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Probing a best suited brown rice cultivar for the development of extrudates with special reference to Physico-chemical, microstructure and sensory evaluation

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Abstract

Seven Pakistani brown rice cultivars (KS-282, SB, C-9, SUPRI, PK-386, IRRI-9 and IRRI-6) were investigated as an alternative raw material to develop directly expanded extrudates. Results indicated that bulk density remained constant in all rice cultivars, whereas SUPRI presented a higher length-breadth (LB) ratio and lower thousand kernel weight and starch content than other cultivars. Amylose content was higher in KS-282, C-9 and IRRI-9 and lowest in SB. SUPRI rice extrudates produced optimum expansion and crispiness with reduced hardness, piece and bulk density. Scanning electron micrographs showed more cell pockets and evenness in porosity per unit area in SUPRI brown rice extrudates, indicating more porous and crispier extrudates. It is also evidenced from the micrographs that cavities were evenly distributed and less ruptured in SUPRI brown rice. Consequently, SUPRI extrudates exhibited better microstructure, crispiness (No. of peaks 9), and porosity (0.838 ± 0.009) along with minimum piece density (0.038 ± 0.001 g/cm^3) and hardness (17.85 ± 1.05 N). Conclusively, low amylose rice cultivar (SUPRI) perform better as substitute raw material for extrudates development.

Keywords: brown rice; extrusion; scanning electron microscopy; sensory evaluation.

Practical Application: Brown rice is a neglected agricultural resource and is not routinely used for cooking purposes. Additionally, probing the most suited cultivar grown in Pakistan for extrusion was not yet explored. This study has pointed out the most suitable brown rice cultivar as alternative raw material for developing directly expanded extrudates with desirable characteristics for the snack industry.

1 Introduction

Rice is principally consumed as polished kernels in most parts of the world. It is the primary staple of numerous countries which satisfy the energy requirement of 50% of the world's population/community (Mohanty, 2013). Polished/white rice is far inferior in nutritional quality but superior in puffing, aroma and culinary grade. Brown rice is a whole grain naturally augmented with bran, edible oil, nutrients and antioxidants. Unfortunately, brown rice is still underutilized due to lengthy cooking time and post-cooking more rigid texture (Chapagai et al., 2016). Brown rice proteins are also suitable vehicle for the transfer of phenolic and volatile compounds (Kelemen et al., 2021). The quality of each cultivar of rice helps the consumer to select the right rice of their choice which depends on the end use of rice (Charoenthaikij et al., 2021). Dietary recommendations have emphasized the intake of whole-grain cereals instead of refined food in the daily diet (Pardhi et al., 2019). These distinctions provoke the addition of brown rice in commercial products which are nutritionally inferior.

Snack foods are the essential food component of the children's daily diet and are usually consumed between significant meals. Consumption of snacks is about six times a day in North American children (Statista, 2014). Health Canada is also endorsing the public to take wholesome and nutritive snacks (Webb, 2011). Crips/Chips, extruded snacks, popcorn, nuts and seeds are the significant savory snacks of Pakistan. The forecast period (2019 to 2024) indicates the Compound Annual Growth Rate (CAGR) of 9.34% in the savory snack market of Pakistan (Mordor Intelligence, 2020).

Extruded snacks have unique features that characterize a modern lifestyle. During extrusion, grain(s) based starchy, protein and fibrous feed material are processed to develop puffed products. This technology is most promising, continuous and efficiently produces no waste (Meng et al., 2010; Lohani & Muthukumarappan, 2017). Moreover, allied beneficial characteristics of extrusion include getting a favorite product shape with desired modified texture. The extrusion also curtails anti-nutritional factors and improves the digestibility and palatability of extrudates (Shah et al., 2017). To check the perception of food products, sensory evaluation becomes the compulsory part of the product development study. Recently a story completion technique is introduced to separate the consumers based on their response (Silva et al., 2021a). In the case of extrusion products, structure, taste and porosity are the main interested parameters of the

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children. Most of the extruded snacks are based on corn starch, corn flour and corn grits which are inferior nutritionally.

Hence, a dire need emerges to investigate the alternative superior raw material for the production of extrudates to strengthen the snack industry. This commodity would add value to Pakistani agricultural raw materials. Whole grains significantly affect the expanded volume and other traits of extruded snacks. Therefore, the current project was planned to investigate the most suited brown rice cultivar to develop extrudates.

2 Material and methods

Seven brown rice cultivars (KS-282, SB, C-9, SUPRI, PK-386, IRRI-9, and IRRI-6) were procured from Rice Research Institute (RRI), Kala Shah Kaku, Sheikhupura, and Galaxy Rice Mills Ltd. Gujranwala, Pakistan. All analytical reagents were from Merck (Merck KGa A, Darmstadt, Germany) and Sigma-Aldrich (Sigma Aldrich, Tokyo, Japan).

