



## Article

# Dry Matter, Starch Content, Reducing Sugar, Color and Crispiness Are Key Parameters of Potatoes Required for Chip Processing

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**Abstract:** To make potato production more sustainable for smallholder farmers, product diversification through processing is critical. On the other hand, the processing sector mandated some stringent standards in order to maintain product quality, hence potato quality evaluations are required for chip processing industries. Specific gravity, starch, reducing sugars, tuber dry matter, and chip color are all important characteristics to consider for processing. This study was designed to find suitable potato varieties with satisfactory attributes for processing chips, in comparison with other processing potato varieties. Keeping this in mind, the study was performed during the winter season of 2019–2020 and 2020–2021 in Bangladesh. Six processing types of potato varieties viz. BARI Alu-25 (Asterix), BARI Alu-28 (Lady Rosetta), BARI Alu-29 (Courage), BARI Alu-68 (Atlantic), BARI Alu-70 (Destiny), and BARI Alu-71 (Dolly) were evaluated for different quality parameters (specific gravity, dry matter, starch content, reducing sugar, chip color, and crispiness). The result of the study showed an ample variation in the studied parameters among the potato varieties. Among the varieties, BARI Alu-28 (Lady Rosetta) and BARI Alu-29 (Courage) were found better for all the quality parameters, such as dry matter, starch, reducing sugar, chip color, and crispiness, and could be recommended for the processing industries.

**Keywords:** potato; specific gravity; starch; reducing sugar; chips

## 1. Introduction

The potato (*Solanum tuberosum* L.) is the world's most vital non-cereal food crop and is ranked as the 4th most important harvested food crop following wheat, corn, and rice [1]. It has a momentous contribution to ensure food and nutritional security because of its yield potential and nutritional value. Considering the high yield potential, it can be a good alternative for cereal crops that have a high harvesting index above 75% [2,3]. Potato is high in starch content and low in sugar and fat. It is a good source of energy, with vitamins including vitamin B6, niacin, folate, vitamin C and minerals such as potassium, iron, phosphorus, and magnesium [4,5]. The potato is also a rich source of natural dietary antioxidants [6,7], which are advantageous to human beings because they defend against cardiovascular disease and reduce blood cholesterol levels [8].

According to the Statistical Database of Food and Agriculture Organization (FAO-STAT) [9], Bangladesh ranks in the 8th position in potato production among the potato producing countries around the world, and the potato is considered the 2nd most important food crop in the country [9]. The country's average yield of potatoes is 20.61 t/ha with a total production of 9.65 million tons (Mt) from 0.47 million hectares (Mha) of land. Potato production has increased from 1.55 Mt to 9.65 Mt and the production area has also increased from 0.136 Mha to 0.47 Mha over the last two decades, which improved the per unit area production by 1.80-fold [9]. The most striking information is that only two-thirds of produced potatoes are used for table purposes, with a small portion for processing potatoes and the rest of the potatoes remain in excess in the country. So, the probable solution for this excess amount of potatoes is to export to other countries or utilize it by processing. Nowadays, the demand for processed potato products is also increasing due to urbanization, increasing attraction to fast foods, employing women's preference for ready-to-eat food, introducing of innovative ethnic food products, increasing income, etc.

Chips, French fries, flakes, and pre-peeled potatoes are all examples of potato-based value-added processed products. Potato chips are a famous potato snack that are eaten all over the world, made by frying thin slices of potato in either oil or fat [10]. Potatoes with the high dry matter, polyphenol, starch, antioxidant, and low sugar content are considered as good processing qualities of potatoes [11]. The cultivars that are used for table consumption have high reducing sugar and low dry matter (<20%), which result in low performance in processing attributes, especially in chip color and crispiness [12]. That is why industrialists always prefer and use the processing cultivars rather than the table purpose cultivars. The demand for processing cultivars is increasing day by day in Bangladesh, as some of the companies, such as Bombay Sweets, Quasem Foods, Ltd., Giant Agro, Pran Agro, Ltd., etc., have already started to make potato-processed products.

The Tuber Crops Research Center (TCRC) of the Bangladesh Agricultural Research Institute (BARI) is working on the development of potato varieties based on different characters and, until now, 91 potato varieties have been released by the Bangladesh Agricultural Research Institute (BARI) [13]. Among the varieties, about 10 varieties were released as processing varieties and multi-location trials of those processing varieties showed higher dry matter (20–25%), low reducing sugar, and higher yield (>30 t/ha). Specific gravity, dry matter, reducing sugar concentration, and chip color score are all well-known processing quality characteristics for potatoes. The dark color and unpleasant taste of processed food during frying have a negative impact on consumer acceptance [14], which happens via the reaction between reducing sugars and amino acids, called the 'Maillard reaction' [15]. So, for the processing of potatoes, a low reducing sugar level is always expected. Reducing sugar and dry matter content of potato tuber largely depends on maturity, temperature, water, mineral nutrition, and storage of tubers [16].

