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COMPARISON OF THE COOKING CHARACTERISTICS AMONG TRUE POTATO SEED (TPS) AND SEED POTATO VARIETIES AFTER MICROWAVE HEATING

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ABSTRACT

The microwave heating has become widely popular in potato processing because of its high heating rate, short processing time, and for controlling undesirable changes in starch. In the experiment potato columns of TPS potato ‘BARI TPS-1’ and local potatoes ‘Diamant’, ‘Tel Pakri’ and ‘Romana’ were heated with 50 mL of water for 0, 20, 40, 60, 90, 120, 240, and 300 sec by a microwave oven; and the changes in potato columns were analyzed physiologically and histologically to investigate how potato tuber and starch condition changes in local potato and TPS tubers after microwave heating. The ‘BARI TPS-1’ potato columns resulted comparatively higher rate of weight loss and firmness loss percentage than the other seed potato varieties, indicating that temperature rapidly increased in TPS tuber columns than that of the others. Among local varieties ‘Tel Pakri’ gave a relatively higher weight loss and firmness loss percentage than the others. This study also showed comparatively higher solubility percentage in ‘BARI TPS-1’ tuber than the other local varieties, suggesting rapid disruption of swollen starch granule and faster starch degradation in TPS than the other local potato starches. Scanning Electron Microscope (SEM) images of starch granule showed rapidly ruptured and clumped starch granules in ‘BARI-TPS-1’ than the others, indicating TPS starch might obtain gelatinization temperature within a shorter period of microwave heating than that of the other varieties.

Keywords: Firmness, microwave heating, potato, starch granule, TPS

INTRODUCTION

Microwave heating is recently being widely used in processing and cooking of potato (*Solanum tuberosum* L.) tuber products including boiled potato, salad, mashed potato, chips, french-fry, starch and alcohol due to its uniform heating and reduced cooking time **(Vollmer, 2003)**. Microwave energy induced significant changes in physicochemical and textural properties of potato tubers, which contributed to the quality of processed potato products **(Sadowska, 2005; Vadivambal and Jayas, 2008)**. The cooking characteristics of potato tubers are also influenced by the properties of different potato cultivars **(Maragoni and Yada, 1994; Wilson, 2002)**.
There are several studies on how microwave treatment affects potato tuber quality. Different cooking conditions have significantly different effects on the properties of potato tubers **(Yang, 2016)**. Weight loss and reduction of firmness in microwave-treated Russet potato tubers after treating by microwave for 0.5, 1, and 2 min at 46, 65, and 90°C temperature, respectively **(Huang *et al.*, 1990)**. Microwave energy produced comparable softening than conventional heating upon a prolonged heating time (**Collins and McCarty, 1969)**. It was also reported by **Orsat *et al.* (2005)**.
Microwave radiation affects the physiochemical properties, structure, and behavior of potato starches **(Lewandowicz *et al.*, 1997)**. Different heating times may inflict a different degree of damages on starch granule condition. Heat moisture treatment causes the starch to swell, alters the structure of granules, and leads to deformation of the starch granules because of the rapid processing of heat in a short time (**Nadiah *et al.*, 2015)**. Another study showed that textural changes in cooked sweet potato were related with starch properties, with a high gelatinization percentage and greater water absorption capacity, which led to produce hydrolysis and cell wall solubilization **(He *et al.*, 2013)**. The heat-moisture treatment of starch can cause damage to granular integrity and birefringence losses **(Singh *et al.*, 2004)**. On the other hand, **(Zylema *et al.*, 1985)** stated that no difference in the swelling of starch granule during microwave and conduction heating at the same heating rate. However, there is considerable varietal variation in the characteristics of potato product texture depending on processing or cooking methods applied **(Hassanpanah *et al.*, 2011)**.
Suitable varieties of high-quality seed potatoes are an essential requirement for profitable and sustainable potato cultivation **(NIVAP, 2007)** as well as potato products. As a useful solution for long storage and low cost transportation, True Potato Seed (TPS) or the actual ‘Botanical potato seed’ were introduced to reduce production costs and increase the availability of high quality disease-free tubers without depending on multiplication of seed tuber. However, there are few studies on the properties of tubers produced from TPS as processed potato compared to common potatoes. These studies could allow determining the texture and starch characteristics of different varieties which may contribute valuable information for processed potato products. Therefore, further research needs to be conducted to study the issue of microwave heating on the structure of local seed potato and TPS tubers. The purpose of this study was to clarify how the local potato and TPS tubers change morphologically and physiologically; and how the starch condition of local potato and TPS tubers changes histologically after microwave heating.