2.1 Preparation of raw materials

Brown rice samples were milled through UDY cyclone mill (Cyclotec Sample Mill, Tecator, Sweden) to obtain flour and sieved (5 Mesh) for extrusion. The fine flour (60 Mesh) was separately collected for analysis. Both samples were packed in zipped polythene bags and stored (25 °C).

2.2 Physical assessment of grains

Randomly selected one thousand rice grains were counted and weighed to calculate the 1000 kernel (TK) weight. For recording the length-breadth (LB) ratio, randomly selected ten kernels were cumulatively measured in mm using Vernier Caliper (Series 500, Mitutoyo, Japan) and divided length by breadth. For bulk density (BD), from a height of 30 cm, 50 g kernels were fallen into a cylinder and weighed. BD (g/mL ratio) was calculated by the occupied volume of rice grains (Thomas et al., 2013).

2.3 Chemical quality assessment

Amylose content

Iodine-binding protocol measured amylose content in rice (Colussi et al., 2015). Rice sample (100 mg) along with 1 mL of ethanol (95%) and 9 mL of 1 N NaOH was thoroughly mixed in a 100 mL volumetric flask, heated for 10 min in a water bath and cooled to ambient temperature for starch gelatinization. Afterwards, 5 mL of gelatinized starch, 1 mL of 1N acetic acid and 2 mL of iodine solution were mixed in a volumetric flask (100 mL), and the final volume was made using distilled water. The entire content was vortex mixed and kept aside for 20 min. A UV-Spectrophotometer (Model AA-6650, Shimadzu Co. Japan) was used for measuring the absorbance at 620 nm. The amylose content was determined using potato amylose as a standard.

Starch content

Rice flour samples (1:2 (w/v) were soaked for 18 h in a 0.18% NaOH solution. After blending, sieved (63 µm) and centrifuged for 5 min at a speed of 1200 × g. The top leathery layer was scratched, and the bottom starch layer was again slurred, washed with NaOH (0.18%), and centrifuged. Starch was again beaten and centrifuged after neutralization (pH 6.5) with HCl (1.0M). Consequently, after thrice washing, starch was dried to 7% moisture content at 40 °C (Lin et al., 2008).

2.4 Extrusion process

An electrically heated extruder (LT-65 Double Screw Extruder, Shandong Light M & E Co, Ltd. PRC) was used for extrusion cooking according to the pre standardized operational parameters *i-e* feed rate (50 kg/h) with moisture content 13%, screw speed (100 rpm) and barrel temperatures (90 °C, 120 °C and 150 °C for 1, 2 and 3 sections respectively). Feed dough was discharged at high pressure through an orifice of metallic circular die (4 mm) and cut by a rotary knife to get the extrudates. Perforated trays were used to collect the hot extrudates and placed for 30 minutes for oven drying at 80 °C. The equalized moisture content of the extruded product was 3-5%. Extrudates were then stored at 25 °C after packing in plastic zippers for further analysis.

2.5 Physical analysis of extrudates

The Piece Density was calculated by measuring the volume and weight of randomly selected ten extrudates by using the formula of Alam & Kumar (2014). The solid displacement method (American Association of Cereal Chemists, 2000) was adopted for volume measurement.

Piece Density = Mass of extrudates (g)/volume of extrudates (cm^3)

The porosity was recorded through the difference between the piece volume and true volume divided by the piece volume (Bisharat et al., 2013). A graduated cylinder recorded the volume of 500 g extrudates, and bulk density was noted by dividing the weight with the observed volume (Cheng & Friis, 2010). The Expansion Ratio was observed by dividing the average diameter (De) with die diameter (Dd) using a vernier calliper (Shah et al., 2017).

Textural and morphological characteristics

Hardness and crispiness (No. of peaks) were calculated through Texture Analyzer (TA-XT Plus, Stable Micro Systems, UK) by adopting the protocol of Shah et al. (2017). The maximum peak force representing hardness (Newton) was measured using a cylindrical probe (diameter 35 mm) with 1.00 mm/s and 2 mm/s test and post-test speeds, respectively and a 5 kg load cell was used for calibration. Representative extrudates were observed for the morphological characteristics through a scanning electron microscope (Jeol Neoscope Benchtop SEM (Model JCM-6000, Peabody, MA, USA); and images were analyzed at an accelerated voltage of 5 kV (Bisharat et al., 2013). The colored rice of Brazil (red and black) when used in the production of gluten free snacks, it was noted that black rice presented better nutritional and phenolic contents, while red for expansion and texture (Rivero Meza et al., 2021). Their results showed that different varieties behaved differently during extrusion.

2.6. Sensory evaluation

Extrudates were tested for sensory attributes (appearance, flavor, texture, crispiness, mouth-feel, and overall acceptability) based on a descriptive 9 points hedonic scale dictating '1' least undesirable and '9' extremely extreme desirable. Twenty panelists judged the product anonymously in separate booths mounted with white fluorescent light at room temperature (Meilgaard et al., 2007). Before testing each sample, panelists were advised to rinse the mouth, and scores were recorded on designed formats.

