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Research

A Simple Mechanical Device for Market Classification of Milled Rice[1]

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ABSTRACT

A mechanical device was developed to quickly and accurately separate milled long grain rice into market categories. Image analysis was used to evaluate the performance of this device. A separation procedure was established and performed. The resulting fractions were evaluated by the Federal Grain Inspection Service (FGIS). The procedure was then refined and verified. The device described in this article was found to provide an objective evaluation tool as an alternative to the current subjective and time-consuming procedure. It can handle 50–100 g of rice in about 30 min, with little or no handpicking required.

Market prices for milled rice are determined according to the amount of broken kernels in a sample of the rice. Whole kernels, being the most consumer acceptable, command the highest price. What has been lacking is a simple mechanical device to enable a non-technical operator to quickly and efficiently separate milled rice into four market categories: whole kernels, second heads, screenings, and brewers rice. The sizing device presently used for official grading is mostly for rough separation of screenings and brewers fractions. It handles only 50 g of rice and requires extensive additional handpicking to achieve an accurate analysis (1). The objective of this work was to develop a method capable of rapidly separating 50–100 g of milled rice using a simple and relatively inexpensive mechanical device.

MATERIALS AND METHODS

Construction of the Device

Each separation board was prepared from a 6.4 mm thick plate of Plexiglass 25.4 cm wide and 48 cm long. Holes were drilled in a pattern such that each plate consists of 48 offset rows, with 1/2 in. spacing, each row having 16 holes. Each plate also has a copper wire embedded near the edge to drain static electricity when the wire is connected to ground. The No. 7 board has holes that are 1.854 mm in diameter; No. 6, 1.829 mm; No. 11, 2.489 mm; and No. 3, 2.565 mm.

The hopper was constructed of Plexiglass with radial grooves at the exit port to spread the rice kernels uniformly onto the separating boards. It remains in position when the separating boards are inserted or removed. A rotating stainless steel corkscrew prevents bridging of rice kernels at the hopper exit (Figs. 1–3).

The orbital shaker is powered by a 1/3 hp motor connected to a control unit for regulating the speed at which the boards rotate. The drive wheels are on adjustable eccentrics to give a circle of rotation of 3.81 cm (1.5 in) diameter. The tilt of the orbital shaker is 5°. The separating plates rotate at 300 rpm.

Image Analysis

A Quantimet 720 image analysis system (Imanco, Cambridge, MA), updated to a model 23A, was used to analyze the rice samples. Image analysis was used only as an analytical tool with which to evaluate the performance of the separating device. This method allowed rapid, accurate analysis of the large number of kernels separated by the sieving device.

The kernels were categorized according to their projected area. The Quantimet 720 utilizes a cathode ray tube-vidicon. The optical system consisted of a Nikkor macro lens (f/55) having a 1:4 magnification; four halogen

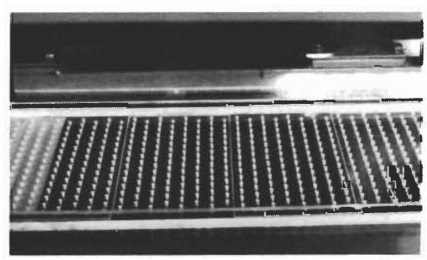

Fig. 2. Close-up view of the separation boards showing offset rows of holes and copper wire embedded in the board.

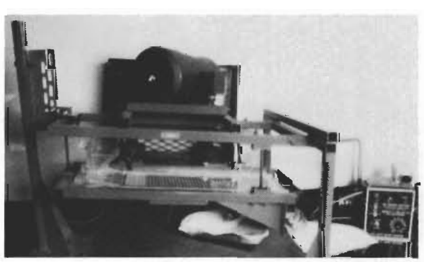

Fig. 1. Side view of separation device showing the orbital shaker, separation boards, hopper, and motor.

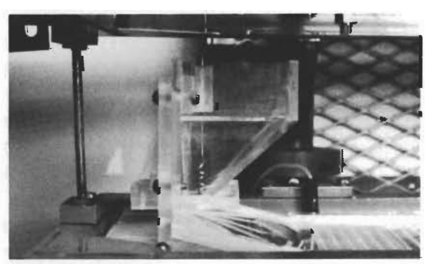

Fig. 3. Close-up view of hopper assembly showing hopper with spiral corkscrew and grounding strap to drain static electricity.

