ludmila’, 35.‘Connect’, 36.‘Svenja’, 37.‘Tomensa’, 38.‘BARI TPS-1’, 39.‘Bat Pakri’ and 40.‘Jam alu’.

The experiment was laid out in a Completely Randomized Design (CRD) with 3 replications.

3.5 Physico-chemical composition of potato tubers

3.5.1 Physical characteristics of potatoes

Physical characteristics of the agricultural produce are the most important parameters in the design of grading, handling, processing and packaging system. Physical characteristics namely weight, volume, specific gravity,

diameter, shape, color, visual observation of skin and flesh color of 40 potatoes varieties were recorded.

3.5.1.1Tuber shape

The tuber sample was scored for shape according to the following key (Wooster and 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

3.5.1.2 Eye depth

The evaluation of the sample, pertaining to tuber eye depth was made as mentioned by Wooster and 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

3.5.1.3 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 and Farooq (1995).

1 = White 2 = Cream 3 = Yellow

3.5.1.4 Total potato defects (TPOD)

Total potato defects were examined externally in terms of presence of green tint, scars, natural depression, skin texture and number of eyes. Internally

TPOD of cut potatoes was visualized for presence of hollow hearts and black spots (Singh *et al.*, 2005).

3.5.1.5 Color measurements

Color was measured with a color spectrophotometer NF 333 (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 = arctg $\frac{a*}{b*}$ and chroma = $\sqrt{a^{*2} + b^{*2}}$ 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.

3.5.1.6 Weight

Weight (g) of 3 potato samples from each variety measured to two nearest decimals were taken and mean weight for the variety was obtained.

3.5.1.7 Volume

Volume of selected 3 potato samples were measured by water displacement method. Volume (cc) of potato tubers was calculated as below and average was taken (Tabatabaeefar, 2002).

Volume (cc) = Volume of water with potato (cc) - Volume of water without potato (cc)

3.5.1.8 Diameter

Three representative samples of uniform shape from each variety were picked. Circumference for each sample was measured using thread of one mm width

across length and breadth of the tubers. Diameter was calculated using the formula and mean diameter was obtained.

$$\text{Diameter (cm)} = \frac{\text{Circumference (cm)}}{\pi\ (3.14)}$$

3.5.1.9 Specific gravity

Weight of each potato sample in the air and weight of water displaced by the same potato was recorded. Specific gravity was calculated using the formula and mean value was expressed (Tabatabaeefar, 2002).

$$\text{Specific gravity} = \frac{\text{Weight in air } (g_1)}{\text{Weight of water displaced } (g_2)}$$

3.5.1.10 Determination of dry matter (DMC) 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^{o} C for 72 hr in a forced air oven. From which the dry matter percentage was calculated with the following formula (Elfinesh *et al.*, 2011)-

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

3.5.1.11 Texture measurements

Fries and crisps texture measurements were performed at room temperature by a puncture test performed in a Texture Analyzer, Sun Rheometer Compac 100 (Sun scientific co. Ltd, Japan) equipped with a wedge probe imitating front teeth. Maximum force needed at a penetration rate of 100 mm/min was recorded. Maximum Force (MF) was defined as the force at which the wedge penetrates the outer layer of the surface of the chips slices (Segnini *et al*., 1999). Each measurement was conducted on 10 potato chips as described by (Vliet *et al*., 2007).

3.5.2 Chemical composition of potatoes

3.5.2.1 Determination of starch content

Starch content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Preparation of phosphate buffer. Dilute 0.74g $NaH_2PO_4 \cdot 2H_2O$ and 0.09g $Na_2HPO_4 \cdot 12H_2O$ into 100 ml Distilled water. Add 0.1 g Enzyme (Amyloglucosidase) and mix well. Keep at -20C for the preservation. Measure 250 ml tap water using a measuring cylinder, and put it into a 250 ml beaker. Take 0.5 ml solution from the beaker into 3 test tubes. Boil the test tubes for 10 min at 100 ˚C. Add 1 ml Amyloglucosidase solution, mix well, and heat at 50-60˚C for 2 hs in hot water. After cooling, add 0.5 ml Copper solution, mix well, heat at 100C for 10 min., cool in tap water, add 0.5 ml Nelson solution, mix well, add 7 ml distilled water, mix well (Final volume = 9.5 ml), and measure the absorbance at 660 nm (Abs). Calculate starch content using the glucose standard curve.

Calculation of starch content

Starch = Abs x 0.9

3.5.2.2 Determination of reducing sugar content

Reducing sugar content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Put 3 ml sample solution into a small glass container. Completely dry up the solution in a sun or on an electric heater, add 3 ml distilled water, and then mix well. Add 0.5 ml Copper solution, put on a glass ball, and boil (100˚C) for 10 min. After boiling, immediately cool the test tube in tap water. Add 0.5 ml Nelson reagent in the test tube, and mix them well. After 20 min., add 8 ml distilled water, and mix well (Total volume = 9.5 ml). Measure the absorbance at 660 nm (Abs), and calculate the reducing sugar content.

3.5.2.3 Determination of non reducing sugar content

Non reducing sugar content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Dilute 0.2 ml invertase solution (1,000 U/0.1 ml) with 50 ml distilled water, and add one drop of Vinegar. Put 0.5 ml IV-6 solution into a test tube. Add 0.5 ml diluted invertase solution (V-1) (20 Unit/0.5 ml), and incubate for 30 min at ambient temperature. Add 0.5 ml Copper solution, put on a glass ball, and boil (100˚C) for 10 min. After boiling, immediately cool the test tubes in tap water. Add 0.5 ml Nelson reagent in the test tubes, and mix them. After 20 min., add 7.5 ml distilled water and mix well (Total volume = 9.5 ml). Measure the absorbance at 660 nm (Abs), and calculate the non reducing sugar content.

3.5.2.4 Determination of total sugar content

Total sugar content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Total soluble sugar content = Reducing sugar + Non reducing sugar

3.5.2.5 Total soluble solids (TSS)

TSS of potato tubers was determined in a drop of potato juice by using portable hand refractometer (ERMA, Tokyo, Japan) Range: 0 to 32% according to (AOAC, 1990) and expressed as °BRIX value.

3.5.2.6 Protein content

The AOAC (2005) No. 2001:11 methods was used in the determination of the protein content with digestion unit and manual titration with 40% NaOH and HCl.

3.5.2.7Ash content

Ash content of tubers was determined by following (Ranganna, 1994). Note the tare weight of tree silica dishes (7-8 cm). Weight 1-3 g of the sample into each. Ignite the dishes and the contents on a Bunsen burner. Ash the material at not

more than 600^0 C for 6 hour; if need be, ash overnight, in muffle furnace. Cool the dishes and weight. The difference in weights gives the total ash contents and is expressed as percentage. From which the dry matter percentage was calculated with the following formula-

% of Ash= 100 $(W_1-W_2)/W$

(W_1= Weight of crucible after ignition, W_2= Weight of empty crucible, W= Sample weight)

3.6 Preparation of chips

Chips from fresh tubers were prepared as per standard procedure given by CPRI, Shimla (Marwaha *et al.*, 2008). Well cured uniform size tubers of weight 100 g to 150 g from each variety were selected to chips preparation. Preliminary trials were conducted for optimization of chips preparation using slicer with adjustable blade for slice width. As standard, the slice thickness 2.0 mm and frying time of potato slices 3 min and frying temperature 190° C to yield potato chips of optimum quality.

3.7 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme (MSTAT, 1991). The significant differences among the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 1% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Potato is one of the most important food crops in developed as well as in developing countries. Bangladesh is amongst the ten major potato producing countries in the world. Many potato varieties have been released in Bangladesh, however the demand for processed potato products has led the manufacturer to select the most suitable and round year available potato variety, so that there will be continuous supply of products in the market. The results of the investigation on different potato cultivars (Plate 2) assessed for physical, chemical and processing has been presented.

4.1 Physico-chemical composition of potato tubers

4.1.1 Physical characteristics of potatoes

4.1.1.1 Salient features of tuber for processing

Tuber characteristics include tuber shape, eye depth, tuber skin color, flesh color and general appearance. These are also called quality characteristics which are important for marketing as well as for processing. The varieties varied for these characteristics (Table 1). 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.

4.1.1.1.1 Tuber shape

Oval shape tubers are preferred for making chips and french fries. The shape of tubers is also controlled by the genetic factors and environment may also affect it to some extent. Most of the varieties had oval shaped tubers (Table 1). In the present study seventeen varieties *viz.*, ‘Diamant’, ‘Binella’, ‘Elgar’, ‘Agila’, ‘Sagitta’, ‘Provento’, ‘Cardinal’, ‘Steffi’, ‘Felsina’, ‘Multa’, ‘Espirit’, ‘Meridian’, ‘Asterix’, ‘Omega’, ‘Amanda’, ‘Svenja’, and ‘Connect’ had oval

shaped tubers, where twelve varieties namely ‘Granola’, ‘Lady Rosetta’, ‘Dheera’, ‘Saikat’, ‘Ailsa’, ‘Rumba’, ‘Endeavour’, ‘Caruso’, ‘Belarossa’, ‘Bat Pakri’, ‘BARI TPS-1’, ‘Tomensa’ had round shaped tubers; Ten varieties *viz.*, ‘Raja’, ‘Jerla’, ‘Dura’, ‘Patrones’, ‘Laura’, ‘Quincy’, ‘Almerah’, ‘Cumbica’, ‘Forza’, ‘Jam alu’ had long oval shaped tubers; and only the variety ‘Ludmila’ had very long oval shaped tubers (Table 1). Potato tubers that are round and oval in shape are found to be suitable for making chips by most processors because they easily make the required crisp diameters (Kulkarni and Govinden, 1994; Kabira and Lamega, 2006; Pandey *et al.*, 2009). Majority of the cultivars were oval shaped with brown colored skin and cream flesh in the present study. Abong *et al.* (2010) reported round shape for most of the Kenya cultivars and showed white, cream or red color skin and flesh with white or cream color.

4.1.1.1.2 Eye depth

In the present trial only two variety ‘Belarossa’ and ‘Bat Pakri’ had very deep eyes whereas other six varieties like ‘Dheera’, ‘Saikat’, ‘Meridian’, ‘Caruso’, ‘Tomensa’, ‘BARI TPS-1’ had deep eyes; six varieties *viz.*, ‘Diamant’, ‘Quincy’, ‘Endeavour’, ‘Amanda’, ‘Connect’, ‘Jam alu’ had deep to medium eyes ; five varieties namely ‘Lady Rosetta’, ‘Sagitta’, ‘Ailsa’, ‘Multa’, ‘Rumba’ had medium eyes ; and twenty one varieties *viz.*, ‘Svenja’, ‘Raja’, ‘Binella’, ‘Jerla’, ‘Elgar’, ‘Agila’, ‘Dura’, ‘Patrones’, ‘Provento’, ‘Cardinal’, ‘Steffi’, ‘Felsina’, ‘Laura’, ‘Espirit’, ‘Asterix’, ‘Almerah’, ‘Cumbica’, ‘Omega’, ‘Forza’, ‘Ludmila’, ‘Granola’ had shallow eyes (Table 1). Shallow to medium deep eyes which were liked by consumers. The characteristic of eye depth is controlled by particular gene and less affected by environment. During evaluation all varieties had either shallow or medium eye depths, which are suitable to reduce losses during trimming and peeling (Kabira and Lamega, 2006).

4.1.1.1.3 Color of skin and flesh

In the present study skin color of twenty nine varieties like 'Granola', 'Diamant', 'Binella', 'Jerla', 'Dheera', 'Elgar', 'Agila', 'Sagitta', 'Patrones', 'Provento', 'Steffi', 'Felsina', 'Ailsa', 'Multa', 'Espirit', 'Quincy', 'Almerah', 'Cumbica', 'Rumba', 'Omega', 'Endeavour', 'Caruso', 'Forza', 'Amanda', 'Ludmila', 'Connect', 'Svenja', 'Tomensa', 'BARI TPS-1' had white colur; and eleven varieties *viz.*, 'Raja', 'Lady Rosetta', 'Dura', 'Saikat', 'Cardinal', 'Laura', 'Meridian', 'Asterix', 'Belarossa', 'Jam alu', 'Bat Pakri' had red in color (Table 1). Many Kenyan consumers have attributed white or red skin coloured tubers to be of good quality for processing (Kabira, 2000). The flesh color of sixteen potato varieties *viz.*, 'Jam alu', 'Raja', 'Lady Rosetta', 'Dheera', 'Elgar', 'Saikat', 'Cardinal', 'Asterix', 'Almerah', 'Rumba', 'Omega', 'Amanda', 'Ludmila', 'Connect', 'Svenja', 'Diamant' had cream in color; eleven varieties namely 'Binella', 'Sagitta', 'Patrones', 'Felsina', 'Ailsa', 'Multa','Quincy', 'Meridian', 'Caruso', 'Bat Pakri','Tomensa' had white in color; and thirteen varieties like 'Granola', 'Jerla', 'Agila', 'Dura', 'Provento', 'Steffi', 'Laura', 'Espirit', 'Cumbica', 'Endeavour', 'Forza', 'Belarossa', 'BARI TPS-1' had yellow in color (Table 1). 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).

4.1.1.1.4 General appearance

General appearance was scored by giving number 9 for excellent to 1 for disliking. Out of forty varieties, 'Granola', 'Steffi', 'Cumbica', 'Omega', 'Forza', 'Amanda', 'Ludmila', 'Binella', 'BARI TPS-1' varieties got maximum score of 8; 'Diamant', 'Raja', 'Dheera', 'Agila', 'Sagitta', 'Saikat', 'Provento',

‘Multa’, ‘Espirit’, ‘Asterix’, ‘Almerah’, ‘Rumba’, ‘Endeavour’, ‘Caruso’, ‘Belarossa’, ‘Svenja’, ‘Connect’ varieties got moderate score of 7 and ‘Lady Rosetta’, ‘Jerla’, ‘Elgar’, ‘Dura’, ‘Patrones’, ‘Cardinal’, ‘Felsina’, ‘Laura’, ‘Ailsa’,’Quincy’, ‘Meridian’, ‘Tomensa’, ‘Bat Pakri’, ‘Jam alu’ varieties got minimum score of 6 (Table 1).

