Identification of Important Physical Properties and Amylose Content in Commercially Available Improved and Traditional Rice Varieties in Sri Lanka

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Abstract— *Commercially available, fourteen different rice varieties (improved and traditional) in Sri Lanka were subjected to determine amylose content and important physical properties. Under physical properties, milling parameters (such as brown rice content, husk content and total milling recovery), hardness and dimensions (length, width & thickness) including water absorption capacity (by dipping at 70°C for four hours) were measured. Amylose content of each rice variety was determined by measuring the optical density of amylose-iodine complex using spectrophotometer, while amylopectin content was obtained using the relationship equation. Results revealed, brown rice content, husk content, total milling recovery, hardness and water absorption capacities of these rice varieties were within the range of 76-78%, 20-23%, 69-72% & 28-30% respectively. Statistical analysis also indicated, those physical properties of fourteen rice varieties were significantly different to each other (p<0.05). Amylose & amylopectin contents of rice varieties were found in the range of 20 to 28% and 71 to 79% respectively, were significantly different (p<0.05) to each other. According to the correlation analysis, weak positive and weak negative correlation ships (p<0.05) were observed for amylose content vs. hardness and amylopectin content vs. hardness respectively. Further, moderate positive correlation ship (p>0.05) was reported in between amylose content and water absorption capacity. While showing negative correlation (p>0.05) between amylopectin and water absorption capacity. Between hardness and water absorption capacity, also had a weak positive correlation ship (p>0.05).*

Keywords— *Milling properties; Hardness; Water Absorption Capacity; Amylose content; Amylopectin content; Rice varieties .*

I. INTRODUCTION

Utilization of rice grains have been increasing considerably, as an major ingredient in other food applications , other than the major staple in domestic usage. The reasons for increasing usage of rice could be depending upon the cost effectiveness, functional properties, and unique medicinal values, appealing organoleptic properties and being a cereal of free from gluten. Consumer acceptability and market value of rice is defined from various quality traits such as milling quality, physical quality, cooking and eating quality or nutritional quality (Bao, 2012; Rebeira*et al.,*2014; Fernando *et al.,*2015).Some of these quality parameters are intrinsically governed by physicochemical properties such as amylose and amylopectin (Rohilla*et al.,* 2000; Rebeira*et al.,*2014). Amylose and amylopectin are the building material of starch in rice endosperm (Martin and Smith, 1997; Duan*et al.,* 2012). Amylose are linear molecules made by linking D-glucose units with α-1.4 glucosidic bonds, while amylopectin are highly branched molecules, consist with both α-1.6 and α-1.4 glucosidic bonds. (Denardin*et al.,* 2012; Kaufmana*et al.,* 2015).

The ratio of these two types of polymeric substances is contributing the functional properties of rice (Kaufmana*et al.,*2015). Amylose content is often contributed, to the differences in cooking and eating qualities of rice about 65 %(Juliano, 1971). Cheng et al. (2012) reveal, higher amylose tends to absorb more water during the cooking process and resulting higher volume expansion of rice. After cooking, it receives dry and fluffy texture and grains can be separated easily. While rice varieties with lower amylose content are moist, chewy, clingy and less separable after cooking (Juliano,1985; Mir *et al.,*2013; Srikaeo and Arranz-Martínez,2015).Amylose content of a rice variety is

positively correlated with its pasting and gelatinization temperatures (Jane *et al.,* 1999; Sodhi& Singh, 2003;Varavinit *et al.,* 2003; Chung *et al.,* 2011), gel hardness (Bao*et al.,* 2006;Lu *et al.,* 2009; Wang *et al.,* 2010), and water solubility index (Kong et al., 2015;Kaur et al., 2014) as well. While amylose content is negatively correlated with the swelling power, adhesiveness and cohesiveness, colour and glossiness, amylopectin content correlated positively.(Cruz and Khush, 2000; Bao*et al.,*2006; Wang *et al.,*2010 ; Kaur *et al.,* 2014; Kong *et al.,* 2015).