The increased demand for processed foods may encourage proper utilization of surplus potatoes of Bangladesh and there is a huge scope for the export of potato chips in neighboring countries, such as Sri Lanka, Nepal, and Bhutan. Until now, the processing varieties were not evaluated only for the processing qualities and this will be interesting work to evaluate these varieties for processing qualities, which will be a game-changer in the chip processing industry of Bangladesh. Considering the above fact, the present research aims to find out the best BARI released processing varieties with better qualities and chemical properties that are required for making potato chips.

## 2. Materials and Methods

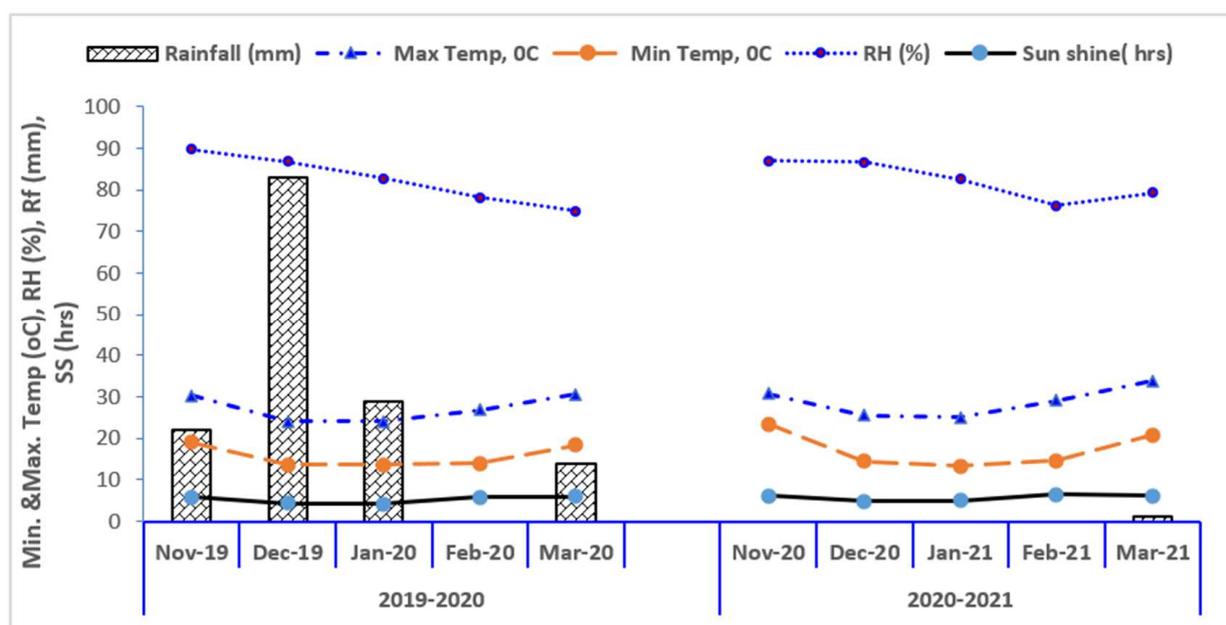
### 2.1. Location and Agro-Climatic Situations

The field research was performed during the rabi season in two consecutive years (2019–2020 and 2020–2021) at the research field (23°59'12.9" N latitude and 90°24'41.5" E longitude) of the Tuber Crops Research Centre (TCRC) of the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The selected site is flat in topography and is at an elevation of 20 m above sea level. The experimental soil was silty clay and

the initial other soil properties are presented in Table 1. During the potato growing period (November–March) the sunshine hours, monthly mean maximum and minimum temperature, rainfall, and relative humidity were documented and are presented in Figure 1. In the first year, there was slight rainfall, and there was no rainfall during the growing season of the second year.

**Table 1.** Initial soil features of the research fields before the experiment.

Soil Texture	pH	OM (%)	Total N (%)	K (meq100g <sup>-1</sup> Soil)	P	S	Z	B
					ppm			
Silty clay	6.3	0.62	0.07	0.11	20	10	0.70	0.2



**Figure 1.** Maximum and minimum mean monthly temperature, relative humidity (RH, %), monthly rainfall (Rf, mm), and sunshine (SS, hour) in 2019–20 and 2020–21.

## 2.2. Experimental Materials and Design

The experimental material was comprised of six BARI released processing type potato varieties, namely BARI Alu-25 (Asterix), BARI Alu-28 (Lady Rosetta), BARI Alu-29 (Courage), BARI Alu-68 (Atlantic), BARI Alu-70 (Destiny), and BARI Alu-71 (Dolly) (Table 2). The study was set up in randomized complete block (RCB) arrangements and replicated three times. The size of each plot was 9 m<sup>2</sup> (3 m × 3 m), plants spacings comprised five rows with 60 cm (between rows) × 15 cm (within rows), and a 1-m-gap was amid plots and replication.