MATERIALS AND METHODS

Plant Material

The experiment was conducted at two universities in Bangladesh and Japan. In October 2015, potato tubers of True Potato seed (TPS) variety of ‘BARI TPS-1’ and seed potato varieties of ‘Diamant’, ‘Romana’ and ‘Tel Pakri’ were harvested and collected from Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Bangladesh (Plate 1). Seventy tubers for each cultivar were taken for the experiment. All the materials were of 25-30 days and non-stored tubers. Size, weight, and the specific gravity of all the tubers were measured. This part of the experiment was conducted at the laboratory of the Department of Agronomy, Faculty of Agriculture, She-e-Bangla Agricultural

University, Bangladesh**.** Both sides of each potato tuber were cut and a column (0.5 cm in diameter × 1 cm in height) from the tuber was drawn out by using a cork borer. The columns were taken for the microwave treatment. The samples were brought to Japan for further analysis. The sample analysis was done at the laboratory of the Department of Bioproduction, Faculty of Agriculture, Yamagata University, Japan.

a. Diamant **b. Romana**

c. Tel Pakri **d. BARI TPS-1**

Plate 1 Potato varieties used for microwave heating

Preparation of microwave-treated samples

Potato column from each cultivar was taken in a container and 50 mL of water was poured into the container. Each potato column was then treated for 0 (without microwave heating) and 20, 40, 60, 90, 120, 240, and 300 sec microwave heating. Each of the samples was always kept in the same position (center) within the microwave to avoid any change in power absorption. Multiple preliminary tests were conducted to select the conditions required for each treatment following the technique previously prescribed by **Palav and Seetharaman (2007).**

Water Loss and Hardness Measurement

Potato columns were weighed before and after the heat treatments for the measurement of water loss or weight loss. Potato firmness was also measured before and after the heat treatments using a Force Gauge equipped with a 5 mm triangle plunger. The weight loss was expressed by the ratio of the weight difference between the fresh and treated samples to the original weight. The firmness loss was also expressed by the ratio of shear force difference between the fresh and treated samples to the original shear force.

Histological analysis of starch granule

Before and after heating by microwave oven three to five cubic samples (approx. 5 mm) were taken from a few parts of each treated column, and dipped into 5 mL Formaldehyde-acetic acid alcohol (FAA), and kept at ambient temperature. All of the treated and untreated tuber samples were stored at -20°C and lyophilized. The microstructure of the dried sample was measured by cutting the cubes half longitudinally along the central pith. Small pieces revealing advanced lesion were prepared for Scanning Electronic Microscope (SEM) studies after coating Pt by ion coater. The rest of the dry samples were then crushed and the powder was stored at -20°c.

Swelling and Solubility

Swelling and solubility of starch were determined by adopting the method prescribed by **Schoch (1964)**. Approximately 0.5 g of powdered samples of each treatment were mixed with 25 mL of distilled water in a centrifuge tube and heated at 85°C in a shaking water bath for 30 min. The starch solution was cooled at ambient temperature and then centrifuged (5100 KUBOTA, Tokyo, Japan) for 15 min at 3500 rpm. After centrifugation, the swelling was determined as sediment weight (g/g), while the supernatant was used for measuring the solubility of starch. The supernatant was carefully decanted to metal crucible dish, and dried overnight at 105ºC in an oven, and solubility was calculated. The swollen starch sediment in the tube was weighed. Swelling and solubility of the starches were calculated using the following formulae:

$$Swelling\ (g/g) = \frac{W_{sd}}{W_{s\ dry\ basis}} \ldots\ldots\ldots\ldots\ldots (1)$$

$$Solubility\ (\%) = \frac{W_d}{W_{s\ dry\ basis}} \times 100 \ldots\ldots\ldots\ldots\ldots (2)$$

Where, W_{sd} = dried sediment mass, W_s = original sample weight, W_d = dried residue.

Statistical analysis

Data were processed by analysis of variance (ANOVA) and reported as the mean ± standard error (SE) and multiple comparison tests were by using Tukey's HSD post-hoc test ($p < 0.05$) by using XLSTAT statistical software (version 2016.1).

RESULTS AND DISCUSSION

Effect of microwave-water treatment on the percentage of potato column weight loss

The percentage of column weight loss of all potato varieties increased continuously throughout the heating treatment. 'BARI-TPS-1' and 'Tel Pakri' showed comparatively faster weight loss percentage than the other two varieties (Figure 1). At 60 sec of heating, columns weight loss of 'BARI-TPS-1' and 'Tel Pakri' reached to 6.89% and 5.55% respectively, which is significantly higher than 'Diamant' (0.94%) and 'Romana' (1.24%), and this tendency continued thereafter. At 90 sec of heating 'BARI-TPS-1' attained 13.69% weight loss which is significantly higher than other varieties; 'Diamant' (3.3%) and 'Romana' (7%), 'Tel Pakri' (7.57%) (Figure 1). Similarly, at 240 sec of heating column weight loss of 'BARI-TPS-1' reached to 38.04% weight loss which was significantly higher than other varieties; 'Diamant' (24.42%) and 'Romana' (29.58%), but significantly lower than to 'Tel Pakri' (44.98%) (Figure 1).