Table1. Salient tuber characteristics of different potato varieties

Variety	Tuber shape	Eye depth	Color of skin	Color of flesh	General appearance
Granola	Round	Shallow	White	Yellow	8
Diamant	Oval	Deep to medium	White	Cream	7
Raja	Long oval	Shallow	Red	Cream	7
Lady Rosetta	Round	Medium	Red	Cream	6
Binella	Oval	Shallow	White	White	8
Jerla	Long oval	Shallow	White	Yellow	6
Dheera	Round	Deep	White	Cream	7
Elgar	Oval	Shallow	White	Cream	6
Agila	Oval	Shallow	White	Yellow	7
Dura	Long oval	Shallow	Red	Yellow	6
Sagitta	Oval	Medium	White	White	7
Saikat	Round	Deep	Red	Cream	7
Patrones	Long oval	Shallow	White	White	6
Provento	Oval	Shallow	White	Yellow	7
Cardinal	Oval	Shallow	Red	Cream	6
Steffi	Oval	Shallow	White	Yellow	8
Felsina	Oval	Shallow	White	White	6
Laura	Long oval	Shallow	Red	Yellow	6
Ailsa	Round	Medium	White	White	6
Multa	Oval	Medium	White	White	7
Espirit	Oval	Shallow	White	Yellow	7
Quincy	Long oval	Deep to medium	White	White	6
Meridian	Oval	Deep	Red	White	6
Asterix	Oval	Shallow	Red	Cream	7
Almerah	Long oval	Shallow	White	Cream	7
Cumbica	Long oval	Shallow	White	Yellow	8
Rumba	Round	Medium	White	Cream	7
Omega	Oval	Shallow	White	Cream	8
Endeavour	Round	Deep to medium	White	Yellow	7
Caruso	Round	Deep	White	White	7
Forza	Long oval	Shallow	White	Yellow	8
Belarossa	Round	Very deep	Red	Yellow	7
Amanda	Oval	Deep to medium	White	Cream	8
Ludmila	Very long oval	Shallow	White	Cream	8
Connect	Oval	Deep to medium	White	Cream	7
Svenja	Oval	Shallow	White	Cream	7
Tomensa	Round	Deep	White	White	6
BARI TPS-1	Round	Deep	White	Yellow	8
Bat Pakri	Round	Very deep	Red	White	6
Jam alu	Long oval	Deep to medium	Red	Cream	6

#Mean of 10 randomly selected potatoes.

4.1.1.2 Total potato defects (TPOD) of potato varieties

Results of the total potato defects of potato cultivars are presented in Table 2. External observation revealed absence of scars in most of the cultivars except for 'Dheera', 'Agila', 'Cardinal', 'Felsina', 'Ailsa', 'Quincy', 'Almerah', 'Omega', 'Forza' and 'Bat Pakri'. Green tint was absent in all the varieties. Skin for most of the cultivars was smooth except in 'Lady Rosetta', 'Agila', 'Ailsa', 'Endeavour', 'Ludmila', 'Connect' and 'Tomensa' which had rough skin. The mean number of eye ranged from 3.0 to 7.6 with least in 'Omega' and highest in 'Bat Pakri'. Natural depression was found in 'Dura', 'Sagitta', 'Patrones', 'Felsina', 'Ailsa', 'Espirit', 'Quincy', 'Rumba', 'Omega', 'Endeavour', 'Belarossa' and 'Jam alu'. The visualized total potato defects on potato skin were found to be negligible. The internal flesh of all the evaluated potato varieties was devoid of hollow hearts and black spots. Besides the desirable morphological and biochemical characters, the tubers of processing varieties should not have green tint more than 3% and the total tuber defects such as growth cracks, hollow heart, internal brown spots and secondary growth etc. also should not exceed 15% (Pandey *et al.*, 2009). Number of eyes was less in most of the cultivars with shallow eye depth, without scars and green tint. Highest number of natural depressions was found in 'Jam alu'. Deep eye depths lead to heavy losses during peeling, trimming and thus lowers overall yield of crisps (Smith *et al.*, 1985; Kabira and Lamega, 2006) which was absent in the tubers of present investigation. Thus the tubers investigated in the present study were suitable for processing due to low total potato defects (TPOD).

Table 2. Total potato defects (TPOD) of different potato varieties

Variety	External (skin)					Internal (flesh)	
	Scars	Green tint	Type of skin	No. of eyes	Natural depression	Hollow heart	Black spot
Granola	Absent	Absent	Smooth	3.1	Absent	Absent	Absent
Diamant	Absent	Absent	Smooth	5.8	Absent	Absent	Absent
Raja	Absent	Absent	Smooth	4.2	Absent	Absent	Absent
Lady Rosetta	Absent	Absent	Rough	4	Absent	Absent	Absent
Binella	Absent	Absent	Smooth	6.4	Absent	Absent	Absent
Jerla	Absent	Absent	Smooth	4.6	Absent	Absent	Absent
Dheera	Present	Absent	Smooth	6.1	Absent	Absent	Absent
Elgar	Absent	Absent	Smooth	6.1	Absent	Absent	Absent
Agila	Present	Absent	Rough	6.3	Absent	Absent	Absent
Dura	Absent	Absent	Smooth	3.9	Present	Absent	Absent
Sagitta	Absent	Absent	Smooth	6	Present	Absent	Absent
Saikat	Absent	Absent	Smooth	5	Absent	Absent	Absent
Patrones	Absent	Absent	Smooth	5.2	Present	Absent	Absent
Provento	Absent	Absent	Smooth	6.1	Absent	Absent	Absent
Cardinal	Present	Absent	Smooth	5.4	Absent	Absent	Absent
Steffi	Absent	Absent	Smooth	6.7	Absent	Absent	Absent
Felsina	Present	Absent	Smooth	7.0	Present	Absent	Absent
Laura	Absent	Absent	Smooth	6.1	Absent	Absent	Absent
Ailsa	Present	Absent	Rough	5.2	Present	Absent	Absent
Multa	Absent	Absent	Smooth	5.9	Absent	Absent	Absent
Espirit	Absent	Absent	Smooth	6.0	Present	Absent	Absent
Quincy	Present	Absent	Smooth	7.2	Present	Absent	Absent
Meridian	Absent	Absent	Smooth	5.1	Absent	Absent	Absent
Asterix	Absent	Absent	Smooth	5.1	Absent	Absent	Absent
Almerah	Present	Absent	Smooth	5.6	Absent	Absent	Absent
Cumbica	Absent	Absent	Smooth	3.3	Absent	Absent	Absent
Rumba	Absent	Absent	Smooth	4.2	Present	Absent	Absent
Omega	Present	Absent	Smooth	3.0	Present	Absent	Absent
Endeavour	Absent	Absent	Rough	5.3	Present	Absent	Absent
Caruso	Absent	Absent	Smooth	4.4	Absent	Absent	Absent
Forza	Present	Absent	Smooth	3.8	Absent	Absent	Absent
Belarossa	Absent	Absent	Smooth	5.2	Present	Absent	Absent
Amanda	Absent	Absent	Smooth	4.1	Absent	Absent	Absent
Ludmila	Absent	Absent	Rough	3.5	Absent	Absent	Absent
Connect	Absent	Absent	Rough	3.2	Absent	Absent	Absent
Svenja	Absent	Absent	Smooth	4.8	Absent	Absent	Absent
Tomensa	Absent	Absent	Rough	4.2	Absent	Absent	Absent
BARI TPS-1	Absent	Absent	Smooth	3.7	Absent	Absent	Absent
Bat Pakri	Present	Absent	Smooth	7.6	Absent	Absent	Absent
Jam alu	Absent	Absent	Smooth	4.3	Present	Absent	Absent

#Mean of 10 randomly selected potatoes.

4.1.1.3 Color of skin

The statistical analysis showed that there were significant differences ($p<0.05$) on different varieties for lightness (L^*), green-red chromaticity (a^*), blue-yellow chromaticity (b^*), chroma and hue angle of potato skin (Table 3). Among forty varieties, the skin of BARI TPS-I had the highest L^* value (63.44) compared to those of others whereas the lowest value (41.82) was observed in 'Saikat'.

The values of 'a^*' were significant for different varieties. The skin of 'Bat Pakri' was characterized by the highest a^* value (12.54) followed by 'Saikat' (12.36), while the lowest value (2.50) was exhibited in 'Patrones' (Table 3). Among the forty varieties, 'Svenja' demonstrated maximum b^* values (29.00) and lowest was observed in 'Meridian' (11.57) and 'Jam alu' (11.56) with no significant difference.

Again, chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of 'Bat Pakri' (30.61) was the highest and lowest was exhibited in 'Raja' (14.56). It was observed that 'Patrones' had the highest hue angle (1.42), while the minimum value (0.83) for hue angle was noted for 'Meridian' and 'Jam alu'.

Table 3. Skin color (L^*, a^*, b^*, chroma, hue angle) of different potato varieties

Variety	Skin color				
	L^*	a^*	b^*	Chroma	Hue angle
Granola	57.84 d-f	4.64 t-v	24.17 k	24.61 i	1.38 a-e
Diamant	56.23 h-j	6.70 i-k	25.58 f	26.45 e	1.31 f-j
Raja	54.75 m-o	8.18 e	12.04 y	14.56 v	0.97 o
Lady Rosetta	50.71 st	9.28 cd	19.36 r	21.47 m	1.12 mn
Binella	56.84 gh	7.21 g-i	26.21 d	27.18 cd	1.30 g-k
Jerla	56.80 gh	5.86 m-p	24.64 ij	25.33 f-h	1.34 d-i
Dheera	55.04 l-n	5.28 p-s	24.54 ij	25.11 h	1.36 b-g
Elgar	54.57 no	7.66 e-g	25.84 ef	26.96 d	1.28 i-l
Agila	58.50 d	3.43 x	16.31 vw	16.67 t	1.36 a-g
Dura	49.78 u	7.06 h-j	16.11 w	17.60 r	1.16 m
Sagitta	55.59 j-l	4.40 uv	22.91 m	23.33 j	1.38 a-e
Saikat	41.82 x	12.36 a	16.62 uv	20.72 o	0.93 o
Patrones	60.41 b	2.50 y	16.84 u	17.03 s	1.42 a
Provento	56.91 gh	5.20 q-t	24.84 hi	25.38 f-h	1.36 a-g
Cardinal	51.86 r	9.63 c	19.46 r	21.71 m	1.11 mn
Steffi	58.04 de	3.33 x	16.96 u	17.29 rs	1.38 a-e
Felsina	57.50 e-g	5.82 m-p	23.62 l	24.33 i	1.33 d-j
Laura	50.97 s	7.79 ef	14.75 x	16.68 t	1.08 n
Ailsa	57.30 fg	5.67 n-q	24.57 ij	25.22 gh	1.34 c-h
Multa	53.09 q	7.42 f-h	25.22 g	26.29 e	1.29 h-l
Espirit	59.42 c	5.53 o-r	20.31 q	21.05 n	1.30 g-k
Quincy	54.25 op	6.10 l-o	24.42 jk	25.17 gh	1.33 d-j
Meridian	44.43 w	10.52 b	11.57 z	15.64 u	0.83 p
Asterix	49.82 u	9.11 cd	18.31 s	20.45 o	1.11 mn
Almerah	55.34 k-m	4.08 vw	21.92 n	22.29 kl	1.39 a-d
Cumbica	55.13 l-n	5.02 r-t	21.52 op	22.10 l	1.34 d-i
Rumba	52.97 q	6.60 j-l	26.22 d	27.04 d	1.32 e-j
Omega	51.67 r	8.75 d	25.99 de	27.43 c	1.25 kl
Endeavour	56.43 hi	3.70 wx	17.84 t	18.22 q	1.37 a-f
Caruso	50.20 tu	6.23 k-n	24.70 h-j	25.47 fg	1.32 e-j
Forza	55.08 l-n	5.62 o-q	25.03 gh	25.65 f	1.35 c-g
Belarossa	54.40 n-p	7.35 f-h	21.30 p	22.54 k	1.24 l
Amanda	55.94 i-k	6.33 k-m	23.51 l	24.35 i	1.31 f-j
Ludmila	57.25 fg	6.55 j-l	18.33 s	19.47 p	1.23 l
Connect	53.83 p	5.20 q-t	21.71 no	22.32 kl	1.34 d-i
Svenja	58.37 d	4.86 s-u	29.00 a	29.40 b	1.40 a-c
Tomensa	50.67 st	7.52 f-h	24.50 i-k	25.63 f	1.27 j-l
BARI TPS-1	63.44 a	4.31 uv	26.80 c	27.15 cd	1.41 ab
Bat Pakri	47.87 v	12.54 a	27.92 b	30.61 a	1.15 m
Jam alu	47.47 v	4.41 uv	11.56 z	15.63 u	0.83 p
SE_{Value}	0.24	0.18	0.12	0.11	0.01
CV (%)	0.77	4.84	0.96	0.87	1.13

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.1.4 Color of flesh

The statistical analysis showed that there were significant differences ($p<0.05$) on different varieties for lightness (L^*), green-red chromaticity (a^*), blue-yellow chromaticity (b^*), chroma and hue angle of potato flesh (Table 4). Among forty varieties in case of flesh, 'Multa' (76.23) and 'Amanda' (76.00) had L^* values that were significantly higher than the values of others, whereas the lowest was observed in 'Almerah' (61.50).

'Amanda' was characterized by a higher a^* value (4.40) while the minimum value (0.07) for a^* was noted for 'Dheera' and 'Cardinal'. Among the forty varieties, 'Omega' demonstrated maximum b^* values (38.80) and lowest was observed in 'Dheera' (15.07) and 'Ailsa' (15.07) with no significant difference.

Again, chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of 'Omega' (38.84) was the highest and minimum value (15.07) for chroma was noted for 'Dheera' and 'Ailsa'. It was observed that 'Dheera', 'Cardinal' and 'Ailsa' had the highest hue angle (1.57), while the minimum value (1.36) for hue angle was noted for 'Binella'. The variation of color can be explained by differences in composition within varieties, particularly in antioxidant content and enzyme activity. 'Multa' (76.23) and 'Amanda' (76.00) varieties produced light colored skin and all the 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. 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 (Tables 3 and 4).