## 2.3. Experimental Procedures and Management

In both years, well maintained and disease-free sprouted A grade (28–40 mm) whole seed tubers were planted in the last week of November. The recommended dose of manure and fertilizers were used in the form of Cow Dung, Urea, Muriate of Potash (MOP), Triple Super Phosphate (TSP), Boric Acid, Zinc Sulfate, and Gypsum [17], where half of the Urea and Muriate of Potash with a complete dose of other fertilizers were thoroughly mixed with the soil before planting. At 35 days after planting, the remaining Urea and Muriate of Potash were added as a side-dressing during earthing up. Necessary intercultural operations, for example, weeding, irrigation, earthing up, and plant preventive measures, were performed according to the recommendation of TCRC, BARI [18]. The crops were

irrigated two times, at 30 and 60 days after planting (DAP). The first irrigation was given at 8–10 DAP to ensure appropriate tuber emergence; the second and third irrigations were applied at 30 and 45 DAP, respectively. Finally, light irrigation was applied at 60 days after planting. By spading in between the ridges and covering the ridges with loose soil, two hand weeding was done before the second (at 30 DAP) and last (at 60 DAP) irrigations. The haulm was removed 10 days before harvesting to harden the skin of the potato tubers, and they were left for ten days in the field.

**Table 2.** List of potato varieties used in the study along with their characteristics.

Variety Name	Origin	Shape	Size	Skin Color	Smoothness of Skin	Flesh Color	Eye Base Color	Eye Depth	Eye Distribution	Image
BARI Alu-25 (Asterix)	The Netherlands	Oval to long oval	Medium to large	Red	Smooth	Light yellow	Red	Shallow	Even	
BARI Alu-28 (Lady Rosetta)	The Netherlands	Round to oval	Medium	Red	Rough	Light yellow	Red	Medium	Predominant	
BARI Alu-29 (Courage)	The Netherlands	Round to oval	Medium	Red	Rough	Cream	Red	Deep	Predominant	
BARI Alu-68 (Atlantic)	America	Round (compressed)	Medium	Yellow	Medium	White	Yellow	Medium	Predominant	
BARI Alu-70 (Destiny)	The Netherlands	Round to short oval	Medium	Yellow	Medium	Yellow	Red	Medium	Predominant	
BARI Alu-71 (Dolly)	France	Round (compressed)	Medium	Red	Rough	Light yellow	Red	Medium	Predominant	

#### 2.4. Data Collection and Parameters Estimation

Data were recorded on different processing and biochemical parameters, specifically, specific gravity, starch content, reducing sugar, crispiness of chips, chip color, external appearance, and tuber dry matter content from randomly selected samples.

##### 2.4.1. Specific Gravity

The method described by Kleinkopf et al. [19] was used to measure the specific gravity of potato. Five kg harvested tubers of various shapes and sizes were selected randomly from each plot were weighed in air and water using a Weltech digital hydrometer (Martin Lishman, Ltd., Bourne, UK, model: PW-2050) and the following formula was used to calculate specific gravity:

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in air} - \text{Weight of tuber in water}}$$

#### 2.4.2. Determination of Dry Matter Content

Ten tubers from the harvested potatoes of each variety were randomly selected for tuber dry matter estimation. After that, the samples were weighted to 200 g two sub-samples, then after washing, cutting, and mixing, the samples were dried in a drying oven (Memmert GmbH, UN-260, Schwabach, Germany) for 72 h at 72 °C. The dry matter was computed as a percentage based on the ratio of dry to fresh mass [20]. Additionally, the dry matter content was also estimated using the digital hydrometer method (Martin Lishman, Ltd., Bourne, UK, model: PW-2050).

#### 2.4.3. Extraction of Sugar and Starch

To evaluate the reducing sugar and starch of each treatment, potato flesh was removed. At first, chopped potato of 1g was taken from the tuber samples and smashed properly with a motor. Then, 5 mL of 80% EtOH (Ethanol) was added and heated in a dry block heat bath for 30 min at 80 °C and the extracts were then centrifuged for 10 min at 5000 rpm. The supernatant was then decanted, and the process was repeated four to five times in total. All of the supernatants were combined and thoroughly mixed together, and 80% ethanol was used to make the final volume 25 mL, and sugar was extracted from this solution. The residues from this extraction process were collected for analysis of starch content.

