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Comparative Study of Physical and Functional Characteristics of Extrudates Prepared with Newly Released Rice Varieties of Telangana State

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Keywords: WGL-44, WGL-283, RNR-2458, texture, bulk density, colour, water absorption and solubility index.

ABSTRACT

The present study “screening of selected rice varieties for extrusion process that are available in Telangana region was conducted in the Department of Foods and Nutrition, Post Graduate Research Centre, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during the year 2016. The present study was executed to screen the selected rice varieties of Telangana region for their suitability for extrusion process. The physical quality characteristics and functional properties of raw rice and the extruded products were studied to emphasize the importance of rice based hot extruded snacks. Significant increase in the volume for WGL-44 (46.00%), WGL-283 (59.00%) and RNR-2458 (63.00%) and in the texture of the rice extrudates prepared with rice varieties WGL-44 (46.00%), WGL-283 (38.57%) and RNR-2458 (42.49%) was observed in the extruded products compared to raw rice. The water absorption index of the raw rice ranged from 3.4g/g to 5.7g/g and found to be increased to 6.2g/g to 7.16g/g in extruded products. The water solubility index of the raw rice ranged from 2.83% to 3.43% and found to be increased to 3.60% to 4.50% in the extrudates prepared with the selected rice varieties.

INTRODUCTION

Extrusion technologies play an important role in food industry as an efficient manufacturing process. Extrusion cooking is an ideal method for manufacturing a number of food products from breakfast cereals to snacks and baby foods (Guy, 2001). Extrusion cooking is unique among heat processes in that the material is subjected to intense mechanical shear, moistened starchy or proteinaceous foods are worked into viscous, plastic- like dough and cooked before being forced through the die (Zhoul, 2005). The physical characteristics of the extrudates play an important role in the acceptability of the product by the consumers. The physical quality characteristics include length, volume, mass, texture, bulk density and colour. The suitability of extruded foods for a particular application depends on their functional properties like water absorption and water solubility indexes, volume expansion index and swelling power (Chinnaswamy, 1993).

MATERIALS AND METHODS

Three rice (Oryza sativa) varieties viz WGL-44, WGL- 283 and KRISHNA (RNR- 2485) from Agricultural Research Station, Rajendranagar, Hyderabad were procured.

The samples were initially cleaned to remove foreign materials such as dust, dirt, grit and hollow grains.

Assessment of physical quality characteristics:

The physical quality characteristics such as colour properties were measured through Hunter's lab, texture measurement, length, diameter, and volume was measured by Singh. *et.al* (2001), bulk density was measured using standard procedure (AOAC, 1990), volume expansion ratio was measured by using Chinnaswamy and Bhattacharya (1984) water absorption index, water solubility index and swelling power were measured by Anderson *et al.* (1969).

RESULTS AND DISCUSSION

Physical quality characteristics of selected rice varieties and extruded products

The results of the physical quality characteristics of three selected varieties of rice grain and rice extrudates i.e. length and diameter, mass, volume, texture, bulk density, colour are given in Table 1 and 2.

Length (mm) and diameter (mm): The mean length of the selected rice varieties (WGL-44, WGL-283, RNR-2458) was 4.32mm, 5.77mm, and 5.41mm respectively (Table 1). The maximum length was observed for the rice variety WGL-283 (5.77mm) whereas minimum in WGL-44 i.e. (4.32mm). There was statistically significant difference ($p < 0.05$) in length among the three varieties.

The mean diameter of the selected rice varieties (WGL-44, WGL-283, RNR-2458) was 1.54mm, 1.61mm and 1.62mm respectively (Table 1). The maximum diameter was observed for RNR-2458 i.e. (1.62mm) and the minimum was for WGL-44 i.e. (1.53mm). There was statistically significant difference ($p<0.05$) in diameter among the three rice varieties.

Mass: The mean mass of the three selected rice varieties (WGL-44, WGL-283, and RNR-2458) was 0.02g (Table 1). The mass of the three rice varieties was observed to be 0.02g. Statistically, significant difference was not observed among the three rice varieties.