Table 4. Flesh color (L^*, a^*, b^*, chroma, hue angle) of different potato varieties

Variety	Flesh color				
	L^*	a^*	b^*	Chroma	Hue angle
Granola	69.64 m	0.27 rs	31.93 ef	31.93 ef	1.56 ab
Diamant	70.41 l	1.03 n-p	28.80 k	28.82 j	1.54 a-f
Raja	72.76 i	1.27 m-o	30.70 g	30.73 g	1.53 a-g
Lady Rosetta	75.44 bc	2.60 f-h	27.74 m	27.86 l	1.48 f-k
Binella	73.37 gh	3.62 c	17.23 x	17.60 v	1.36 m
Jerla	70.76 l	3.27 cd	24.12 s	24.34 r	1.44 j-l
Dheera	66.72 r	0.07 s	15.07 z	15.07 x	1.57 a
Elgar	75.62 b	3.20 de	26.22 q	26.41 op	1.45 i-l
Agila	67.12 q	0.47 qr	26.26 pq	26.27 p	1.55 a-c
Dura	68.46 p	2.10 i-k	25.20 r	25.29 q	1.49 d-j
Sagitta	69.56 m	2.10 i-k	21.51 w	21.61 u	1.47 g-k
Saikat	70.60 l	1.87 j-l	23.22 u	23.30 s	1.49 c-j
Patrones	70.42 l	0.70 pq	27.12 n	27.13 m	1.55 a-d
Provento	68.57 p	1.40 mn	26.58 o	26.62 no	1.52 a-h
Cardinal	71.32 k	0.07 s	30.12 h	30.12 h	1.57 a
Steffi	66.20 s	0.23 rs	28.01 m	28.01 l	1.56 ab
Felsina	73.56 f-h	2.27 hi	26.11 q	26.21 p	1.48 e-k
Laura	65.03 t	0.93 op	29.00 jk	29.01 ij	1.54 a-e
Ailsa	73.39 gh	4.00 b	15.07 z	15.07 x	1.57 a
Multa	76.23 a	1.33 mn	29.81 i	29.84 h	1.53 a-g
Espirit	71.83 j	0.70 pq	37.80 c	37.81 c	1.55 a-c
Quincy	70.64 l	1.20 m-o	29.00 jk	29.02 ij	1.53 a-g
Meridian	71.10 k	0.17 rs	22.40 v	22.40 t	1.56 ab
Asterix	73.31 h	2.90 ef	22.42 v	22.61 t	1.44 i-l
Almerah	61.50 u	3.43 cd	23.03 u	23.29 s	1.42 kl
Cumbica	71.27 k	2.80 f	25.03 r	25.19 q	1.46 h-l
Rumba	73.81 ef	1.23 m-o	32.65 d	32.68 d	1.53 a-g
Omega	71.27 k	1.81 kl	38.80 a	38.84 a	1.52 a-g
Endeavour	72.66 i	0.53 qr	38.10 b	38.10 b	1.56 ab
Caruso	68.99 no	0.30 rs	29.20 j	29.20 i	1.56 ab
Forza	69.57 m	1.57 lm	31.64 f	31.68 f	1.52 a-h
Belarossa	69.30 mn	2.43 g-i	29.10 jk	29.20 i	1.49 d-j
Amanda	76.00 a	4.40 a	26.53 op	26.89 mn	1.41 lm
Ludmila	75.12 cd	3.53 cd	23.80 t	24.06 r	1.42 kl
Connect	73.70 fg	2.74 fg	28.32 l	28.45 k	1.47 g-k
Svenja	71.12 k	1.26 m-o	32.00 e	32.03 e	1.53 a-g
Tomensa	74.84 d	2.23 ij	32.00 e	32.08 e	1.50 b-i
BARI TPS-1	69.03 no	0.27 rs	30.01 hi	30.01 h	1.56 ab
Bat Pakri	74.07 e	1.17 no	31.90 ef	31.92 ef	1.53 a-g
Jam alu	68.77 op	0.70 pq	16.32 y	16.34 w	1.53 a-g
SE_{Value}	0.11	0.11	0.10	0.10	0.01
CV (%)	0.29	12.22	0.67	0.66	0.39

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.1.5 Average tuber weight

Average tuber weight of potato tuber ranged from 38.93 to 138.60 g (Table 5). Maximum weight was found in 'Omega' (138.6 g) followed by 'Diamant' (138.10 g), 'Rumba' (137.80 g), 'Ailsa' (137.00 g), 'Laura' (137.90 g) and 'Steffi' (137.70 g) while 'Jam alu' had minimum weight (38.93 g). The difference may be attributed to genotypes and adequate 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) and 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).

4.1.1.6 Volume

The statistical analysis for volume of different potato varieties showed significant variation (Table 5). The highest value for volume was found in 'Steffi' (130.20 ml) closely followed by 'Laura' (129.10 ml). The minimum volume was observed in varieties 'Jam alu' (35.39 ml). The difference in volume among the varieties could be due to difference in range of diameter and mass (Kabira and Lamega, 2006; Abong *et al.,* 2009).

4.1.1.7 Diameter

The results regarding diameter of different potato varieties are given in (Table 5), which showed that the diameter of varieties differed significantly. The diameter was found the highest (6.58 cm) in potato varieties 'Omega' and followed by 'Rumba' (6.56 cm) with no significant difference. The potato variety 'Jam alu' showed the least diameter (3.86 cm). Varietal difference is one of the important factors that affect the physical parameters. Tuber size influences chips. Size, influences post frying handling. Tubers of size more than 60 mm diameter yield crisps which are fragile and break easily during

packaging and transport (Abong *et al*., 2010). The processing varieties are graded into four different sizes *viz.*, 20-40, 40-60, 60-80 and >80 mm diameter by Central Potato Research Institute, Shimla (Anon., 2009) and has recommend that tuber size of 60-80 mm is most suitable for processing. In present investigation, the diameter of tubers ranged from 4.5 cm to 5.8 cm which was slightly lower than reported by Central Potato Research Institute, Shimla (Anon., 2009) but was on par with those reported by Lisinska and Leszczynski (1989). Large size tubers (>80 mm) generally showed hollow heart ranging between 33-100 per cent in different varieties. In contrast, the size preferred for processing is 40-60 mm and >45 mm diameter by Goel *et al.* (2007) and Pandey *et al*. (2008a) respectively. In the present study, size of most tubers except 'Jam alu' fall within the range of 40-60 mm and thus were suitable for processing.

Table 5. Average weight, volume and diameter of different potato varieties

Variety	Average weight (g)	Volume (ml)	Diameter (cm)
Granola	121.60 a-d	113.80 a-c	6.11 d-f
Diamant	138.10 a	126.70 ab	6.20 c-e
Raja	73.14 i	67.10 jk	4.42 rs
Lady Rosetta	72.84 i	66.21 jk	4.51 q-s
Binella	76.21 hi	71.22 h-k	4.44 rs
Jerla	79.21 hi	75.43 f-j	4.58 p-r
Dheera	81.34 g-i	74.62 f-k	4.43 rs
Elgar	82.87 g-i	76.02 f-j	5.11 mn
Agila	123.10 a-c	115.00 a-c	6.01 e-g
Dura	76.60 hi	72.26 h-k	4.54 p-r
Sagitta	91.00 f-i	85.84 e-h	5.12 mn
Saikat	77.80 hi	72.71 g-k	4.75 op
Patrones	91.97 f-i	85.15 e-i	5.36 kl
Provento	95.24 f-h	90.70 ef	5.65 ij
Cardinal	89.75 f-i	82.34 e-j	5.37 kl
Steffi	136.70 a	130.20 a	6.32 b-d
Felsina	87.53 f-i	81.80 e-j	5.49 jk
Laura	136.90 a	129.10 a	6.43 a-c
Ailsa	137.00 a	125.70 ab	6.52 ab
Multa	85.00 g-i	77.98 f-j	5.23 lm
Espirit	73.00 i	69.52 h-k	4.91 no
Quincy	84.44 g-i	78.17 f-j	5.35 kl
Meridian	74.00 i	68.52 i-k	4.31 s
Asterix	104.0 d-f	96.28 de	5.78 hi
Almerah	79.30 hi	58.16 k	4.87 o
Cumbica	124.60 a-c	115.4 a-c	5.91 f-h
Rumba	137.80 a	127.60 ab	6.56 a
Omega	138.60 a	126.00 ab	6.58 a
Endeavour	120.90 a-d	111.90 bc	6.10 d-f
Caruso	131.30 a-c	118.30 a-c	6.21 c-e
Forza	135.20 ab	124.00 ab	6.25 cd
Belarossa	128.50 a-c	119.00 a-c	6.15 de
Amanda	85.11 g-i	78.09 f-j	5.32 k-m
Ludmila	98.85 e-g	89.05 e-g	5.54 jk
Connect	113.20 c-e	107.80 cd	5.87 g-i
Svenja	75.75 i	70.13 h-k	5.25 lm
Tomensa	117.80 b-d	106.10 cd	5.79 g-i
BARI TPS-1	74.31 i	68.81 i-k	4.69 o-q
Bat Pakri	80.85 g-i	74.85 f-j	5.67 ij
Jam alu	38.93 j	35.39 l	3.86 t
SE_{Value}	5.36	4.92	0.07
CV (%)	9.83	9.32	2.32

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.1.8 Specific gravity

Specific gravity of the genotypes is given in (Table 6). Varieties varied with respect to specific gravity, which ranged from 1.053 to 1.123. It was observed that 'Ludmila' and 'Tomensa' had the highest specific gravity (1.123) with no significant difference, while the minimum value for specific gravity (1.053) was noted for 'Espirit', 'Almerah' and 'Connect'. Genotypes varied with respect to specific gravity, which ranged from 1.0343 to 1.1443 (Abbas *et al.,* 2011). Abong *et al.* (2010) also presented similar result with significant difference in specific gravity among the cultivars. Raj and Lal (2008) exhibited specific gravity of 1.10 in Kufri Chipsona-2 which is slightly lesser than the value recorded for Kufri Chipsona-2 in this study. The difference in specific gravity among the varieties could be due to difference in range of diameter and mass (Kabira and Lamega, 2006; Abong *et al.,* 2009). 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 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 'Ludmila' and 'Tomensa' were outstanding for this character.

4.1.1.9 Dry matter (%)

Dry matter ranged from 13.56 to 24.60 % (Table 6). Maximum dry matter was found in 'Ludmila' (24.60%) followed by 'Tomensa' (24.53%) and 'Caruso' (24.52%), while 'Almerah' had minimum dry matter (13.56%) followed by 'Espirit' (14.18%) and 'Connect' (14.41%). 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 to 26%) in La Molina (Amoros *et al.,* 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 works revealed that the genotypes 'Diamant', 'Raja', 'Lady Rosetta', 'Dheera', 'Elgar', 'Cardinal', 'Ailsa', 'Omega', 'Endeavour', 'Caruso', 'Forza', 'Belarossa', 'Amanda', 'Ludmila', 'Tomensa', 'Rumba' and 'Jam alu' had higher dry matter over 20% and hence are suitable for processing. 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). Dry matter is positively correlated with starch, specific gravity but exhibited an inverse relationship with reducing sugars (Abbas *et al.*, 2011). Dry matter is one of the most important characters determining the end use of potato for processing and production efficiency. High dry matter results in higher yield of processed products, mealiness, crispness and reduced oil consumption in fried products (Grewal and Uppal, 1989). Dry matter content of 20.5 per cent in Kufri Chipsona-2 is on par with the findings reported by (Singh and Ezekiel, 2008) and Das *et al.* (2001), while that of Kufri Jyoti was 18 per cent which is on par with the value reported by Marwaha (2000) and Das *et al.* (2001). Tubers with high dry matter content yield more chips while tuber with low dry matter content produces fewer chips with high absorption of oil. The difference in dry matter content among the cultivars could be due to variation in hereditary factors, agro-climatic conditions as well as agronomic practices followed for raising the crop (Singh and Ezekiel, 2008; Sood *et al.*, 2008; Talburt and Smith, 1975; Lisinska and Leszczynski, 1989; Abong *et al.,* 2010; Kumar *et al.,* 2003).

4.1.2 Chemical composition of potatoes

4.1.2.1 Starch content (%)

Starch comprises 65 to 80% of the dry weight of tubers (Kadam *et al.,* 1991). Maximum starch was depicted in 'Ludmila' (18.93%) followed by 'Tomensa' (18.86%) and 'Caruso' (18.83%). The minimum starch was noted in 'Almerah' (6.80%) as shown in Table 3. 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). Starch content is influenced by genotypes and it was found to be positively correlated to dry matter and specific gravity (Abbas *et al.,* 2011). The difference in starch content and its component among the cultivars may be due to difference in morphology of tubers as well as internal distribution of nutrients (Kroner and Volksen, 1950; Talburt and Smith, 1975), due to their differential root absorption pattern and translocation to aerial parts, finally distribution to potato tubers for their various metabolic activities (Sood *et al.*, 2008).