2.7 Statistical analysis

The results obtained were statistically analyzed using SPSS 23.0 statistical software (IBM SPSS, Inc., Chicago, IL, USA) to conclude the significance level ($P \leq 0.05$) by analyzing variance (ANOVA) and completely randomized design (CRD). Duncan's multiple range test (DMR) was applied to compare the means. All data were given as means ± SD.

3 Results and discussion

3.1 Physical assessment of grains

The results presented in Figure 1A, B, C showed a non-significant ($P > 0.05$) impact of brown rice cultivars on BD, while TK weight and LB ratio were significantly affected ($P < 0.05$). Among all the cultivars, SUPRI performed better in having the lowest TK weight (13.86 ± 0.90 g), which is considered a desirable factor for extrusion (Moraru & Kokini, 2003). Chapagai et al. (2017) also reported the significant difference (13.86 ± 0.16 to 22.04 ± 0.05 g) in the TK weight of brown rice varieties, which are very close to the present findings. The TK weights of Malaysian rice cultivars (16.97-19.43 g) reported by Thomas et al. (2013) showed relatively lower values than the present study.

LB ratio determines the shape of rice kernel of specific variety as long, and medium grains also possess higher bulk density (Chapagai et al., 2017). The maximum LB ratio was estimated in SUPRI (5.14 ± 0.01) due to its long and thin kernels. Contrarily, KS-282 produced a lower LB ratio (3.68 ± 0.03) and was slotted as short and bulky among all rice cultivars. Brown rice is classified based on LB ratio as short (≤ 2), medium (2.1 to 3) and slender (≥ 3.1) (Bergman, 2019). In the present study, all rice cultivars were classified as long slender, which are close to the previous finding (2.09-3.75) of Thomas et al. (2013), who founded glutinous rice varieties as slender.

3.2 Chemical quality assessment

Starch and amylose content

Starch and amylose contents are depicted in Figure 1D, E. Among all the seven brown rice cultivars, the highest starch content (87.59 ± 2.10%) was determined in PK-386, followed by KS-282 (86.10 ± 2.16%) and IRRI-9 (82.40 ± 3.15%), while the lowest starch content was determined in C-9 (71.30 ± 3.65%).

