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Determination of Changes Occurrence in Important Physical Properties of Paddy during Early Storage

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Abstract: Rice (Oryza sativa L.) is the staple food in Sri Lanka. Knowledge on physical & chemical changes occurring during storage is important for post-harvest handling of paddy as the harvest has to be stored for a considerable period of time before consumption. Freshly harvested paddies of three rice varieties BG 300, BG 352 & AT 362 were taken, cleaned and dried and stored at ambient environmental conditions (RH 70%-80%, Temperature 26^0C -30^0C) for four months. Swelling power, water binding capacity & water absorption capacities all varieties were determined in every two weeks up to four months. Swelling power of BG 352, BG 300 & AT 362 varieties were increased from 7.49±0.06 g/g, 7.15±0.10 g/g, and 7.29±0.04 g/g of to 8.43±0.03 g/g, 8.05±0.09 g/g and 7.73±0.05 g/g during four months storage. Hydration properties were also increased and these incremental values after 4 months storage are significantly different from the initial value ($p<0.05$).

Key words: Sri Lankan rice varieties, Swelling power, Water binding capacity, Water absorption capacity, Paddy storage

1. Introduction

Rice (*Oryza Sativa* L.) is the second important cereal crop in the world following wheat. It is the staple food for over three billion people including half of the world population. Rice is cultivated in different parts of the world in various climatic & agricultural conditions [1]. In Sri Lanka rice is the staple food and about 1.8 million families are engaged in paddy cultivation island wide. Rice is mainly cultivated in two seasons**,** the Yala and Maha. Hence harvest is to be stored for a considerable period before consumption [2].

Eating and nutritional quality of starchy food products depends on the changes that occur in starch during processing, cooking & storage. Consequently these changes significantly impact properties such as water uptake, granule swelling, formation of a viscoelastic paste during heating, followed by re-association of dispersed starch chains on cooling and formation of a gel [3]. Stored rough rice undergoes different biological, chemical and physical changes. These changes are simply explained as rice aging. The changes can be either favorable or unfavorable to end user depending on consumer preference [4].

As far as swelling ability is concerned amylose tend to inhibit swelling of granules and swelling is a property of amylopectin [5]. Water uptake during thermal treatment, which involves starch gelatinization and protein denaturation, is assessed by determining the water absorption index or swelling capacity and swelling power [6]. A greater amount of amylose and longer amylopectin branch chain length in Long-grain would both lead to a reduction in swelling [7]. Hermanasson and Svegmark reported that waxy starches have a more open structure that allows rapid water penetration, swelling, and solubility [8].

Aging is initiated before harvest and it continues as a time, temperature and moisture dependent process. Comprehensive knowledge on aging is beneficial in determining cooking and eating quality of rice [9]. Aging results in various physical and chemical changes that lead to have high head rice yield on milling, high water absorption and expansion on cooking & harder less sticky texture upon cooking. The changes include flavor, color and compositional variations. Effects of aging are more prominent in stored non-waxy rice (high amylose) compared to waxy rice [10]. Perez and Juliano stated that minimum three month period is required to observe the changes that occur due to aging process[11] [12]. Previous studies stated that changes in aging are mainly due to modification in protein fraction rather than starch fraction. They further suggested di-sulfide bonding would be the reason for physical and chemical changes during aging [13] [14] [9].This formation can affect the swelling ability of starch. Hardness, cohesiveness, chewiness increases with aging whilst stickiness reduces [10] [15]. Abeysundara *et al* reported that amylose and amylopectin contents of three paddy varieties grown in Sri Lanka had not shown significant variations during four months storage [16]. Comprehensive knowledge on chemical physical changes occur during storage is important for the production of rice based value added food products. Studies on physical and chemical changes occurring during storage in paddy varieties cultivated in Sri Lanka are not available yet. The changing pattern and the time of initiation of changes are crucial in value addition and post-harvest handling of paddy. Hence this study was designed to determine the variations of hydration properties and swelling ability of widely cultivated three rice varieties in Sri Lanka naming BG 352, BG 300 and AT 362.

