EFFECT OF WATER RECIRCULATION, AERATION AND pH OF SOAKING WATER ON MOISTURE ABSORPTION RATE OF PADDY DURING SOAKING

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ABSTRACT

Paddy is processed in to rice either as raw or parboiled forms. Parboiling is a hydrothermal treatment which involves soaking, steaming and drying prior to milling. The main objective of paddy soaking in parboiling is to facilitate quick gelatinization and reduce energy requirement for steaming. There are two main soaking methods in practice; cold water soaking and hot water soaking. In cold water soaking, paddy is soaked in stagnant cold water for 36-72 h at room temperature. Depending on the grain type and frequency of water change, it consumes 1.3 to 8 m^3 of water per one tonne of paddy. Only 3 to 18% of that water is absorbed into the grains and the rest is discharged as effluent without proper treatment although it is of high BOD (1350-1800 ppm). Therefore, the objective of this study was to study the means of reducing water use in paddy soaking through water recirculation, submerged aeration and manipulation of pH of soaking water.

***Keywords*:** Parboiling, cold water soaking, water recirculation, **S**ubmerged aeration, pH

1. INTRODUCTION

Rice (*Oryza Sativa* L.) occupies the 3rd place of food grains in terms of global production and it is the staple food of half of the global population [1]. Rice is the staple food grain and the annual per capita consumption in Sri Lanka is reported as 108.6 kg and about 55% of the total rice consumption is parboiled [3]. Rice also provides 45% total calorie and 40% total protein requirement of an average Sri Lankan [4]. Rice is processed either as raw or parboiled form. Parboiling is a hydrothermal treatment which involves soaking, steaming and drying prior to milling. It is mainly done to increase the milling quality but it also enhances the nutritional quality as well. The main objective of soaking is to facilitate quick gelatinization and reduce the energy requirement for steaming [10]. To achieve this objective the grain moisture content should be increased to a minimum of 30% (w/w). There are three soaking processes in practice for different grains such as cold soaking, hot soaking and vacuum soaking. Cold water soaking is done by allowing paddy grains to soak in stagnant water inside cement tanks at room temperature for 36-72 h depending on grain type and age. Soaking water requirement also varies from 1.3 to 8 m^3 per one tonne of paddy [6]. However, only about 2.9 - 17.6% of soaking water is used to increase the moisture content while the rest is discharged as effluent with a high BOD value (1350-1800 ppm) [8]. Cold soaking causes starch fermentation due to fungi and some other anaerobic microorganisms proliferating in the soaking water and develops foul odor [9]. Gunarathne *et al* [5] reported that most of the mills located in major rice growing and marketing areas in Sri Lanka are either small or semi-modern mills which have higher production costs and with low milling outturn resulting low profitability. Therefore, such millers usually discharge effluent directly to the environment polluting the whole ecosystem.

It is well known that soaking is the most time-consuming operation in the parboiling process partly due to the presence of husk and bran layers as barriers to moisture absorption. Absorption rate is basically dependent on existing moisture gradient, environmental factors and grain properties [1]. Extensive research work has been conducted to reduce soaking time. Pillaiyar *et al* [7] proposed to increase the temperature of water, generally to the starch gelatinization temperature to shorten the soaking time. According to Velupillai and Verna [9] hydrostatic pressure during soaking accelerates hydration process. Another method reported by Bello *et al* [2] to increase the rate of water absorption by de-husking. But de-husking is not practical as the main objective of parboiling is to minimize grain breakage during milling. Soaking of paddy by sprinkling and circulation of water has been also been reported by Senanayake *et al* [8] in order to reduce soaking time and effluent strength. However, except hot water soaking, none of the other methods are adopted by the industry due to various limitations.