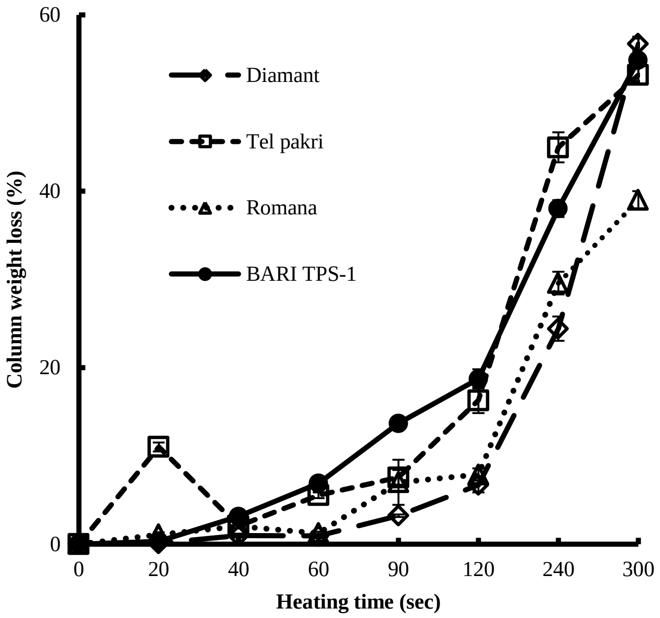

Figure 1 Effect of microwave heating on percentage potato column weight loss for a different period. Vertical bars indicate the standard error of the means (n = 10 ± SE).

Effect of microwave-water treatment on the percentage of potato column firmness loss

Although the percentage of firmness losses of all potato varieties increased continuously throughout heating treatment, BARI-TPS-1' showed more rapid firmness loss percentage compared to other potato varieties (Figure 2). At 60 sec of heating firmness loss of BARI TPS-1 reached to 83.17% which was significantly higher than other varieties 'Diamant' (20.88%), 'Romana' (45.47%) and 'Tel Pakri' (26.06%) (Figure 2), and this tendency continued thereafter. At 90 sec of heating, 'BARI TPS-1' attained 93.41% firmness loss which was also significantly higher than other varieties 'Diamant' (44.06%) and 'Romana' (47.73%), 'Tel Pakri' (74,14%) (Figure 2) and stayed constant until 300 sec of microwave heating. The other three varieties attained approximately 90% firmness losses after 240 sec of microwave heating and remained constant after 300 sec of microwave treatment (Figure 2).

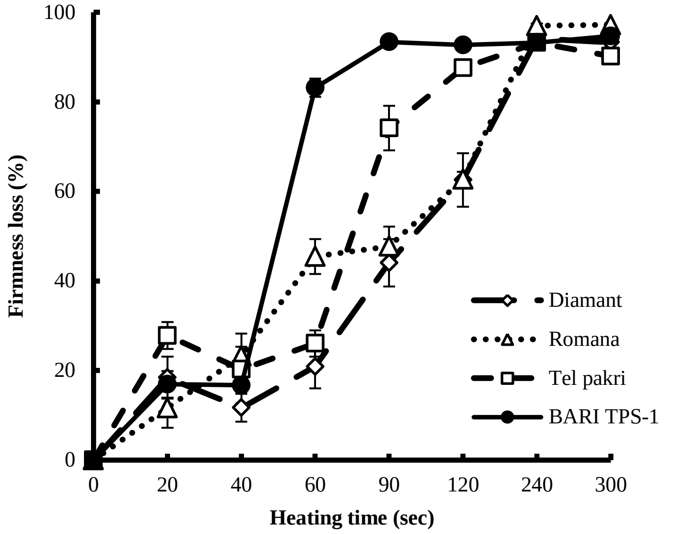

Figure 2 Effect of microwave heating on percentage potato column firmness loss for a different period. Vertical bars indicate the standard error of the means (n = 10 ± SE).

The rapid weight losses and firmness losses of potato columns after microwave water treatment for a different period are presented in Figure 1 and 2. Microwave treatment of potato cube promotes weight loss caused by combined loss of weight and dry matter **(Severini *et al.*, 2003)**. **Błaszczak *et al.* (2004)** also reported 19–23% weight loss due to microwave treatment in transgenic potatoes. In this experiment, BARI TPS-1 and Tel Pakri potato column showed a comparatively higher rate of weight loss and firmness loss percentage than other cultivars (Figure 1 and 2). This implies that these two cultivars might obtain gelatinization temperature with a shorter period of heating in the microwave **(Kaur *et al.*, 2002)**. Microwaved cooking of potato for 4 min resulted in rapid weight loss in tuber; they also reported softening of starchy tubers after microwaving **(Ibrahim *et al.*, 2012)**. However, softness or firmness did not reply to temperature solely with microwave heating. The softening of potato tissue indicated the degradation of the cell wall structure and middle lamella and starch gelatinization because of heating **(Bordoloi *et al.*, 2012).**

Effect of microwave-water treatment on potato column swelling and solubility

A significant increase was observed in swelling power for all potato column starches after heating with water. Swelling capacity started to increase after 60 sec of heating in all four varieties and maintained a similar pattern of swelling thereafter (Figure 3). When microwave heating was applied, water absorption and heating caused the water molecules to enter into the starch granule and cause swelling of granules **(Zhu, 2015).** The disrupted hydrogen bonds with the exposed hydroxyl groups of amylose and amylopectin cause swelling of the starch granule during thermal gelatinization **(Charles *et al.*, 2016)**.

