DEVELOPMENT OF AN OPTICAL COLOR SORTER FOR QUALITY IMPROVEMENT IN PADDY SEED

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ABSTRACT

Optical Color Sorting technology is a modern technology used to remove defective or unwanted material based on its color difference, ensuring a higher quality of the final product. A combination of LED light sources, high resolution camera, and a separating algorithm allow this technology to rapid remove the impurities based on color wavelength discrepancies with continuous and high operational efficiency. Impurities in paddy seeds can be defined as an extraneous substances or undesirable compounds found in the harvested paddy seeds such as foreign matter, immature seed, weedy, and chalky. Effective separation of these impurities in a post-harvest processing is vital to ensure high quality of paddy seed can be produced, thus avoid spread of pests and diseases in rice fields. Therefore, this paper describes the development of an optical color sorter for quality improvement in paddy seed. The objective of the study was to determine the paddy seed quality produced by an optical color sorter. Samples were randomly collected to compare the paddy seed quality produced with (CS) and without (GS) an optical color sorter. Laboratory quality analyses were conducted to compare these two samples. According to the study, the moisture content did not significantly change ($p>0.05$) when processed with an optical color sorter, with the GS sample's moisture content being 12.30% and the CS sample's being 12.36%. In terms of physical quality, the optical color sorter significantly reduced ($p<0.05$) the presence immature seeds, weeds, and chalky to 0.16%, 0.47%, and 0.45%, respectively, from 5.64%, 16.83%, and 1.20%, respectively, without processed through an optical color sorter (GS). However, CS samples showed no significant changes ($p>0.05$) in foreign matter compared to GS samples, which were 0.16% and 0.33%, respectively. In conclusion, an optical color sorter was found effective in removing immature seeds, weeds, and chalky from the cultivar seed. Therefore, much higher seed quality was achieved in the samples processed through an optical color sorter (CS). Hence, utilizing an optical color sorter technology in all paddy seed processing facilities is crucial for improving the quality of paddy seeds and raising the nation's rice yield.

Keywords: optical color sorter, seed quality, paddy seed, post-harvest processing

INTRODUCTION

Paddy seeds are crucial resource for rice cultivation and overall rice production at the national level. Producing high-quality paddy seeds can improve germination rates, mitigate issues with pests and disease in the fields, ultimately resulting in higher productivity and bolstering the nation's food security (Asnawi et al., 2023). Hence, it is crucial to focus on the quality control of paddy seeds throughout the production chain, particularly during the handling and post-harvest processing phases. Removing impurities is one of the major concerns and challenges in post-harvest processing to ensure high quality paddy seeds can be produced.

Generally, impurities in paddy seeds is an extraneous substances or undesirable compounds found in the harvested paddy seeds. Typical impurities commonly present in paddy seeds include straw and plant remnants, dust and soil, stones, insects and insect fragments, as well as seeds that are damaged, immature or discolored. The presence of impurities can impact the overall quality of the paddy seed production. In essence, the quality control requirements for paddy seeds provided by the Department of Agriculture Malaysia (DOA), as outlined in MS469:1993, specify various elements. To adhere to these guidelines, the purity percentage of the variety must meet a minimum rate of 98% for the production of basic seed. Basic seed samples must not contain impurities exceeding 2%. It is crucial to focus on screening and sorting technologies through post-harvest processing line to meet the paddy seed standard outline.

Screening and sorting impurities is a vital step to effectively eliminate all undesirable materials or impurities. Effective processing can produce superior paddy seeds, thereby mitigating problems associated with the proliferation of pests and illnesses in the paddy fields.

Optical colour sorting technology is a new modern sorting technology involving a combination of LED light sources (high-luminance LED modules) and high-resolution camera technology with an application of R, G, B that enables screening, filtering and separating impurities of paddy seed based on color wavelength discrepancies (Inamdar et al., 2014). Utilization of an advanced imaging technology and optical sensors to identify and rapid remove impurities allows this technology to operate continuously with high operational efficiency. Thus, an optical color sorter is widely used in contemporary paddy seed processing mills to ensure seeds fulfil consumer quality standards. Technological developments in optics, image processing, and sorting algorithms have led to increased efficiency and reliability of these technologies throughout the years (Timothy H. et al., 2017).

Therefore, this paper aimed to determine the improvement of paddy seed quality processed through an optical color sorter.