Amylose is also responsible for the retrograding of starch by forming hydrogen bonds between molecules by creating a firm gel matrix (Gani*et al.,*2013;Kong *et al.,*2015) and is a vital quality parameter of staling of starch base foods. (Mariotti*et al.,* 2009; Shifeng*et al.,* 2009 ; Hug-Iten*et al.,* 2003). As in many other Asian counters, Sri Lanka cultivates plenty of rice varieties (improved & traditional) commercially, with largely diversify physical properties, including amylose & amylopectin content too. Hence, the aim of this study is to determine the imported physical properties (milling properties, dimensions, hardness, water absorption capacity) and amylose/amylopectin content of selected improved & traditional rice varieties in Sri Lanka.

II.   MATERIALS AND METHODS
2.1 Collection and Preparation of Test Samples
Commercially available seven improved and seven traditional rice varieties were purchased from recognized paddy suppliers in Sri Lanka. Each rice/paddy sample was stored six months, under ambient condition (28-30°C/R.H.70-75%) in plastic containers. Subsequently, two kilos of samples from each rice variety were drawn and divided using a sample divider to obtain the test portions. There after the test portion was divided into four sub portions and each portion was used to determine milling properties, dimensions, water absorption capacity (WAC), hardness and amylose content.

2.2 Milling Properties & Dimensions
At the beginning, moisture contents of the rough rice (paddy) samples were measured using digital grain moisture meter (G-Won -GMK303A) and found it was within the range of 12-14%. 150g of rough rice samples from each rice variety were de-husked using SATAKE-THU de-husker. The barn of brown rice (unpolished) were removed up to 8±1.1% using SATAKE TMO-5 Polisher. At each point, brown rice yield, husk percentage & total milling recovery were calculated according to the equations given below,

Brown Rice %=(Weight of de-husked rice) ×100 /Weight of rough rice

Husk %=(Weight of husk) ×100 /Weight of rough rice
Total Milling Recovery %=(Weight of milled rice) ×100 /Weight of rough rice

Dimensions such as length, width & thickness of fifty rice kernels from each variety were measured using laboratory thickness indicator at 0.01mm resolution.

2.3 Hardness
Hardness of rice kernels were determined by placing randomly selected fifty brown rice grains on the platform of rigidity tester (KIYA) & applied the force by rotating the screw head down words. Readings were taken at the point of rupturing the grains individually and means of hardness were calculated.

2.4 Water Absorption Capacity (WAC)
The Water Absorption Capacity of rice varieties was investigated as stated in Thilakarathna et al.(2015). About 10g of rough rice samples in each variety were soaked in hot water at 70 ^{0}C for 4 hours. The temperature of the soaking water was maintained throughout the soaking period with the aid of thermostatic water bath (Gallenkamp-BKS350).Soaked rice samples were removed from the water bath and the remained water was drained off. Subsequently, wet rice grains were blotted quickly with filter papers to remove superficial water. Weights of the damp rice grains were measured with digital weighing scale (OHAUS-Discovery) and moisture increments of each rice variety was estimated using a hot air oven (Leader), maintain at 105±2°C for 24hours.

2.5 Amylose & Amylopectin Content
Amylose content was determined based on simplified colorimetric method outlined by Juliano (1971) & ISO 6647-2: (2015) with slight modifications. Initially, milled rice samples were ground to fine powder using a disk mill (FFC-23) and sieved (180µm pore size) using a sieve shaker (IMPACAT).Sieved rice samples were packed in a metalized pouches and stored at 4°C. Prior to the analysis, samples were kept at room temperature for three hours and moisture content was measured using digital moisture analyzer (SHIMADZU-MOC63u).

Then, accurately, 100 ± 0.5mg of prepared rice flour sample was weighed into a 100 ml conical flask. To the same flask, 1.0 ml of 95% ethanol was pipetted out and wetted by shaking slightly. Then, 9.0ml of 1N sodium hydroxide solution was pipetted into the same conical flask, mixed well and allowed to stand in overnight. The completely disperse rice flour in the conical flask was transferred to a 100ml volumetric flask and empty volume was made up with distilled water to prepare initial stock solution. Finally, 5.0ml of stock solution, 1.0 ml of 1N acetic acid and 2.0 ml of 2%

iodine solution were added into another 100 ml volumetric flask and the volume was made up with distilled water to get a coloured solution. The colored solution was mixed by inverting and let stand for 20 minutes in a dark place avoiding direct light. The absorbance was measured at 620 nm using UV-Vis spectrophotometer (HACH-DR6000).