Volume: The mean volume of the selected rice varieties (WGL-44, WGL-283, RNR-2458) was 16.71cm^3, 10.33cm^3, 10.41cm^3 respectively (Table 1) (Fig-1). The maximum volume was observed in the rice variety WGL-44 i.e., 16.72cm^3 and minimum in WGL-283 i.e., 10.33cm^3. There was statistically significant difference ($p<0.05$) in volume among the three rice varieties.

Texture: The mean texture of the selected rice varieties (WGL-44, WGL-283, RNR-2458) was 43.20, 47.41, 47.58 respectively (Table 1) (Fig-2). The maximum texture score was observed in RNR-2458 i.e., 47.58 whereas minimum in WGL-44 i.e., 43.20. There was statistically no significant difference in mean texture score between the varieties RNR-2458 and WGL-283 but statistically significant ($p<0.05$) difference was found between the rice varieties WGL-283 and WGL-44 and between RNR-2458 and WGL-44.

Bulk density: The mean score for mass of the selected rice varieties (WGL-44, WGL-283, RNR-2458) was 0.42g/cm^3, 0.35g/cm^3, 0.38g/cm^3 respectively (Table 1) (Fig-3). The maximum bulk density was observed in the rice variety WGL-44 i.e., 0.42 and the minimum in WGL-283 i.e., 0.35. There was statistically significant difference in bulk density ($p<0.05$) among the three rice varieties.

Colour: Colour scores of the selected rice varieties were presented as L*, a*, b* values in the Table 2. Generally the L* values ranges from 0 to 100 indicating luminance or lightness component along with two chromatic component, a* component from green to red and the b* component from blue to yellow. The L*, a*, b* units are often used in food research studies to determine the uniform distribution of colours as L*, a*, b* units are very close to human perception of colours. The colour of food ingredients is important as it has a bearing on the visual appeal of the product to which they are added (Shahin *et al*, 2011). Significant difference were observed between colour parameters like L*, a*, b* among the rice varieties. The WGL-283 (L*-81.10) was found to be darkest followed by RNR-2458 (L*- 86.76), whereas the WGL-44 (L*-88.73) was observed to be lightest. The difference in colour of the rice kernels may be due to the difference in genetic makeup, coloured pigments and composition of flour. There was statistically no significant difference in the L* value among the three rice varieties.

The mean colour a* value of the selected rice varieties WGL-44, WGL-283 and RNR-2458 was 4.16, 2.62 and 3.98 respectively (Table 2). The maximum a* value was observed for the rice variety WGL-44 i.e., 4.16 and minimum for WGL-283 i.e., 0.12.There was statistically significant difference in a* value (p<0.05%) among the three rice varieties.

The mean colour b* value of the selected rice varieties WGL-44, WGL-283 and RNR-2458 was 3.99, 2.11 and 2.07 respectively. The highest b* value was observed in the sample WGL-44 (3.99) and lowest in the sample RNR-2458 (2.07). Statistically significant difference (p<0.05) was found in b* value among all the three rice varieties (Table 2).

WGL-44: There was strong positive correlation between volume of raw rice and mass of extrudates (r = 1.00, p < 0.001) but strong negative correlation was seen between mass of raw rice with mass of extrudates at 0.001 level of significance where r = -1.00 (Un published data).

WGL-283: There was strong positive correlation between bulk density of raw rice with diameter of processed rice, water solubility index of raw rice with volume of processed rice, water solubility index of raw rice with colour b* value of processed rice at 0.05 level of significance (r = 0.99, p < 0.05). There was strong positive correlation between volume of raw rice and bulk density of processed rice, between mass of raw rice with bulk density of processed rice (r = 1.00, p < 0.001) but strong negative correlation between diameter of raw rice with bulk density of processed rice at 0.001level of significance (r = -1.00, p < 0.001) (Unpublished data).

RNR-2458: There was strong positive correlation between water absorption index of raw rice with mass of processed rice(r = 0.99, p < 0.05) but strong negative correlation between water solubility index of raw rice with volume of processed rice, water solubility index of raw rice with diameter of processed rice at 0.05 level of significance(r = -0.99, p < 0.05). There was positive correlation between volume of raw rice and colour a* of processed rice and between mass of raw rice with bulk density of processed rice (r = 1.00, p < 0.001) and strong negative correlation between diameter of raw rice with bulk density of processed rice at 0.001 level of significance (r = 1.00, p < 0.001) (Unpublished data).

