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Effects of Varying Air Temperature in the Polishing Component of Single-Pass Mill on the Quality of Rice

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Abstract**—**The effects of varying air temperature (full, ¾ full, ½ full aircon adjustment, no aircon) in polishing component of Single-Pass Mill on the quality of Philippine inbred rice variety, was investigated. Parameters measured were milling recovery (MR), headrice recovery (HR), and percentage with bran streaks. Cooling method (with aircon) increased MR, HR, and percentage with bran streaks of milled rice. Highest MR and HR (67.62%; 47.33%) were obtained from ¾ full adjustment whereas no aircon were lowest (66.27%; 39.76%). Temperature in polishing component at ¾ full adjustment was 33°C whereas no aircon was 45°C. There was increase of 1.35% in MR and 7.57% in HR. Additional cost of milling per kg due to aircon cooling was P0.04 at 300 tons/yr volume, with 0.15 yr payback period. Net income was estimated at ₱98,100.00. Percentage of kernels with bran streaks increased from 5%–14%, indicating more nutrients of milled rice.

Keywords**—**Aircon, air temperature, polishing component, quality, Single-Pass Mill.

I. Introduction

ONE of the main goals of agriculture particularly in rice production is to attain self-sufficiency and competitiveness. At present, considerable losses in quantity and quality has been incurred during postharvest operations such as harvesting, threshing, drying, storage, and milling. Losses in rice milling accounts for the largest share of losses incurred in the whole postharvest chain of operation, estimated at 3–10% of the potential [1]. The loss is mainly due to poor technical performance of milling machinery [2]. The losses in yield and poor milling quality are problems that this study wanted to address.

In order to address the above concerns, modification of the existing Single-Pass mills is seen as very promising. The Single-Pass Mill is commonly used in the country with a total of 24,420 units distributed nationwide. Milling recoveries range from 55–60% compared to the theoretical milling recovery of good quality rice of 68–70% [2]-[3].

The Single-Pass Mill is composed of a husker and polisher. After the paddy is dehulled, it goes directly to the polishing component. Because it involves a batch, single-pass milling process (unlike in multi-pass mills), a large amount of heat is generated and accumulated in the equipment mainly in the polishing component and rice during milling, which causes a decrease in the milling and headrice recoveries [4].

It is hypothesized then that the high air temperature in the polishing component of the Single-Pass Mill may affect the milling quality of rice (milling recovery (MR), headrice recovery (HR), degree of milling or percentage of kernels with bran streaks). Hence, this study was conceived.

This study will play a vital role in the success of the rice industry. It will guide the rice millers or processors to produce more and better quality rice. Increasing the MR (even only for around 1–2%), HR and quality of rice would help in the attainment of rice sufficiency and competitiveness in the country.

This study then aimed to determine the effects of varying air temperatures in the polishing component of the Single-Pass Mill on the milling quality of rice. Specifically, it aimed to determine the: 1) effects of varying air temperatures (through aircon cooling) in the polishing component of the Single-Pass Mill on the MR, HR, and degree of milling (percentage of kernels with bran streaks); and 2) economic feasibility of using the Rice Mill-Aircon system.

II. Materials And Methods

A. Milling Experiment

A Philippine inbred rice variety harvested during the 2012 wet season in Cabugao, Ilocos Sur was used. The moisture content (MC) of the samples before milling was around 12% MC, wet basis (w.b.).

The batch-type, Single-Pass Mill, which has 1 ton hr^{-1} capacity, was used in the experiment. A 1-hp aircon (which has four temperature settings or adjustments: ¼, ½, ¾, full) was attached to the rice mill to provide the cooling effect to the polishing component or milling chamber. Fig. 1 shows the schematic diagram of the Rice Mill-Aircon set-up.

Samples were subjected to different temperatures (full, ¾ full, ½ full adjustment, no aircon or control) in the polishing component. After each test run, a break time was observed to allow the temperature to stabilize.

The temperatures of the polishing component and milled rice were taken using a digital thermometer. The initial and final weights of the samples were also taken using a 100-kg weighing balance.