Table 6. Specific gravity, dry matter content and starch content of different potato varieties

Variety	Specific gravity	Dry matter content (%)	Starch (%)
Granola	1.063 b-e	16.72 pq	10.30 o-q
Diamant	1.090 a-c	21.36 g-i	15.40 gh
Raja	1.093 a-c	21.45 f-i	15.43 gh
Lady Rosetta	1.093 a-c	23.07 c-e	17.17 c-e
Binella	1.067 b-e	17.46 o-q	11.17 n-p
Jerla	1.057 b-e	16.75 pq	10.30 o-q
Dheera	1.087 a-c	22.05 fg	16.10 fg
Elgar	1.083 a-c	20.17 jk	14.03 ij
Agila	1.067 b-e	17.63 n-p	11.37 m-o
Dura	1.067 b-e	17.39 o-q	11.03 n-q
Sagitta	1.057 b-e	16.63 pq	10.20 pq
Saikat	1.077 a-d	19.50 kl	13.33 jk
Patrones	1.077 a-d	19.12 lm	12.97 kl
Provento	1.057 b-e	16.93 pq	10.57 o-q
Cardinal	1.087 a-c	21.55 f-h	15.53 f-h
Steffi	1.057 b-e	16.46 q	10.03 q
Felsina	1.067 b-e	18.74 lm	12.53 kl
Laura	1.067 b-e	16.97 pq	10.60 o-q
Ailsa	1.093 a-c	23.33 b-d	17.50 b-d
Multa	1.083 a-c	18.96 lm	12.80 kl
Espirit	1.053 b-e	14.18 r	7.56 rs
Quincy	1.073 a-e	18.70 lm	12.50 kl
Meridian	1.083 a-c	19.33 k-m	13.20 jk
Asterix	1.073 a-e	18.28 m-o	12.03 l-n
Almerah	1.053 b-e	13.56 r	6.80 s
Cumbica	1.073 a-e	17.48 o-q	11.17 n-p
Rumba	1.083 a-c	21.29 g-i	15.30 gh
Omega	1.093 a-c	22.45 d-f	16.57 d-f
Endeavour	1.083 a-c	20.52 ij	14.50 hi
Caruso	1.103 ab	24.52 a	18.83 a
Forza	1.093 a-c	23.53 bc	17.80 bc
Belarossa	1.083 a-c	20.59 h-j	14.53 hi
Amanda	1.093 a-c	23.53 bc	17.73 bc
Ludmila	1.123 a	24.60 a	18.93 a
Connect	1.053 b-e	14.41 r	7.83 r
Svenja	1.073 a-e	17.67 n-p	11.40 m-o
Tomensa	1.123 a	24.53 a	18.86 a
BARI TPS-1	1.073 a-e	18.54 l-n	12.30 k-m
Bat Pakri	1.073 a-e	18.73 lm	12.57 kl
Jam alu	1.093 a-c	22.25 e-g	16.33 e-g
SE_{Value}	0.01	0.32	0.34
CV (%)	2.41	2.85	4.43

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.2.2 Reducing sugars (%)

Significant difference was recorded among the varieties with respect to the reducing sugar percentage (Table 7). Maximum reducing sugar (0.61%) was recorded in 'Almerah'. The reducing sugar was least (0.02%) in 'Ludmila' and 'Caruso' followed by 'Tomensa' (0.03%) and 'Ailsa' (0.03%) with no significant difference. Significant difference was recorded among the genotypes with respect to the reducing sugar percentage (Abbas *et al.,* 2011). Reducing sugars were negatively correlated with specific gravity (Feltran *et al.,* 2004). A significant decrease in the reducing sugar content was mentioned (Wilde *et al.,* 2004). Table 7 revealed that reducing sugars ranged from 0.61% in 'Almerah' to 0.02% in 'Ludmila' and 'Caruso', while the other varieties 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 to 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$100g^{-1}$ on fresh weight (Pandey *et al.,* 2008b). Average reducing sugar content was higher in Kufri Lauvkar (43.74 mg $100g^{-1}$ on fresh weight) than Atlantic (14.68 mg $100g^{-1}$ 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^{-1} 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 were 150-250 mg $100g^{-1}$ on fresh weight (Ezekiel *et al.*, 1999; Ezekiel *et al.,* 2003). Singh *et al.* (1999) reported below 150 mg $100g^{-1}$ on fresh weight basis.

The reducing sugar content, measured right after harvesting met the standard requirements (0.15 to 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^{-1} fresh weight in cv. Atlantic to 35.7 mg $100g^{-1}$ 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) and the present work 'Ludmila' (0.02%), 'Caruso' (0.02%), 'Tomensa' (0.03%) and 'Ailsa' (0.03%) was outstanding for this character.

4.1.2.3 Non reducing sugars (%)

It is evident from (Table 7) that all the varieties were significantly different in terms of non reducing sugars. 'Amanda' was found to have the highest non reducing sugars percentage (0.53%), while lowest value (0.09%) was recorded in variety 'Almerah' followed by 'Sagitta' (0.12%) with no significant difference. 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).

4.1.2.4 Total sugars (%)

Significant difference was found in terms of total sugar in potato varieties (Table 7). The variety ‘Agila’ had the maximum total sugar (0.78%) and ‘Espirit’ showed statistical similar value (0.76%). The variety ‘Caruso’ had the lowest value of total sugar (0.27%) followed by ‘Lady Rosetta’ (0.28%), with no significant difference. Total sugars or a particular sugar and dry matter are heritable characters for potato, but are 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).

There is a close correlation among specific gravity, dry matter and starch content. In the present investigation specific gravity correlated positively with dry matter and starch. This could be due to the fact that starch comprises a major proportion of the dry matter and that the percentage of non starch solids in the fresh tubers is relatively constant, around 6 per cent (Burton, 1948).

Table 7. Reducing sugars, non reducing sugars and total sugars content of different potato varieties

Variety	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)
Granola	0.29 ef	0.17 fg	0.46 k-n
Diamant	0.13 h	0.37 cd	0.50 h-k
Raja	0.11 hi	0.37 cd	0.48 k-m
Lady Rosetta	0.05 ij	0.23 e	0.28 qr
Binella	0.32 de	0.16 gh	0.48 j-m
Jerla	0.41 c	0.15 g-i	0.56 f-j
Dheera	0.06 ij	0.33 d	0.39 m-o
Elgar	0.16 h	0.35 cd	0.51 g-k
Agila	0.34 de	0.44 b	0.78 a
Dura	0.15 h	0.43 b	0.58 d-h
Sagitta	0.52 b	0.12 hi	0.64 c-f
Saikat	0.24 fg	0.33 d	0.57 f-i
Patrones	0.25 fg	0.36 cd	0.61 d-f
Provento	0.34 de	0.32 d	0.66 c-e
Cardinal	0.06 ij	0.40 bc	0.46 k-n
Steffi	0.54 b	0.16 gh	0.70 a-c
Felsina	0.44 c	0.23 ef	0.67 cd
Laura	0.34 de	0.26 e	0.60 d-f
Ailsa	0.03 j	0.36 cd	0.39 no
Multa	0.34 de	0.36 cd	0.70 a-c
Espirit	0.54 b	0.22 ef	0.76 ab
Quincy	0.35 d	0.25 e	0.60 d-f
Meridian	0.16 h	0.25 e	0.41 l-o
Asterix	0.15 h	0.36 cd	0.51 g-k
Almerah	0.61 a	0.09 i	0.70 a-c
Cumbica	0.25 fg	0.36 cd	0.61 d-f
Rumba	0.14 h	0.35 cd	0.49 i-l
Omega	0.05 ij	0.31 d	0.36 op
Endeavour	0.13 h	0.45 b	0.58 d-h
Caruso	0.02 j	0.25 e	0.27 r
Forza	0.07 ij	0.36 cd	0.43 k-o
Belarossa	0.14 h	0.44 b	0.58 e-h
Amanda	0.06 ij	0.53 a	0.59 d-g
Ludmila	0.02 j	0.33 d	0.35 o-q
Connect	0.44 c	0.13 g-i	0.57 e-i
Svenja	0.16 h	0.44 b	0.60 d-f
Tomensa	0.03 j	0.26 e	0.29 p-r
BARI TPS-1	0.34 de	0.35 cd	0.69 bc
Bat Pakri	0.22 g	0.35 cd	0.57 f-i
Jam alu	0.13 h	0.24 e	0.37 o
SE_{Value}	0.01	0.01	0.02
CV (%)	14.89%	11.47%	8.84%

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.2.5 Total soluble solid (TSS) %

Significant difference was recorded among the varieties with respect to the total soluble solid (TSS) percentage (Table 8). Maximum TSS (6.66%) was recorded in 'Tomensa' followed by 'Amanda' (6.50%) with no significant difference. The reducing sugar was least (3.00%) in 'Elgar' and 'Dura' followed by 'Binella' (3.10%), 'Svenja' (3.10%), 'Saikat' (3.20%), 'Quincy' (3.26%) and 'Felsina' (3.36%) with no significant difference.

4.1.2.6 Protein content (%)

The statistical analysis for protein content of different potato varieties showed significant variation (Table 8). The highest value for protein content was found in 'Ailsa' (3.87%) followed by 'Caruso' (3.77%) with no significant difference. The minimum value for protein was observed in varieties 'Espirit' (0.79%) followed by 'Saikat' (0.81%), 'Sagitta' (0.85%), 'Binella'(0.85%) and 'Jam alu' (0.87%) with no significant difference. 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) and the present study showing it's variation from 0.79 to 3.87 %.

4.1.2.7 Ash content (%)

The results regarding ash content of different potato varieties are given in (Table 8), which showed that the ash content of varieties differed significantly. The ash content was found the highest (1.53%) in potato varieties 'Tomensa' and 'Sagitta'. The potato variety 'Connect' showed the least ash content (0.76%) followed by 'Saikat' (0.82%), 'Lady Rosetta' (0.83%), 'Binella' (0.83%), 'Rumba' (0.83%) and 'Multa' (0.82%) with no significant difference. 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). The results regarding ash content of 24 different potato varieties are given which showed that the ash content of genotypes differed significantly (Abbas *et al.*, 2011).

Table 8. Total soluble solid (TSS), protein and ash content of different potato varieties

Variety	TSS (%)	Protein (%)	Ash (%)
Granola	4.73 e-h	1.31 i-k	0.93 l
Diamant	4.73 e-h	2.78 cd	1.02 i-k
Raja	4.30 hi	2.73 c-e	1.14 h
Lady Rosetta	4.33 hi	3.32 b	0.83 mn
Binella	3.10 j	0.85 l	0.83 mn
Jerla	4.43 f-i	1.77 hi	1.33 cd
Dheera	5.03 d-g	2.52 c-f	1.03 ij
Elgar	3.00 j	2.66 c-f	0.95 j-l
Agila	4.00 i	1.53 h-k	1.15 gh
Dura	3.00 j	1.62 h-j	1.25 de
Sagitta	4.26 hi	0.85 l	1.53 a
Saikat	3.20 j	0.81 l	0.82 mn
Patrones	4.30 hi	1.65 hi	1.44 b
Provento	4.40 g-i	1.33 i-k	1.35 c
Cardinal	4.26 hi	3.28 b	0.96 j-l
Steffi	5.30 de	2.43 c-f	1.45 b
Felsina	3.36 j	1.45 h-k	1.05 i
Laura	4.23 hi	2.22 fg	1.23 e-g
Ailsa	4.30 hi	3.87 a	0.95 j-l
Multa	4.40 g-i	2.39 d-f	0.84 mn
Espirit	5.26 de	0.79 l	1.23 e-g
Quincy	3.26 j	1.43 h-k	1.26 de
Meridian	4.26 hi	1.67 hi	1.15 gh
Asterix	5.43 cd	1.51 h-k	1.14 h
Almerah	4.13 hi	1.13 kl	1.38 bc
Cumbica	5.26 de	2.29 ef	0.95 j-l
Rumba	4.50 f-i	3.34 b	0.83 mn
Omega	6.00 bc	2.86 c	1.17 f-h
Endeavour	5.03 d-g	1.86 gh	1.44 b
Caruso	4.80 d-h	3.77 a	1.24 ef
Forza	4.50 f-i	3.35 b	1.43 b
Belarossa	5.06 d-f	2.66 c-f	0.94 kl
Amanda	6.50 ab	2.50 c-f	0.89 lm
Ludmila	6.00 bc	3.33 b	1.17 f-h
Connect	3.96 i	1.12 kl	0.76 n
Svenja	3.10 j	2.41 c-f	0.95 j-l
Tomensa	6.66 a	1.16 kl	1.53 a
BARI TPS-1	4.13 hi	2.60 c-f	1.05 i
Bat Pakri	4.23 hi	1.17 j-l	1.25 de
Jam alu	4.50 f-i	0.87 l	0.92 l
SE_{Value}	0.19	0.13	0.02
CV (%)	7.48%	11.41%	3.65%

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

4.1.3 Optimization of processing of potato products

4.1.3.1 Color of chips

The statistical analysis showed that there were significant differences ($p<0.05$) on different varieties for lightness (L^*), green-red chromaticity (a^*), blue-yellow chromaticity (b^*), chroma and hue angle of potato chips (Table 8). Among forty varieties, the chips of BARI TPS-I had the highest L^* value (77.51) compared to those of others whereas the lowest value (53.54) was observed in 'Multa'. 'Almerah' was characterized by a higher a^* value (11.13) whereas the lowest value (-4.80) was observed in 'Ailsa'. Among the forty varieties, 'Granola' demonstrated maximum b^* values (39.96) and lowest value (18.52) was observed in 'Multa'. Again, chroma and hue angle were significantly affected by varieties. Among the variety the chroma of 'Granola' was the highest value (39.97) and lowest value (18.55) was exhibited in 'Multa'. It was observed that 'Meridian' (1.56), 'Quincy' (1.55) and 'Granola' (1.55) had the highest hue angle with no significant different, while the minimum value for hue angle was noted for 'Caruso' (-1.56), 'Omega' (-1.55) and 'Forza' (-1.54) with no significant different. 'BARI TPS-1' varieties produced light colored chips and all the varieties produced light colored chips ($L^* > 50$) which indicates that there was no excessive darkening. This can be attributed to low reducing sugars levels exhibited by the varieties. The varieties who tended towards the negative values of redness parameter (a*) of chips 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 (Tables 8). In an experiment, Ooko and Kabira (2011) also found significant varietal differences in color and textural properties of crisps and French fries with the product and variety. This result also is in agreement with the findings of Ooko and Kabira (2011) where they reported that, significant varietal differences in color and textural properties of

crisps and French fries were found with the product and variety. This might be attributed due to genetically, environmental or cultural factors. This color 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.

4.1.3.2 Crispness of chips

Crispness of chips significantly influenced by the varieties (Table 9). 'Ludmila' (4.56 N) had higher crispness whereas; the minimum (0.16 N) was recorded from the variety ''Quincy'' followed by ''Meridian'' (0.23 N) and ''Patrones'' (0.23 N). This might be due to varietal characters. 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). Cultivar affects starch concentration and thus texture (Abbas, *et al.*, 2012).