#### 2.4.4. Reducing Sugar Content Determination

The Somogyi method [21] with slight modifications was used to determine the reducing sugar of the tested potato varieties. At first, a small glass container was taken, and 3 mL of the extracted solution was added to it, and using an electric heater, dried properly. After that, 3 mL of distilled water was cojoined and mixed well with the help of a vortex. Second, the solution (0.5 mL) was taken from the glass container into a test tube and added 0.5 mL of copper solution in the test tube. Then the mixture was boiled for 10 min at 100 °C and cooled with running water immediately after boiling. After that, 0.5 mL Nelson reagent was added and diluted thoroughly. After 20 minutes, the final volume was made 9.5 mL by adding and mixing 8 mL of distilled water. Finally, the absorbance was quantified with a spectrophotometer at 660 nm wavelength (Abs) against a blank sample. Then, reducing sugar was enumerated from the absorbance value and stated as  $\text{mg g}^{-1}$  FW.

#### 2.4.5. Starch Content Determination

The amount of starch in a potato was quantified following the Somogyi–Nelson method [21] with some adjustments. At first, 0.09 g  $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$  and 0.74 g  $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$  was added into double-distilled water of 100 mL and prepared a phosphate-buffered solution. Second, 0.1 g of Amyloglucosidase was mixed properly into the solution and kept at  $-20$  °C. After the sugar extraction, the remaining residues were rinsed numerous times with distilled water to ensure that they were free of any soluble sugar. After that, the authors filled a beaker with distilled water up to 250 mL and stirred it with a magnetic stirrer. The solution (0.5 mL) was then transferred to a test tube and heated at 100 °C for 10 min while stirring, with 1 mL of stored solution added, then blended properly, and then heated for 120 min in a hot water at 50–60 °C. Then the mixture was cooled down and 0.5 mL of copper solution was mixed well with the mixture and boiled for 10 min at 100 °C. Again, the mixture was cooled down, then 0.5 mL Nelson solution was added, followed by 7 mL of distilled water, and it was carefully blended to make a final volume of 9.5 mL. Finally, the absorbance was measured against a blank sample using a spectrophotometer at a 660 nm wavelength (Abs). Using a glucose standard curve, the starch content was determined and expressed as  $\text{mg g}^{-1}$  FW.

#### 2.4.6. Blanching and Potato Chip Preparation

Blanching is a crucial step in the frying of potatoes for improving the texture and color of the fried potatoes, as well as reducing oil uptake of surface starch through gela-

tinization [22]. It also inactivates discoloration-related enzymes [23], reduces the sugar content [24], and makes them crispier. The chips were prepared after one month of harvesting with all the conditions of industrial processing. Ten healthy potato tubers were randomly picked from each replication and washed, peeled, and sliced using a hand-operated chip cutter. The thickness of the slice was 1.5 mm thick, and after slicing, the slices were promptly washed in tap water for about 1 min. Then the slices were blanched at approximately 60 °C for 1 min and then cooled in normal water. Finally, the slices were covered with tissue paper to soak up excess surface water to make it dry. After drying the potato slices, they were fried according to Kita et al. [25] with slight modifications. Ten liters of refined soybean oil was heated in a deep fryer (Longer, LG-1000, ZhengZhou, China) to raise the temperature to 180 °C and checked with a thermometer. After that, 500 g of blanched potato slices were deep-fried in the fryer for 3 min. The fried chips were drained for 5 min on a wire screen and cooled to room temperature, stored in plastic bags, and kept in the ambient environment for future experiments.

#### 2.4.7. Assessment of Potato Chips Color

The method of Dervisi et al. [26] was used to measure the external color of the potato chips with a Chroma meter (Model CR-400, Minilta Corp., Japan). CIE L\*a\*b\* coordinates were recorded using D65 illuminants and a 10° standard observer was used as a reference system. Here, a\*(-greenness to +redness) and b\* (-blueness to +yellowness) are chromaticity coordinates, while L\* is lightness. The chroma [ $C^* = (a^{*2} + b^{*2})^{1/2}$ ] and hue angle [ $H^* = \tan^{-1}(b^*/a^*)$ ] were calculated by the converted value of a\* and b\*. The device was calibrated against a standard white tile before the measurement and the values of Lightness (L\*), Hue angle (H\*), and Chroma (C\*) were then adjusted. Besides this, the chips were again scored using a color card on a 1–10 scale according to Ezekiel et al. [27], where 1 represents a light color and 10 represents a dark brown color.

#### 2.4.8. Measurement of Chips Crispiness

The crispiness of the fried chips was evaluated through a TA.XT plus texture analyzer (Stable Micro Systems, Ltd., Surrey, Godalming, UK). The probe of the analyzer was inserted through the middle of the chips by the back extrusion technique. The operative characteristics of the instrument were determined using the test mode compression with a speed of 1 mm/s. After removing the chips from the frying oil, the texture measurements were completed two hours later. For each replication, three potato chips were analyzed, and the average data were recorded. The crispiness was determined by measuring the probe's travel distance (mm) prior to the first break, which was indicated by a sharp drop in force. If the amount of distance was lower, chips were assumed to be crispier.