MATERIALS AND METHODS

Material

Paddy seeds were harvested from the same plot located at MARDI Parit station, Parit, Perak, during the second season of 2023. The variety of paddy seeds used in this study was MR315. The samples did not undergo the rouging process. The harvested paddy seed were collected and process at the paddy seed processing mill, MARDI Parit, Parit Station, Perak. The paddy seed samples underwent the same basic processing machines comprising pre-cleaner, drying, fine cleaner, indented cylinder and gravity sorter before entering the optical colour sorting technology.

Optical color sorter

The optical color sorting technology used was the ICGA-480 Series model from the country of China. The sensitivity sorting parameters for first cycle were set to 49% for grey A, 0%, for grey B, and 54% for discolor A, respectively. The feeding rate speed was set to 14%. The table 1 below shows the specifications of the ICGA-480 optical color sorting technology used:

Table 1: Specification of an optical color sorter

No.	Title	Specification
	Model	ICGA-480
	Size	Length : 1700mm Width : 1500mm Tinggi : 1800mm
	Capacity	1-3 tonnes/hour
	Feeding method	Chute
	Chute	8 unit
	Channel	60 channel/chute
	Process	Continues operation

Preparation of sample

Samples that were not processed with an optical colour sorting technology were obtained randomly through the discharge point of vertical bucket elevator E7 before the paddy seeds entered the optical colour sorting technology and, labeled as GS. Samples that underwent optical colour sorting processing system were collected randomly through the discharge point of vertical bucket elevator system E4, which discharged the isolated paddy seeds from the colour sorting technology into the tempering bin, and were labelled as CS. The samples were obtained randomly by 30 minutes intervals for 16 hours processing period.

Analysis of moisture content

The moisture content of the paddy seed sample was measured according to the standard method of AOAC (2000). The sample was dry at 105ºC in a hot-air oven, and all data were recorded. Moisture content analysis was conducted in triplicates, with each replicate analyzed three times. The percentage of moisture content loss in the sample was calculated using the following equation:

$$\text{Moisture content, (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Analysis of paddy seed quality

Paddy seed quality analysis was conducted in the quality laboratory to compare the percentage difference of foreign matter, immature, weedy, and chalky seed between GS and CS samples. The coning and quartering method was employed to transform each sample into a working sample. Each working sample was weighed at 40g using an analytical balance and recorded as W_1. The impurities, including foreign matter, immature seed, weedy, and chalky, were sorted manually by visual inspection. The total impurities in each working sample were weighed using analytical balance and recorded as W_2. The percentage of impurities was determined by using the equation below:

$$\text{Impurities (\%)} = \frac{W_2}{W_1} \times 100 \qquad 2)$$

Statistical analysis

A one-way analysis of varians (ANOVA) was used for statistical analysis. The studied factor was the processing method, either with or without the use of an optical color sorter. All factors were compared using Tukey's test method with a confidence level of 95%. Statistical analysis was performed using Minitab Software version 19 (Minitab Inc., State College, PA, USA).

RESULTS AND DISCUSSIONS

Moisture content evaluation

Moisture content refers to the amount of water present in paddy seeds. Optical color sorting technology fully utilizes an air ejector supplied by compressed air to remove impurities from paddy seeds. Improper maintenance of compressed air could result in water droplets that might affect the moisture content of paddy seeds. Additionally, additional processing steps might lead to extended processing times, which could affect the moisture content of paddy seeds due to high relative humidity in the processing mill. According to the paddy seed regulation standards set by the Department of Agricultural Malaysia (DOA), the moisture content must not exceed 14%. Based on the result obtained in Table 2, the moisture content of paddy seed that did not undergo the optical color sorting (GS) was 12.30% while the moisture content of paddy seeds that underwent the optical color sorting process (CS) was 12.36%. The difference in moisture content might be attributed to the additional operation time during the processing. However, statistically analysis via ANOVA indicates that there is no statistically significant increase in the moisture content percentage. Moreover, the moisture content percentage of the CS sample remains below the required maximum limit of 14% set for paddy seeds in the regulatory standard MS469:1993.

Table 2. Moisture content analysis of paddy seeds with and without process with an optical color sorter technology

Analysis	Moisture content
GS	12.30 ± 0.27^{a}
CS	12.36 ± 0.16^{a}

*Means within each row with different superscript letters indicate significant differences (P<0.05) as measured in Tukey's Comparison Test

Paddy seed quality evaluation

The evaluation of paddy seed quality is conducted by comparing the percentage of impurities between GS and CS samples. Four categories of impurities exhibiting distinct hues in contrast to the cultivar paddy seeds have been sorted out, which include foreign matter, immature seeds, weedy seeds, and chalky kernels. With its specialized function of screening and separating impurities based on color wavelength differences, an optical color sorter is capable of effectively reducing all these impurities. According to the paddy seed regulation standard MS469:1993, it is necessary to ensure that the proportion of total impurities does not exceed 2%.