Amylose content of rice varieties were calculated from the calibration curve, constructed using purified amylose standard- from potatoes (Sigma Aldrich). Final results were given as percentage by mass on dry basis. Amylopectin contents (%) of rice varieties were calculated by subtracting the obtained amylose content (%) from hundred (%) as describe by Juan et al. (2006).

2.6 Statistical Analysis

The experiment was complete randomized design. Descriptive analysis, analysis of variance (ANOVA) and Pearson correlation analysis were performed using minitab statistical software, at 95% confidence level.

III. RESULTS AND DISCUSSION

3.1 Physical properties

Physical properties such as milling properties, hardness, dimensions, size & shape of rice grains obtained from fourteen different rice varieties including improved & traditional, were given in Table 01.

Table.1: Milling properties, Hardness, Dimensions(length, width, thickness), Size & Shape of Improved and Traditional rice varieties

Sample Code	Variety	Brown Rice (%)	Husk (%)	TMR (%)	Hardness (N)	Length (mm)	Width (mm)	Thickness (mm)	Grain Size	Grain shape
IM1	AT307	78.98±1.65	20.48±1.22	72.71±1.36	24.60±1.31	5.51±0.19	2.57±0.15	1.95±0.07	Intermediate	Bold
IM2	BG300	76.48±0.29	22.71±0.62	70.43±0.54	33.20±2.67	5.71±0.25	2.54±0.09	1.88±0.06	Intermediate	Bold
IM3	BG352	78.37±0.76	21.36±0.81	71.99±0.84	34.18±1.41	5.60±0.11	2.63±0.08	1.94±0.06	Intermediate	Bold
IM4	BG358	78.42±0.10	22.73±0.92	71.77±0.32	21.31±1.66	4.19±0.14	2.36±0.15	1.71±0.08	Short	Round
IM5	BG360	76.78±0.54	23.13±1.08	70.12±0.64	29.82±1.84	4.15±0.19	2.09±0.09	1.52±0.09	Short	Round
IM6	BG366	76.47±0.74	23.22±1.14	70.39±0.88	26.02±0.53	5.51±0.20	2.44±0.12	1.79±0.09	Intermediate	Bold
IM7	BW367	77.59±0.09	21.64±0.23	71.38±0.11	23.94±1.85	4.11±0.13	2.54±0.12	1.80±0.08	Short	Round
TR1	Hangimuttan	78.20±0.98	22.98±0.37	72.48±0.65	26.96±1.97	4.26±0.16	2.14±0.13	1.57±0.09	Short	Round
TR2	Kahamaala	78.78±0.76	22.83±0.15	71.92±0.99	36.10±2.74	5.64±0.16	2.33±0.11	1.85±0.05	Intermediate	Bold
TR3	Kahawanu	75.97±0.37	23.73±0.05	69.94±0.34	28.37±1.69	4.26±0.16	2.87±0.09	1.99±0.06	Short	Round
TR4	Rathna Samba	76.27±0.23	22.62±0.51	70.09±0.22	26.57±1.59	4.45±0.11	2.07±0.14	1.54±0.08	Short	Bold
TR5	Suduru Samba	76.77±0.25	23.03±0.56	70.47±0.45	25.90±1.44	3.85±0.30	1.65±0.10	1.36±0.07	Short	Bold
TR6	Suwandall	77.18±0.60	22.41±0.90	71.26±0.36	26.10±2.12	4.02±0.21	2.10±0.13	1.66±0.07	Short	Round
TR7	Unakola Samba	76.06±0.43	22.92±0.06	69.92±0.32	26.68±0.98	4.21±0.18	2.16±0.09	1.62±0.06	Short	Round

❖ (All the data given in the table were means ± SD of replicated samples(n). n=3 for all milling properties)/ for hardness and dimensions n=50.)

❖ IM- Improved ; TR-Traditional =The letters depicted two rice categories

Physical properties of rice grains are important quality components, since it Impacts on the market demand and production cost. Kernel size, shape, milling recovery, degree of milling and grain appearance are frequently assessing as physical properties (Cruz &Khush, 2000).Referring to the data given in Table 01, 76-78% of brown rice content and 20 – 23 % husk content were observed for improved and traditional rice varieties. Total milled recoveries (TMR) were ranged from 70- 72 % and 69- 72% for improved and traditional rice varieties respectively. TMR is an important index when economizing the rice milling operations, however, efficacy of milling equipment's, natural diversity of rice varieties, and hydrothermal treatments can change those readings (Falade& Christopher, 2015).