#### 2.4.9. Sensory Evaluation of Chips

The sensory quality attributes of the potato chips of different varieties were evaluated by a few panel tests after 15 days of frying. A judgment panel was formed comprised of 10 members from the Tuber Crops Research Center inter-divisional scientists to evaluate the appearance, aroma, taste, and overall acceptability of the chips based on a (0–9) hedonic scale [28].

### 2.5. Statistical Data Analysis

The collected data on different parameters were analyzed through analysis of variance (ANOVA) by statistical computer software R x 64-program v3.3.2 [29]. The treatment means were compared to find the significant variation among the treatments by the Least Significant Difference (LSD) test at a 5% level of probability. The Pearson correlation coefficients were also calculated among the quality parameters (specific gravity, starch, dry matter, reducing sugar, crispiness, and chip color) using the Metan package of R.

### 3. Results and Discussion

#### 3.1. Specific Gravity and Dry Matter Content

Dry matter and specific gravity are the index of good processing quality for potatoes, which mostly controls the crispiness, color, oil absorption, flavor, and texture [30]. The results showed significant variation both in the case of specific gravity and dry matter content (Table 3). Among the varieties, BARI Alu-28 (1.085), BARI Alu-29 (1.084), and BARI Alu-71 (1.083) demonstrated maximum specific gravity than the other varieties. On the other hand, BARI Alu-28 (22.61%) exhibited maximum dry matter content followed by BARI Alu-29 (21.72%) in the oven-dry method, and BARI Alu-28 (21.42%) followed by BARI Alu-71 (21.11%), BARI Alu-68 (20.73%), and BARI Alu-29 (20.29%) in the digital Hydrometer method. The existing variation in dry matter and specific gravity may be because of genetic differences, as all the varieties were grown and evaluated providing similar management practices. Processing efficiency, i.e., the maximum recovery of processed produce, is greatly influenced by the dry matter content of the tuber [31].

**Table 3.** Various processing quality parameters of potato varieties.

Varieties	Specific Gravity	Dry Matter (%) (Oven Dry Method)	Dry Matter (%) (Digital Hydrometer Method)	Starch (mg/g Fresh wt.)	Reducing Sugar (mg/g Fresh wt.)	Crispiness (mm)
BARI Alu-25 (Asterix)	1.074 <sup>bc</sup>	19.88 <sup>d</sup>	18.72 <sup>b</sup>	21.15 <sup>c</sup>	0.724 <sup>b</sup>	0.880 <sup>b</sup>
BARI Alu-28 (Lady Rosetta)	1.085 <sup>a</sup>	22.61 <sup>a</sup>	21.42 <sup>a</sup>	26.06 <sup>a</sup>	0.591 <sup>c</sup>	0.723 <sup>c</sup>
BARI Alu-29 (Courage)	1.084 <sup>a</sup>	21.72 <sup>ab</sup>	20.29 <sup>ab</sup>	24.66 <sup>b</sup>	0.619 <sup>c</sup>	0.731 <sup>c</sup>
BARI Alu-68 (Atlantic)	1.079 <sup>ab</sup>	20.89 <sup>bc</sup>	20.73 <sup>a</sup>	21.36 <sup>c</sup>	0.787 <sup>ab</sup>	0.947 <sup>a</sup>
BARI Alu-70 (Destiny)	1.068 <sup>c</sup>	20.63 <sup>cd</sup>	19.04 <sup>b</sup>	21.47 <sup>c</sup>	0.809 <sup>a</sup>	0.748 <sup>c</sup>
BARI Alu-71 (Dolly)	1.083 <sup>a</sup>	21.38 <sup>bc</sup>	21.11 <sup>a</sup>	22.26 <sup>c</sup>	0.645 <sup>c</sup>	0.902 <sup>ab</sup>
CV (%)	0.396	2.495	4.277	2.760	5.994	4.238
Significance Level	**	**	*	***	***	***

CV (%)—coefficient of variation; Means with a similar letter(s) in the same column are statistically the same and values with a different letter(s) are significantly different; (\* directs  $p \leq 0.05$ , \*\* directs  $p \leq 0.01$ ; \*\*\* directs  $p \leq 0.001$ , highly significance).

#### 3.2. Starch Content of Different Processing Varieties

Starch content (mg/g FW) among the potato varieties was found to vary significantly, ranging between 26.06 mg/g FW to 21.15 mg/g FW (Table 3). BARI Alu-28 (26.06 mg/g FW) showed maximum starch content followed by BARI Alu-29 (24.66 mg/g FW). The differences in starch content may be demonstrated because of genetic makeup and cultural practices at the time of growing, or due to the variation in dry matter of the tested processing potato varieties since starch content of potato tubers has a strong association with dry matter content [12,16,32]. The starch content of tubers is related to their dry matter content [33]. Tubers with higher levels of dry matter and starch have a crispier texture, provide more chips, and limit fat absorption during frying [34].