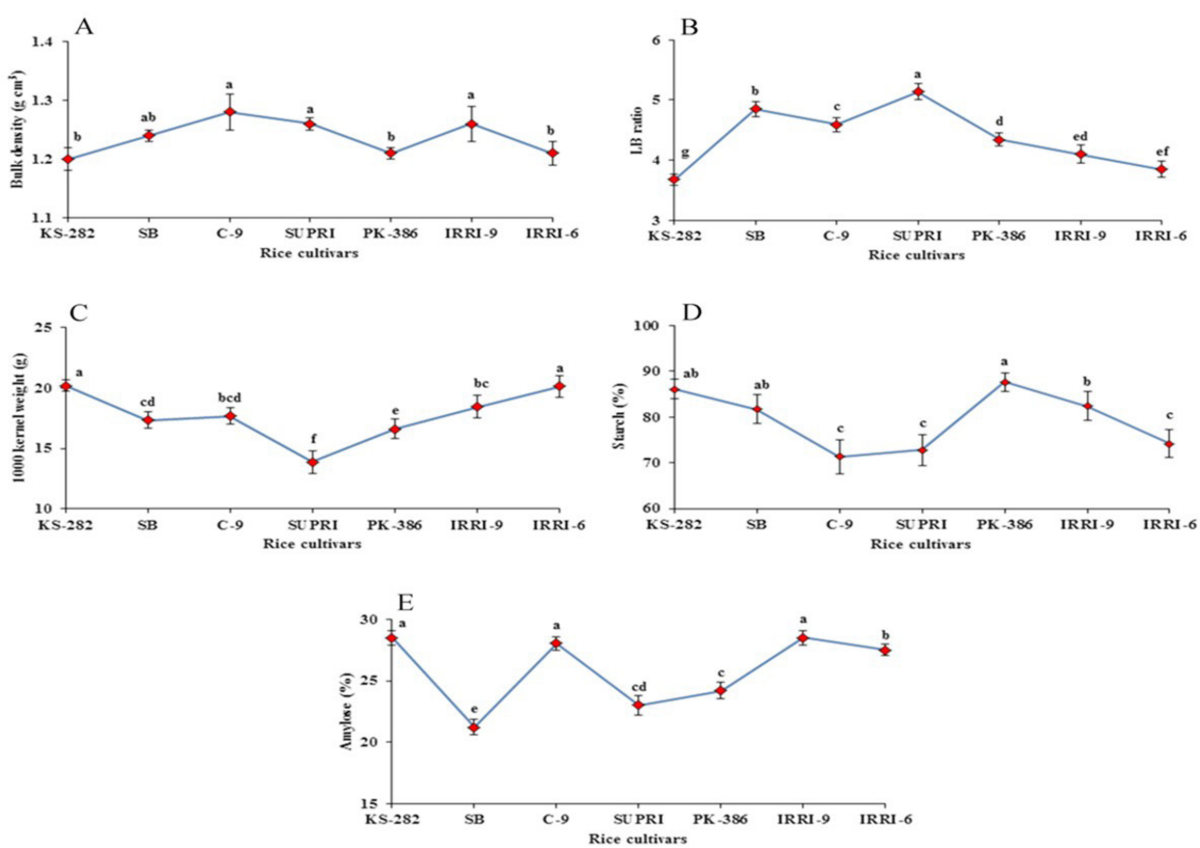

Figure 1. Physicochemical characteristics of raw brown rice cultivars; Bulk density (A), LB ratio (B), 1000 kernel weight (C), Starch (D), Amylose (E).

Likewise, amylose content revealed significant differences ($P < 0.05$) among all cultivars. Minimum amylose content (21.2 ± 0.63%) was determined in SB. Successively, SUPRI and PK-386 exhibited 23 ± 0.77 and 24.2 ± 0.7% amylose content, respectively. Cultivars, namely C-9 and IRRI-9, produced the highest amylose content, 28.02 ± 0.52% and 28.50 ± 0.57%, respectively. Intermediate amylose content in SB is responsible for tender and elongated cooked rice (Juliano & Pascual, 1980). However, coarse rice varieties produce dry, less tender, and comparatively complex textures after cooking (Shabbir et al., 2008). This infers the regain of crispiness of extrudates after extrusion. Varieties possessing less amylose revealed tender and gummy texture, unlike varieties containing high amylose percentage. Additionally, stiffness and fluffy texture are attributed to high amylose varieties (Asghar et al., 2012). Factually, brown rice possesses lower amylose content than polished rice primarily due to its reduced starch content. The expansion ratio of the extruded products is inversely correlated with the amount of amylose in the rice flour (Chinnaswamy & Hanna, 1988). SB and SUPRI extrudates produced optimal expansion in the current study due to their lower amylose content.

3.3 Physical characteristics of brown rice cultivars extrudates

Piece density

Cultivars difference produced a significant difference ($P < 0.05$) in piece density (Table 1) which decreased from 0.074 to 0.038 g/cm^3. The highest value for piece density was measured for IRRI-9 (0.074 ± 0.001 g/cm^3) followed by KS-282 (0.062 ± 0.001 g/cm^3), while the lowest piece density with lightweight was exposed by SUPRI (0.038 ± 0.003 g/cm^3). The remaining cultivars' extrudates produced similar results for piece density (0.056 ± 0.001 g/cm^3). Piece density describes puffing, air pockets, and the cell structure of puffed snacks. Raw material and processing parameters are also key determinants of the piece density. Numerous studies confirmed the three-dimensional network among starch, protein, and water which affects the expansion and piece density (Shah et al., 2017; Sharif et al., 2014). Brown rice flour, aside from starch, contains protein, lipids and other constituents which hamper the expansion and piece density (Parada et al., 2011).

Porosity

Porosity is an essential parameter of extrudates that influence the eating quality. Enhanced porosity was noted in SUPRI (0.838 ± 0.001) trailed by C-9 (0.822 ± 0.001) and KS-282 (0.806 ± 0.002). PK-386 and SB produced intermediate porosity values *i-e.*0.779 ± 0.002 and 0.761 ± 0.003, respectively, while minimum porosity (0.637 ± 0.003) was calculated in IRRI-9. Scanning electron microscopy (Figure 2) also confirmed the porosity difference among extrudates of different cultivars with no rupture equally distributed air cells. SUPRI extrudates photograph (Figure 3D) also pointed out the desirable porous extrudates in the present study. In contrast to these findings, reduced porosity of rice-based extrudates is linked to the raw material's enhanced protein and fiber content (Choudhury & Gautam, 2003).

Bulk density

Means for BD and expansion ratio (ER) mentioned that minimum BD (0.028 ± 0.002 g/mL) was observed in SUPRI (Table 1). Unlikely, highest BD (0.041 ± 0.001 g/mL) was measured in IRRI-9 and C-9 (0.040 ± 0.001 g/mL) while 0.034 ± 0.001 and 0.032 ± 0.002 g/mL BD were noted in PK-386 and SB. The earlier results confirm that extrudates with reduced hardness and piece density also produced lower BD with a maximum expansion ratio. Results are that lower BD produces a lesser hardness of extruded puffs (Yuliani et al., 2006). High shear during extrusion destroys polymers structure, especially protein and starch; consequently, extrudates with a low density are produced (Wani & Kumar, 2016).

