[Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences](https://scholarworks.uark.edu/discoverymag)

Volume 1 Article 8

Fall 2000

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ABSTRACT

Fissures are fractures of a rice kernel that can be created during the drying and tempering process. They cause tremendous postharvest losses in milling yield. Understanding why and how rice kernels fissure will lead to optimal drying and tempering operations. This information could also provide input to plant breeders for producing rice cultivars that are more resistant to fissuring. Rice kernels were dried using various air conditions in a controlled environment chamber. The kernels were viewed by video microscopy to observe the occurrence of fissures. A videocassette recorder recorded the images for a 24-hour period after the drying process. The tapes were reviewed to reveal characteristics of the fissures. The rice cultivars used in this experiment were 'Bengal', 'Cypress', and 'Drew'. The tests showed that Cypress kernels were more resistant to fissuring than were the other two cultivars. The recorded images from the microscopy chamber showed that fissures begin from the inside of the kernel. Also, fissures were observed to form almost instantaneously.

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INTRODUCTION

The overall goal of this project was to increase the quality and value of rice. Currently, fissures cause immense losses in the value of domestic rice. Rice kernels with fissures tend to break during the milling process. Lower head rice yields, to a large extent, are the result of these broken kernels. Since head rice, or whole kernels, are typically worth twice that of broken kernels, it is imperative that the number of broken kernels be minimized.

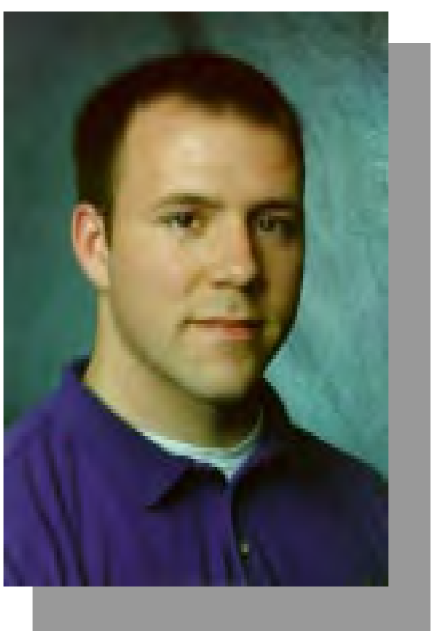
Physical properties such as specific heat, specific volume, expansion coefficients, and viscoelasticity of rice kernels change as the starch is heated past a moisture content-dependent temperature known as the glass transition temperature, T_g. The moisture content (MC) gradient created during drying may cause different regions of the kernel to vary in temperature, either higher or lower than the T_g. Tempering is a step used in the commercial rice drying process to reduce MC gradients. In commercial mills, tempering is done by temporarily storing the rice after drying in tempering bins for a certain period of time to allow the moisture to equilibrate before subsequent milling or storage. It is hypothesized that if the tempering environment produces a change of state of starch, differential stresses within the kernel resulting from the MC gradient could cause kernel fissuring (Perdon and Siebenmorgen, 1999; Cnossen *et al.*, 1999). This hypothesis would indicate that if there were sufficient MC gradients inside the kernel, this state transition by some parts of the kernel would create fissuring. The work in this study was conducted within the framework of this hypothesis to result in characteristics of fissures.

MATERIALS AND METHODS

An environmental chamber (Figure 1) was constructed at the University of Arkansas Rice Processing Lab. The chamber was constructed of aluminum and insulated with polystyrene to reduce heat loss. The chamber had two air ducts that allowed air to be provided at the desired conditions. A glass door allowed viewing of the rice as it was tested.

The environmental chamber was equipped with video microscopy equipment. A CCD camera with a 35X lens was mounted inside the chamber to view an individual kernel as it dried and then tempered. A lamp and fiber optic cable shone light on one end of the rice kernel so fissures of the kernel were visible. The image of the rice kernel was continuously viewed on a monitor and recorded by a VCR.

Samples were prepared from three rice cultivars:



Jerry Fendley

Meet the Student-Author

After graduating from Arkadelphia High School in 1996, I entered the University of Arkansas, where I received a degree in biological and agricultural engineering last May. I have received numerous scholarships over the past several years. In addition, I was a member of a team of engineering students who won first place in the AGCO National Student Design Competition this past year.

