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Cooking Qualities of Thin Layered Humidified Paddy

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Authors' contributions

This work was carried out in collaboration between both authors. Author KCSS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NV managed the analyses of the study, provided literature and corrected the manuscript. Both the authors read and approved the final manuscript.

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ABSTRACT

A thin layer dryer was modified by replacing the heating section of the dryer was replaced with humidification chamber. The equipment consists of a blower which sucks ambient air, which was passed through heater coils. There was a nozzle located after the heating unit, which sprays water as tiny droplets. The heated air was passed on the tiny droplets of the water, now the air gets humidified and is passed on to the paddy which was placed in a perforated tray as a thin layer. After undergoing humidification (soaking), steaming, drying and milling, the cooking qualities of the humidified paddy were determined. The extent of humidification of paddy was studied by knowing the cooking characteristics of the parboiled rice. The different cooking qualities determined during the study were cooking time, water uptake ratio, grain elongation ratio on cooking.

Keywords: Soak water; thin layer; humidification chamber and moisture content.

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1. INTRODUCTION

There are several studies carried on parboiling of paddy using different equipment. Rice mills processing paddy after parboiling will discharge large quantities soak water as an effluent and this effluent is an environmental concern [1]. Paddy soaked for 2-3 days in conventional rice mills which follow the traditional cold-soaking and double steaming method. There is development of off-flavors during soaking of paddy due to fermentative changes and the water discharged in land and sewers is a public health nuisance [2].

Rice mills process several tonnes of paddy per day. For parboiling, they require large quantities of water and more than half of this water becomes effluent [3]. According to pollution elution control board, the effluents coming from the industries must be treated and it incurs additional cost. It must not be discharged into rivers and ponds as it is contaminated and lots of insects and pests build up due to stagnant water in the rice mill surrounding [1]. So this study can eliminate the soak water by humid air for undergoing the soaking process.

As there are lot of environmental effects due to the effluent produced during soaking of paddy, a study was undertaken at Indian Institute of Crop Processing Technology, Thanjavur, India, to minimize effluent in the soaking process by designing and developing a new technique for soaking of paddy which produces zero effluent. The ultimate aim of this study was to overcome all the above mentioned factors and come up with solution to modern rice parboiling mills.

2. MATERIALS AND METHODS

2.1 Step by Step Process of the Study

Step 1: Air is sucked through the suction valve (Valve positions 1/4th, 1/2th, 3/4th and full).
Step 2: Air at suitable velocity is passed on the heating unit (2.05 to 7.15m/s)
Step 3: The heating unit is set at required temperature to heat the air (55 to 80°C)
Step 4: The heated air is passed perpendicular to the water jet (droplets of water from nozzle at a flow rate of 1l/h to 10.05l/h)
Step 5: The air is humidified (RH of 65 to 93.75%).
Step 6: The humidified air is passed on to paddy in thin layer.
Step 7: Moisture absorption studies of paddy [4].
Step 8: Milling qualities [5].
Step 9: Cooking qualities.

2.2 Cooking Qualities

The paddy was humidified, steamed, dried and milled. After that the humidified paddy was subjected for cooking studies. The different cooking qualities determined during the study were cooking time, water uptake ratio, grain elongation ratio on cooking [6].

Cooking time: Five grams of milled rice of each sample were weighed in triplicate and poured into 135 ml of vigorously boiling distilled water in a 400 ml beaker and covered with a watch glass. After 10 minutes of further boiling, 10 grains were taken out every minute with a perforated ladle. The grains were pressed between two petri dishes and were considered cooked when at least 9 out of 10 grains no longer had opaque centers. The time was then recorded [7].

Water uptake ratio: Two grams' of rice was cooked with 20 ml water in a 100 ml beaker placed on an electric heater. Samples were removed at cooking time to weigh and calculated by equation [8].

$$\text{Water uptake ratio (\%)} = \frac{\text{weight of cooked rice}}{\text{weight of raw rice}} \quad (1)$$

Elongation ratio on cooking: Two grams' rice was cooked with 20 ml water in a 100 ml beaker placed on an electric heater. Samples were removed at cooking time to measure with length and wide (before and after cooked) and calculated by equation [9].

$$\text{Elongation ratio} = \frac{\text{Average length of cooked grains}}{\text{Average length of raw grains}} \quad (2)$$

2.3 Data Analysis

The results were analyzed using the design expert 10.02 (Stat-Ease) RSM. The step-wise method was employed to eliminate the insignificant model-terms. Test for significance of the regression model and the lack-of-fit test were also performed. From the analysis of variance (ANOVA), the following coded equation for cooking time, water uptake ratio and elongation ratio can be devised.