Conversely, in this study, only brown rice was extruded, which confirmed the reporting of the previous research. Increased BD in brown rice-based extrudates is also attributed to the reduced elasticity through plasticization of melt and reduced gelatinization (Thymi et al., 2005). This could be established that brown rice contains relatively more minor starch content than polished grains, which caused the reduction in plasticization, which bumper the bulk density and reduced expansion. Enhanced melt viscosity during the extrusion of starch leads to denser extrudates (Manoi & Rizvi, 2010).

Expansion ratio

The expansion ratio represents the degree of the popping of extrudates as these escape the die of the extruder. Puffed

Table 1. Effect of cultivar difference on the physical properties of extrudates prepared using different brown rice cultivars.

Cultivars	Hardness (N)	Crispiness (No. of peaks)	Piece-Density (g/cm^3)	Porosity	Bulk-Density (g/cm^3)	Expansion Ratio
KS-282	23.14 ± 1.20^{c}	8.00 ± 0.10^{c}	0.062 ± 0.0011^{a}	0.806 ± 0.002^{ab}	0.030 ± 0.003^{cd}	3.79 ± 0.02^{e}
SB	20.5 ± 1.13^{de}	12.01 ± 0.08^{a}	0.056 ± 0.0013^{bc}	0.761 ± 0.003^{ab}	0.032 ± 0.002^{cd}	3.95 ± 0.02^{d}
C-9	19.81 ± 1.12^{e}	9.00 ± 0.09^{b}	0.056 ± 0.0013^{bc}	0.822 ± 0.001^{ab}	0.040 ± 0.001^{ab}	4.16 ± 0.01^{c}
SUPRI	17.85 ± 1.05^{f}	9.00 ± 0.09^{b}	0.038 ± 0.0015^{d}	0.838 ± 0.001^{a}	0.028 ± 0.002^{d}	4.20 ± 0.03^{c}
PK-386	20.59 ± 1.12^{d}	6.99 ± 0.12^{d}	0.056 ± 0.0013^{bc}	0.779 ± 0.002^{ab}	0.034 ± 0.001^{c}	3.79 ± 0.02^{e}
IRRI-9	28.75 ± 0.75^{a}	5.00 ± 0.13^{f}	0.074 ± 0.0010^{a}	0.637 ± 0.003^{ab}	0.041 ± 0.001^{a}	4.50 ± 0.02^{a}
IRRI-6	24.03 ± 1.22^{b}	6.00 ± 0.11^{e}	0.053 ± 0.0012^{c}	0.812 ± 0.001^{ab}	0.036 ± 0.001^{bc}	4.30 ± 0.01^{b}

Similar letters within the column indicated non- significant ($P > 0.05$) difference, values are means ± SD.