Table 9. Chips color (L^*, a^*, b^*, chroma, hue angle) and crispness of different potato varieties

Variety	Chips color					Crispness (N)
	L^*	a^*	b^*	Chroma	Hue angle	
Granola	74.20 de	0.67 st	39.96 a	39.97 a	1.55 ab	0.34 m-o
Diamant	73.13 g	2.50 m	23.37 p	23.51 r	1.46 e-h	1.46 g
Raja	73.32 fg	1.22 qr	30.34 g	30.36 g	1.53 a-c	1.50 g
Lady Rosetta	74.53 d	-1.50 w	23.30 p	23.35 rs	-1.51 rs	2.45 d
Binella	70.86 i	0.97 rs	21.35 r	21.37 t	1.53 a-d	0.81 h-k
Jerla	65.62 o	7.20 e	26.64 k	27.60 l	1.31 m	0.55 j-n
Dheera	75.56 c	-3.20 x	30.35 g	30.52 g	-1.47 qr	1.75 fg
Elgar	72.00 h	2.90 kl	28.92 i	29.06 j	1.47 c-h	0.27 m-o
Agila	63.33 r	8.98 c	25.82 l	27.34 lm	1.23 n	1.45 g
Dura	68.27 l	4.30 hi	23.80 o	24.19 pq	1.39 jk	1.47 g
Sagitta	68.93 k	1.90 no	24.50 n	24.57 o	1.49 b-g	0.75 i-k
Saikat	66.47 n	4.97 g	19.74 wx	20.36 v	1.32 lm	0.57 j-n
Patrones	68.56 kl	6.00 f	29.00 i	29.62 i	1.37 kl	0.23 no
Provento	64.70 p	2.60 lm	20.80 st	20.96 u	1.45 f-i	0.55 j-n
Cardinal	72.30 h	-1.86 w	31.00 f	31.06 f	-1.51 rs	2.03 ef
Steffi	72.51 h	1.96 no	29.14 i	29.21 j	1.50 a-f	0.40 l-o
Felsina	63.47 r	3.54 j	20.07 vw	20.38 v	1.39 i-k	0.34 m-o
Laura	68.30 l	2.92 kl	26.89 k	27.04 m	1.46 e-h	0.70 i-l
Ailsa	75.65 c	-4.80 y	22.54 q	23.05 s	-1.36 p	3.37 c
Multa	53.54 v	1.03 rs	18.52 y	18.55 x	1.52 a-e	0.34 m-o
Espirit	58.90 u	10.25 b	21.20 r	23.55 r	1.12 o	0.47 k-o
Quincy	67.47 m	0.66 st	28.00 j	28.01 k	1.55 ab	0.16 o
Meridian	70.32 j	0.35 t	32.40 cd	32.40 d	1.56 a	0.23 no
Asterix	64.07 q	0.90 rs	20.55 tu	20.57 v	1.53 a-d	0.90 h-j
Almerah	59.64 t	11.13 a	22.43 q	25.04 n	1.11 o	0.31 m-o
Cumbica	62.30 s	5.83 f	20.32 uv	21.14 tu	1.29 m	0.78 h-k
Rumba	66.75 n	1.50 pq	24.90 m	24.95 n	1.51 a-f	0.33 m-o
Omega	72.47 h	-0.54 uv	28.20 j	28.20 k	-1.55 s	1.58 g
Endeavour	65.55 o	2.22 mn	21.06 rs	21.18 tu	1.47 d-h	0.56 j-n
Caruso	67.40 m	-0.22 u	31.43 e	31.43 e	-1.56 s	3.82 b
Forza	73.75 ef	-0.80 v	23.90 o	23.91 q	-1.54 s	0.99 hi
Belarossa	67.36 m	3.16 k	31.34 ef	31.50 e	1.47 c-h	1.55 g
Amanda	76.20 b	-3.30 x	27.00 k	27.20 m	-1.45 q	2.19 de
Ludmila	68.35 l	-1.60 w	24.30 n	24.35 op	-1.51 rs	4.56 a
Connect	68.65 kl	2.20 mn	34.92 b	34.99 b	1.51 a-f	1.68 g
Svenja	65.48 o	4.00 i	26.83 k	27.12 m	1.42 h-k	1.10 h
Tomensa	71.18 i	-1.46 w	29.97 h	30.01 h	-1.52 rs	3.54 bc
BARI TPS-1	77.51 a	4.40 h	32.75 c	33.05 c	1.44 g-j	0.60 j-m
Bat Pakri	63.57 r	8.05 d	32.35 d	33.34 c	1.33 lm	1.46 g
Jam alu	67.50 m	1.73 op	19.47 x	19.55 w	1.48 c-h	0.77 h-k
SE_{Value}	0.17	0.13	0.12	0.01	0.01	0.10
CV (%)	0.44	10.28	0.84	0.81	1.44	14.98

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.01 level of probability

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from March to June 2013 to study the assessment of potato varieties for processing industry in Bangladesh. The single factor experiment consisted of forty potato varieties as 'Granola', 'Diamant', 'Raja', 'Lady Rosetta', 'Binella', 'Jerla', 'Dheera', 'Elgar', 'Agila', 'Dura', 'Sagitta', 'Saikat', 'Patrones', 'Provento', 'Cardinal', 'Steffi', 'Felsina', 'Laura', 'Ailsa', 'Multa', 'Espirit', 'Quincy', 'Meridian', 'Asterix', 'Almerah', 'Cumbica', 'Rumba', 'Omega', 'Endeavour', 'Caruso', 'Forza', 'Belarossa', 'Amanda', 'Ludmila', 'Connect', 'Svenja', 'Tomensa', 'BARI TPS-1', 'Bat Pakri' and 'Jam alu'. The experiment was laid out in a Completely Randomized Design (CRD) with 3 replications.

The data on physical characteristics of potatoes like tuber shape, eye depth, color of skin, color of flesh, general appearance, total potato defects (TPOD), average weight, volume, diameter, specific gravity, dry matter content (DMC) and texture measurement. Chemical composition of potatoes like starch content, reducing sugar content, non reducing sugar content, total sugar contents, total soluble solids (TSS), protein content and ash content. Data were analyzed using MSTAT package. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) at 1% level of significance.

In the present study, seventeen varieties *viz.*, 'Diamant', 'Binella', 'Elgar', 'Agila', 'Sagitta', 'Provento', 'Cardinal', 'Steffi', 'Felsina', 'Multa', 'Espirit', 'Meridian', 'Asterix', 'Omega', 'Amanda', 'Svenja', 'Connect' had oval shaped tubers; Twelve varieties namely 'Granola', 'Lady Rosetta', 'Dheera', 'Saikat', 'Ailsa', 'Rumba', 'Endeavour', 'Caruso', 'Belarossa', 'Bat Pakri', 'BARI TPS-1', 'Tomensa' had round shaped tubers; Ten varieties *viz.*, 'Raja',

‘Jerla’, ‘Dura’, ‘Patrones’, ‘Laura’, ‘Quincy’, ‘Almerah’, ‘Cumbica’, ‘Forza’, ‘Jam alu’ had long oval shaped tubers; and only the variety ‘Ludmila’ had very long oval shaped tubers. In the present trial only two varieties ‘‘Belarossa’’ and ‘‘Bat Pakri’’ had very deep eyes whereas other six varieties like ‘Dheera’, ‘Saikat’, ‘Meridian’, ‘Caruso’, ‘Tomensa’, ‘BARI TPS-1’ had deep eyes; six varieties *viz.,* ‘Diamant’, ‘Quincy’, ‘Endeavour’, ‘Amanda’, ‘Connect’, ‘Jam alu’ had deep to medium eyes ; five varieties namely ‘Lady Rosetta’, ‘Sagitta’, ‘Ailsa’, ‘Multa’, ‘Rumba’ had medium eyes; and twenty one varieties *viz.,* ‘Svenja’, ‘Raja’, ‘Binella’, ‘Jerla’, ‘Elgar’, ‘Agila’, ‘Dura’, ‘Patrones’, ‘Provento’, ‘Cardinal’, ‘Steffi’, ‘Felsina’, ‘Laura’, ‘Espirit’, ‘Asterix’, ‘Almerah’, ‘Cumbica’, ‘Omega’, ‘Forza’, ‘Ludmila’, ‘Granola’ had shallow eyes. In the present study skin color of twenty nine varieties like ‘Granola’, ‘Diamant’, ‘Binella’, ‘Jerla’, ‘Dheera’, ‘Elgar’, ‘Agila’, ‘Sagitta’, ‘Patrones’, ‘Provento’, ‘Steffi’, ‘Felsina’, ‘Ailsa’, ‘Multa’, ‘Espirit’, ‘Quincy’, ‘Almerah’, ‘Cumbica’, ‘Rumba’, ‘Omega’, ‘Endeavour’, ‘Caruso’, ‘Forza’, ‘Amanda’, ‘Ludmila’, ‘Connect’, ‘Svenja’, ‘Tomensa’, ‘BARI TPS-1’ had white colur; and eleven varieties *viz.,* ‘Raja’, ‘Lady Rosetta’, ‘Dura’, ‘Saikat’, ‘Cardinal’, ‘Laura’, ‘Meridian’, ‘Asterix’, ‘Belarossa’, ‘Jam alu’, ‘Bat Pakri’ had red in color. The flesh color of sixteen potato varieties *viz.*, ‘Jam alu’, ‘Raja’, ‘Lady Rosetta’, ‘Dheera’, ‘Elgar’, ‘Saikat’, ‘Cardinal’, ‘Asterix’, ‘Almerah’, ‘Rumba’, ‘Omega’, ‘Amanda’, ‘Ludmila’, ‘Connect’, ‘Svenja’, ‘Diamant’ had cream in color; eleven varieties namely ‘Binella’, ‘Sagitta’, ‘Patrones’, ‘Felsina’, ‘Ailsa’, ‘Multa’,’Quincy’, ‘Meridian’, ‘Caruso’, ‘Bat Pakri’,’Tomensa’ had white in color; and thirteen varieties like Granula, ‘Jerla’, ‘Agila’, ‘Dura’, ‘Provento’, ‘Steffi’, ‘Laura’, ‘Espirit’, ‘Cumbica’, ‘Endeavour’, ‘Forza’, ‘Belarossa’, ‘BARI TPS-1’ had yellow in color. General appearance was scored by giving number 9 for excellent to 1 for disliking. Out of forty varieties, ‘Granola’, ‘Steffi’, ‘Cumbica’, ‘Omega’, ‘Forza’, ‘Amanda’, ‘Ludmila’, ‘Binella’, ‘BARI TPS-1’ varieties got maximum score of 8; ‘Diamant’, ‘Raja’, ‘Dheera’, ‘Agila’, ‘Sagitta’, ‘Saikat’, ‘Provento’, ‘Multa’, ‘Espirit’, ‘Asterix’, ‘Almerah’, ‘Rumba’, ‘Endeavour’, ‘Caruso’, ‘Belarossa’,

‘Svenja’, ‘Connect’ varieties got moderate score of 7 and ‘Lady Rosetta’, ‘Jerla’, ‘Elgar’, ‘Dura’, ‘Patrones’, ‘Cardinal’, ‘Felsina’, ‘Laura’, ‘Ailsa’,’Quincy’, ‘Meridian’, ‘Tomensa’, ‘Bat Pakri’, ‘Jam alu’ varieties got minimum score of 6.

Results showed that the external observation revealed absence of scars in most of the cultivars except for ‘Dheera’, ‘Agila’, ‘Cardinal’, ‘Felsina’, ‘Ailsa’, ‘Quincy’, ‘Almerah’, ‘Omega’, ‘Forza’ and ‘Bat Pakri’. Green tint was absent in all the varieties. Skin for most of the cultivars was smooth except in ‘Lady Rosetta’, ‘Agila’, ‘Ailsa’, ‘Endeavour’, ‘Ludmila’, ‘Connect’ and ‘Tomensa’ which had rough skin. The mean number of eye ranged from 3.0 to 7.6 with least in ‘Omega’ and highest in ‘Bat Pakri’. Natural depression was found in ‘Dura’, ‘Sagitta’, ‘Patrones’, ‘Felsina’, ‘Ailsa’, ‘Espirit’, ‘Quincy’, ‘Rumba’, ‘Omega’, ‘Endeavour’, ‘Belarossa’ and ‘Jam alu’. The visualized total potato defects on potato skin were found to be negligible. The internal flesh of all the evaluated potato varieties was devoid of hollow hearts and black spots.

Among forty varieties, the skin of BARI TPS-I had the highest L^* value (63.44) compared to those of others whereas the lowest value (41.82) was observed in ‘Saikat’. The skin of ‘Bat Pakri’ was characterized by the highest a^* value (12.54) followed by ‘Saikat’(12.36), while the lowest value (2.50) was exhibited in ‘Patrones’. Among the forty varieties, ‘Svenja’ demonstrated maximum b^* values (29.00) and lowest was observed in ‘Meridian’ (11.57) and ‘Jam alu’ (11.56) with no significant difference. Again, chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of ‘Bat Pakri’ (30.61) was the highest and lowest was exhibited in ‘Raja’ (14.56). It was observed that ‘Patrones’ had the highest hue angle (1.42), while the minimum value for hue angle (0.83) was noted for ‘Meridian’ and ‘Jam alu’.

Among forty varieties in case of flesh, ‘Multa’ (76.23) and ‘Amanda’ (76.00) had L^* values that were significantly higher than the values of others, whereas the lowest was observed in ‘Almerah’ (61.50). ‘Amanda’ was characterized by a higher a^* value (4.40) while the minimum value (0.07) for a^* was noted for

‘Dheera’ and ‘Cardinal’. Among the forty varieties, ‘Omega’ demonstrated maximum b^* values (38.80) and lowest was observed in ‘Dheera’ (15.07) and ‘Ailsa’ (15.07) with no significant difference. Again, chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of ‘Omega’ (38.84) was the highest and minimum value (15.07) for chroma was noted for ‘Dheera’ and ‘Ailsa’. It was observed that ‘Dheera’, ‘Cardinal’ and ‘Ailsa’ had the highest hue angle (1.57), while the minimum value (1.36) for hue angle was noted for ‘Binella’.

Average tuber weight of potato varieties ranged from 38.93 to 138.60 g. Maximum weight was found in ‘Omega’ (138.6 g) followed by ‘Diamant’ (138.10 g), ‘Rumba’ (137.80 g), ‘Ailsa’ (137.00 g), ‘Laura’ (137.90 g) and ‘Steffi’ (137.70 g) while ‘Jam alu’ had minimum weight (38.93 g). The highest value for volume was found in ‘Steffi’ (130.20 ml) followed by ‘Laura’ (129.10 ml) with no significant difference. The minimum value (35.39 ml) for volume was observed in ‘Jam alu’. The diameter was found the highest (6.58 cm) in potato varieties ‘Omega’ and followed by ‘Rumba’ (6.56 cm) with no significant difference. The potato variety ‘Jam alu’ showed the least diameter (3.86 cm).

Varieties varied with respect to specific gravity, which ranged from 1.053 to 1.123. It was observed that ‘Ludmila’ and ‘Tomensa’ had the highest specific gravity (1.123) with no significant difference, while the minimum value for specific gravity (1.053) was noted for ‘Espirit’, ‘Almerah’ and ‘Connect’. Dry matter ranged from 13.56 to 24.60 %. Maximum dry matter was found in ‘Ludmila’ (24.60%) followed by ‘Tomensa’ (24.53%) and ‘Caruso’ (24.52%), while ‘Almerah’ had minimum dry matter (13.56%) followed by ‘Espirit’ (14.18%) and ‘Connect’ (14.41%). Maximum starch was depicted in ‘Ludmila’ (18.93%) followed by ‘Tomensa’ (18.86%) and ‘Caruso’ (18.83%). The minimum starch was noted in ‘Almerah’ (6.80%).