[1] Cooperative investigation between the U.S. Department of Agriculture, Agricultural Research Service: U.S. Grain Marketing Research Laboratory, Manhattan, KS; and the Department of Chemical Engineering, Kansas State University. Mention of firm names or trade products does not constitute endorsement by the U.S. Department of Agriculture over others not mentioned.

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lamps were used for illumination. The optical image causes the formation of a matching image, made up of electrical charges varying in image brightness. The charged image is scanned by an electron beam to produce a video output. This video image was transmitted and displayed on the television monitor. The host computer for this system was a PDP 11/03-L (DEC) computer with two 10-megabyte hard disks. The electronic digitizing equipment was set to achieve optimal conditions for detection. Under such conditions, the digitized image is a good approximation of the shape of the rice particle.

Rice samples were placed on black velvet paper to provide maximum contrast between the samples and the background (Fig. 4). Each separated fraction of rice from the new mechanical device was randomly divided into five subsets containing 45–60 pieces. These subsets were grouped to produce an image that filled the monitor screen. To test the results of the separation, approximately 225 kernels (or particles) were measured for each fraction, 900 for each rice sample. The range of kernel size for each category was established by statistical evaluation.

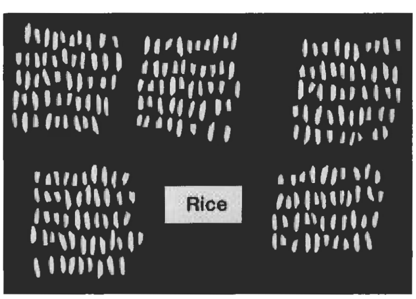

Fig. 4. Rice kernels on black velvet as seen by the image analyzer.

Separation Procedure

A sample of 100 g of rice (2 times the weight required by USDA; consists of approximately 1,000 pieces) was placed in a No. 18 Tyler sieve and rotated manually at a moderate speed in a circular motion for 15 sec. Throughs were collected, and the procedure was repeated twice more using the overs. All broken pieces going through this sieve were categorized as brewers.

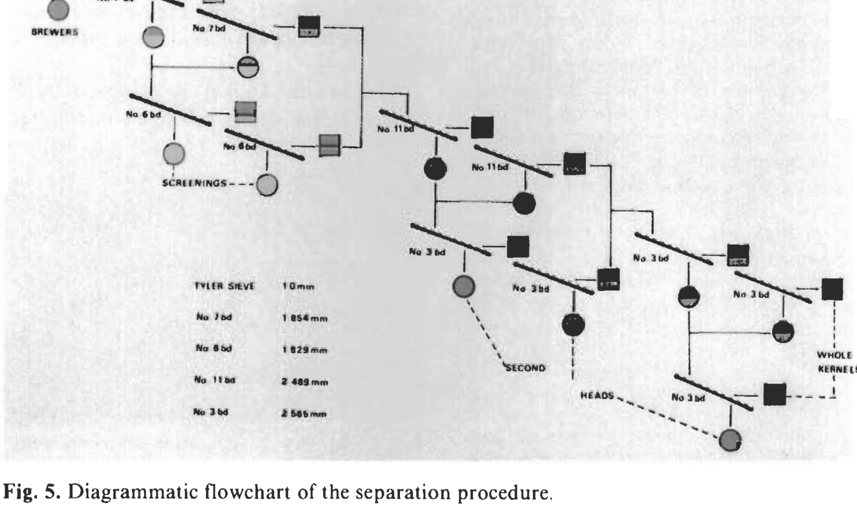

Fig. 5. Diagrammatic flowchart of the separation procedure.