Hardness of rice grains were varied between 21N to 36N for both type of varieties (Table 01). Highest grain hardness was reported by BG352 and Kahamaala while BG358 and Suduru samba given the lowest value. Statistical analysis revealed that the hardness of fourteen types of rice varieties were significantly different to each other at p<0.05. Hardness of raw rice is important criteria in many areas, especially for identifying the changes occurrence during storage and aging process, to determine the breakages during milling operation, drying and handling etc. (Kunze& Hall, 1965; Barber, 1972 ;Kunze& Choudhury 1972 ; Moritake&Yasumatsu 1972 ; Villareal*et al.,*1976; Pomeranz& Webb 1985).

Lengths of brown rice kernels were varied from 3.85 to 5.71mm for all varieties (Table 01). Grains with smallest dimensions were observed among the traditional rice varieties than improved varieties. Lowest grain dimensions (length, width and thickness) were shown by traditional variety called Suduru samba. Highest grain length was given by BG300 and highest grain width & thickness was indicated by Kahawanu. However, the dimensions for improved and traditional rice varieties were significantly different to each other (P<0.05).

Classification of rice grains were carried out, according to their sizes and shapes based on Juliano (1985). Size of the rice grains were determined as per grain length while grain shape was determined by means of length & width ratio of rice kernel. In local market, rice is classified as *Samba* (short grain) and *Nadu* (long grain) based on the size of the grain (Pathiraje*et al.,* 2010). According to the grain classifications (Table 01), majority of rice varieties were belongs to the short round or short bold (*Samba*) types, except varieties like, BG300, BG352, BG366, AT307 and Kahamaala, that comes under the intermediate bold (*Nadu*) type. Although consumer choice on size and shape of the rice grain can be

vary broadly, Sri Lankans are more consuming *Nadu* rice than *Samba* rice (Department of census and statistics, 2013; Rebeira*et al.*, 2014). Water absorption capacities (WAC) of improved and traditional rice varieties are graphically illustrated in Figure 01.

A cold or hot soaking process facilitates the water absorption of rice grains & is an essential practice in parboiling, wet milling or cooking operations (Kashaninejad et al., 2007). As in Figure 01: rice varieties were showed different water absorption capacities after four hours of hot soaking at 70 ^{0}C. Generally, the final moisture contents of all rice varieties were reached to 28-30% (w.b.). Among the all rice varieties, highest WAC was shown by Unakola samba (30.65%, w.b.) and lowest was displayed by Rathna samba (28.32%, w.b.). Under the improved rice varieties, highest water absorption was reported by BG300 (30.34%, w.b.) and lowest was given by BG358 (28.82%, w.b.).BG300, Suduru samba, Kahamaala and Suwandall showed comparatively higher WACs (>30%) than the other varieties.

During soaking, water enters into the starch granules and void spaces in the rice endosperm, as a result of molecular absorption, capillary absorption and hydration (Navaratne, 2015). However, the water absorption rate of the grains is also impacted varietal difference, consisting differences in physical and chemical characteristics (Kaewwihar*et al.,*2012 ; Thilakarathna et al.,2015,2016). Falade and Christopher, (2015) reported various internal forces associate with the granule structure, the extent of hydrogen and covalent bonds and availability of moisture binding sites, imposed the variations in starch structure which cause for the difference in water absorption between the rice varieties.
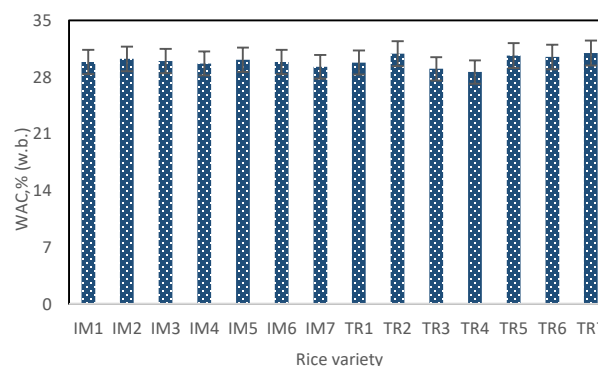