Physical quality characteristics of rice extrudates

Physical characteristics play a very important role for the acceptability of the final product. The results of the physical quality characteristics i.e. length, diameter, mass, volume, texture, bulk density and colour are summarized and given in Table 1 and Table 2

Length (mm) and diameter (mm): The length of the extruded snacks prepared with WGL-44, WGL-283 and RNR-2458 was 24.37 mm, 25.23mm, and 24.70mm respectively (Table 3). The maximum length was observed for RNR-2458 i.e., 25.23 mm, and minimum for WGL-283 i.e., 24.37 mm. There was statistically no significant difference in length of extruded snacks among three varieties.

The diameter of the extruded snacks prepared with WGL-44, WGL-283 and RNR-2458 was 9.73mm, 7.69mm, and 8.08mm respectively (Table 3). The diameter of extrudates prepared with WGL-283 was maximum (9.73mm) and minimum was observed for RNR-2458 (7.69mm). There was statistically significant difference (P<0.05%) in diameter between WGL-44 and WGL-283 but no significant difference between RNR-2458 compared to other two rice varieties.

Similar values were reported by Lakshmi *et al.*, (2009) for sorghum and rice based extruded snacks. The length was observed to be around 27mm to 28mm and the diameter ranged from 7.78 to 8.87 mm. The length and diameter of the rice based extruded snacks were higher when compared to that of the extruded snacks that were prepared from sorghum, rice and bengal gram flour indicating lesser expansion.

Mass (gm): The mass of the extruded snacks prepared with WGL-44, WGL-283 and RNR-2458 was 0.021 g, 0.024 g, and 0.026 g respectively (Table 3). The maximum mass was observed in the sample prepared with RNR-2458 (0.026 g), and minimum in WGL-44 (0.021g). There was statistically no significant difference in mass between RNR-2458 and WGL-283 but there was significant difference ($p<0.05$) in mass between WGL-44 compared to both RNR-2458 and WGL-283. Lakshmi Devi *et al.*, (2009) reported that extrudates made from sorghum in combination with rice, bengal gram, legume mix and soy ranged from 1.3 to 2.4g which was higher than that of the products prepared from rice, this might be because of the higher unit weight of the ingredients used.

Volume (cm^3): The volume is measured using the length and diameter of the extruded products. The length and diameter are directly proportional to the volume. The volume of the extruded snacks prepared with WGL-44, WGL-283 and RNR-2458 was 30.37cm^3, 38.23cm^3, and 31.37cm^3 respectively (Table 3) (Fig-1). The volume of extrudates made with WGL-283 was highest (38.2cm^3) whereas the samples prepared from WGL-283 showed lowest volume (30.33cm^3). There was significant difference ($p<0.05$) in volume among the extruded products prepared with all the three rice varieties. There was 46%, 59% and 63% increase in the volume of the extrudates compared to the respective raw rice varieties (Figure 4.2). The increase in volume of the rice extrudates might be due to high temperature.

Texture: The texture of the extruded products is of great importance to quality and directly affects acceptability of the consumers. The texture of the extruded snacks prepared with WGL-44, WGL-283 and RNR-2458 was 62.96, 67.80 and 65.70 respectively (Table 3) (Fig-2). Less shear force results in less hardness of the extrudate. Use of high shear force was required to cause rupture of the extruded products prepared with RNR-2458 i.e., 67.80. For the WGL-44 and WGL-283 samples, the force used was 62.96 and 65.70 respectively. The requirement of shear force was high because, the extruded products were prepared only with rice, without addition of any other ingredients such as pulses, corn etc which will result in generally in lowering the shear force which caused higher gelatinization of starch in rice based samples that led to little hardening of the extruded snacks. There was no significant difference in texture between the samples prepared with WGL-283 and WGL-44, but there was significant difference ($p<0.05$) between RNR-2458 and WGL-44.

There was 46.00%, 38.57% and 42.49% increase in texture of the extruded snacks prepared with rice varieties WGL-44, WGL-283 and RNR-2458 respectively (Figure 4.1) compared to the rice grains as the high temperature (above 110^oC) gives crunchy texture to the product which was not easily ruptured by the sheer force than compared to the rice grain as the higher temperature cause gelatinization of starch which led the extruded snacks to give harder texture compared to the extruded snacks that had other ingredients in combination with it. A similar study was given by Sawant *et.al,* (2012), where the texture of the extruded products made from rice grits and lupine showed values that ranged from 62.05 to 48.47 requiring high shear for rupturing the extruded samples.