Maximum reducing sugar (0.61%) was recorded in ‘Almerah’. The reducing sugar was least (0.02%) in ‘Ludmila’ and ‘Caruso’ followed by ‘Tomensa’

(0.03%) and ‘Ailsa’ (0.03%) with no significant difference. ‘Amanda’ was found to have the highest non reducing sugars percentage (0.53%), while lowest value (0.09%) was recorded in variety ‘Almerah’ followed by ‘Sagitta’ (0.12%) with no significant difference. The variety ‘Agila’ had the maximum total sugar (0.78%) closely followed by ‘Espirit’ (0.76%). The variety ‘Caruso’ had the lowest value of total sugar (0.27%) followed by ‘Lady Rosetta’ (0.28%), with no significant difference.

Maximum TSS (6.66%) was recorded in ‘Tomensa’ followed by ‘Amanda’ (6.50%) with no significant difference. The reducing sugar was least (3.00%) in ‘Elgar’ and ‘Dura’ followed by ‘Binella’ (3.10%), ‘Svenja’ (3.10%), ‘Saikat’ (3.20%), ‘Quincy’ (3.26%) and ‘Felsina’ (3.36%) with no significant difference. The highest value for protein content was found in ‘Ailsa’ (3.87%) followed by ‘Caruso’ (3.77%) with no significant difference. The minimum value for protein was observed in varieties ‘Espirit’ (0.79%) followed by ‘Saikat’ (0.81%), ‘Sagitta’ (0.85%), ‘Binella’(0.85%) and ‘Jam alu’ (0.87%) with no significant difference. The ash content was found the highest (1.53%) in potato varieties ‘Tomensa’ and ‘Sagitta’. The potato variety ‘Connect’ showed the least ash content (0.76%) followed by ‘Saikat’ (0.82%), ‘Lady Rosetta’ (0.83%), ‘Binella’ (0.83%), ‘Rumba’ (0.83%) and ‘Multa’ (0.82%) with no significant difference.

Among forty potato varieties, the chips of BARI TPS-I had the highest L^* value (77.51) compared to those of others whereas the lowest value (53.54) was observed in ‘Multa’. ‘Almerah’ was characterized by a higher a^* value (11.13) whereas the lowest value (-4.80) was observed in ‘Ailsa’. Among the forty varieties, ‘Granola’ demonstrated maximum b^* values (39.96) and lowest value (18.52) was observed in ‘Multa’. Again, chroma and hue angle were significantly affected by varieties. Among the variety the chroma of ‘Granola’ (39.97) was the highest and lowest was exhibited in ‘Multa’ (18.55). It was observed that ‘Meridian’ (1.56), ‘Quincy’ (1.55) and ‘Granola’ (1.55) had the highest hue angle with no significant different, while the minimum value for

hue angle was noted for ‘Caruso’ (-1.56), ‘Omega’ (-1.55) and ‘Forza’ (-1.54) with no significant different. ‘Ludmila’ (4.56 N) had higher crispness whereas; the minimum (0.16 N) was recorded from the variety ‘‘Quincy’’ followed by ‘‘Meridian’’ (0.23 N) and ‘‘Patrones’’ (0.23 N).

Thus most of the potato cultivars were suitable for processing in terms of physical parameters viz., tuber shape, eye depth, color of skin, color of flesh, general appearance and diameter. Size of most tubers fall within the range of 40 to 60 mm which is a desirable size for processing. With absence of scars and green tints majority of tuber varieties were in oval or round shape with shallow eye depths that were either acceptable or highly acceptable. Among the varieties, twenty eight varieties exhibited more than 1.07 specific gravity, seventeen varieties contain more than 20% dry matter content but only ‘Lady Rosetta’, ‘Ailsa’, ‘Caruso’, ‘Forza’, ‘Amanda’, ‘Ludmila’, and ‘Tomensa’, had optimum dry matter, starch, reducing sugar, non reducing sugar and total sugar as well as better color score which were demonstrated better performance in respect of most of the processing quality studied in this experiment. However, this has to be investigated further conducting trials.

References

REFERENCES

Abbas, G., Frooq, K., Hafiz, I.A., Hussain, A., Abbasi N.A. and Shabbir. G. (2011). Assessment of processing and nutritional quality of potato genotypes in Pakistan. *Pakistan J. Agri. Sci.* **48**(3):169-175.

Abbas, G., Hafiz, I.A., Abbasi, N.A. and Hussain A. (2012). Determination of processing and nutritional quality attributes of potato genotypes in Pakistan. *Pakistan J. Bot.* **44**(1): 201-208.

Abong, G.O., Okoth, M.W. Imungi, J.K. and Kabira, J.N. (2010). Evaluation of selected Kenya potato cultivars for processing into potato crisps. *Agric. Biol. J. N. America.* **1**(5): 886-893.

Abong, G.O., Okoth, M.W., Karuri, E.G., Kabira, J.N. and Mathoko, F.M. (2009). Influence of potato cultivar and stage of maturity on oil content of french fries (chips) made from eight kenyan potato cultivars. *African J. Food Agri. Nutri. Devlpt.* **9**(8): 1667-1682.

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.

Amoros, W., Espinoza, J. and Bonierbale, M. (2000). Assessment of variability for processing potential in advanced potato populations. CIP Program Report. pp.185-195.

Anonymous. (2009). Annu. Rep. (2008-09). Central Potato Res. Inst., Shimla. pp. 37-39.

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

AOAC. (1990). Official Methods of Analysis. Association of official Analytical Chemist (15^{th} edn), AOAC, Washington, DC, USA.

AOAC. (2005). Official Method of Analysis. Association of official Analytical Chemists (18th edn), Gaitherburg, Maryland 2087-2417, USA.

Barry-Ryan, C., Burke, R. and Gilsenan, C. (2010). A study of the physico chemical and sensory properties of organic and conventional potatoes (*Solanum tuberosum*) before and after baking. *Intl. J. Food Sci. Technol*. **45**: 475–481.

Basuny, A.M.M., Mostafa, D.M.M. and Shaker, A.M. (2009). Relationship between chemical composition and sensory evaluation of potato chips made from six potato varieties with emphasis on the quality of fried sunflower oil. *World J. Dairy Food Sci.* **4**(2): 193-200.

BBS (Bangladesh Bureau of Statistics). (2013). Agricultural Statistics Yearbook-2013.

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

Burton, W.G. (1948). The potato, Chapman and Hall, London. pp. 44-48.

Das, M., Ezekiel, R. and Sekhawat, G.S. (2001). Quality of dehydrated potato chips produced from fresh and heap stored tubers. *J. Indian Potato Assoc.* **28** (1): 174-175.

Dean, B.B. and Thornton, R.E. (1992). The specific gravity of potatoes. Extension Bullentin 1541, Washington State University, Cooperative Extension, Pullman, W.A.

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

Elfinesh, F., Tekalign, T. and Solomon, W. (2011). Processing quality of improved potato (*Solanum tuberosum* L.) cultivars as influenced by growing environment and blanching. *African J. Food Sci.* **5**(6): 324-332.

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

Ezekiel, R. and Dahiya, P.S. (2004). Storage behaviour and processing quality of potatoes stored in heaps and pits in the Malwa region. *Potato J.* **31**(1-2): 21-28.

Ezekiel, R. and Rani, M. (2006). Oil content of potato chips: Relationship with dry matter and starch contents and rancidity during storage at room temperature. *Potato J.* **33**(1-2): 44-49.

Ezekiel, R., Singh, B. and Dinesh, D.K. (2003). A reference chart for potato chip color for use in India. *J. Indian Potato Assoc.* **30**: 259-265.

Ezekiel, R., Virma, S.C., Sukumaran, N.P. and Shekhawat. G.S. (1999). A Guide to Potato Processor in India. Central potato Research Institute, Shimla, India. Technical Bulletin No. **48**: 14-39.

FAOSTAT (FAO, Statistics Division). (2013). Statistical Database. Food and Agricultural Organization of the United Nations, Rome, Italy.

Feltran, J.C., Lemos, L.B and Vieites, R.L. (2004). Technological quality and utilization of potato tubers. *Sci. Agric.* **61**: 598-603.

Gall, H., Griess, H., Nege, W. and Vogel, J. (1965). Zuchtungsfortschritt bei Kartoffeln in der DDR. *Ziichter* **35**: 186-197.

Ganga, H. and Kulkarni, U.N. (2014). Optimization and screening of potato varieties for microwave baking. *Intl. J. Farm Sci.* **4**(2): 163-171.

Ganga, H., Kulkarni, U.N., Yenegi, N.B., Basavaraj, N., Uppinal, N. and Ramachandra, K.N. (2013). Study on physical characteristics of potato genotypes. *Karnataka J. Agric. Sci.* **26** (2): 281-284.

Gaur, P.C., Pandey, S.K., Singh, S.V., Kumar, D., Marwaha, R.S. and Kumar, D. (1998). Kufri Chipsona-1: A potato variety for processing. *J. Indian Potato Assoc.* **25** (3-4): 113-118.

Goel, K., Kumar, A.R. and Mann, S.S. (2007). Postharvest management and value addition, Daya Publlishing House, New Delhi. pp. 40-43.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for agricultural research. Second Edn. Intl. Rice Res. Inst. John Wiley and Sons. New York. pp. 1-340.

Gray, D. and Hughes. J.C. (1978). Tuber quality. In: Harris, P. M. (Ed.), the Potato Crop. Chapman & Hall, London. pp. 504-544.

Grewal, S.S. and Uppal, D.S. (1989). Effect of dry matter and specific gravity on yield, color and oil content of potato chips. *Indian Food Packer.* **43**(1): 17-20.

Hassanpanah, D., Hassanabadi, H. and Chakherchaman, A.S.H. (2011). Evaluation of cooking quality characteristics of advanced clones and potato cultivars. *American J. Food Technol.* **6**(1): 72-79.

Illeperuma, D.C.K. and Wickramasinghe, N.K. (2000). Suitability of locally available potato varieties for chipping. *J. Natn. Sci. Foundation Srilanka.* **28**(2): 143-151.

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

Iritani, W.M. and Weller. L.D. (1976). Relationship of specific gravity to sugar accumulation in stored Norgold and Russet Burbank potatoes. *American Potato J.* **53**: 57-65.

Jansen, G., Flamme, W., Schuler, K. and Vandrey, M. (2001). Tuber and starch quality of wild and cultivated potato species and cultivars. *Potato Res.* **44**: 137-146.

Jansky, S.H. (2008). Genotypic and Environmental Contributions to baked potato flavour. *American J. Potato Res.* **85**: 455–465.

Joshi, S. and Nath, N. (2002). Effect of pre-treatments on quality and shelf life of fried chips from sprouted tubers of potato variety 'Kufri Chandramukhi'. *J. Food Sci. Technol.* **39**(3): 251-257.

Kabira, J.N. (2000). French fries and crisps processing characteristics of selected potato varieties in Kenya. African Potato Association, Uganda. pp. 507-511.

Kabira, J.N. and Lamega, B. (2006). Potato processing: Quality evaluation processing for research and food industries application in east and central Africa. Kenya Agricultural Research Institute, Nairobi, Kenya. pp. 9-15.

Kadam, S.S., Dhumal, S.S. and Jambhale, N.D. (1991). Structure nutritional composition and quality. In: Salunkhe, D.K., S.S. Kadam and S.J. Jadhav (Eds.), Potato Production Processing and Products. Boca Raton. CRC Press. **2**:9-35.

Kita, A. (2002). The influence of potato chemical composition on crisp texture. *Food Chem*. **76**: 173-179.

Kita, A., Lisinska, G. and Golubowska, G. (2007). The effects of oils and frying temperatures on the texture and fat content of potato crisps. *Food Chem*. **102**: 1-5.

Kroner, W. and Volksen, W. (1950). The Potato. *Johann Ambrosius Barth. Leipzig.* pp. 6-18.

Kulkarni, K.D. and Govinden, N. (1994). Crisp quality of two potato varieties: Effect of dehydration and rehydration. *J. Sci. Food Agric.* **64**(2): 205-210.

Kumar, D. and Ezekiel, R. (2004). Distribution of dry matter and sugars within a potato tuber of potato cultivars grown under short day conditions. *Potato J.* **31**(3-4): 129-134.

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

Kumar, D., Ezekiel, R. and Khurana, S.M.P. (2003). Effect of location, seasons and cultivar on the processing quality of potatoes. *J. Indian Potato Assoc.* **30**(3-4): 247-251.

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

Kumar, D., Singh, B.P. and Khurana, S.M.P. (2006). Processing quality of potato hybrid HT/92-621 during storage at intermediate temperatures along with sprout suppressant treatment. *Potato J.* **33**: 90-93.

Lauer, F. and Shaw, R. (1970). A possible genetic source for chipping potatoes from 40°F storage. *American Potato J.* **47**:275-78.

Lisinska, G. and Leszczynski, W. (1989). Potato science and technology. Elsevier Science Publishers Ltd., America, New York. pp. 11-202.

Liu, Q., Tarn, R., Lyncch, D. and Niel, M.S. (2007). Physico-chemical properties of dry matter and starch from potatoes grown in Canada. *Food Chem.* **105**: 897-907.

Marwaha, R.S. (1998). Factors determining processing quality and optimum processing maturity of potato cultivars grown under short days. *J. Indian Potato Assoc*. **25**: 95-102.

Marwaha, R.S. (1999). Chipping quality and related processing characteristics of Indian potato varieties grown under short day conditions. *J. Food Sci. Technol.* **36**(2): 157-159.

Marwaha, R.S. (2000). Processing quality of low and high sugar potato cultivars as influenced by storage temperature. *J. Indian Potato Assoc.* **27**(1-2): 5-11.

Marwaha, R.S., Kumar, D., Singh, S.V. and Pandey, S.K. (2008). Influence of blanching of potato varieties on chipping quality. *J. Food Sci. Technol.* **45**(4): 364-367.

Marwaha, R.S., Kumar, D., Singh, S.V. and Pandey, S.K. (2009). Chipping and nutritional qualities of Indian and exotic potato processing varieties stored under different conditions. *J. Food Sci. Technol.* **46**(4): 354-358.