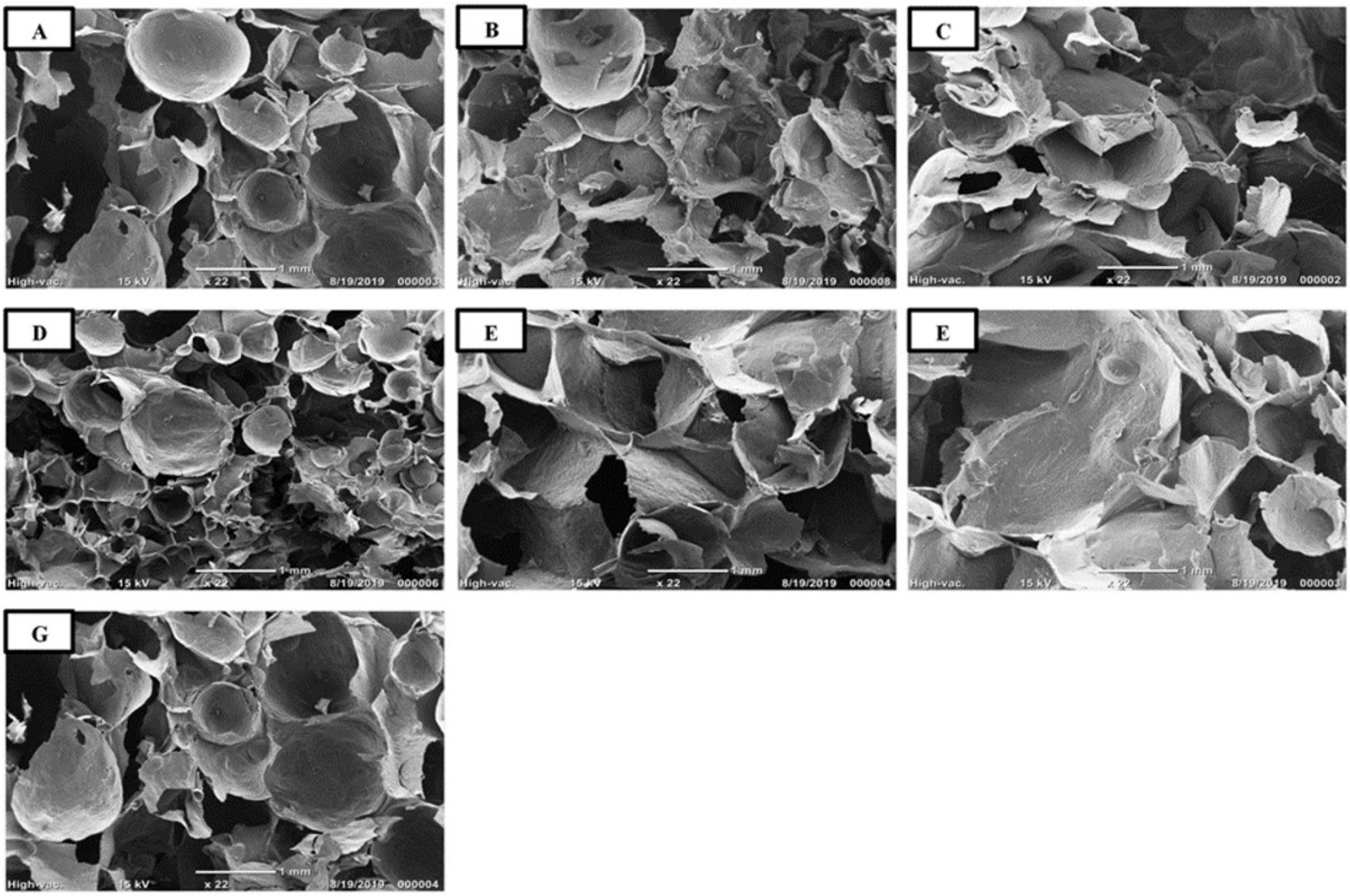

Figure 2. Scanning electron micrographs (x22) of 100% brown rice flour based extrudates of various cultivars; KS-282 (A), SB (B), C-9 (C), SUPRI (D), PK-386 (E), IRRI-9 (F), IRRI-6 (G).

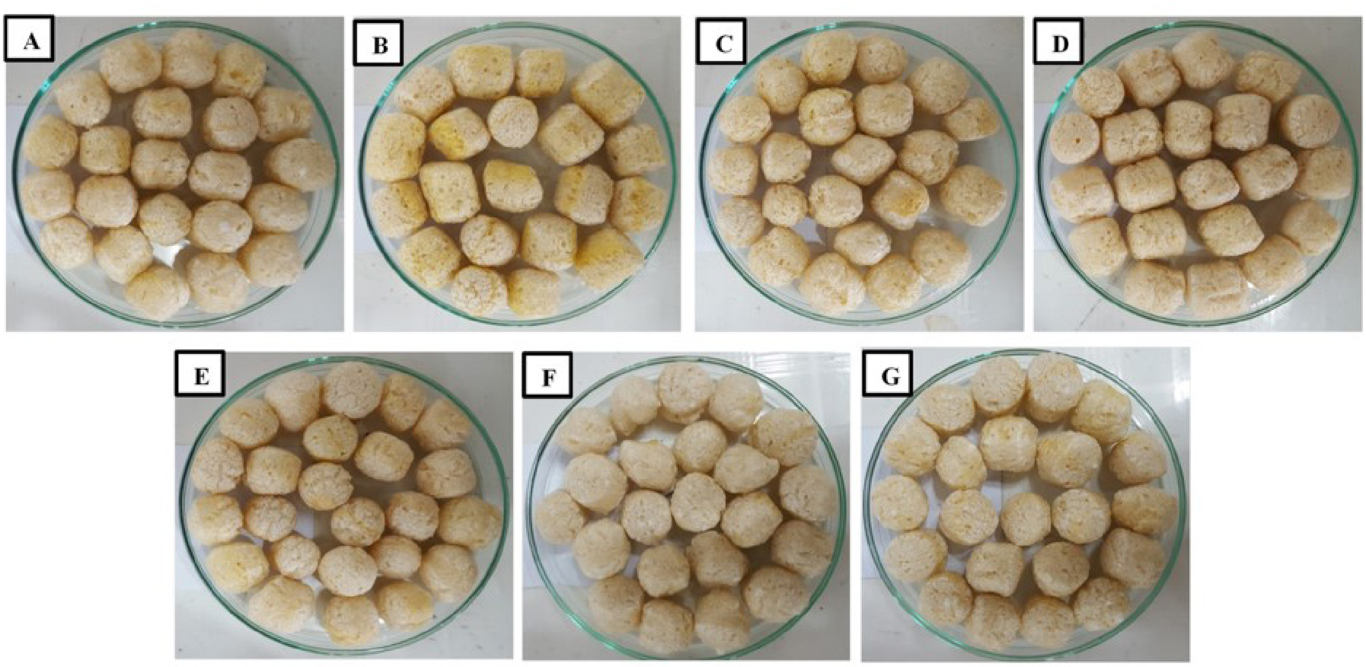

Figure 3. Extrudates prepared using brown rice cultivars; KS-282 (A), SB (B), C-9 (C), SUPRI (D), PK-386 (E), IRRI-9 (F), IRRI-6 (G).