2. Materials & Methods

Sample collection

Initially 10 kg of commercially available, improved, three prominent paddy varieties were selected for the study (BG 300, BG 352 and AT 362).[1]Freshly harvested BG-352 rice variety was obtained from commercial paddy farmers in Buttala area in Moneragla district. AT-362 was taken from the Ambalantota rice research center in Hambantota district. BG-300 rice variety was obtained from Labuduwa rice research center in Galle district. 10 months old paddy samples of same varieties were obtained from same fields and institutions.

Sample storage

All the samples were cleaned and impurities such as stones, broken husks, parts of hay were removed and all paddy samples were sun dried under shade conditions for three days. Then samples were stored in plastic baskets in house conditions (RH-70-80%, Temperature-26-30^{0}C). Samples were dried & homogeneously mixed in every two weeks under sundry conditions.

Flour preparation

The paddy samples were de-husked manually using small wooden mortar & pestle. After de-husking, rice grains were ground using a blender at medium speed. Mortar and pestle as well as the blender parts were thoroughly cleaned in order to avoid mixing of varieties. Rice flour was sieved using 100 mesh sieve and sieved flour was stored in air tight containers for subsequent use of the study.

Determination of swelling power (SW)

Swelling power of rice flour was determined using the method described by Thumrongchote with slight modifications [17]. According to this method, about 295.0 ±5 mg of rice flour samples were weighed into centrifuge tubes in triplicates and 10 ml of distilled water were added. The suspensions were heated in thermostatic water bath (GEMMYCO, Model: YCW-010E) at 80 ^{0}C for 30 minutes. Then they were centrifuged at 4,000 rpm for 20 min. The supernatants were carefully poured into weight known aluminum dishes and dried at 105 ^{0}C until constant

[1]**BG**- Bathalegoda ; **AT-**Ambalangoda - The letters depicted two
Paddy research centers in Sri Lanka

weight was achieved. Weight of the sediment gel and weight of the dried solids were taken. SW was calculated using following equation.

$$SW = \frac{\text{Weight of sediment}}{\text{Weight of the flour} - \text{weight of dried solids in supernatant}}$$

Determination of water binding capacity (WBC)

Water binding capacity of four types of flours were determined according method describe by Hera *et al* [6]. In this method about 1.000±.005g of flour samples in triplicates were measured into centrifuge tubes and 10ml of distil water was added to each sample and centrifuged at 2000 rpm for 10 minutes. Thereafter, the supernatants were decanted & weights of hydrated flour gels were taken. The weight of the absorbed water was calculated by taking difference of sample weight and weight of the hydrated gel. Water binding capacity was calculated using the following equation.

$$WBC = \frac{\text{Weight of the hydrated gel} - \text{sample weight}}{\text{Sample weight}}$$

Determination of water absorption capacity of paddy (WAC)

Water absorption capacity of paddy was determined according to the method explained Thilakaratne *et al* with slight modifications [18]. About 5.00g of paddy from three rice varieties were measured into boiling tubes in triplicates. Then equal volume of distilled water was added to each sample (Water: Paddy=3:1). Then samples were heated in a preheated thermostatic water bath (GEMMYCO, Model: YCW-010E) at 70^{0}C. Excess water was drained out and quickly blotted three-four times using filter paper until the superficial water was removed. Thereafter, the grains were transferred to a clean dry metal container with a lid and reweighing was done using the same balance. Then the samples were dried to constant weight at 105^{0}C in moisture oven to determine the absorbed water content.

$$WAC = \frac{\text{Weight of heated \& blotted paddy} - \text{dried weight of paddy}}{\text{Weight heated dried paddy}}$$

All the tests were carried out in every two weeks period up to 13 weeks. Aforementioned tests were carried out for 40 weeks old samples of same varieties as well.