#### 3.3. Reducing Sugar Content of Different Processing Varieties

Significant variation (0.591–0.809 mg/g FW) for reducing sugar was found among the processing varieties. Reducing sugar content was lowest in BARI Alu-28 (0.591 mg/g FW), followed by BARI Alu-29 and BARI Alu-71 (Table 3). The ability to have a high or low sugar content of a potato variety is a heritable feature and influenced by the genotype, environmental and cultural factors (temperature, moisture, nutrition, etc.), area, year, tuber maturity, and storage condition [16,35]. Sharker et al. [36] reported that to keep the light color of potato chips during frying, the reducing sugar content should be less than 2.5–3 mg per gram of potato. Tubers have low quantities of reducing sugars and yield light-colored chips immediately after harvest [37]. In this experiment, the higher reducing sugar content of the varieties could be attained by the different weather conditions than the original weather conditions, as these are exotic potato varieties. It has been reported that the reducing sugars of potatoes are regulated by variety, cultural, and environmental factors [38]. Acrylamide, a potentially carcinogenic substance found in potato chips,

varies based on the chemical makeup of the tubers utilized, particularly the reducing sugar level [35].

### 3.4. Chips Crispiness and Color

The potato varieties differed significantly in the quality of crispiness (Table 3). The potato varieties BARI Alu-28, BARI Alu-29, and BARI Alu-70 showed the lowest value for crispiness (0.723 mm, 0.731 mm, and 0.748 mm, respectively), which means that they were crispier than the other varieties. The crispiness of chips depends on the dry matter of the raw potato. Chips from the raw potato with a high dry matter content have a hard texture, resulting in crispy chips, whereas chips from a potato with low dry matter contained more oil, appeared greasy, and had sticky textures [39]. The crispiness is also directly associated with the amount of starch and reducing sugar of the potato [40].

There was a wide variation found in the Lightness ( $L^*$ ), Hue angle ( $H^*$ ), and Chroma ( $C^*$ ) parameters of the tested genotypes (Table 4). Light colored chips ( $L^* > 50$ ) were found from all the tested varieties, which indicates that there was no unnecessary dark color but chips produced from BARI Alu-28, BARI Alu-29, and BARI Alu-71 were lighter than the others (Figure 2). This can be attributed to low reducing sugar levels exhibited by the varieties. The chroma and hue angle were also significantly affected by the varieties. A significantly similar chroma value ( $27.21 \pm 1.78$ – $28.96 \pm 0.66$ ) was found in BARI Alu-28, BARI Alu-29, BARI Alu-70, and BARI Alu-71. The hue angle ( $H^*$ ) value was also highest in BARI Alu-28 and BARI Alu-29. Similarly, in sensory evaluation scoring of chip color, BARI Alu-28 was noted for the lowest score ( $1.38 \pm 0.07$ ) and lightest color. The chip color for the other varieties was also in the acceptable range. The chip color variation could be the differences in composition within the varieties. Color is the first visual attribute that controls the consumers' choice for fried products, wherein a light color is acceptable compared to a brownish color. The result of this experiment conforms with the findings of Ooko and Kabira [41] and Rahman et al. [42]. Many factors influence the color and sensory qualities of potato chips, including cultivar, storage conditions prior to processing, slice thickness, frying duration, and temperature [43]. There is a limitation of the present study that the nutritional quality of the chips after frying was not analyzed, and it should be analyzed in a future experiment.

**Table 4.** Chip color (lightness, chroma, hue angle, and sensory evaluation) of different processing potato varieties.

Varieties	Chips Color			
	Lightness ( $L^*$ )	Chroma ( $C^*$ )	Hue Angle ( $H^*$ )	Sensory Evaluation Score
BARI Alu-25 (Asterix)	$60.77 \pm 2.00^c$	$20.02 \pm 0.40^b$	$83.38 \pm 1.28^{bc}$	$3.27 \pm 0.05^b$
BARI Alu-28 (Lady Rosetta)	$71.77 \pm 3.16^a$	$28.96 \pm 0.66^a$	$88.62 \pm 0.98^a$	$1.38 \pm 0.07^e$
BARI Alu-29 (Courage)	$70.88 \pm 3.71^a$	$27.24 \pm 0.56^a$	$87.50 \pm 0.65^a$	$1.82 \pm 0.07^d$
BARI Alu-68 (Atlantic)	$59.59 \pm 3.17^c$	$19.07 \pm 1.07^b$	$82.17 \pm 3.58^{bc}$	$3.17 \pm 0.15^b$
BARI Alu-70 (Destiny)	$65.29 \pm 2.65^b$	$27.21 \pm 1.78^a$	$79.68 \pm 2.44^c$	$3.82 \pm 0.10^a$
BARI Alu-71 (Dolly)	$69.35 \pm 1.37^a$	$28.69 \pm 1.94^a$	$85.95 \pm 1.70^{ab}$	$2.83 \pm 0.11^c$
CV (%)	3.276	4.647	2.621	3.679
Significance Level	***	***	**	***