Bulk density: The bulk density of the extruded products prepared with WGL-44, WGL-283 and RNR-2458 was 0.15g/cm^3, 0.08g/cm^3 and 0.11g/cm^3 respectively (Table 3) (Fig-3). The extruded sample that was prepared with the rice variety WGL-44 (0.15g/cm^3) had highest bulk density whereas the lowest bulk density value was observed for the samples prepared with WGL-283 (0.08g/cm^3). The bulk density of the rice was high when compared to that of the extruded rice varieties as the length and breadth ratio of the rice varieties was lower when compared to that of the extruded rice products because of expansion after extrusion (Fig-4.3). The highest value for bulk density could be due to retention of high moisture content. Similar values were reported by Jyothi *et.al.* (2009), for arrow shoot starch extruded snacks in which the bulk density ranged from 0.13 to 0.19g/cm^3. There was statistically significant difference ($p<0.05$) in bulk density among all the three extruded products.

Colour: Colour is an important attribute of the extruded sample. The colour measured through Hunter lab is usually depicted in three values. L*- which indicated lightness of the sample, a*- which indicates red, b*- which indicates yellow. The extrudates developed from the three rice varieties obtained higher values of luminosity (85.86- 91.26) (Table 4) where the maximum value was observed for the sample WGL-283 (91.21) and minimum for the sample WGL-283 (85.28) (Table 4). There was statistically significant difference ($p<0.05$) in L* value of colour among all the three extruded products.

The a* value of the extruded products prepared with WGL-44, WGL-283 and RNR-2458 was 0.10, 1.1 and 1.43 respectively, not showing any reddish colour in the samples There was significant difference (p<0.05%) in a* value of colour between WGL-283 and WGL-44 and between RNR-2458 and WGL-44 whereas there was statistically no significant difference (p>0.05%) found between RNR-2458 and WGL-283.

The b* value of the extruded products prepared with WGL-44, WGL-283 and RNR-2458 was 8.12, 6.47, 5.57 respectively showing light yellowish colour in the product. The highest b* value was observed i.e., for the sample WGL-44. Statistically significant difference ($p<0.05$) was found in b* value among all the three extruded products.

Similar values were observed in the studies given by Oliveira *et al,* (2015) where the samples that were prepared from rice and lupine showed L* value that ranged from 81.1 to 91.1, where the highest value was seen in the products that were prepared from broken rice grits. The a* value ranged from 5.0 to 0.1, whereas the lowest value was found in the products that were prepared from broken rice grits. The b* value ranged from 8.1 to 32.0, where the highest value was observed in the products prepared with ground lupine and the lowest value was observed in the products prepared with broken rice grits.

Table 1 Physical quality characteristics of raw rice and rice extrudates prepared with selected rice varieties

Physical quality characteristics	**Length**		**Diameter**		**Texture**		**Volume**		**Mass**		**Bulk density**	
Rice variety	RR	EP	RR	EP	RR	EP	RR	EP	RR	EP	RR	EP
WGL-44	4.32±0.40^{a}	24.70±0.26^{ab}	1.54±0.01^{a}	8.08±0.54^{a}	43.20±0.79^{ac}	62.96±0.72^{a}	16.71±0.00^{a}	31.37±0.15^{a}	0.02±0.00^{a}	21.67±0.33^{a}	0.42±00.01^{a}	0.15±0.01^{a}
WGL-283	5.77±0.04^{b}	24.37±0.15^{bc}	1.61±0.06^{b}	9.73±0.11^{b}	47.41±1.97^{ab}	65.70±1.45^{ab}	10.33±0.01^{b}	30.37±0.18^{b}	0.02±0.00^{b}	24.33±0.88^{b}	0.35±0.01^{b}	0.08±0.00^{b}
RNR-2458	5.41±0.06^{c}	25.23±0.20^{ca}	7.69±0.00^{c}	7.69±0.41^{c}	47.58±0.30^{c}	67.80±0.85^{c}	10.41±0.00^{c}	38.23±0.19^{c}	0.02±0.00^{c}	26.00±0.58^{c}	0.38±0.01^{c}	0.11±0.00^{c}
Mean	5.17	24.76	1.59	8.50	46.06	65.48	12.48	33.32	0.02	24.00	0.38	0.11
CD	0.08	0.92	0.01	1.42	3.15	3.94	0.01	0.69	0.00	2.44	0.02	0.04
CV% value	0.75	1.64	0.41	7.41	3.08	2.66	0.04	0.91	5.03	4.50	2.94	18.91