Submerged aerated soaking reported by Kannan *et al* [6] by maintaining a positive dissolved oxygen concentration in soaking water through intermittent soaking water recirculation to reduce the high energy requirement in aerated soaking and delay the germination of paddy grains. Both Senanayake *et al* [8] and Kannan *et al* [6] have reported that water absorption rate of paddy under re-circulation is faster than soaking in still water. Therefore both of them have confirmed that the water recirculation and aeration on moisture absorption in to paddy grains. It is reported that the rate of absorption of raw rice in aqueous acidic solutions at 25^{o}C much lower than in plain water at the same temperature. Raw rice soaked in NaOH aqueous solutions and Na_2CO_3 aqueous solutions gave higher absorption rate than raw rice soaked in plain water [2].

Therefore, this study was conducted to investigate grain moisture absorption rate under water recirculation and aeration, and study the effect of soaking water pH on moisture absorption.

2. MATERIAL AND METHODS

A newly harvested short-grain paddy variety BG 358 was used for all the tests in this study. The experimental soaking tanks were designed using 100 mm diameter PVC pipes of 1.3m in height as shown in Figure 1. The height was selected based on the height of the commercial soaking tanks. As shown in the Figure 1, three sets of above soaking tanks were used as conventional stagnant soaking unit, aerated circulation soaking unit and un-aerated circulation soaking unit. In all three tanks 40mm standing water level was maintained above the paddy level to create submerged condition and water level was kept 100mm below the top of the pipe edge for convenient water recirculation. Water recirculation was done using two 12V DC pumps and they were automated by a calibrated microprocessor based timer. Water sprinkled using a shower with fine holes for aerated recirculation while pumping into the water column for un-aerated recirculation. During the first 12 hours, paddy was allowed to soak without water recirculation as the Dissolved Oxygen (DO) level does not drop to zero [6]. Then, both the pumps were operated as 10 minutes on 20 minutes off cycles for next 21 h. Finally, a resting period of 3 h was given similar to conventional stagnant soaking for both recalculating tanks.

Electrical Conductivity (EC), pH and Dissolved Oxygen (DO of soaking water were measured at two hour intervals and moisture content of paddy was measured by oven drying at 130 ^{o}C for 24 h at six hours intervals. Final BOD and COD values of three treatments were measured. The experiment was replicated thrice.

Since there was a significant pH increase with aeration, a separate study was conducted to study the effect of pH on moisture absorption rate of paddy. Paddy samples were allowed to soak for 48 h in solutions having 4, 6, 8, 10 and 11 pH. Both paddy and brown rice were used as the controls.

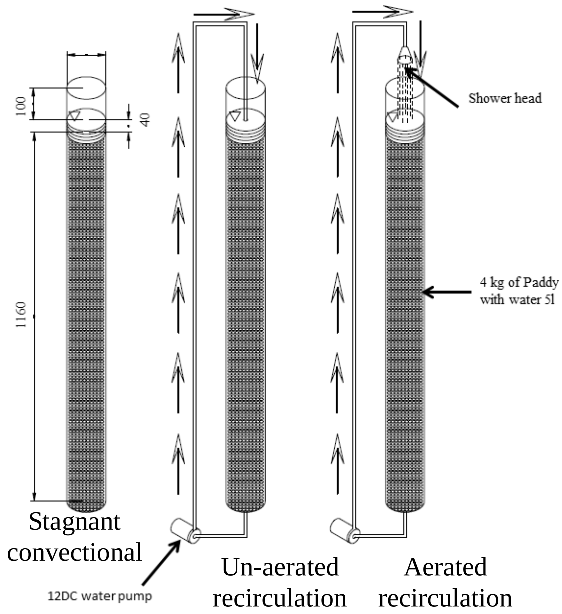

Figure 1: Experimental setup used for paddy soaking in stagnant water, un-aerated circulation and aerated recirculation