CV (%)—coefficient of variation; Means with a similar letter(s) in the same column are statistically the same and values with a different letter(s) are significantly different; (\* directs  $p \leq 0.05$ , \*\* directs  $p \leq 0.01$ ; \*\*\* directs  $p \leq 0.001$ , highly significance).

### 3.5. Sensory Evaluation of Chips

To evaluate the processing quality of a variety, it is very important to check the appearance, taste, aroma and overall acceptability of fried potatoes. Acceptance of potato chips is a critical requirement for the potato processing sector, and it is based entirely on consumer perception. There was a variation in appearance, aroma, taste and overall acceptability among the tested varieties. In appearance BARI Alu-29 (Courage) showed better (8.70)

which were very close in scoring to BARI Alu-28 (Lady Rosetta). BARI Alu-28 (Lady Rosetta) obtained the highest score in taste (8.97), aroma (7.47) and overall acceptability (8.40) which was very close to BARI Alu-29 (Courage) (Table 5). The most essential sensory elements on which customers base their evaluation of potato chips are flavor, aroma, color, and texture [44]. Aroma is an important quality of a product and some authors from the previous studies reported that consumers did not appear willing to negotiate on a product's flavor, regardless of its health advantages or other good consequences. [45]. Besides this, the taste is also controlled consumer acceptance of a food product [46].

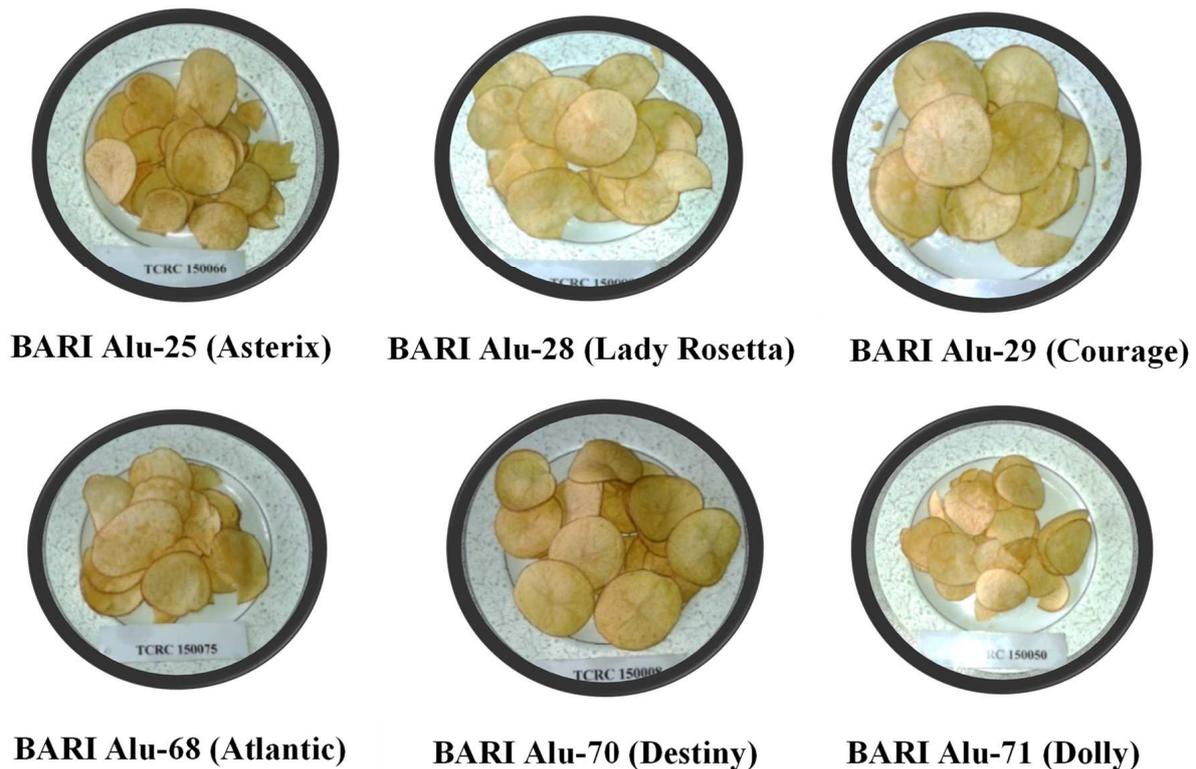


Figure 2. Chips color of various processing varieties.