Note: Value presented as mean ± standard deviation of three determinations

RR- Raw rice

EP- Extruded products

Means within the same column followed by a common letters (a-c) do not significantly differ at 5% level ($p\leq0.05$).

Table 2 Colour values of raw rice and rice extrudates prepared with selected rice varieties

Colour	L*		a*		b*	
Rice variety	**RR**	**EP**	**RR**	**EP**	**RR**	**EP**
WGL-44	88.73 ± 3.88[ab]	91.26 ± 0.13[a]	4.16 ± 0.12[a]	6.11 ± 0.01[ab]	3.99 ± 0.10[a]	3.52 ± 0.3[a]
WGL-283	81.10 ± 0.17[bc]	85.86 ± 0.15[b]	2.62 ± 0.04[b]	4.02 ± 0.01[ba]	2.11 ± 0.03[b]	2.12 ± 0.02[b]
RNR-2458	86.75 ± 1.2[ca]	89.14 ± 0.03[c]	3.98 ± 0.57[c]	5.63 ± 0.02[bc]	2.07 ± 0.15[c]	2.22 ± 0.15[c]
Mean	88.87	88.75	1.85	1.92	7.72	9.15
CD	6.12	0.18	0.77	0.03	0.22	0.04
CV% value	3.04	0.09	18.35	0.60	0.47	0.18

Note: Value presented as mean ± standard deviation of three determinations

RR- Raw rice

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EP- Extruded products

Means within the same column followed by a common letters (a-c) do not significantly differ at 5% level ($p \leq 0.05$).