Comparatively stabilized swelling capacity after 90 sec heating (Figure 4) might be due to rapid temperature rise and high retention of water that entered the granule, resulting in a high swelling capacity, which induced packing of gelatinized starch granules **(Sjoo *et al.*, 2009)**. The rapid increase of swelling power was reported in corn starches after heat-moisture-treatment between 65 and 75°C temperature, followed by a slow or almost constant swelling rate above 75-80°C **(Iromidayo *et al*., 2010)**. Similarly, an observation was reported by **Barminas *et al.* (2008)**. At higher temperature starches tend to lose their granular structure resulting in lower water binding capacity which leads to lower swelling capacity **(Barminas *et al.*, 2008; Alam and Hasnain, 2009)**. This can also be explained by the observation of **Demiate *et al.* (2011),** who indicated that when Starch granules swell to the peak value the swollen granules disintegrate to leach out starch molecules out of the granules and led to increase solubility.

In this study, starch Solubility started to increase significantly after 60 sec of microwave heating and rapidly increased thereafter in all varieties (Figure 3). Percentage of solubility was higher in 'BARI TPS-1' (21.61%) than other varieties; 'Diamant' (16.33%), 'Romana (19%) and 'Tel Pakri (14.94%) after 60 sec of microwave heating and rapidly increased thereafter for 90 to 300 sec of heating, resulting in a significant difference with other varieties (Figure 3). Thus, microwave treated starch of 'BARI TPS-1' was more soluble compared to the other local potato varieties. Solubility represents the amount of solubilized starch molecules at a certain temperature. The loss of granular structure at higher temperatures increases the solubility of starch. **Alam and Hasnain (2009)** reported similar results on taro starch.

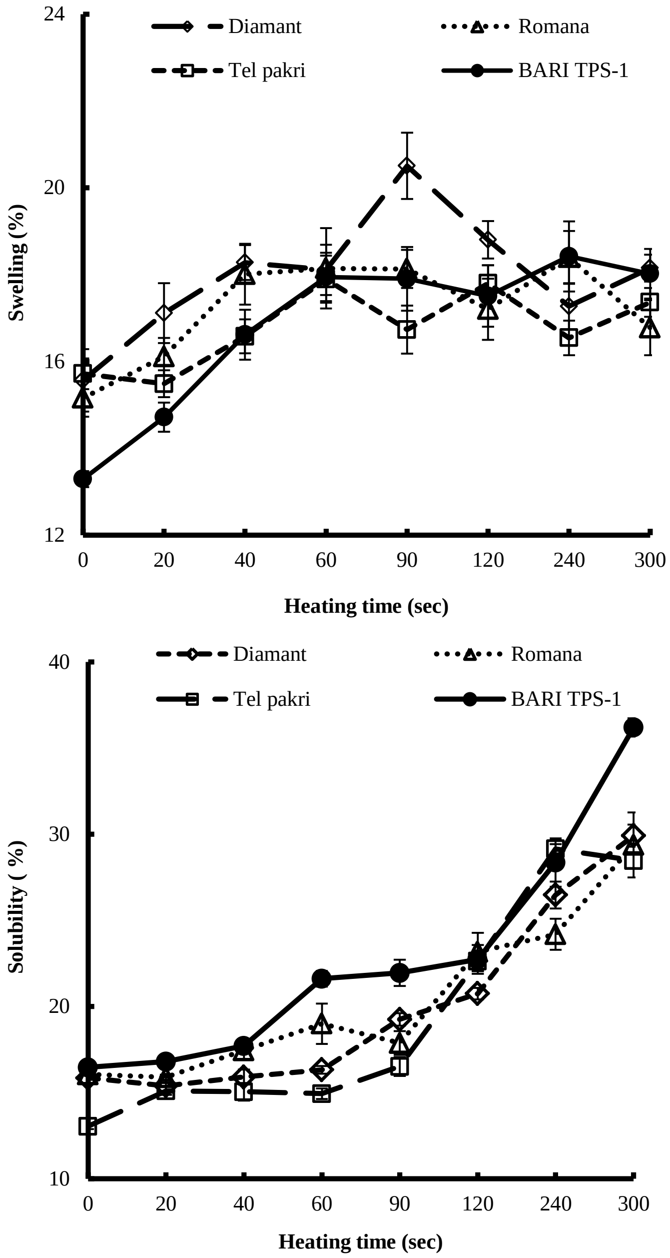

Figure 3. Effect of microwave heating on potato column swelling and solubility for a different period. Vertical bars indicate the standard error of the means (n = 10 ± SE).