3. RESULTS AND DISCUSSION

Cooking time: Cooking time is a function of gelatinization temperature, as the gelatinization

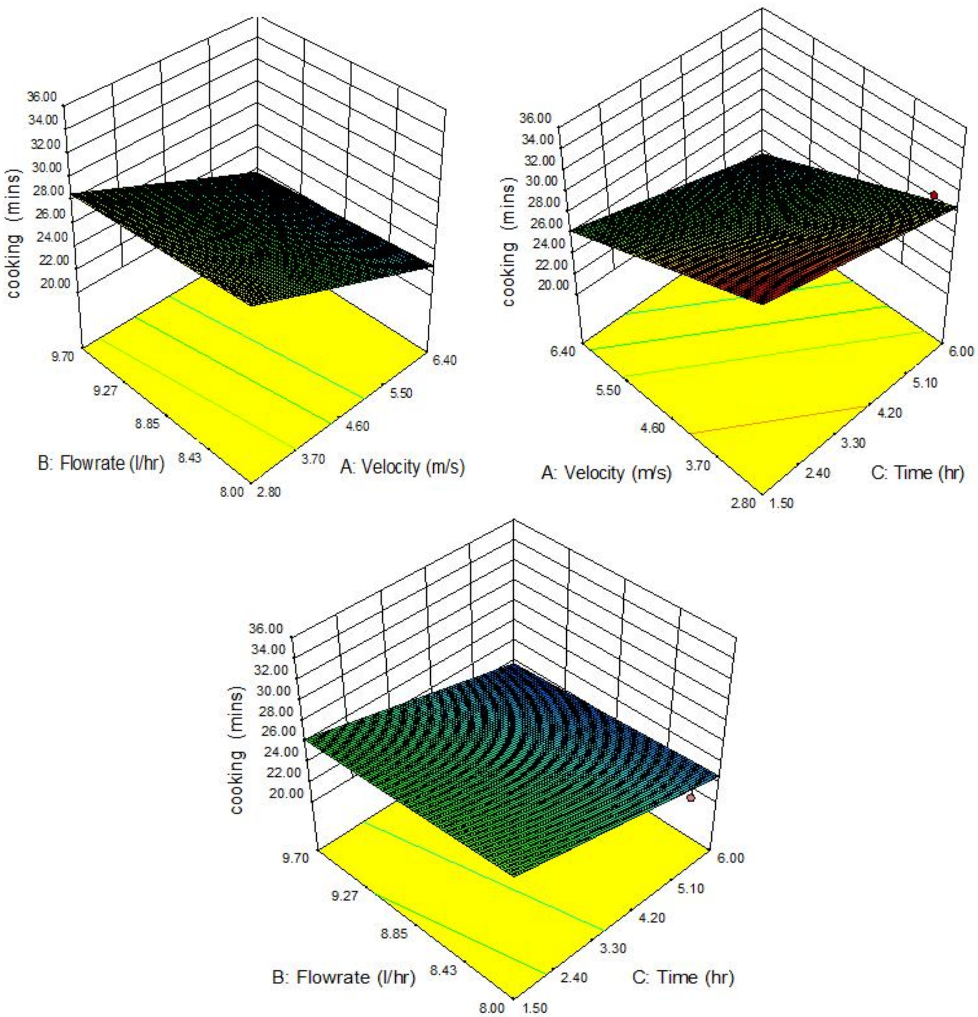

Fig. 1. Variation of cooking time with velocity, flow rate and humidification time

temperature increased, the cooking time of rice increased, a similar trend was reported by [7]. Cooking time decreases with increase in soaking temperature [9]. Here in this study, we observed minimum cooking time of 21 minutes at a maximum humidification period of 5.34 hours. The effect of water flow rate, velocity and time of cooking time is shown in the Fig. 1.

Using the design expert 10.02 (Stat-Ease) RSM, a linear model is adequate for modelling the cooking time. The step-wise method was employed to eliminate the insignificant model-terms. Test for significance of the regression model and the lack-of-fit test were also performed. From the analysis of variance (ANOVA), the following coded equation for the temperature (Y_1) can be devised:

$$Y_1 = 28.14 - 3.53A - 0.53B - 2.39C \quad (3)$$

Where $-1 \leq A, B, C \leq 1$ corresponds to

$$\left\{ \begin{array}{l} A: 2.05 \leq \text{velocity} \leq 7.15 \\ B: 7.65 \leq \text{flow rate} \leq 10.05 \\ C: 0.57 \leq \text{time} \leq 6.93 \end{array} \right\}$$

The adjusted R^2 coefficient, predicted R^2 coefficient and the adequate precision are found to be 0.8245, 0.6576 and 11.992 respectively. The Predicted R^2 of 0.6576 is in reasonable agreement with the adjusted R^2 0.8245, i.e. the difference is less than 0.2. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 11.992 indicates an adequate signal. This model can be used to navigate the design space.