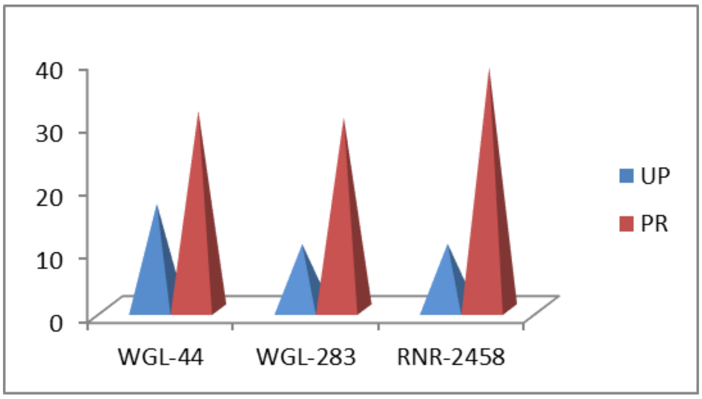

Fig 1: Change in volume of rice extrudates compared with raw rice

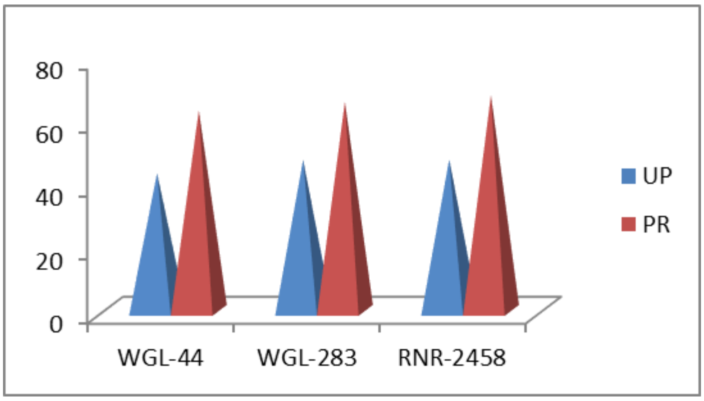

Fig 2: Change in texture of rice extrudates compared with raw rice

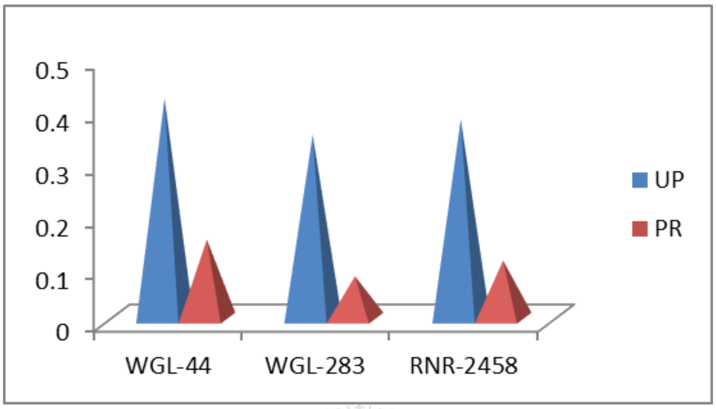

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Fig 3: Change in bulk density of rice extrudates compared with raw rice

Functional properties of selected rice varieties and extruded products

The suitability of extruded foods for a particular application depends on their functional properties like water absorption and water solubility indexes, volume expansion index and swelling power. Functional properties of selected rice varieties and developed extruded products are presented in Table 3and Table 4.

Water Absorption Index (WAI) and Water Solubility Index (WSI): Water absorption characteristics represent the ability of a sample to re-associate with water under conditions where water is limiting (Shabir *et al.*, 2013). The variation in WAI and WSI among different rice varieties are depicted in Table 5 and 6. The results indicated the varietal difference in WAI ranging from 3.4g/g to 5.7g/g in raw rice samples and found to be increased to 6.2g/g to 7.16g/g in respect to extruded products (Table 5 and 6)(Fig- 4 and Fig-5). This might be due to the more damaged starch present in the extrudates at higher temperatures to imbibe and hold water. However, after extrusion the solubility was also enhanced in all the three rice varieties. Water solubility index of raw rice samples of different rice varieties ranged from 3.6% to 4.5% after extrusion. The increase in WAI and WSI due to extrusion in the present study could be supported by the observations of various cereal flours with an enhanced WAI and WSI during different processing conditions as shown in literature (Chinnaswamy *et al.*, 1993).

Similar results were observed in the studies given by Meng *et. al.*, (2010) where the WAI of the extruded products prepared from yam, rice and corn flour ranged from 4.06 to 7.37g/g. A study conducted by Dibyakanthseth *et. al.*, (2012), showed that the WSI of the extruded snacks prepared with sorghum, soy and rice ranged from 37.67% to 13.18%. The mentioned reason for wide variation was due to the positive interaction of the sorghum and soy may be due to rich protein contents that increase the WSI of the extruded snacks.

Swelling Power (SP): The swelling power of native rice varieties and extruded products are presented in Table 3and Table 4, Fig-6. The swelling power of rice varieties ranged from 4.74g/g to 6.30g/g. After extrusion of rice products the swelling power was increased (8.73 to 10.28g/g). Statistically significant increase in swelling power after hot extrusion was observed in the extruded samples. A study given by Visvanatha *et. al.*, (2014) reported that the SP of the extruded snacks prepared with rice, finger millet and maize ranged from 8.32 g/g to 5.12 g/g. Swelling power of starches reflects the interactions between water molecules and starch chains in amorphous and crystalline domains, respectively. As the starch content in rice is higher when compared to the combination of the millets and maize, the SP of rice based extruded snacks are higher when compared to that of the extruded snacks that are prepared with rice, finger millet and maize. There was significant difference ($p<0.05$) among the three rice varieties.

Volume Expansion Ratio (VER): The VER of the selected rice varieties and extruded products are presented in the Table 3 and 4, Fig-7. The VER of rice varieties ranged from 1.42m/cm^3 to 2.56m/cm^3. The maximum VER was observed for WGL-44 i.e., 1.61 and the minimum for RNR-2458 i.e., 1.33. The VER of extruded products ranged from 2.56 m/cm^3 to 3.24 m/cm^3. A significant increase in VER after hot extrusion was observed in the extruded samples due to high temperatures applied during the process. There was significant difference ($p<0.05$) among the three rice varieties. A study given by Mary *et al.*, (2014) showed that the Expansion Ratio (ER) of the extruded snacks prepared with a composite blend of rice, soyabean flour and sorghum ranged from 2.0 to 2.6. The ER of the extrudates increased with the increase of the temperature up to 130^oC and thereafter decreased with further increase in the temperature. The ER of the rice extrudates was higher when compared to the snacks prepared from the blends of these composite flours, as the temperature used for these extrudates was higher to that of the samples prepared from rice extruded snacks.