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B. Experimental Design and Layout

The experiment was replicated three times and the treatments were laid out in a Completely Randomized Design (CRD).

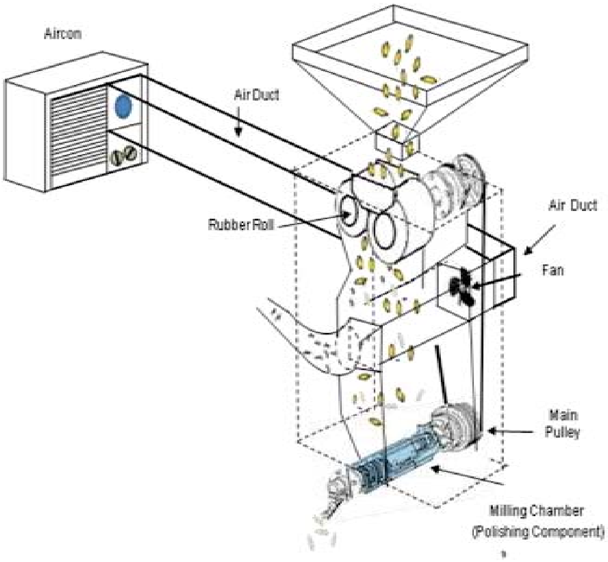

Fig. 1 Schematic diagram of the Rice Mill-Aircon set-up

C. Measurement of Quality of Milled Rice

The quality of the milled rice was determined in terms of the milling recovery, headrice recovery, and degree of milling (percentage of kernels with bran streaks). The MR is the percentage of milled rice based on the initial rough rice weight. The HR is the percentage of milled rice with length greater or equal to three quarters of the average length of the whole kernel, expressed on a % paddy or rough rice basis [5], [1].

The degree of milling (percentage of kernels with bran streaks) is the extent in which the bran layers and germ have been removed. This is to determine whether the milled rice is "undermilled", "regular-milled", "well-milled", or "over-milled" as defined by the National Food Authority (NFA) standards. This was determined using the alcoholic alkali bran-staining test method.

The HR and percentage of kernels with bran streaks were measured and evaluated by the NFA in Bantay, Ilocos Sur.

D. Statistical Analysis

The ANOVA for CRD in single factorial experiment was used to determine the effect of the air temperature in the polishing component of the Single-Pass Mill on the MR of rice. The most effective aircon adjustment or air temperature in the polishing component that resulted to highest MR, HR, and bran streaks content were also determined.

The LSD test was used to determine the differences among the different air temperatures in the polishing component of the rice mill.

III. Results and Discussion

A. Effect of Aircon Cooling on Milling Temperature

The use of aircon cooling significantly decreased the temperature in the polishing component of the rice mill, minimizing the generation and accumulation of heat during the milling process. The polisher temperature subjected to aircon cooling at different adjustments (32–34^{o}C) were significantly lower than those of the control or no aircon cooling (45^{o}C), i.e., more than 10^{o}C difference (Table I).

The decrease in the polisher temperature due to aircon cooling also resulted in lower temperatures of milled rice than the control. At three aircon adjustments (½, ¾, full), the milled rice temperatures were significantly lower than that of the control. This result confirmed the report [4] that the use of different cooling methods reduced both initial and final cutter bar temperature which resulted in lower milled rice temperature than the control. However, at ½ and ¾ full adjustments, the milled rice temperatures were not significantly different from each other but significantly different to those at full adjustment and control.

B. Effect of Aircon Cooling on Milling Quality of Rice

The ¾ full aircon thermostat adjustment gave the highest MR (67.62%) and the no aircon (control) gave the lowest (66.27%), an increase of 1.35% in the MR. The increase in the milled rice recovery may be due to the reduced moisture loss and lowered breakage associated with the lower milled rice temperature [6].