A significant reduction of solubility in potato starch granules after microwave heating in water suspension was observed by **Ma *et al*. (2015)**. However, this study resulted in an increase in solubility of potato columns after microwave-water treatment for the different periods. Starches treated after 90 to 300 sec of microwave heating with water were more soluble compared to other treatments (Figure 3). This could be explained by the prolonged heating time on starches which led to the loss of granular structure and release of amylase fraction caused by weaker inter- and intramolecular hydrogen bonds after heat-moisture treatments **(Lawal, 2009)**. As heating continued, the mobility and collision of starch granules increased and amylose molecule leached out resulting in enhanced solubility **(Sodhi and Singh, 2003)**.

In the present study also showed comparatively higher solubility percentage in 'BARI TPS-1' tuber than the other local varieties. Solubility is determined by the amylose content and swelling power by amylopectin **(Ritika *et al*., 2010)**. The high solubility in TPS variety could be affected by the loosely held granule structure and low molecular weight amylose which resulted in leaching out of an amorphous portion of starch granule **(Nwokocha *et al.*, 2009)**.

Changes of potato columns after microwave heating

Representative potato columns from each variety after microwave treatment for the different periods (0, 60, 90, 120, 240, and 300 sec) are shown in (Plate 2 and 3). The changes of potato column from each variety after each microwave treatment are summarized in Table 1. Textural changes of potato columns were observed throughout the different periods of the microwave treatment. After 60 sec of microwave heating, all of the potato samples started to show slight depression. A decrease in brightness and increase in yellowness were also observed in all the heat-treated potato columns (Plate 2 and 3); and brownish appearance on 'BARI TPS-1'column might imply triggering of enzymatic browning **(Severini *et al.*, 2003)**. This immediate weakening potato sample tissue after microwave heating might occur due to swelling of gelatinized starch **(Wang *et al.*, 2010)**.

As the treatment continued for 90, 120, 240, and 300 sec, all the potato column samples eventually obtained noticeable ruptured structure and central depression, but 'BARI TPS-1' column showed visible central depression and slightly brownish appearance after 90 sec of heating which is faster than other potato varieties (Plate 2 and 3).

Table 1 Changes of potato columns after microwave treatment

Variety	Heating time (sec)					
	0	60	90	120	240	300
Diamant	Uniform sized column	Color changed in the center portion, became less bright,	Color changed in the center portion, slight yellowness	Color changed in center portion gave the yellowish appearance	Slightly ruptured from center depression visible	Ruptured from the side, center depression, mostly deformed
Romana	Uniform sized column	Became less bright, Slight depression visible in the center portion	Slight depression visible, slightly yellowish	central portion became yellowish, slightly center depression	Ruptured from the side, slight center depression	Ruptured from the side, slight center depression, mostly deformed
Tel Pakri	Uniform sized column	center portion gave the yellowish appearance, slight center depression	Color changed in the center portion and became more yellowish	Depressed center region visible, started to deform, slightly brownish appearance	Ruptured from the side, slightly center depression, mostly deformed	Ruptured from the side, slight center depression, mostly deformed
BARI TPS-1	Uniform sized column	Columns started to show yellowness, center depression visible	Columns had a brownish appearance, center depression visible	Center depression and brownish appearance in color	Center depression, ruptured side regions	Ruptured from the side, prominent center depression, mostly deformed

Table 2 Changes of potato column structures after microwave treatment

Variety	Heating time (sec)							
	0	20	40	60	90	120	240	300
Diamant	Small individual granules	Mostly individual small granules	Small to medium swollen granules	Cell wall started to rupture, small to medium swollen granules	Swollen clustered granules	Cell wall ruptured, clumped region	Irregular, swollen granule visible	Ruptured from the side, center depression, mostly deformed
Romana	Small individual granules	Small individual granules	Mostly individual small granules, slightly swollen	Medium to large swollen granules	Ruptured cell wall no individual granule	Color change in the central portion, slightly center depression	Ruptured, clumped region	Gelatinized, small intercellular space
Tel Pakri	Small individual granules	Mostly individual small granule	Swollen, medium to large clumped granules	Cell wall ruptured, small to medium clumped granules	Large, swollen, cell cluster	Ruptured, clumped region	Ruptured, clumped region	Gelatinized, small intercellular space
BARI TPS-1	Small individual granules	Mostly individual small granules	Swollen clustered granules	Cell wall completely ruptured, individual granules no longer visible	Ruptured, clumped region	Ruptured, clumped region	Clumped, slightly gelatinized regions	Gelatinized, no intercellular space

Changes of potato column structure after microwave heating

Plate 4 and 5 are represented the SEM images of changes in the structure of starch granule due to microwave treatment. **Liu *et al.* (2012)** also observed structural change of potato starch granule after microwave heating. The changes in potato column structure from each variety after each microwave treatment are summarized in Table 2.