3.1 Water Uptake Ratio

The water uptake ratio was increased with increase in duration of soaking and moisture absorbed [6]. The maximum water uptake ratio was observed at maximum humidification time of 5.34 hours which was 2.63 where the relative humidity was 93.35%, flow rate 9.70l/h and velocity was 6.40m/s which was shown in Fig. 2.

Using the design expert 10.02 (Stat-Ease) RSM, that a linear model is adequate for modelling the water uptake ratio. The step-wise method was employed to eliminate the insignificant model-terms. Test for significance of the regression model and the lack-of-fit test were also performed. From the analysis of variance (ANOVA), the following coded equation for the water uptake ratio (Y_2) can be devised:

$$Y_2 = 2.39 + 0.18A + 0.027B + 0.11C \quad (4)$$

Where $-1 \leq$ A, B, C ≤ 1 corresponds to

$$\left\{ \begin{array}{l} A: 2.05 \leq \text{velocity} \leq 7.15 \\ B: 7.65 \leq \text{flow rate} \leq 10.05 \\ C: 0.57 \leq \text{time} \leq 6.93 \end{array} \right\}$$

The adjusted R^2 coefficient, predicted R^2 coefficient and the adequate precision are found to be 0.8957, 0.8257 and 16.029 respectively. The Predicted R^2 of 0.8257 is in reasonable agreement with the adjusted R^2 0.8957, i.e. the difference is less than 0.2. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 16.029 indicates an adequate signal. This model can be used to navigate the design space.

3.2 Elongation Ratio

The elongation ratio increased with the increase in the moisture absorption and humidification

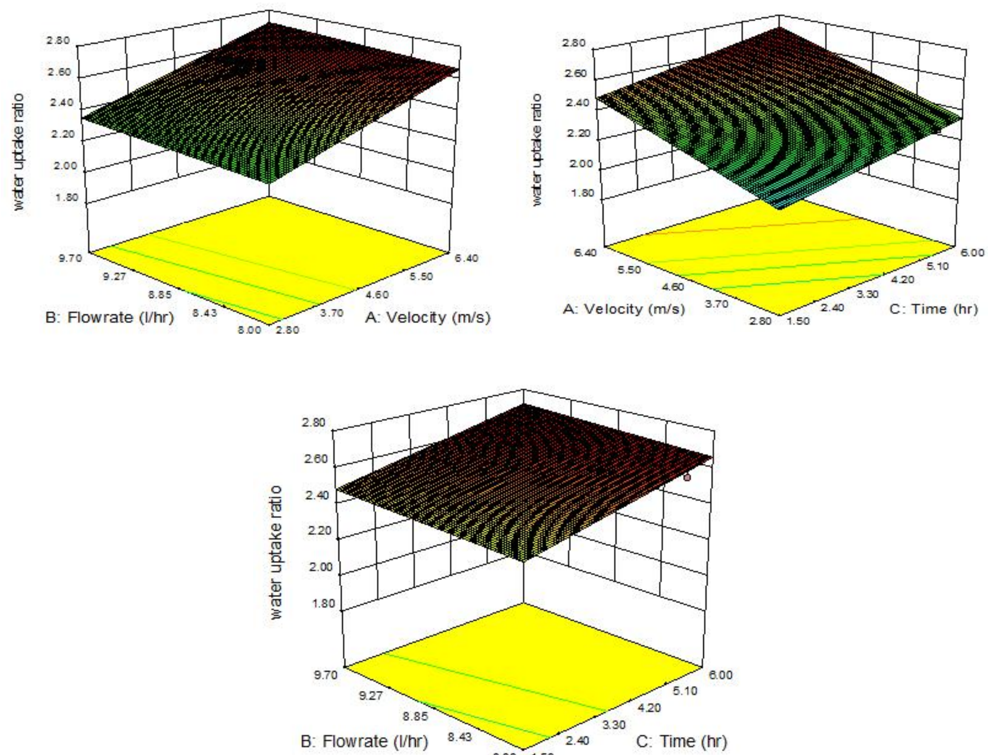

Fig. 2. Variation of water uptake ratio with velocity, flow rate and humidification time