Foreign matter in paddy seeds refers to extraneous substances such as dirt, stones, husks, insects, or any debris collected during harvesting and handling. According to the results obtained in Table 3, the foreign matter content in paddy seed samples taken from the vertical bucket elevator before entering the optical color sorter (GS) was 0.33%. The foreign matter in paddy seeds taken from the discharge point of the optical color sorter's vertical bucket elevator (CS) was reduced to 0.16%. Based on the statistical analysis results, there was no significant difference (p>0.05) in the amount of foreign matter between GS and CS samples, as illustrated in Figure 1(a). This is likely because most of the foreign matter contamination has been isolated at the early processing stages, specifically during passage through the pre-cleaner, gravity separator, and indented cylinder. The desired physical purity of paddy seeds can be significantly improved when seeds are processed through the pre-cleaner, gravity separator, and indented cylinder (Rabindra, 2016).

Immature paddy seeds refer to seeds that have not fully developed or ripened during harvesting, typically exhibiting different levels of green color compared to the cultivar seed. Based on the results in Table 3 and Figure 1(b), the percentage of immature seeds in the CS sample was reduced to 0.16%, significantly lower ($p<0.05$) than the result of the GS sample, which was 5.64%. The differing color wavelengths of the immature seeds compared to the cultivar seed have been analyzed in real-time by the sophisticated image processing algorithms of the optical color sorter. These algorithms analyze the R, G, B values of each pixel in the image of the immature seed to determine the color wavelength before being sorted out by the air ejector (Ayman et al., 2012).

Weedy seeds refer to undesirable plants with unfavorable agronomic traits for rice production. According to the results, the optical color sorter improves paddy seed quality by significantly reducing ($p<0.05$) the percentage of weedy seeds to 0.47% compared to the percentage of weedy seeds in the GS sample, which was 16.83% as illustrated in Figure 1(c). Weedy seeds are commonly referred to as red rice due to the red pigmentation on their pericarp (Dilipkumar et al., 2020). Thus, the differing color wavelengths of the red pigmentation on the weedy pericarp have been identified and ejected by the combination of advanced imaging technology and sorting algorithms used in the ICGA-480 optical color sorter.

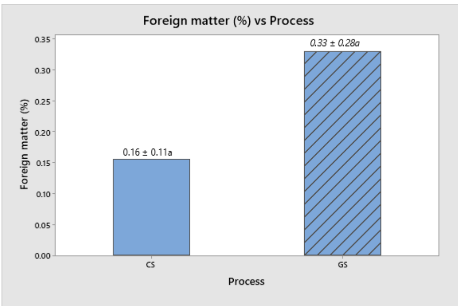
Chalky seeds, also known as chalky kernels, are caused by incomplete or irregular development of starch granules within the rice kernel (Long Z. et al., 2019). According to the results in Table 3 and Figure 1(d), the optical color sorter is able to significantly reduce ($p<0.05$) the percentage of chalky kernels in the paddy seed sample to 0.45%, compared to 1.20% of chalky seeds contained in the GS sample. This reduction may be attributed to the distinctive whiteness appearance in the endosperm of chalky seeds, which can be detected and isolated by the optical color sorter.

Table 3. The percentage (%) amount of impurities in the sample processed through an optical color sorter (CS) and without processed through an optical colour sorter (GS)

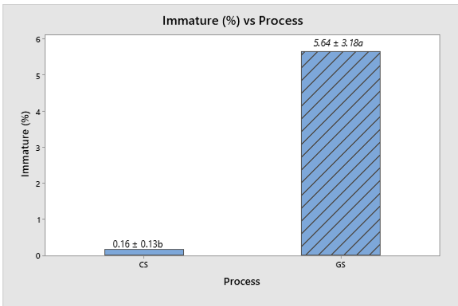
Impurities	GS	CS
Foreign matter	0.33 ± 0.28^{a}	0.16 ± 0.11^{a}
Immature seed	5.64 ± 3.18^{a}	0.16 ± 0.13^{b}
Weedy	16.83 ± 6.19^{a}	0.47 ± 0.41^{b}
Chalky	1.20 ± 0.25^{a}	0.45 ± 0.28^{b}

*Means within each row with different superscript letters indicate significant differences ($P<0.05$) as measured in Tukey's Comparison Test