After 40 sec of microwave heating more or less all of the potato samples started to show individual compacted granules (Plate 4). This deformation occurred progressively until the starch granules were almost completely ruptured from 60 to 300 sec of microwave treating in all potato samples. A similar observation was reported by **Palav and Seetharaman (2007)**, which showed a gradual deformation of starch granule structure from 0 to 15 sec by microwave heating. However, 'BARI TPS-1' was intended to obtain clumped and ruptured starch granule more rapidly than other potato variety, and started to show clumped and ruptured granules after only 60 and 90 sec of heating (Plate 4 and 5). Studies showed that microwave heating can cause total disruption of potato starch granule by affecting the water molecules presented in the crystalline region and promote deformation **(Karakkainen *et al.*, 2011; Fan *et al*., 2014)**.

In this study, different potato varieties showed different swelling and deformation pattern at different heating times. This might suggest different microwave heating patterns and temperature gradient and different time regimes **(Xie *et al.*, 2013)**. **Xie *et al.* (2013)** also reported that after 15 sec of heating with 80°C final temperature showed surface fractures and deformation, further 20 sec of heating with 95°C final temperature showed heavily deformed and collapsed starch granule. However, the least consistency in TPS starch granules structure compared to other varieties probably indicated accelerated gelatinization of TPS starch granules after microwave heating **(Severini *et al.*, 2005)**. 'Tel Pakri' variety showed slightly similar starch granule deformation with the 'BARI-TPS-1'variety after 120 and 240 sec of heating (Plate 5).