WGL-44: There was strong positive correlation between WAI and WSI of raw rice with swelling power of extrudates ($r = 1.00$, $p < 0.001$) but strong negative correlation was seen between swelling power of raw rice with volume expansion ratio of extrudates at 0.05 level of significance where ($r = -0.99$, p< 0.05) (Unpublished data).

WGL-283: There was strong positive correlation between volume expansion ratio of raw rice with WAI and ($r = 0.99$, $p < 0.05$) and strong negative correlation between WAI of raw rice with WSI of processed rice at 0.05 level of significance ($r = -0.99$, $p < 0.05$). There was strong positive correlation between bulk density of raw rice and volume expansion ratio of processed rice, between volume expansion ratio of raw rice with swelling power of processed rice at 0.001level of significance ($r = 1.00$, $p < 0.001$).

RNR-2458: There was strong positive correlation between length of raw rice with WSI of processed rice ($r = 0.05$, $p < 0.05$) and strong negative correlation between WSI of raw rice with volume expansion ratio of processed rice at 0.05% level of significance ($-r = 0.05$, $p < 0.05$).

Table 5: The Functional properties of the rice varieties

Functional quality characteristics	**Water absorption index**		**Water solubility index**		**Swelling power**		**Volume expansion ratio**	
Rice variety	RR	PR	RR	PR	RR	PR	RR	PR
WGL-44	3.42 ± 0.01[a]	6.36 ± 0.02[ab]	3.42 ± 0.01[a]	4.50 ± 0.11[a]	5.43 ± 0.24[a]	9.12 ± 0.00[a]	1.60 ± 0.00[a]	2.69 ± 0.10[a]
WGL-283	5.27 ± 0.06[b]	7.16 ± 0.06[a]	3.18 ± 0.03[b]	4.26 ± 0.08[b]	6.30 ± 0.09[b]	10.28 ± 0.07[ab]	1.42 ± 0.00[b]	3.24 ± 0.02[b]
RNR-2458	4.67 ± 0.02[c]	6.20 ± 0.05[bc]	2.83 ± 0.04[c]	3.60 ± 0.17[bc]	4.74 ± 0.09[c]	8.73 ± 0.01[bc]	2.56 ± 0.01[c]	2.56 ± 0.07[ac]
Mean	4.45	6.57	3.14	4.12	5.49	9.38	1.45	2.53
CD	0.08	0.17	0.09	0.56	0.24	0.17	0.03	0.25
CV% value	0.88	1.19	1.39	5.99	1.98	0.83	1.12	7.32

Note: Value presented as mean ± standard deviation of three determinations

Means within the same column followed by a common letters (a-c) do not significantly differ at 5% level ($p \leq 0.05$).