Fig.1: Water Absorption Capacities (WAC) of improved & traditional rice varieties

(Code name of rice varieties -IM1-AT307,IM2-BG300,IM3-BG352,IM4-BG358,IM5-BG360,IM6-BG366,IM7-BW367,TR1-Hangimuttan,TR2-Kahamaala,TR3-Kahawanu,TR4-Rathna Samba,TR5-Suduru Samba,TR6-Suwandall and TR7- Unakola Samba)

3.2 Amylose and Amylopectin Content

Total endospermic starch content in rice, is generally consisted with 0–30% fraction of amylose content and 70–100% fraction of amylopectin content (Martin & Smith, 1997).Nevertheless, rice varieties can be grouped based on its amylose content into higher (25-33%), intermediate (20-25%), low (12-20%), very low (2-12%) and waxy (0-5%) (Juliano, 1971). Amylose and amylopectin contents of improved and traditional rice varieties are graphically illustrated in Figure 02.

As presented in Figure 02, amylose contents of improved rice varieties were found in between 25.02 – 27.62%. Thus, all of these varieties belongs to the higher amylose class (>25%). Under the improved rice category, BG352 reported the highest amylose content while BG360 reported the lowest. Traditional rice varieties displayed broad range for amylose content compared to the improved rice varieties. Amylose content of traditional rice varieties was found to be in the range of 20 -28 %. According to the data, traditional varieties had to be grouped under higher (>25%) and intermediate (20-24%) amylose classes. The variety known as Kahawanu reported the highest amylose content of 28.6%. Kahamaala, Hangimuttan, Rathna samba &Unakola samba were the other varieties having with the higher amylose contents (>25%).
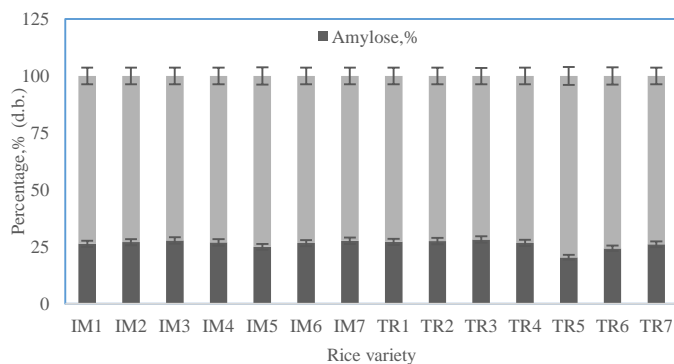

Fig.2: Amylose and Amylopectin content of improved and traditional rice varieties
(Code name of rice varieties -IM1-AT307,IM2-BG300,IM3-BG352,IM4-BG358,IM5-BG360,IM6-BG366,IM7-BW367,TR1-Hangimuttan,TR2-Kahamaala,TR3-Kahawanu,TR4-Rathna Samba,TR5-Suduru Samba,TR6-Suwandall and TR7- Unakola Samba)

The linear and compacted nature of amylose polymers, mitigate the access for digestive enzymes like α- amylase (Denardin*et al.,* 2012). Thus, high amylose rice beneficial to control diabetes and obesity owing to the low glycemic index and slow emptying rate at human gastrointestinal tract.(Behall&Scholfield, 2005 ; Denardin*et*

*al.,*2007).Amylose aids to prevent constipation by increasing in fecal water content(Cherbut*et al.,* 1997). The fermentation of low digestible amylose at colon, enhances the activities of intestinal micro flora and reducing the health risks associate with human intestinal tract (Brouns*et al.,* 2002; Denardin*et al.,* 2012). Higher amylose rice flour can be used to develop food products such as noodles with sound texture profile with low GI. (Yoenyongbuddhagal&Noomhorm, 2002;Fu, 2008).Although both Suwandall and Suduru samba can be grouped under the intermediate amylose classes, lowest amylose content of 20.4% among all rice varieties, was reported by Suduru samba. Amylose content of Suwandall was 24.32%. The rice with intermediate amylose is much accepted by consumers because its moist and tenderness after cooking (Rohilla*et al.,*2000). According to the statistical analysis of data, amylose contents of selected rice varieties were significantly different (p<0.05) to each other.