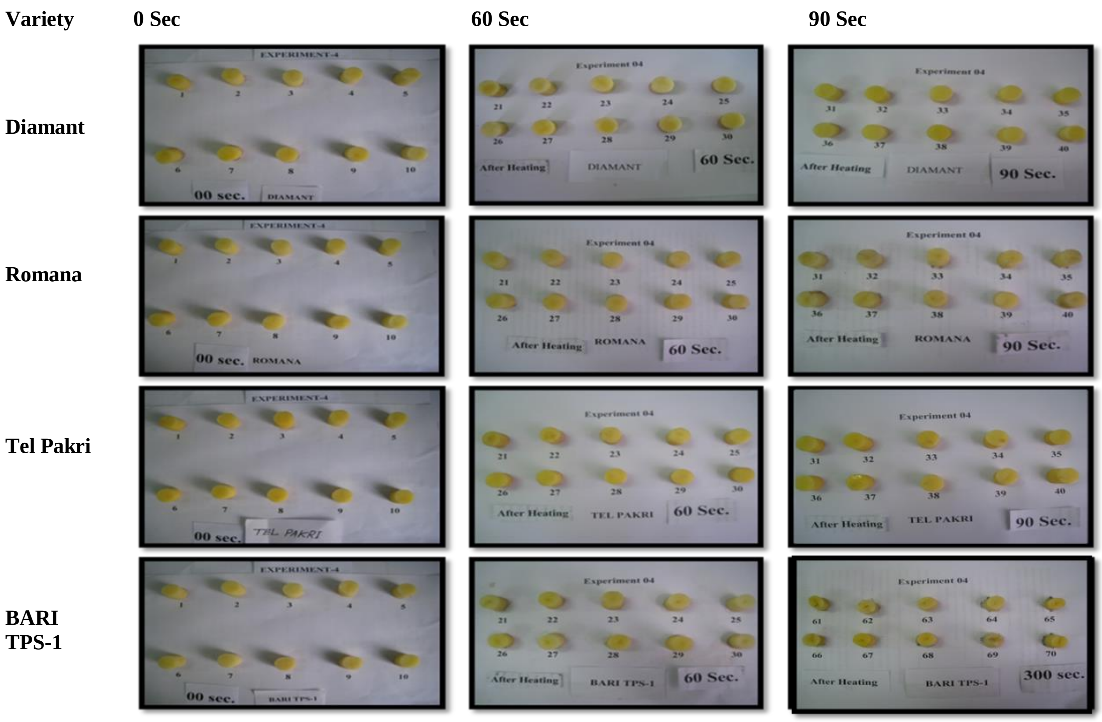

Plate 2 Images of potato columns after microwave treatment for 0, 60 and 90 sec

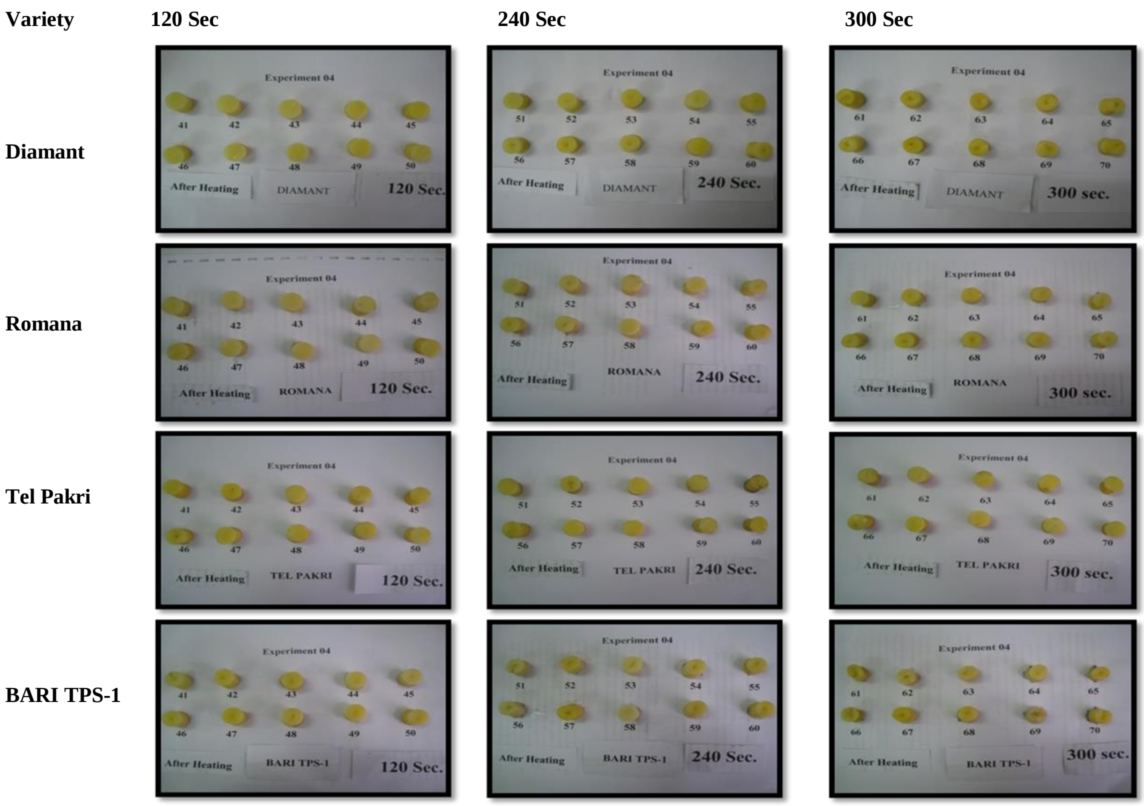

Plate 3 Images of potato columns after microwave treatment for 120, 240 and 300 sec