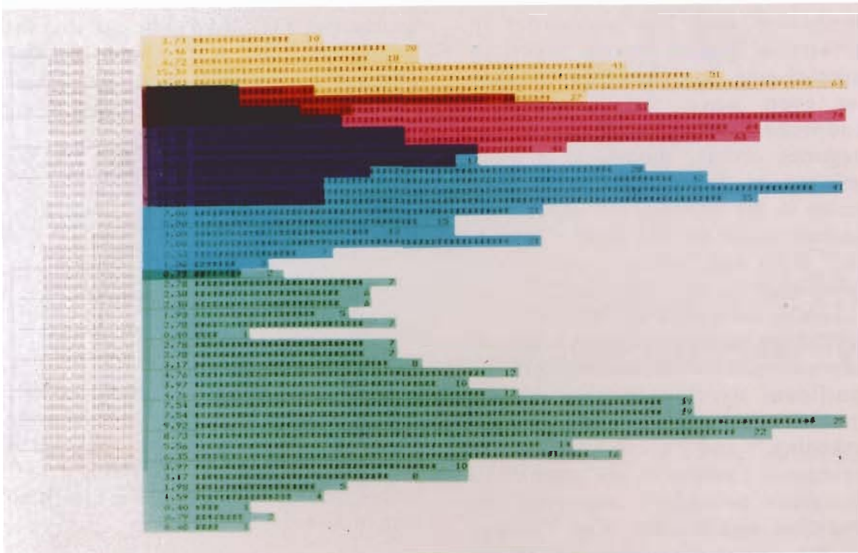

Fig. 6. Histogram showing distribution of rice kernels within each separated fraction from a handpicked sample from FGIS.

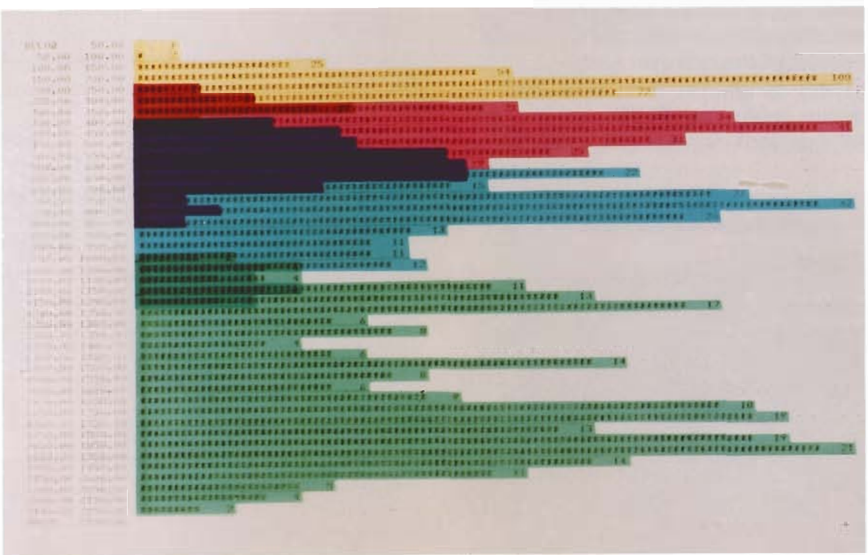

Fig. 7. Histogram showing distribution of rice kernels within each separated fraction under non-optimal conditions.

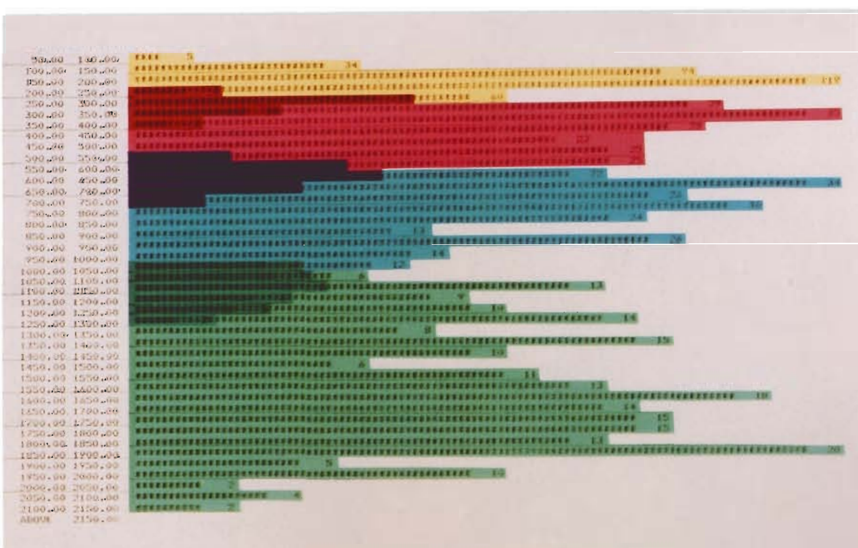

Fig. 8. Histogram showing distribution of rice kernels within each separated fraction under optimized conditions.

The rest of the sample remaining on the sieve was transferred to the hopper of the separation device and run over a No. 7 board. The throughs were collected and the overs put back over the No. 7 board again. The throughs from the No. 7 board were pooled and run over a No. 6 board. The throughs were collected and the overs put back over the No. 6 board. All pieces of rice going through the No. 6 board were categorized as screenings.