The full aircon adjustment resulted in lower MR than the ¾ full adjustment. This may be due to fact that the decrease in the temperature of the milled rice (from 49^{o}C to as low as 42^{o}C) made it less rubbery and less elastic, hence causing more breakage that resulted in lower MR. There may be change of states of the starch in rice that occurred at the glass transition temperature (temperature at which an amorphous solid such as polymer becomes brittle on cooling, or soft on heating); the transition from a rubbery to glassy state, or vice versa [7]. Moreover, at full adjustment, the moisture content of the grain may also increase, hence, causing fissuring and eventually, greater breakage. At 49^{o}C milled rice temperature, when there was no aircon cooling, the MR was lowest.

TABLE I
Milling Recovery (MR) of Rice at Different Temperatures of the Polishing Component of the Single-Pass-Aircon System

Aircon Thermostat Control	Polisher Temperature (^{o}C)	Milled Rice Temperature (^{o}C)	MR (%)
	***	**	
Full	32 a	42.33 a	66.33
¾ Full	33 a	45.67 b	67.62
½ Full	34 a	46.00 b	66.43
No Aircon or Control	45 b	49.00 c	66.27

Means followed by the different letters are significantly different; *** - highly significant at 0.1%; ** - significant at 1% level of significance using LSD

The HR (47.33%) was highest when samples were subjected to ¾ full adjustment whereas control and full adjustments were comparable with each other (≈40%) (Table II). The headrice based on milled rice is used by NFA in evaluating rice mill outputs that qualify rice mill owners to contract with NFA.

Moreover, Table III shows that degree of milling (percentage of kernels with bran streaks) of the milled rice increased with decreasing temperature in the polishing component. At full adjustment, the percentage bran streaks quadrupled that of the no aircon or control. Greater percentage of the rice kernels were with bran streaks when milled at lower temperature in the polishing component. This indicates that the milled rice contains more vitamin (mostly vitamin B complexes), protein, mineral, and oil contents [1]. This is due to the fact that the bran layer contains much of these micronutrients and anti-oxidants needed by the body.

Only the no aircon or control was classified as “well-milled rice” based on NFA Standards. All the samples subjected to aircon cooling were all classified as “regular-milled” rice. “Regular-milled rice” are rice grains from which the hull, the germ, the outer layer and the greater part of the inner bran layer have been removed, but parts of the lengthwise streaks of the bran layers may still be present on more than 10% but not to exceed 30% of the kernels stet and “well-milled rice” if parts of the lengthwise streaks of the bran layers may still be present on not more than 10% of the kernels [5].

People who stick to eating well-milled rice are prone to be protein-deficient or even malnourished, thus, it is not surprising that some dieticians recommend eating regularly milled or even undermilled rice [1].

TABLE II
HEADRICE RECOVERY (HR) OF RICE AT DIFFERENT TEMPERATURES OF THE POLISHING COMPONENT OF THE SINGLE-PASS-AIRCON SYSTEM

Aircon Thermostat Control	HR (%)	Headrice Based on Milled Rice (%)
	***	***
Full	39.80 c	60 c
¾ Full	47.33 a	70 a
½ Full	40.52 b	61 b
No Aircon or Control	39.76 c	60 c

Means followed by the different letters are significantly different; *** - highly significant at 0.1% level of significance using LSD

TABLE III
DEGREE OF MILLING (PERCENTAGE WITH BRAN STREAKS) OF RICE AT DIFFERENT TEMPERATURES OF THE POLISHING COMPONENT OF THE SINGLE-PASS-AIRCON SYSTEM

Aircon Thermostat Control	Degree of Milling (% with Bran Streaks)	Classification
	***	
Full	20 a	Regular-milled
¾ Full	14 b	Regular-milled
½ Full	12 c	Regular-milled
No Aircon or Control	5 d	Well-milled

Means followed by the different letters are significantly different; *** - highly significant at 0.1% level of significance using LSD

C. Cost Analysis

Table IV shows the cost analysis using the Rice Mill-Aircon system with the assumptions used.

The assumptions include the annual volume of paddy milled in a year at 300 tons/yr correspondingly estimated at 600 h operation in a year.