Table 5. Different sensory attributes (appearance, taste, aroma, overall acceptability) of potato chips.

Varieties	Sensory Attributes			
	Appearance	Taste	Aroma	Overall Acceptability
BARI Alu-25 (Asterix)	7.07 ± 0.25 <sup>cd</sup>	8.77 ± 0.21 <sup>ab</sup>	7.23 ± 0.25 <sup>a</sup>	7.97 ± 0.15 <sup>ab</sup>
BARI Alu-28 (Lady Rosetta)	8.67 ± 0.12 <sup>a</sup>	8.97 ± 0.06 <sup>a</sup>	7.47 ± 0.32 <sup>a</sup>	8.40 ± 0.40 <sup>a</sup>
BARI Alu-29 (Courage)	8.70 ± 0.10 <sup>a</sup>	8.83 ± 0.15 <sup>ab</sup>	7.33 ± 0.29 <sup>a</sup>	8.30 ± 0.26 <sup>a</sup>
BARI Alu-68 (Atlantic)	8.27 ± 0.15 <sup>b</sup>	7.87 ± 0.21 <sup>c</sup>	7.20 ± 0.30 <sup>ab</sup>	7.87 ± 0.38 <sup>ab</sup>
BARI Alu-70 (Destiny)	7.37 ± 0.15 <sup>c</sup>	8.60 ± 0.26 <sup>b</sup>	6.90 ± 0.30 <sup>b</sup>	7.50 ± 0.30 <sup>b</sup>
BARI Alu-71 (Dolly)	6.73 ± 0.32 <sup>d</sup>	8.63 ± 0.15 <sup>ab</sup>	7.37 ± 0.21 <sup>a</sup>	7.60 ± 0.26 <sup>b</sup>
CV (%)	2.375	2.240	2.427	3.770
Significance Level	***	***	*	*

Hedonic Scale: 9 = Like Extremely, 8 = Like Very Much, 7 = Like Moderately, 6 = Like Slightly, 5 = Neither Like nor Dislike, 4 = Dislike Slightly, 3 = Dislike Moderately, 2 = Dislike Very Much, 1 = Dislike Extremely; CV (%)—coefficient of variation; mean ± standard deviation; Means with a similar letter(s) in the same column are statistically same and values with a different letter(s) are significantly different; (\* directs  $p \leq 0.05$ ; \*\*\* directs  $p \leq 0.001$ , highly significance).

### 3.6. Correlations

Correlation studies among different processing parameters found a significant relationship of tested potato varieties (Table 6). Varieties with high specific gravity displayed a positive correlation with dry matter ( $r = 0.67^{**}$ ) and starch ( $r = 0.687^{**}$ ); in contrast, specific gravity exhibited a negative correlation with reducing sugars ( $r = -0.69^{**}$ ). The amount of reducing sugar in the chips demonstrated a substantial and positive relationship with the color of the chips ( $r = 0.83^{***}$ ). Tuber specific gravity is frequently used in the processing industry to estimate dry matter quickly and in this study, these two parameters are passively correlated, which conforms with the result of Killick and Simmonds [47] and Grewal et al. [48].

**Table 6.** Correlation studies among specific gravity, dry matter, starch, reducing sugar, chip color, and crispiness of potato varieties.

Parameters	Dry Matter	Starch	Reducing Sugar	Chips Color	Crispiness
Specific gravity	0.67 **	0.68 **	−0.69 **	−0.75 ***	−0.09
Dry Matter		0.84 ***	−0.63 **	−0.77 ***	−0.50 *
Starch			−0.76 ***	−0.92 ***	−0.69 **
Reducing Sugar				0.83 ***	0.35
Chips Color					0.48 *

\* Indicates the correlation is significant at  $p \leq 0.01$ ; \*\* at  $p \leq 0.01$ ; \*\*\* at  $p \leq 0.01$ .

### 4. Conclusions

Potatoes are potential food for the creation of unique food products (chips) with health advantages. However, myriads of factors influence the quality of potato chips, including varietal performance, agronomic techniques, management, environment, blanching time, and drying kinetics as well as dry matter, starch content, reducing sugar, color, and crispiness. To recapitulate from the two-year study, potato variety should be selected for potato chip processing with combined characteristics of high starch and dry matter content, a low amount of reducing sugars, and a satisfactory light color. Based on these parameters, BARI Alu-28 (Lady Rosetta) and BARI Alu-29 (Courage) demonstrated exceptional chip processing qualities and these varieties could be recommended for making chips for potato processing industries. The nutritional quality of the chips after storage and the individual role of each factor needs to determine in future research.

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