RR- Raw Rice

EP- Extruded Products

WAI- Water Absorption Index

WSI- Water Solubility Index

SP- Swelling Power

VER- Volume Expansion Ratio

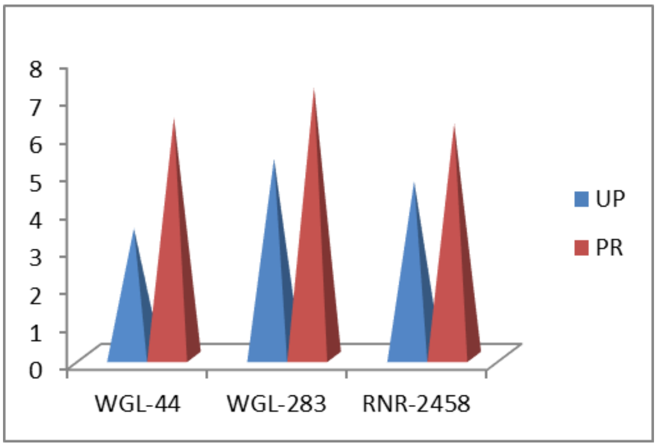

Fig 4: Comparison between Water Absorption Index of raw rice and extrudates

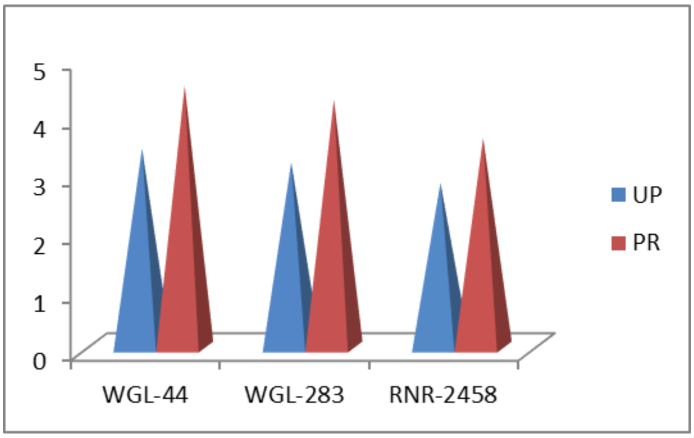

Fig 5: Comparison between Water Solubility Index of raw rice and extrudates

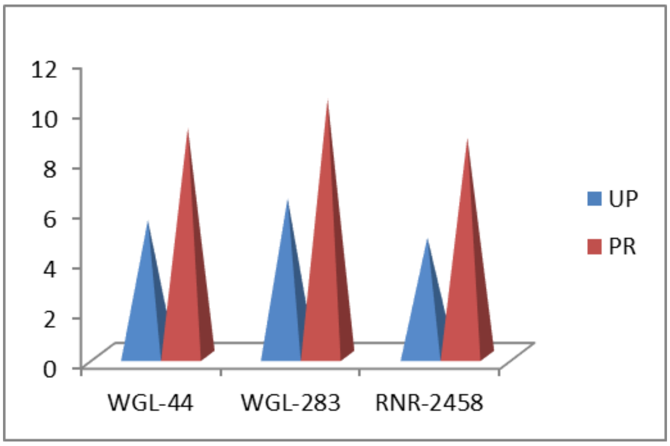

Fig 6: Comparison between Swelling Power of raw rice and extrudates

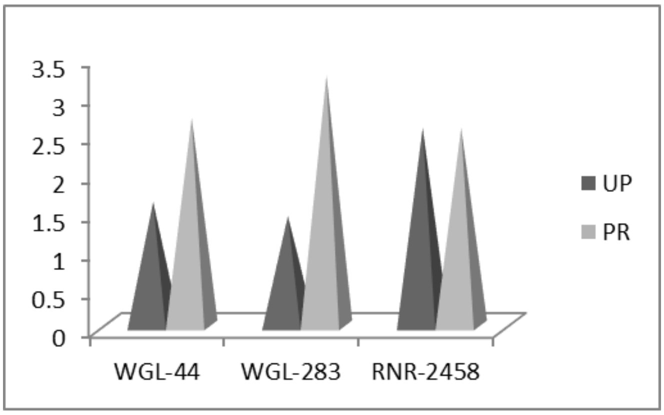

Fig 7: Comparison between Volume Expansion Ratio of raw rice and extrudates

CONCLUSION

Significant increase in the volume for WGL-44 (46.00%), WGL-283 (59.00%) and RNR-2458 (63.00%) was observed in the extruded products compared to raw rice. Statistically significant difference ($p<0.05$) in the volume was observed among all the three extruded products prepared with selected rice varieties. Statistically significant increase was observed in the texture of the rice extrudates prepared with rice varieties WGL-44 (46.00%), WGL-283 (38.57%) and RNR-2458 (42.49%) respectively compared to the raw rice grains.

HUMAN

The WAI of the raw rice ranged from 3.4g/g to 5.7g/g and found to be increased to 6.2g/g to 7.16g/g in extruded products. The water solubility index of the raw rice ranged from 2.83% to 3.43% and found to be increased to 3.60% to 4.50% in the extrudates prepared with the selected rice varieties. Statistically significant difference ($p<0.05$) in water absorption index was observed among all the three experimental extruded products prepared with selected rice varieties.

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