The Single-Pass Mill with aircon system has more advantages than the stand alone Single-Mill (control). With an investment of ₱15,000 for the aircon system, additional costs such as utility (electric), repair and maintenance, among other costs entail an additional milling cost of ₱0.04/kg. The investment cost is estimated to be recovered in 37 days of operation, with a net income of ₱98,100.00.

With the 1.35% increase in milling recovery using the Rice Mill-Aircon system, additional 4,050 kg milled rice is obtained. As of 2010 as reported by PhilMech, there were 24,420 units Single Pass Mills in the country, that could give 98.9 tons of additional milled rice when using this particular system.

TABLE IV
COST ANALYSIS OF USING THE SINGLE PASS MILL-AIRCON SYSTEM

Assumptions	
Annual utilization (5 hr/day; 20 days/mo; 6 mos/yr), hr	600
Annual capacity of paddy, kg	300,000
Investment cost (IC), P	15,000
Fixed Cost	
Annual depreciation (10% SV, 5 yrs life), P	2,700
Interest (10% of IC), P	1,500
Repair and maintenance (5% of IC), P	750
Taxes and insurance (2% of IC), P	300
Variable Cost	
Electric cost (P10/kw-hr), P	6,000
Cost of Aircooling, P/kg	0.04
Benefit (1.35% in milling recovery; No Aircon=66.27%), kg	4,050
Cost of Milled Rice (@P27/kg), P	109,350
Net Income, P	98,100
Payback period, yr	0.15
Benefit-cost ratio	8.72

D. Socio-Economic Acceptability

As shown in Tables V and VI, the Rice Mill-Aircon system was better than the no aircon or control in terms of income and quality of milled rice. The benefits or advantages derived from the Rice Mill-Aircon system include: 1) affordability or low investment cost; 2) more customers; 3) less labor; 4) less repair and maintenance; and 5) savings in time.

Some of the rice millers claimed that with the Rice Mill-Aircon system, replacement of worn out bearings requires them only after six months, instead of two months. Hence, savings on repair and maintenance costs, time, and labor are realized.

Table VI shows that all of the millers are willing to use the Rice Mill-Aircon system in their milling business. Three out of the 12 millers have two Rice Mill-Aircon systems and another one have three units. The millers claimed that they can hardly pass the 65% headrice, 35% brokens policy of the NFA before with their no aircon rice mill. With the introduction of the new system, NFA has contracted them due to the improved quality of their milled rice.

Twenty-one rice mills in Ilocos Sur, La Union and Abra are now using the system, one of which is the cooperator in Cabugao, Ilocos Sur.

TABLE V
MILLERS' RESPONSE ON THE BENEFITS/ADVANTAGES OF USING THE RICE MILL-AIRCON SYSTEM (N=12)

Question	Millers' Response (%)	
	Yes	No
Material		
Increased income	92	8
High quality of milled rice (higher milling recovery, headrice recovery and whiteness)	100	
Affordable investment cost	100	
Social		
More customers	92	8

TABLE VI
MILLER'S RESPONSE ON USING THE RICE MILL-AIRCON SYSTEM AGAIN (N=12)

Question	Miller's Response (%)	
	Yes	No
Will you use the Rice Mill-Aircon system again (n=12)	100	

IV. SUMMARY AND CONCLUSION

Samples subjected to ¾ full aircon adjustment gave the highest milling recovery, headrice recovery and percentage with bran streaks of rice. An increase of 1.35% over the no aircon or control was obtained. The headrice recovery and % with bran streaks were also increased by 10% and 9%, respectively at ¾ full aircon adjustment.

The 1.35% increase in milling recovery yields additional 4,050 kg milled rice which is obtained from a single unit of Rice Mill-Aircon system. Given this additional recovery, and if 24,420 units Single-Pass Mills in the country adopt the system, 98.9 tons of additional milled rice will be produced. This will result to considerable increase in milled rice production. Moreover, the increase in headrice recovery and percentage with bran streaks indicates better quality. The system will be very helpful in the attainment of rice self-sufficiency and competitiveness.

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