Data analysis

One way ANOVA method was used for all the parameters to determine variations during storage. (CI =95%). Minitab 17 software was used for statistical analysis.

3. Results and Discussion

Determinatio (2) ing power during storage

Swelling power of BG 352, BG 300 and AT 362 rice varieties during 13 weeks storage are given in table 1.

Table 1 Variation of swelling power

Week/Time	BG 352(g/g)	AT 362(g/g)	BG 300 (g/g)
1	$7.49{\pm}0.06^{d}$	$7.29{\pm}0.04^{c}$	$7.15{\pm}0.10^{cd}$
3	$7.37{\pm}0.19^{d}$	$7.22{\pm}0.05^{cd}$	$6.99{\pm}0.08^{d}$
5	$7.39{\pm}0.06^{d}$	$7.15{\pm}0.02^{d}$	$7.09{\pm}0.13^{cd}$
7	$7.58{\pm}0.07^{d}$	$7.43{\pm}0.05^{b}$	$7.07{\pm}0.11^{cd}$
9	$7.90{\pm}0.09^{c}$	$7.51{\pm}0.08^{b}$	$7.32{\pm}0.15^{bc}$

11	8.14±0.16[bc]	7.54±0.03[b]	7.60±0.06[b]
13	8.43±0.03[b]	7.73±0.05[a]	8.05±0.09[a]
Old/40	9.57±0.08[a]	7.26±0.02[cd]	7.48±0.12[b]

Values that do not share a letter are significantly different (within columns). $P<0.05$

The data given in table 1 indicate that there is a significant difference between swelling power of all three rice varieties during 13 weeks storage ($p<0.05$). Swelling power values of BG 300, BG 352 & AT 362 have increased significantly during early storage. From 1st week to 5th week the increment is not remarkable. But swelling power values of all varieties have increased remarkably after 7th and 9th week. Hence, it is evident that swelling power values of BG 300, BG 352 and AT 362 increase during early storage. The increments of swelling power of BG 300, BG 352 and AT 362 varieties from 1st week to 13th week are 12.58%, 12.5% & 6.03% respectively.

To further validate this outcome, swelling power of 40 weeks old paddy samples of same varieties were analyzed. Result revealed that swelling power of 40 weeks old rice samples of BG 300 and AT 362 rice varieties had lower values compared to the values of 13 weeks old paddy. Hence it is evident that swelling power values of rice varieties do not have incremental trend during storage. It can be assumed that swelling power has an incremental pattern during early storage and subsequently it declines during long storage. Previous studies of Sowbhagya and Bhattacharya and Patindol *et al* reported such behavior in their studies [4] [14]. But swelling power value of 40 week old rice sample of BG 352 variety has shown higher value than other values taken during storage. Chrastil has reported the same observation for North American rice varieties during aging. He further stated that swelling power is increased more rapidly in rice stored at elevated temperatures [19]. Further it is evident that swelling behavior during storage also differs on the variety as well.

Patindol stated that the increase in flour paste peak viscosity following storage may be ascribed to enhanced polysaccharide leaching as a result of starch degradation particularly at elevated storage temperatures [4].

Shibulya mentioned that the initial increase in swelling power and peak viscosities in rice starch were due to the progressive decrease in alpha- amylase enzyme activity [14]. Previous research studies have ascribed variation of swelling power during aging to the changes in structural organization. Further they explained starch component of grains make interactions with proteins especially with Oryzennin through formation of di-sulfide bonds. Therefore structural and consequent physical changes are attributed to di-sulfide bond formation [4] [9] [10] [13] [14].

Determination Water Binding Capacity (WBC)

Water binding capacity of BG 352, BG 300 & AT 362 rice varieties during storage are given in table 2.