extrudates with higher expansion ratios are desirable. The maximum expansion ratio was observed in IRRI-9 (4.50 ± 0.02) followed by SUPRI (4.20 ± 0.03), C-9 (4.16 ± 0.01), and SB (3.95 ± 0.02). However, a minimum increase in expansion ratio was recorded for PK-386 and KS-282 (3.79 ± 0.02). The difference in the expansion of the brown rice cultivars extrudates is the resultant of numerous factors, including layers of bran on the kernel (Oko et al.,2012) and degree of milling (Sompong et al., 2011) as polished broken rice produced remarkably higher expansion than brown rice grains (Gujral & Singh, 2002). This difference is linked to the compositional differences among milled and brown rice as high protein, lipid, fiber and ash contents are available in brown rice (Juliano et al., 1992). Non-starchy constituents in the raw material cause reduced expansion of the extrudates due to collapsing has been reported by Seth & Rajamanickam, (2012).

Hardness and crispiness

For hardness, the peak force required to deform the unit area of the extrudates is measured. The harder the sample, the maximum peak force will be needed to break the extrudates. Table 1 summarizes that cultivars imposed a significant effect ($P < 0.05$) on the hardness of the extruded product. The lowest hardness (17.85 ± 1.05N) exhibited by SUPRI was led by C-9 (19.81 ± 1.12N) and SB (20.5 ± 1.13N), while the hardest texture was produced by IRRI-9 (28.75 ± 0.75N) and KS-282 (23.14 ± 1.20 N). The difference in hardness among cultivars is directly related to the variation in crude protein, fiber and ash content (Juliano et al., 1992). Another experiment further confirms reduced bubble growth and denser product (Pardhi et al., 2019) as observed in KS-282 and IRRI-9 extrudates. In the present study, KS-282 produced the harder texture extrudates due to its higher amylose, starch and TKW with lower LB. SUPRI, in contrast to this, developed less hard and crispier texture might be linked to the reduced amylose and TKW. IRRI-9 extrudates denoted hardest in texture could be attributed to the highest piece and BD with reduced porosity (Table 1).

Additionally, the time and extent of polishing significantly affect the bran removal as it determines the expansion and hardness of the puffed products (Babu et al., 2009). The crispiness is the resultant of bubble growth, small and thin cells with reduced density of the extrudates. The results predicted that SB (fine rice variety) generated the highest score for crispiness (No. of peaks = 12). Among the coarse rice cultivars, SUPRI and C-9 remained second best with crispiness (No. of peaks = 9), followed by KS-282 (No. of peaks = 8) and PK-386 (No. of peaks = 6.99). The least number of peaks (6 & 5) were gained by IRRI-6 and IRRI-9, respectively. The crispiness is negatively correlated with hardness, and more peaks reflect the crispiness in the product (Sharif et al., 2014). In this study, the least crispiness was observed in IRRI cultivars is directly related to the more rigid texture with minimal air cells and collapsing confirmed by electron micrographs (Figure 2F, G). Contrarily, cultivars with crispier textures could also be evidenced in similar pictures. In a recent study extruded snacks were prepared using rice and chickpea flour using milk extrusion (Altaf et al., 2021). They reported that quality of extrudates was good and this technology can be applied at larger scale for the manufacturing of other products. Sacchetti et al. (2005) concluded in a study that physical characteristics of extrudates are highly effected by the moisture content of the products and temperature of extrusion.

3.4 Scanning Electron Microscopy (SEM)

Micrographs of axial cross-sectional cuts of extrudates revealed that cultivars significantly affected the microstructure. It is evident from the scans that KS-282 based extrudates (Figure 2A) produced comparatively large-sized cells, which are undesirable. Large pores decrease the crispiness during instrumental texture as recorded number of peaks. Micrographs of extrudates developed with SB rice flour generated better pores distribution (Figure 2B) than the other five extrudates. The remaining micrographs of extrudates (Figure 2C, E, F, G) exhibited a similar microstructure. SUPRI rice extrudates (Figure 2D) produced relatively homogenous, small, evenly distributed and less ruptured pockets within the unit area of extrudates, unlike extrudates prepared with the rest of the cultivars. Mir et al. (2019) studied the microstructure of snacks. They reported similar findings as a more compact and homogenous internal structure exhibited by snacks prepared using 100% brown rice flour than the chestnut supplemented flour. Sharif et al. (2014) also stated that substitution of rice flour with soy protein concentrate (SPC) and soy flour (SF) as protein fortificant reduced expansion and crispiness due to a decrease in average bubble diameter. The optimum protein content could be the factor for desirable bubble growth in SUPRI flour extrudates.