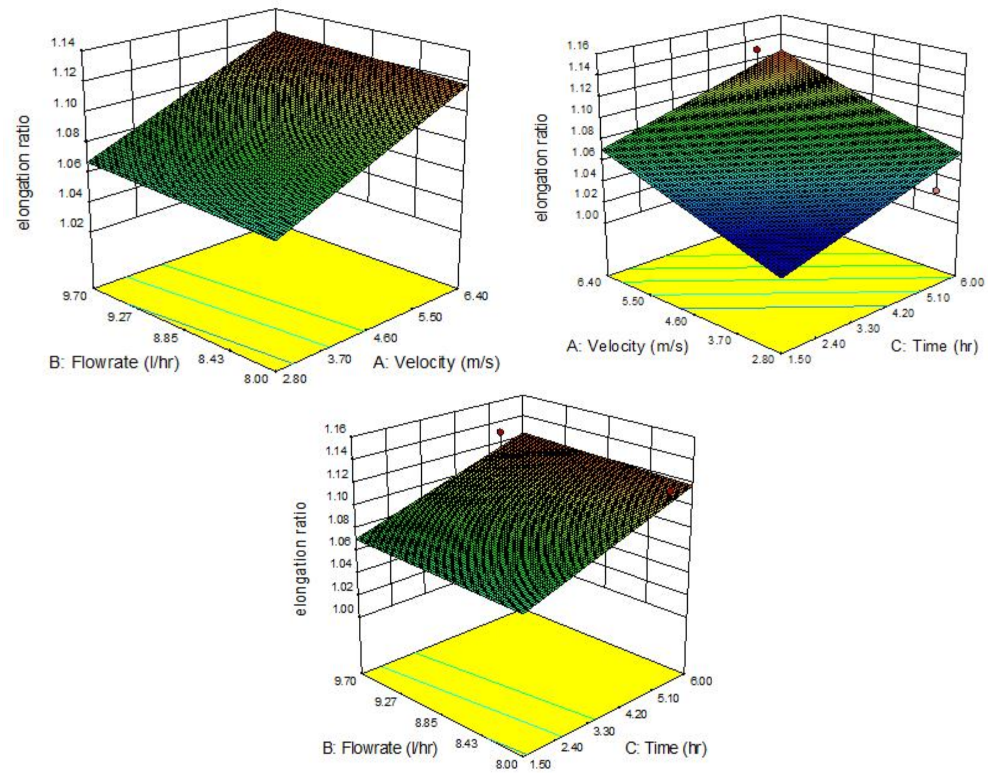

Fig. 3. Variation of elongation ratio with velocity, flow rate and humidification time

time. The effect of temperature also plays an important role in case of elongation and it will increase with an increase in soaking temperature [9]. Here the maximum elongation ratio was obtained at maximum humidification time of 5.34 hours, the moisture content of 30.74% (w.b) was 1.13.

Using the design expert 10.02 (Stat-Ease) RSM, that a linear model is adequate for modelling the elongation ratio. The step-wise method was employed to eliminate the insignificant model-terms. Test for significance of the regression model and the lack-of-fit test were also performed. From the analysis of variance (ANOVA), the following coded equation for the water uptake ratio (Y_3) can be devised:

$$Y_3 = 1.07+0.028A+(3.018E\text{-}0.03)\,B+0.027C \quad (5)$$

Where $-1 \leq A, B, C \leq 1$ corresponds to

$$\begin{cases} A: 2.05 \leq \text{velocity} \leq 7.15 \\ B: 7.65 \leq \text{flow rate} \leq 10.05 \\ C: 0.57 \leq \text{time} \leq 6.93 \end{cases}$$

The adjusted R^2 coefficient, predicted R^2 coefficient and the adequate precision are found to be 0.8206, 0.6501 and 11.453 respectively. The Predicted R^2 of 0.6501 is in reasonable agreement with the adjusted R^2 0.8206, i.e. the difference is less than 0.2. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 11.453 indicates an adequate signal. This model can be used to navigate the design space.

The equations in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

4. CONCLUSION

The different cooking qualities were determined, cooking time decreases with increase in soaking temperature here in this study we observed minimum cooking time of 21 minutes at a maximum humidification period of 5.34 hours, the maximum water uptake ratio was observed at maximum humidification time of 5.34 hours which was 2.63, maximum elongation ratio was obtained at maximum humidification time of 5.34 hours, moisture content of 30.74% (w.b) was 1.13.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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