Table 2 Variation of Water Binding Capacity of paddy varieties

Week	BG 352(g/g)	AT 362 (g/g)	BG 300 (g/g)
1	0.97±0.007[ef]	1.199±0.082[d]	0.956±0.052 [de]
3	0.96±0.007[f]	1.246±0.075[d]	0.994±0.008[cde]
5	0.99±0.010[e]	1.302±0.004 [cd]	0.937±0.071[de]
7	1.057±0.009[d]	1.309±0.010 [cd]	0.907±0.013[e]
9	1.047±0.003[d]	1.365±0.011 [c]	1.087±0.008 [bc]
11	1.099±0.002[c]	1.407±0.010 [bc]	1.034±0.002[bcd]
13	1.179±0.021[b]	1.520±0.008 [b]	1.112±0.070 [b]
Old/ 40	1.418±0.006[a]	1.742±0.008[a]	1.453±0.008 [a]

Values that do not share a letter are significantly different (within columns). $P<0.05$

The values given in table 2 indicate that water binding capacity of all rice varieties are gradually increasing with the period of storage because the mean variation is slightly increasing throughout 13 weeks period of storage. To justify this conclusion**,** same variety of paddy kept at same storage condition for 40 weeks was analyzed for water binding capacity. Result revealed, the value pertaining to the WBC has increased remarkably.

The reason for the deviation would be the formation of protein disulphide bonds that result in forming of protein starch matrix which is capable of arresting more water than the tightly packed structure. The increments of WBCs of BG 352, BG 300 & AT 362 from 1st week to 13th week are 21.5%, 16.31 and 26.7% respectively. WBCs have increased remarkably after 7thand 9th week period of storage. Chrastill & Pushpamma& Reddy have reported same behavior of paddy during storage [19] [20].

Determination of Water Absorption Capacities (WAC)

WAC values of BG 352, BG 300 & AT 362 rice varieties during 13 weeks storage are given in table 3.

Table 3 Variation of Water Absorption Capacity of three paddy varieties

Time/ week	BG 352 %	AT 362 %	BG 300
5	26.265±0.046^{bc}	27.800±0.163^{c}	28.773±0.032^{cd}
7	25.768±0.023^{c}	27.587±0.212^{c}	28.760±0.097^{cd}
9	25.760±0.149^{c}	27.229±0.128^{c}	29.027±0.181^{c}
11	26.830±0.203^{b}	25.619±0.125^{d}	28.263±0.017^{d}
13	29.543±.0391^{a}	29.516±0.184^{b}	29.799±0.029^{b}
Old/40	30.161±0.082^{a}	33.252±0.037^{a}	31.577±0.292^{a}

Values that do not share a letter are significantly different (within columns). $P<0.05$

The values given in table 3 clearly indicate that WACs of all three rice varieties are increasing during storage. The increment is more prominent after 9th& 11th week of storage. Since, 40 weeks old rice samples have given higher WAC values compared to the values of fresh paddy; it is evident that hydration properties of BG 352, BG 300 & AT 362 varieties were increasing during storage. Reason for this consequence is simple sugars which are abundant in fresh paddy do not have WAC. However, only starch is having this property. Due to respiration at early stage, all most all simple sugars are exhausted. Thereafter the grain tends to utilize starch. As a result of that, empty spaces in the grain (Previously occupied by starch granules) are gradually increased. Thus these spaces tend to hold more water.

Chrastil and Tsugita reported that there was an increment in hydration properties during storage [20] [21]. But some studies have shown contradictory data. They reported that hydration ability of rice decreased during aging [15] [9]. There was an increment followed by depletion in hydration properties of rice in prolonged aging. Rice shows decrease in hydration and swelling ability after one year of storage [14]. According to Abeysundara *et al* amylose content of BG 352, BG 300 & AT 362 paddy varieties remained constant following four months storage. Hence it can be assumed that amylose is not the single factor that governs swelling & hydration properties of paddy during storage [16].

4. Conclusion

Swelling power of BG 300, BG 352 & AT 362 rice varieties increase during early stage of storage. But swelling power does not have continuous incremental trend during storage. Water absorption capacities and water binding capacities of all three rice varieties increased during storage. Changes occur in structure of the rice kernel would be the reason for the variation that occurs during storage.

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