On the other hand, Launay & Lisch (1983) linked reduced expansion and melted elasticity to starch degradation in cross-linked extruded products. Conclusively, extrusion of whole grains based extruded products possess compactness in microstructure with reduced bubble diameter linked to the higher amount of fiber content in the formulations (Mariotti et al., 2006). In another study, the marked morphological difference with numerous cavities of different sizes was observed in puffed rice. It was also observed that during gelatinization, air spaces were occupied by a complex formed by denatured proteins and starch (Mir et al., 2016).

3.5 Sensory evaluation

Statistical analysis regarding sensory evaluation indicated highly significant ($P < 0.01$) variation among all rice cultivars concerning appearance, crispiness and overall acceptability (Table 2). SUPRI acknowledged as superior in appearance (8.27 ± 0.18), second highest in flavor (7.65 ± 0.09), texture (8.15 ± 0.29), and third-best in crispiness (7.32 ± 0.48). Mean values showed that SUPRI was liked a lot in terms of overall acceptability (8.21 ± 0.57) while SB was positioned as second best with a score (7.93 ± 0.37). The distinction of SUPRI in texture and crispiness is linked to the evenness in pores and less collapsing of air bubbles in extrudates (Figure 2D). Moreover, the sleek outer surface makes SUPRI extrudates project a better appearance (Figure 3D). The SB rice (Figure 3B) based extrudates were voted by the judges excellent in terms of flavor and mouth-feel might be due to the generation of 2-acetyl, 1pyroline during extrusion (Buttery et al., 1983), which is absent in coarse rice varieties. SUPRI contains comparatively lesser amylose

Table 2. Effect of cultivar difference on the sensory evaluation of extrudates prepared using different brown rice cultivars.

Cultivars	Appearance	Flavor	Texture	Crispiness	Mouth-feel	Overall acceptability
KS-282	5.13 ± 0.12[c]	5.02 ± 0.18[c]	5.09 ± 0.11[c]	5.15 ± 0.13[c]	5.01 ± 0.43[c]	5.39 ± 0.23[c]
SB	7.45 ± 0.37[b]	7.71 ± 0.39[b]	6.17 ± 0.56[d]	7.89 ± 0.37[b]	8.65 ± 0.67[a]	7.93 ± 0.37[b]
C-9	7.11 ± 0.57[c]	7.27 ± 0.87[c]	7.15 ± 0.68[b]	6.99 ± 0.77[d]	7.87 ± 0.55[c]	6.75 ± 0.77[d]
SUPRI	8.27 ± 0.18[a]	7.65 ± 0.09[a]	8.15 ± 0.29[a]	8.02 ± 0.29[a]	8.53 ± 0.08[b]	8.21 ± 0.57[a]
PK-386	6.33 ± 0.26[d]	5.64 ± 0.05[f]	5.95 ± 0.11[d]	7.32 ± 0.48[c]	7.13 ± 0.19[d]	7.22 ± 0.07[c]
IRRI-9	5.45 ± 0.25[f]	5.15 ± 0.15[f]	6.05 ± 0.17[e]	5.19 ± 0.22[f]	5.45 ± 0.55[f]	5.15 ± 0.38[f]
IRRI-6	6.03 ± 0.76[e]	5.65 ± 0.23[e]	6.91 ± 0.98[c]	6.56 ± 0.44[e]	6.18 ± 0.81[e]	5.96 ± 0.22[e]

Similar letters within the column indicated non- significant ($P > 0.05$) difference, values are means ± SD.

content linked to the improved flavor and better mouth-feel of SUPRI extrudates. With the SB rice exception, the rest of the rice cultivars extrudates undertaking sensory evaluation in the current study earned votes between 5 and 7 hedonic scores (denoting neither liked nor disliked to liked moderately) for the attributes mentioned in Table 2. Sensory traits, especially color and tastes, are also affected by the high percentage of ash content (Buttery et al., 1983). In a current research work, a group of researchers study the perception of frozen dessert containing water soluble extract of rice byproduct and prebiotics using the preferred attributes elicitation methodology. They find out that the most elicited attributes were, yellow color, brightness, creamy appearance creamy texture, passion fruit flavor and acid taste (Silva et al., 2021b)

4 Conclusion

This study is the first to explore the coarse brown rice cultivar grown in Pakistan best suited alternative raw material for extrudates development. Cultivar differences significantly affected all cultivars' physical, chemical, microstructural and sensory attributes of uncooked rice kernels. Among the cultivars investigated, SUPRI brown rice produced the most acceptable extrudates. Moreover, it exhibited better microstructure, crispiness and porosity, and minimum piece density and hardness. Conclusively, SUPRI containing low amylose could perform better as substitute raw material for extrudates development. However, advanced exploration is necessary to map out the technological and nutritional characteristics of the brown rice cultivars and their extrudates.

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