The amylose content of BG360, BG300, BG352, BG358,Bg366, Suwandall and Suduru samba have already been determined by early studies of Fari et al. (2011); Darandakumbura et al.(2013); Rebeira et al.(2014);Fernando et al.(2015) and Pathmanathapillai et al. (2016). Most of data obtained in present experiment are agreed with the outcome of previous studies. Instead of experimental differences, most variations in amylose content delivers either from extrinsic factors or intrinsic factors, or by the interaction of both. Environmental factors such as climatic and soil conditions during grain development (Wang *et al.,* 2002; Singh *et al.,* 2006; Wang *et al.,* 2010), genetic factors and cultural practices(Kim &Wiesenborn, 1995) can cause for the variations.

The amylopectin content of rice varieties were varied from 71.7 to 79.6%. Under traditional varieties, highest amylopectin content was reported by Suduru samba and the lowest amylopectin content was found in Kahawanu. BG360 reported the highest amylopectin content from improved varieties and BG352 reported the lowest. Further, statistical analysis of data to amylopectin contents of rice varieties were also significantly different (p<0.05) to each other. Sclafani et al. (1987) and Ramirez, (1991) reveals, rice with higher amylopectin content or highly branched chain structures are more palatable than higher amylose or less branched structure. In contrast with amylose, branched and expanded nature of amylopectin, permits for greater access for digestive enzymes. Therefore, amylopectin provides a higher glucose compared to that of amylose and influenced the body weight gain and increasing serum triglycerides and cholesterol (Denardin*et al.,* 2012).

An important observation in this study was, relatively higher amylopectin contents were in Suduru samba, Suwandall and BG360. The rice flour obtained from these three varieties are ideal for producing bakery and extruded products. As revealed by Navaratne (2015), stickiness or pasting property of amylopectin can be utilized to trap the gases evolve during the bakery fermentation. While heat moisture treatment and fine particle size (<200micron) of starch will further improve this phenomena by providing more surfaces for creating hydrogen bonds amongst amylopectin and water molecules. Flour or starch obtained from these rice varieties can also be used as binders in food industry such as process meat, confectioneries etc. An inherited taste & aromatic properties of rice (e.g. Suwandall) can be used to deliver appetizing sensation to regular bakery and other food products too.

3.3 Effect of Amylose and Amylopectin Content on Hardness and WAC

In order to investigate the relationship between amylose & amylopectin content, against the test parameters, "amylose vs. hardness", "amylopectin vs. hardness", amylose vs. WAC", "amylopectin vs. WAC" and "hardness vs. WAC" are given in scatter diagrams of Figure 03.
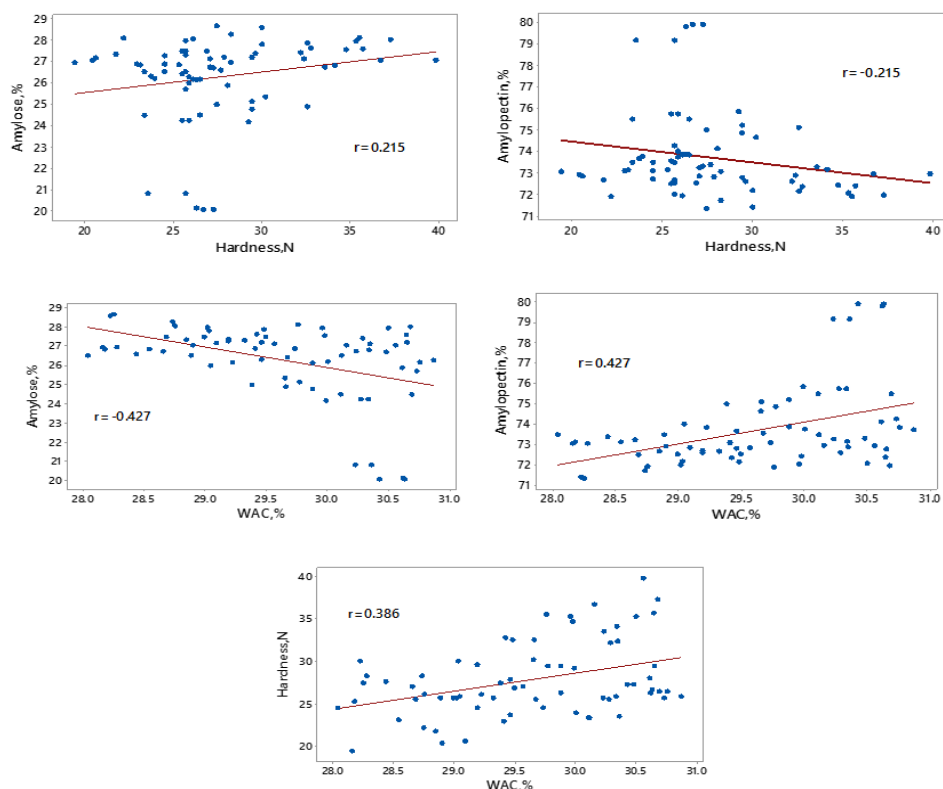