Mathur, A. (2003). Studies on phosphorylation status of starch in potato tubers (Solanum tuberosum L.). MSc. Thesis, Department of Biotechnology and Environmental Sciences, Thapar Institute of Engineering and Technology, Patiala. pp. 10-14.

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

Mestdagh, F., Wilde, T. D. and Delporte, K. (2008). Impact of chemical pre-treatments on the acrylamide formation and sensorial quality of potato crisps. *Food Chem.* **106**: 914-922.

Misra, J.B. and Chand, P. (1990). Relationship between potato tubers size and chemical composition. *J. Food Sci. Technol.* **27**(1): 63-64.

Moreira, R.G., Castell-Perez, M.E. and Barrufet, M.A. (1999). Deep fat frying: Fundamentals and Applications. Aspen publishers: Gaithersburg. pp. 75-108.

MSTAT. (1991). Users manual for MSTAT-C. Michigan State University, East Lansing, Michigan. p. 450.

Nelson, N. (1944). A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* **187**:375-380.

Nema, P.K. and Prasad, S. (2004). Effect of frying oil temperature on quality and yield of potato chips. *J. Food Sci. Technol.* **41**(4): 448-450.

Ooko, G.A. and Kabira, J.N. (2011). Suitability of three newly released Kenyan potato varieties for processing into crisps and French fries. *African J. Food. Agri. Nutria. Devlpt.* **11**(6): 5266-5281.

Pandey, P.C., Luthra, S.K., Singh, S.V., Padey, S.K. and Singh, B.P. (2008a). Kufri Sadabahar: a potato variety for Uttar Pradesh. *Potato J.* **35**:111-117.

Pandey, S.K., Khurana, S.M.P., Singh, S.V., Kumar, D. and Kumar, P. (2005). Evaluation of Indian and exotic potato varieties for sustaining processing industries in North Western plains of India. *Indian J. Hort.* **62**: 155-159.

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

Pandey, S.K., Singh, S.V., Kumar, D., Manivel, P., Marwaha, R.S., Kumar, P., Singh, B.P. and Gupta, V.K. (2008b). Kufri Himsona: A chipping cultivar for Hill regions of India. *Potato J.* **35** (1-2): 1-8.

Pandey, S.K., Singh, S.V., Kumar, P., Kumar, D. and Manivel, P. (2004). Sustaining potato chipping industry from Western and Central Uttar Pardesh: adoption of suitable varieties. *Potato J.* **31**: 119-127.

Pandey, S.K., Singh, S.V., Marwaha, R.S. and Pattanayak, D. (2009). Indian potato processing varieties: Their impact and future priorities. *Potato J.* **36**(3-4): 95-114.

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

Pedreschi, F. and Moyano, P. (2004). Effect of pre-drying on texture and oil uptake of potato chips. *LWT Food Sci. Technol.* **38**: 599-604.

Peschin, A. (2000). Influence of storage temperature and reconditioning on the biochemical composition of potato tubers. *J. Food Sci. Technol*. **37**(2): 126-129.

Pokharkar, S. and Mahale, D. (2001). Optimization of process variables for preparation of fresh fried potato chips. *J. Food Sci. Technol.* **38**(4): 369-370.

Raj, D. and Lal, B.B. (2008). Effect of cultivars, cold storage and frying media on yield and processing qualities of potatoes. *J. Food Sci. Technol*. **45**(1): 20-27.

Ramasawmy, G., Goburdhun, D. and Ruggoo, A. (1999). Effect of different preparation technologies on proximate composition and calorie content of potato products. *Sci.Technol. Res. J.* **4**: 181-194.

Ramezani, R. and Aminlari, M. (2004). Comparing chemical composition of four potato varieties for processing. *J. Food Sci. Technol.* **41**(6): 680-691.

Ranganna, S. (1994). Handbook of Analysis and Quality Control for Fruits and Vegetable products. 2nd edn. Tata MC. Graw- Hill Publishing Co. Ltd. New Delhi.

Rastovski, A., Van Es, A., Hartmans, K.J., Buitelaar, N., Haan, P.H., Maijers, C.P., Van der Schild, J.H.W., Sijbring, P.H., Sparenberg, H. and Van Zwol, B.H. (1981). Storage of potatoes: post-harvest behavior, store

design, storage practice and handling. Center for Agricultural Publishing and Documentation, Wageningen, Netherlands. P. 462.

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

Rowe, R.C. and Powelson, M.L. (2002). Potato early dying: management challenges in a changing production environment. *Plant Diseases* **86**: 1184-1193.

Sandhu, K.S. and Parhawk, B. (2002). Studies on the preparation of dehydrated potato cubes. *J. Food Sci. Technol*. **39**: 594-602.

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.

Segnini S, Dejmek, P. and Oste, R. (1999). Reproducible texture analysis of potato chips. *J. Food Sci.* **64:** 309–312.

Shallenberger, R.S., Smith, O. and Treadway, R.H. (1959). Role of the sugars in the browning reaction in potato chips. *J. Agric. Food Chem.* **7**: 274-277.

Singh, B. and Ezekiel, R. (2008). Reducing sugar content and chipping quality of tubers of potato cultivars after storage and reconditioning. *Potato J.* **35**(1-2): 23-30.

Singh, J. and Kaur, L. (2009). Advances in Potato Chemistry and Technology, 1st Ed. Academic Press of Elsevier, USA. p.167.

Singh, S.V., Gaur, P.C., Pandey, S.K. and Kumar, D. (1999). Indian potato varieties for processing, CPRI, Shimla. Technical Buletin No.50.

Singh, S.V., Kumar, D., Pandey, S.K., Patel, N.H., Kumar, P., Manivel, P. and Marwaha, R.S. (2005). MP/97-644: A promising hybrid for making potato chips and dehydrated products. *Potato J.* **32**(3-4): 137-138.

Singh, S.V., Marwaha, R.S., Kumar, D., Kumar, P. and Pandey, S.K. (2009). Suitability of potato varieties grown in north-eastern Indian plains for processing. *Potato J.* **36**(1-2): 25-34.

Sinha, N.K., Cash, J.N. and Chase, R.W. (1992). Differences in sugars chip color, specific gravity and yield of selected potato cultivars grown in Michigan. *American Potato J.* **69**: 385-389.

Smith, L.M., Clifford, A.J., Creveling, A.K. and Hamblin, C.L. (1985). Lipid content and fatty acid profiles of various deep-fat-fried foods. *J. America Oil Chem. Soc.* **62**(6): 996-998.

Sood, D.R., Kalim, S. and Shilpa. (2008). Biochemical evaluation of potato tubers and peels. *Indian J. Nutr. Dietet.* **45**(10): 410-421.

Storey, M. (2007). The Harvested Crop. In: D. Vreugdenhil (Ed.), Potato Biology and Biotechnology Advances and Perspectives. Elsevier, Oxford. pp. 441-470.

Tabatabaeefar, A. (2002). Size and shape of potato tubers. *Int. Agro. Physics.* **10**: 301-305.

Talburt, M.S.W.F. and Smith, O. (1975). Potato Processing, the AVI Publishing Company, Inc., United States of America. pp. 67-363.

Toolangi, T.K. (1995). Potatoes: factors affecting dry matter. Agriculture notes, April. State of Victoria, Department of Primary Industries, USA.

Troncoso, E., Pedreschi, F. and Zuniga, R.N. (2009). Comparative study of physical and sensory properties of pre-treated potato slices during vacuum and atmospheric frying. *LWT Food Sci. Technol*. **42**: 187-195.

Uppal, D.S. (1995). Free sugars and invertase activity in stored potato tubers. *J. Indian Potato Assoc.* **22**(1-2): 46-51.

Uppal, D.S. (1999). Quality traits and chipping performance of newly released potato varieties. *J. Indian Potato Assoc.* **26**: 139-142.

Uppal, D.S. (2000). Chip color and processing parameters of potatoes grown during spring and autumn in north western plains. *J. Indian Potato Assoc.* **27**(3-7): 141-144.

Uppal, D.S. and Khurana, S.M.P. (2001). Chipping performance of potato varieties grown at different locations. *J. Indian Potato Assoc.* **28**(2-4): 233-236.

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

Vliet, T., Visser, J. E. and Luyten, H. (2007). On the mechanism by which oil uptake decreases crispy/crunchy behavior of fried products. *Food Res. Int.* **40:** 1122–1128.

Watada, A. and Kunkel, R. (1955). The variation in reducing sugar content in different varieties of potatoes. *American Potato J.* **32**: 132-140.

Wilde, T.D., Meulenaer, B.D., Mestdagh, F.D.R., Govaert, Y., Ooghe, W., Fraselle, S.P., Demeulemeester, K., Peteghem, C.V., Calus, A., Degroodt, J.M. and Verhe, R. (2004). Selection criteria for potato tubers to minimize acrylamide formation during frying. *J. Agric. Food Chem.* **54**: 21-99.

Wooster, P. and Farooq, K. (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.

Yaghbani, M. Mohammadzadeh, J. and Najafi, M. (2006). Composition and characterization of starch extraction from various potato cultivars in Golestan province of Iran. *J. Food Sci. Technol.* **43**(6): 667-670.

Zeiruk, V.N., Pshechenkov, K.A., Elansky, S.N., Davydenkova, O.N. and Maltsev, S.V. (2007). Influence of potato growth and storage conditions on the quality of fresh table potato and potato products in the central part of Russia. Potato production and innovative technologies. pp. 130-134.

Appendices

APPENDICES

Appendix I. Analysis of variance of the data on skin color (L^*, a^*, b^*, chroma, hue angle) of different potato varieties

Source of variation	df	Mean square				
		Skin color				
		L^*	a^*	b^*	Chroma	Hue Angle
Replication	2	0.144	0.377	0.002	0.005	0.001
Treatment	39	55.596**	15.788**	76.350**	51.665**	0.070**
Error	78	0.173	0.099	0.042	0.039	0.001

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix II. Analysis of variance of the data on flesh color (L^*, a^*, b^*, chroma, hue angle) of different potato varieties

Source of variation	df	Mean square				
		Flesh color				
		L^*	a^*	b^*	Chroma	Hue Angle
Replication	2	0.043	0.020	0.038	0.027	0.001
Treatment	39	30.541**	4.428**	95.284**	92.521**	0.008**
Error	78	0.041	0.043	0.033	0.032	0.001

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix III. Analysis of variance of the data on average weight, volume, diameter, specific gravity and dry matter content of different potato varieties

Source of variation	df	Mean square				
		Average weight	Volume	Diameter	Specific gravity	Dry matter content
Replication	2	430.587	381.113	0.696	0.001	0.048
Treatment	39	2033.428**	1795.934**	1.614**	0.011**	25.553**
Error	78	95.173	72.804	0.016	0.001	0.309

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on starch content, reducing sugars, non reducing sugars, total sugars and total soluble solid (TSS) of different potato varieties

Source of variation	df	Mean square				
		Starch content	Reducing sugars	Non reducing sugars	Total sugars	Total soluble solid (TSS)
Replication	2	0.046	0.001	0.007	0.009	0.201
Treatment	39	30.324**	0.082**	0.032**	0.051**	2.397**
Error	78	0.350	0.001	0.001	0.002	0.113

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on protein, ash content and chips color (L^*, a^*, b^*) of different potato varieties

Source of variation	df	Mean square				
		protein	ash content	Chips color		
				L^*	a^*	b^*
Replication	2	0.035	0.001	0.331	0.365	0.549
Treatment	39	2.429**	0.146**	79.888**	38.822**	73.873**
Error	78	0.057	0.002	0.089	0.054	0.048

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on chips color (chroma, hue angle) and crispness of different potato varieties

Source of variation	df	Mean square		
		Chips color		Crispness
		Chroma	Hue angle	
Replication	2	0.618	0.001	0.011
Treatment	39	71.011**	4.966**	3.431**
Error	78	0.046	0.001	0.034