The overs from the No. 6 and No. 7 boards were pooled and passed over a No. 11 board. The throughs were collected and the overs were again passed over the No. 11 board. The throughs were pooled and passed over a No. 3 board. The overs were passed over a No. 3 board again. The throughs were categorized as second head rice.

The overs from the No. 11 and No. 3 boards were passed over a No. 3 board. The overs were passed over a No. 3 board again. The throughs were combined and passed over a No. 3 board yet again. As before, the throughs from the final run on the No. 3 board were classed as second heads. Both over fractions were categorized as whole kernels. This procedure is shown diagrammatically in Figure 5.

RESULTS AND DISCUSSION

Twelve boards, each with different size holes, were prepared. Experiments were begun using all of them to determine the size of rice kernel allowed to pass through each board. Bulk rice samples supplied by FGIS were passed over different combinations of boards to produce fractions that would correspond to currently used market classifications. These samples were sent to FGIS Board of Appeals and Review for evaluation by professional inspectors. The procedure was refined until the separation was acceptable to them.

Verification

Several methods were then used to verify objectively that four reproducible categories corresponding to market classifications had been achieved using the mechanical separator. The purpose of using image analysis was to introduce an objective evaluation of the separated fractions. Measurement data were output in the form of distribution graphs (histograms) of the area vs the number of kernels. A histogram of projected area with corresponding statistics such as minimum, maximum, mean, median, and standard deviation was generated after each sample run.

The image analyzer is capable of measuring a number of morphological parameters of the rice kernels including length of the long and short axes of each, perimeter, and projected area. We chose to use the projected areas for the analysis of the separated fractions of rice. Distributions for each category were determined by using samples that had been handpicked by FGIS, which then served as learning sets. The learning set data is presented in the form of a histogram in Figure 6.

This histogram illustrates the size distribution over four categories in numbers of pieces having a certain projected area. It is clear from the data that even when the kernels are handpicked, some overlap on the categories occurs, though it is more prevalent in the smaller pieces. The overlap in the handpicked samples was relatively small for the larger "second-head" (SH) and "whole kernel" (WK) categories.

Fig. 9. Sample of mixed dyed rice before separation on sizing device.

Initially, the separation sequence used with the new mechanical device produced fractions which gave histograms showing significant overlap in size ranges, especially among "second head," "screening," and "brewers" (Fig. 7). Subsequent changes in the mechanical separation procedure improved the separation significantly (Fig. 8), such that the degree of overlap among the various categories was small and approximately equal. These changes involved the boards used, the sequence of use, the speed and eccentricity of the oscillation of the boards, and the number of passes of the rice over each.

These conditions were then used to separate additional FGIS rice samples. The separated rice was sent to FGIS for evaluation. FGIS had indicated that the separation of greatest interest was that between SH and WK. Their inspection of these samples resulted in the following data:

Sample	SH in the WK (%)	WK in the SH (%)
A	2.0	2.9
B	2.8	4.3
C	2.1	2.7
Mean	2.3 ± 0.4	3.3 ± 0.8

It is clear from the histograms and the FGIS evaluation that four separate fractions have been achieved and that the separation of greatest marketing significance (i.e., WK from SH) has been accomplished.

Visual Confirmation

Samples of each of the categories separated by this mechanical device were dyed with food coloring for 30 min and then air dried. Next, the fractions were mixed together, a 100 g sample taken, and the mixture separated according to the described procedure.

The starting mixture and the four separated fractions are shown in Figures 9 and 10, respectively. It can be seen that the separation among the colored kernels is quite good with relatively little overlap. Many of the red (whole) kernels observed in the green (SH) fraction are actually broken WK which do belong to the SH category. The majority of the green kernels observed in the red fraction are large kernels of broken rice which, if judged subjectively, would be classified as either WK or SH depending on the inspector.

Fig. 10. Separated dyed rice showing efficiency of the separation under conditions described in text.

CONCLUSION

A simple mechanical device has been developed for separating milled long grain rice into four currently used market categories. The procedure requires only 30–40 min to separate 100 g of rice and requires little or no hand adjusting.

While we have not presented data on short and medium grain rice, it is anticipated that the system could be modified to suit grading of these classes. The breakage problem is more pronounced in long grain rice since the larger ratio of long axis to short axis leads to an increased incidence of breakage during milling and handling.

This device was intended to show a promising, simple method from which to proceed. It provides an objective evaluation tool for a procedure which currently is highly subjective and time consuming.

Reference

1. USDA Inspection Handbook for the Sampling, Inspection, Grading and Certification of Rice. June 1974.