Fig.3: Relationship between amylose content, amylopectin content, hardness and   WAC

According to the Figure 03, there was no strong linear correlation ship between the test parameters and the obtained coefficient of correlation indicate the weak or moderate correlation ship. A weak positive correlation ship was observed between amylose content and grain hardness, while weak negative correlation ship (r=-0.215) was reported in between amylopectin content and hardness. Both these correlations were statistically insignificant (p>0.05). However, amylose content and WAC had moderately negative correlation ship (r= -0.427,p<0.05).Amylopectin contents and WACs of tested rice varieties were given moderately positive correlation ship (r=0.427, p<0.05), by signifying the contribution of amylopectin for absorbing and holding the water in rice. Correlation pattern of amylose and amylopectin content with WAC were compatible with the swelling power as well. More compact and linear nature of the amylose molecules less tend to absorb and hold water than highly branched & expanded structures of the amylopectin. Instead of that, hydrophilic parts of proteins and carbohydrates structures are responsible for enhancing

the WAC of the grains (Lawal&Adebowale, 2004). The correlation analysis for hardness and the WAC was shown weak positive correlation ship (r=0.386, p<0.05).

IV.   CONCLUSION

Pertaining to the milling properties of the selected Improved and traditional rice varieties, 76-78% of brown rice content, 20 – 23 % of husk contents and 69- 72% of total milled recovery (TMR) were recorded. These rice varieties consisted with different grain dimensions as well (highest length- BG300; highest width & thickness-Kahawanu ; lowest dimensions -Suduru samba).Sizes and shapes of most rice varieties were short round or short bold (*Samba*), except, BG300, BG352, BG366, AT307 and Kahamaala, those of which were coming under the intermediate bold(*Nadu*). Hardness of both rice categories were varied between 21.31N to 34.18N. BG352 had the highest grain hardness and BG358 was the lowest. After four hours of soaking process at 70 ^{0}C, final moisture contents of rice varieties were reached to 28-30% (wet basis). Unakola samba showed the highest water absorption capacity (WAC) (30.65%, w.b.) and Rathna samba takes the lowest (28.32%, w.b.). BG300, Suduru samba, Kahamaala and Suwandall were recognized as the varieties with comparatively higher water absorption capacities (>30%). Measured dimensions (length,width,thickness), hardness and WACs were significantly different (p<0.05) among the selected rice varieties

Amylose contents of selected rice varieties were varied from 20-28% (d.b.). BG352 reported the highest amylose content (27.62%) and BG360 reported the lowest (25.02%) among the improved rice varieties. All improved rice varieties can be grouped under higher amylose class(>25%).Traditional rice varieties such as Suwandall and Suduru samba were grouped under intermediate amylose class (20-25%) and other traditional rice varieties were coming under higher amylose class. Kahawanu reported the highest Amylose content (28.6%) and lowest was given by Suduru samba (20.4%).The amylopectin contents of all of these varieties were varied from 71-79 %. Highest and lowest amylopectin contents were reported by Suduru samba and Kahawanu respectively. There was no strong linear correlation ship between those test parameters like amylose content, amylopectin content, hardness and WACs, therefore, none of these parameters are affected along, on the behavior of the other parameter. However, the combine effect of several different factors (chemical & physical) associated with the raw rice grains itself should be the circumstance for variability of each and every parameter.

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