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

PLATES

Plate 1: Experimental view

Plate 1: Experimental view

Plate 1: Experimental view

Plate 2: Days to emergence

V_9As_0

$V_{10}As_0$

$V_{14}As_2$

Plate 3: Plant height at 30 DAP

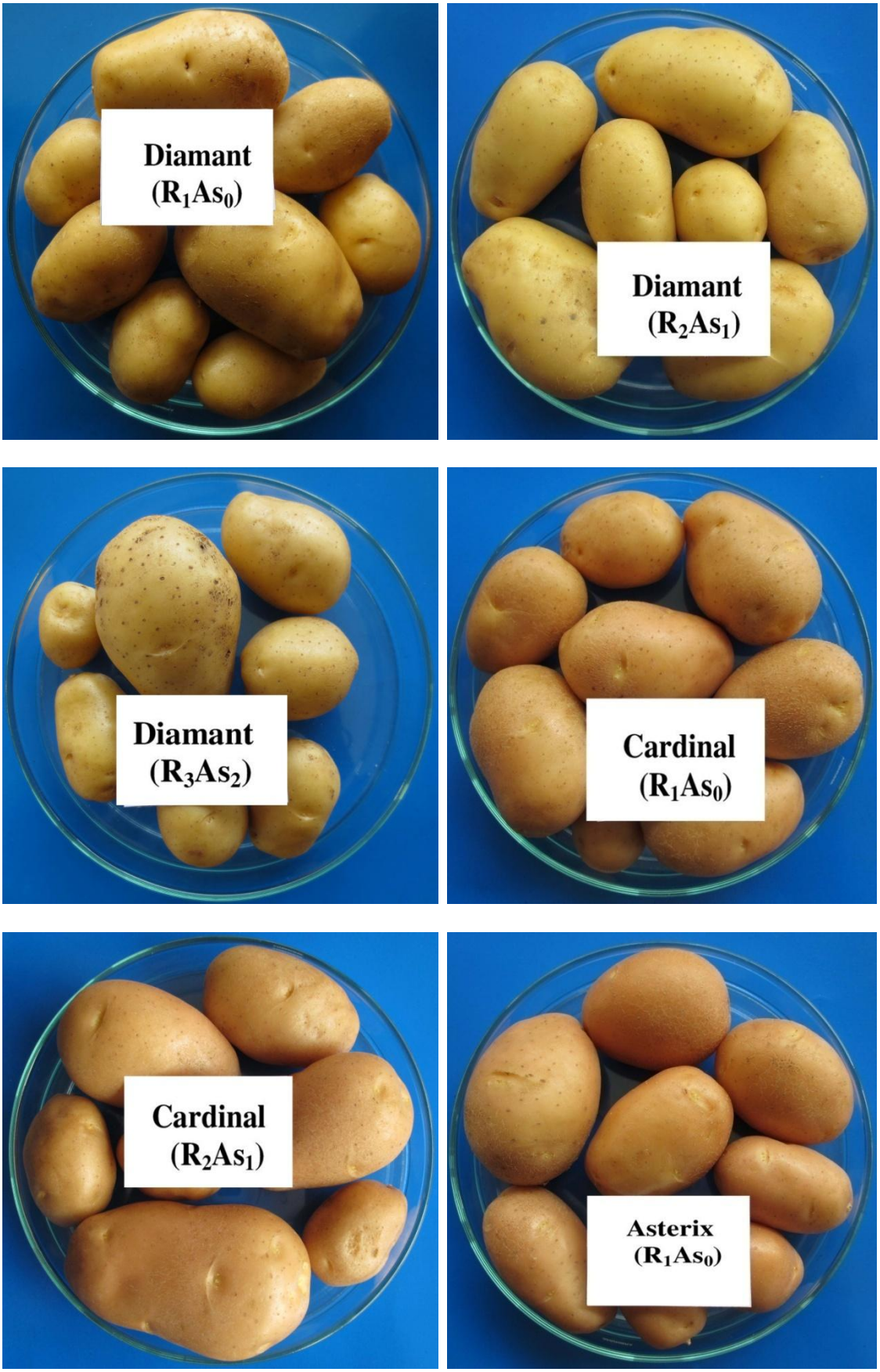


Plate 4: Potatoes produced from different treatment combinations

Plate 4: Continued

Plate 4: Continued

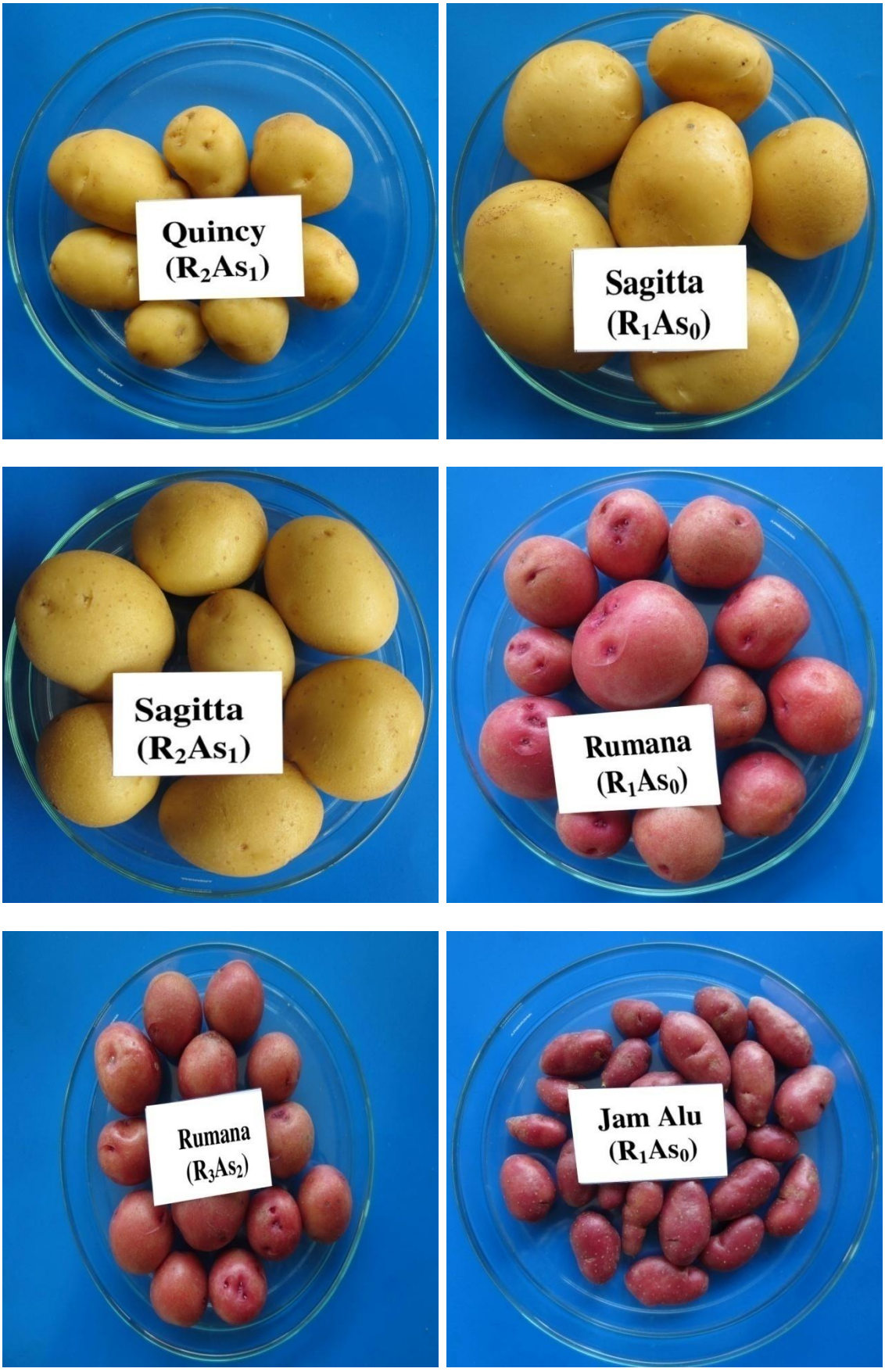


Plate 4: Continued

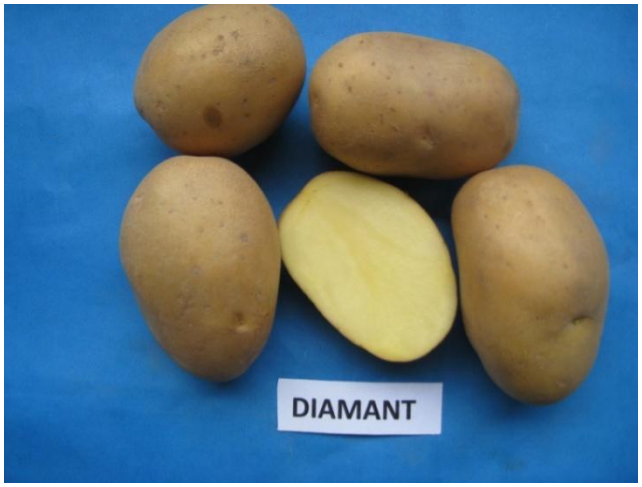


Plate 2. Different potato varieties

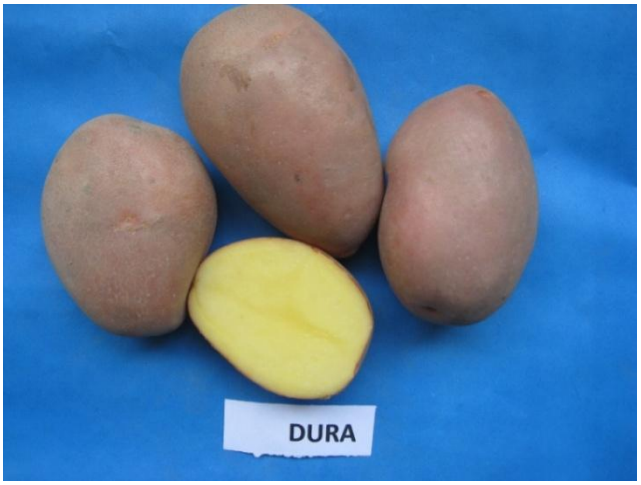
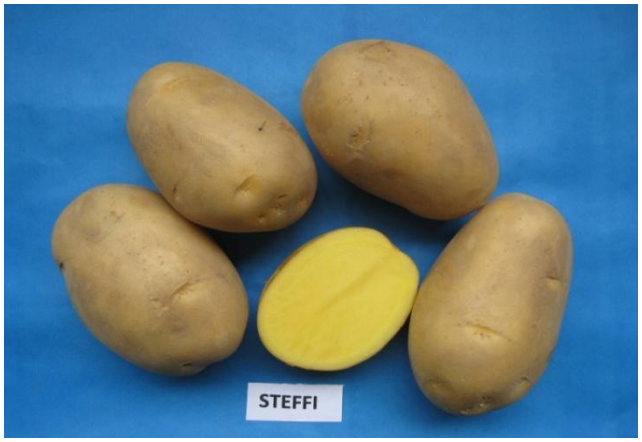


Plate 2. Different potato varieties (Continued)



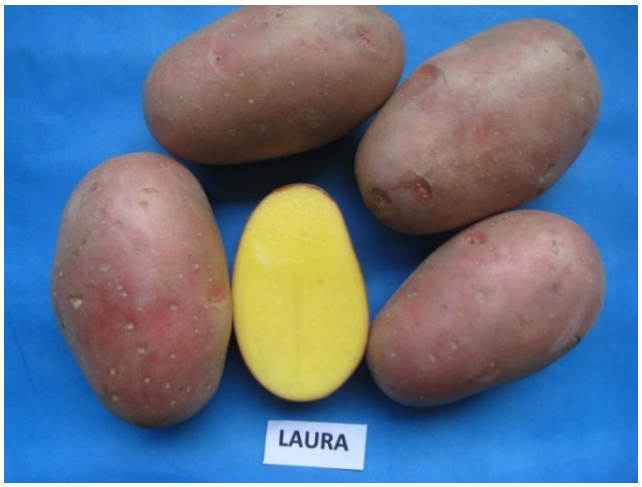


Plate 2. Different potato varieties (Continued)

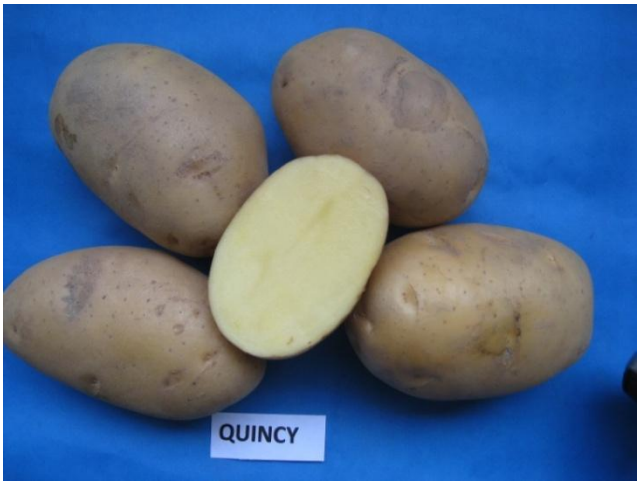


Plate 2. Different potato varieties (Continued)

Plate 2. Different potato varieties (Continued)

Plate 2. Different potato varieties (Continued)

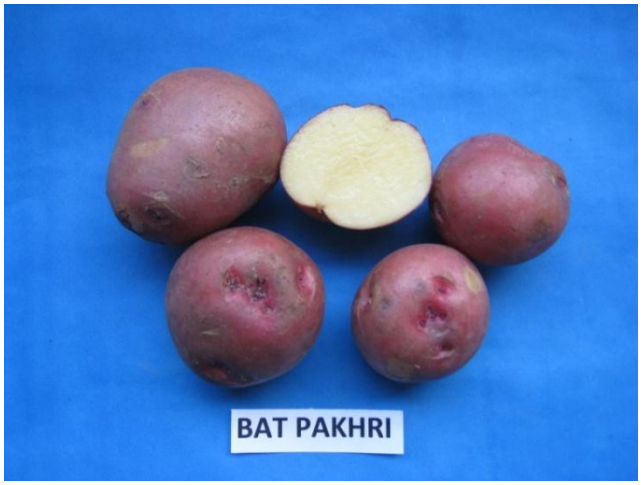
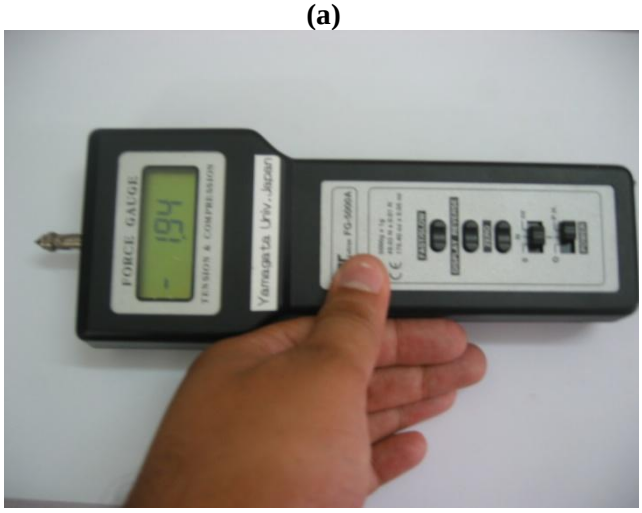


Plate 2. Different potato varieties (Continued)

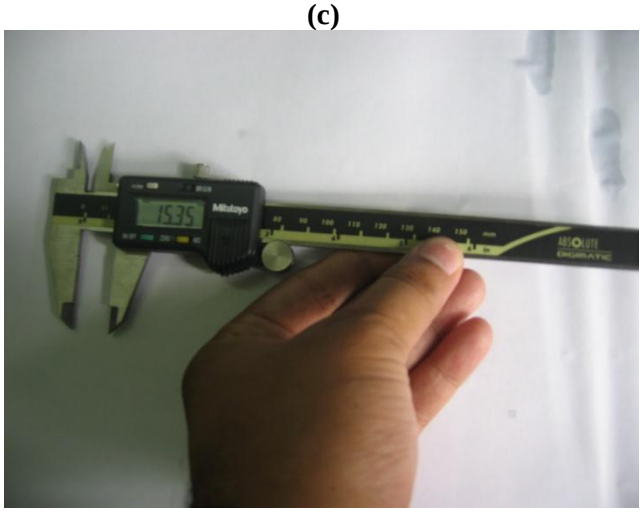
(a)

(b)



(c)

(d)



(e)

(f)

Plate 3. (a) Electronic precision balance in gram (g) **(b)** Color meter NF 333 (Nippon Denshoku, Japan) **(c)** Texture Analyzer, (Sun scientific co. Ltd, Japan) **(d)** Portable hand Refractometer (ERMA, Tokyo, Japan) **(e)** Digital Caliper (DC-515) in millimeter (mm) **(f)** Spectrophotometer (Apel, PD-303S, Japan)