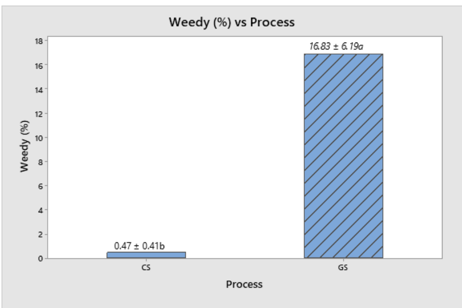
Figure 1: Percentage (%) of (a) foreign matter, (b) immature, (c) weedy, and (d) chalky impurities in a sample processed through optical color sorter (CS) and without processing with optical color sorter (GS)



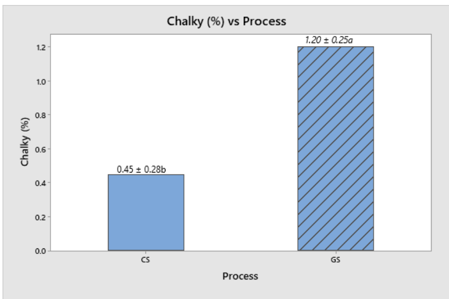
(a)



(b)



(c)



(d)

Based on observations from all the experimental data, the optical color sorter has proven to be capable and reliable in improving paddy seed quality by reducing three significant impurities: immature seeds, weedy material, and chalky grains. Therefore, the optical color sorter is effective in removing impurities that exhibit differences in color wavelengths.

CONCLUSION

The efficiency of the optical color sorter in domestic post-harvest processing lines is vital for ensuring the production of high-quality grade paddy seeds. The findings of this study demonstrate that the optical color sorter processing system employed in the paddy seed factory, MARDI Parit, Perak, has the ability to improve paddy seed quality by effectively reducing impurities such as foreign matter, immature seeds, weedy material, and chalky grains. These results are also in line with the quality standards outlined in seed MS469:1993. These findings indicate that the optical color sorter system is highly effective in segregating paddy seeds based on their distinct physical features and color differences.

In summary, the findings of this study can assist paddy seed producers in regularly assessing the efficiency and effectiveness of the processing system at paddy seed processing mills. The acquired data can also provide fundamental information to potential entrepreneurs and production managers interested in entering the paddy seed industry. Thus, it is anticipated that this research data can offer valuable insights and knowledge to paddy seed producers and mill operators, aiming to optimize the efficiency of optical color sorter technology. This will ensure the production of superior quality seeds and ultimately enhance rice yield in the country

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REFERENCES

Amyita Witty Ugap (2015). Kawalan Kualiti Benih Padi. Kursus Pengeluaran dan Pengesahan Benih Padi, pp. 1-68.

Asnawi S., Wan Mohd Fariz W.A., Saiful Azwan A., Masniza S., Teoh C.C., Azzami Adam M.M., Faewati A.K., Ahmad Fadhlul Wafiq A.R., Muhammad Aliq J., Mohammad Shukri J., Muhammad Syakir A.G.. Penilaian prestasi keberkesanan sistem teknologi pemprosesan lepas tuai benih padi. MARDI Res. Bull. 36 (2023), 189-200.

Ayman H., Amer E., Ayman A., Abdul Khalik (2012). Understanding color image processing by machine vision for biological materials. Structure and function of food engineering.doi:10.5772/50796

Chamhuri S., Nor Diana M.I., Muhammad Y., Golam M. (2014). Issues and challenges facing rice production and food security in the granary areas in the east coast economic region (ECER), Malaysia. Research Journal of Applied Science, Engineering and Technology. 7(4):711-722

Dilipkumar M., Badrulhadza A., Mohd Khusairy K., Mohd Shahril Firdaus A.R. Chong T.V., Chuah T.S.(2020). Manual Teknologi Kawalan Padi Angin. ISBN 978-967-936-689-1.

Gurdv K. (2003). Productivity Improvements in Rice (2003). Nutrition reviews. 61(6), 114-116.

Inamdar A.A., Suresh D.S (2014). Application of color sorter in wheat milling. International Food Research Journal. 21(6), 2083-2089.

Long Z., Linglong Z., Jing Z., Xiuling C., Qiaoquan L., Cunxu W. (2019). Relationship between transparency, amylose content, starch cavity, and moisture of brown rice kernels. Journal of cereal science. Doi:10.1016/j.jcs.2019.102854

Rabindra K. (2016). Effectiveness of seed processing machinery on seed quality improvement in paddy (oryza sativa L.). Journal of AgriSearch. 3(3);187-190

Standard Jabatan Pertanian Malaysia, Malaysia Standard MS469: 1993 (2011). Jabatan Pertanian Malaysia, pp. 1-10.