3. RESULTS AND DISCUSSION

Figure 2 illustrates the behavior of moisture absorption of paddy under three soaking methods. After 36 hours of soaking, the highest moisture content of 29.4% was reached under aerated recirculation while the paddy soaked under un-aerated recirculation and stagnant soaking reached 27.7% and 26.6%, respectively. According to the results of paddy soaking, it was found that the moisture absorption rate is relatively high under water circulation than soaking in stagnant water. Kannan *et al* [6] has reported that a solute concentrated boundary layer is formed around the paddy grains due to solids leaching from paddy grains and that may reduce the moisture diffusion by reducing the vapour pressure gradient. However, this experiment revealed that the increased absorption not only due to the agitation of the boundary layer as the un-aerated recirculation was less than aerated recirculation. Therefore, aeration of soaking water pH has main influence on grain moisture absorption.

The DO level in aerated recirculation was higher than the un-aerated. The pH value of conventional stagnant soking and un-aerated recirculation reduced from 5.5 to 5.3 after 34 hours of soaking by showing similar pattern of changes. Aerated circulation soaking reported an increae of pH reaching 6.4 after 34 hour of soaking. Therefore, results confirms that aeration increases the pH of soaking water.

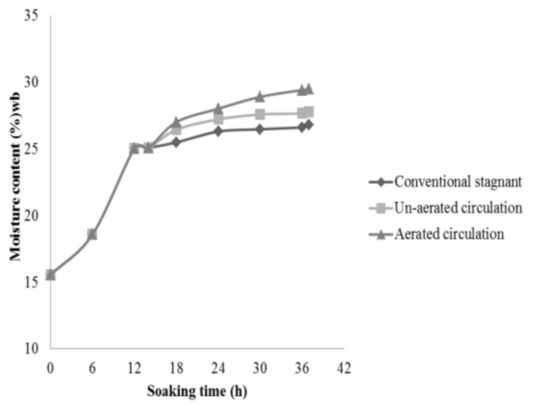

Figure 2: Paddy soaking under conventional stagnant, un-aerated recirculation and aerated recirculation

EC of the conventional stagnant soaking and un-aerated recirculation soaking gradually increased with fluctuations from 1.39 to 1.43 mS/cm and 0.86 to 1.28 mS/cm, respectively. Conventional stagnant soaking reported the highest EC value and aerated recirculation reported the least EC value of 0.46 mS/cm. Under the aerated recirculation the EC decreased with time. EC of a solution is dependent on the solute concentration. Aerated recirculation soaking is under aerobic condition while other two were under anaerobic conditions. The treatments are needed for effluent before discharge.

As shown in Figure 3 the final moisture contents of paddy in 4, 6, 8, 10 and 11 pH were 24.3%, 25.3%, 28.7%, 29.5% and 32.4%, respectively.
The final moisture content of the control (paddy) was 28.8%.

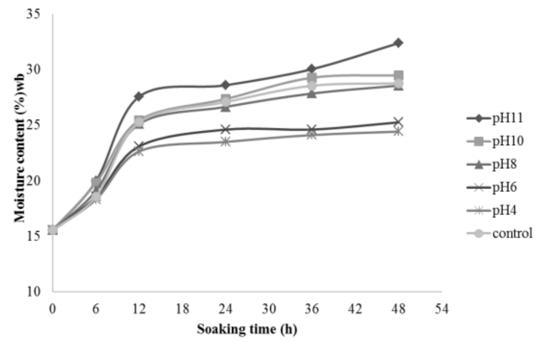

Figure 3: Effect of pH on hydration

However, brown rice in control and paddy at 11pH reached a moisture content of about 27.6% after 6 hours while paddy in control took more than 24 hours to reach that level.

4. CONCLUSION

Results revealed that paddy grain soaking can be accelerated slightly by water recirculation coupled with aeration. Aeration changed the chemical properties of soaking water especially pH and that may have influenced the paddy grain hydration rate. Further study shows that increase of pH in soaking water is the main reason for increased rate of moisture absorption into paddy grains.

5. REFERENCES

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