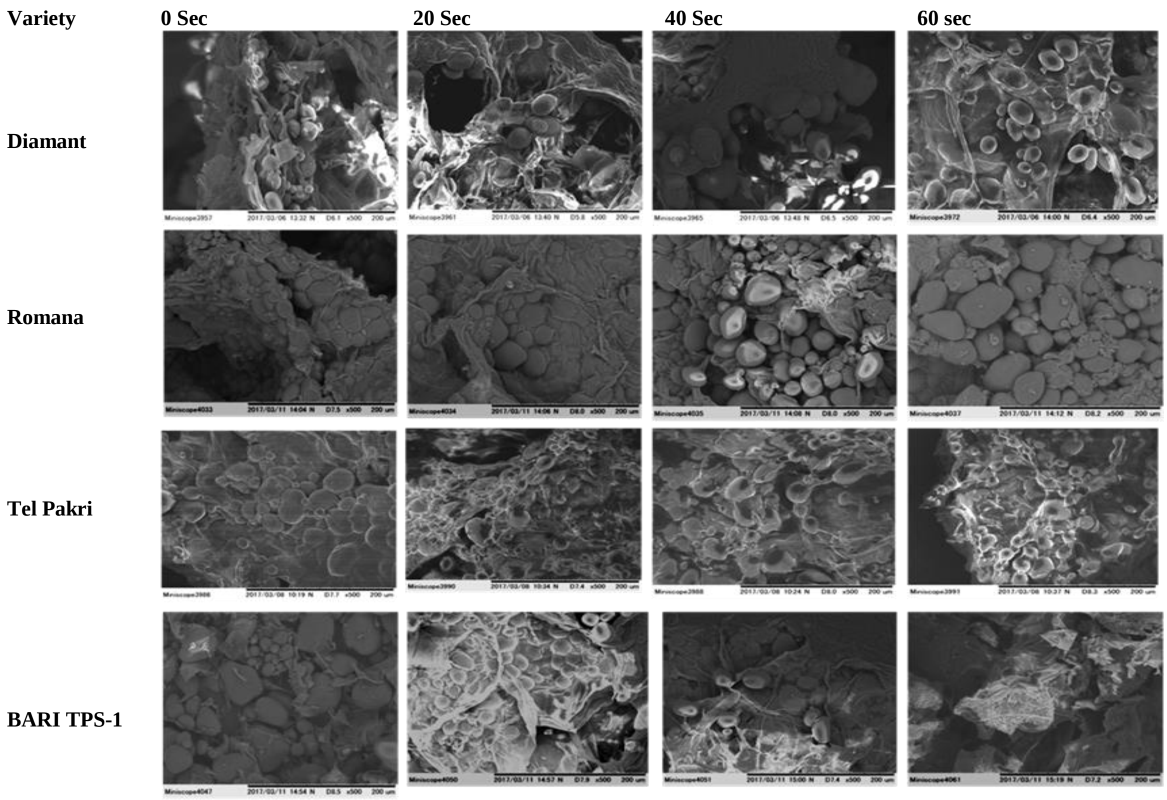

Plate 4 SEM Images of cross-sections of microwave heated potato columns for 0, 20, 40 and 60 sec

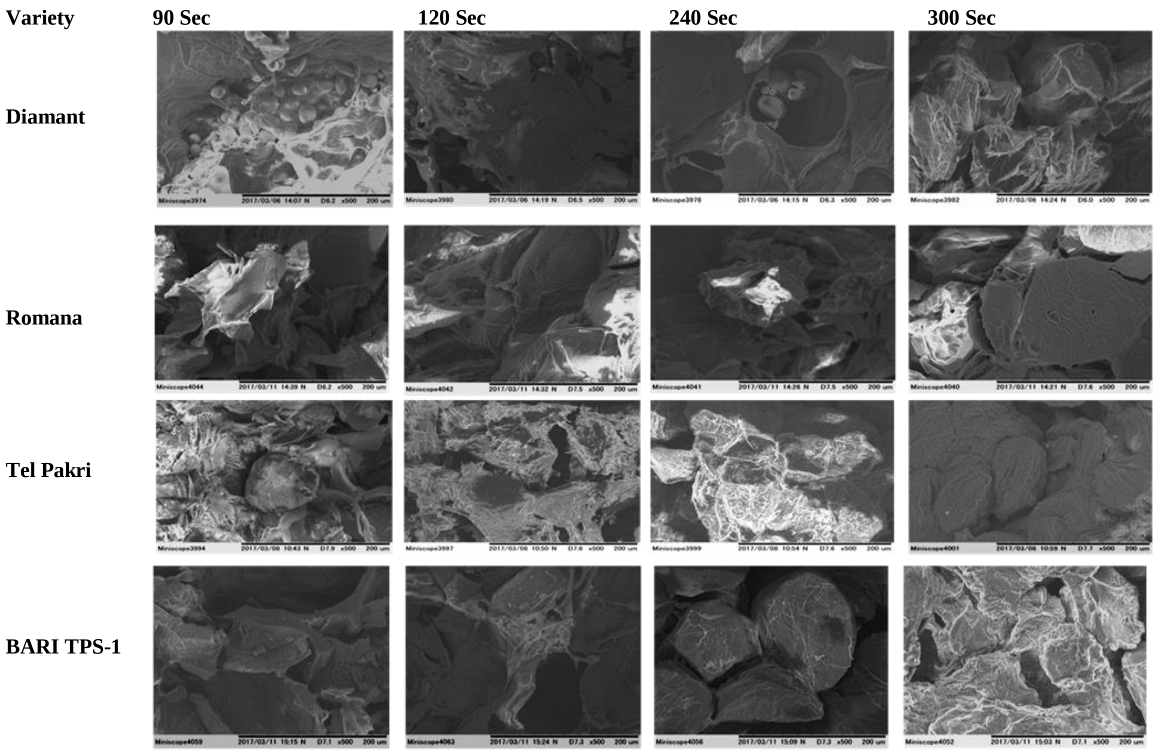

Plate 5 SEM Images of cross-sections of microwave heated potato columns for 90, 120, 240 and 300 sec

CONCLUSION

The microwave heating with water for a different period affected the treated potato tubers and resulted in some considerable changes. The 'BARI TPS-1' tuber column had comparatively higher weight loss and firmness loss percentages, which indicated a faster heating rate in TPS tuber and also softer texture compared to the other local varieties. The 'Tel Pakri' potato tuber showed slightly similar properties with the TPS compared to the other local tubers The Higher solubility percentage in 'BARI TPS-1' column also implied rapid leach out of starch molecules and forming of a network that held water and form gelatinized structure. Therefore, TPS tuber may acquire pasting temperature within a shorter heating period, suggesting as an option for using as cooking potato products like mash potato, potato puree, or as a salad. However, it can be said that different potato varieties may achieve different quality parameters. As potato is widely consumed and processed in home and industries, further studies on quality attributes and tuber processing techniques may help to understand the potentiality of independent potato tubers or cultivars in potato tuber processing.

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