I plan to go on to graduate school for my master's degree, and then to either enter a Ph.D. program or seek a career in designing food processing equipment.

I chose my research project because of the importance of rice fissuring in the rice processing industry. In the process of conducting my research, I learned how important it is to set up an experiment properly so that the data observed will be accurate.

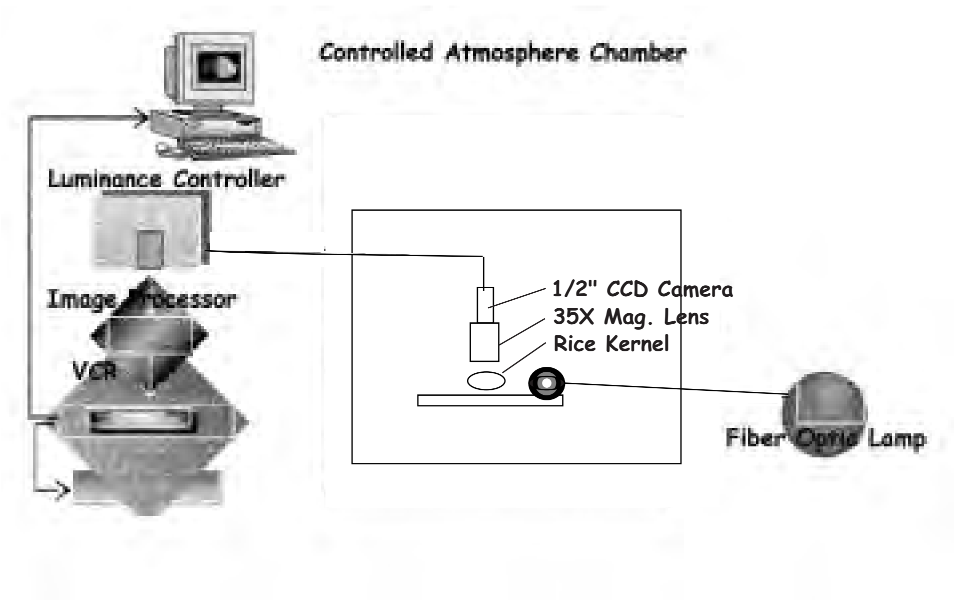


Fig. 1. Schematic of the video microscopy system.

'Bengal', a medium-grain kernel, and two long-grain kernels, 'Cypress' and 'Drew'. The environmental chamber was allowed to equilibrate to the desired conditions before the samples were placed. A single rough rice kernel was hulled, and its weight was recorded and placed under the camera lens for observation using the microscope. Once the rice was inside and the environmental chamber sealed, the VCR started recording images. Simultaneously, 100 rough rice kernels of each cultivar were hulled by hand and placed in a mesh container beside the single kernel in the chamber to investigate the percentage of fissured kernels. Three replications were made for each treatment. Thermocouples were used to monitor the air temperature during the drying process.

During the first set of tests, rice from each cultivar was dried inside the chamber at various temperatures (60, 55, 50, and 45ºC). The rice was dried to approximately 12% MC, and then the chamber was opened to ambient conditions in the lab at approximately 22ºC and 45% relative humidity (RH). During the second set of tests, each cultivar was again dried to approximately 12% MC inside the chamber at 60, 55, 50, and 45ºC. However, for the second set of tests, the dried rice was then tempered at 40ºC and 20% RH for 2 hours. After the tempering process, the chamber would again be opened to ambient conditions in the lab. Thus in the first set of tests, the kernels were not tempered before they were exposed to ambient conditions, while in the second set of tests they were tempered. Tempering is used to reduce the moisture gradient inside rice kernels due to drying. According to the T_g hypothesis, the second set of tests should have resulted in fewer fissured kernels.

The video recordings of the rice kernels were viewed to determine the number of fissures resulting from the

Table 1. Percentage of rice kernels fissured due to drying without tempering.

	Air temperature (ºC)			
Cultivar	45	50	55	60
Bengal	8	61	N/A	94
Drew	17	52	89	97
Cypress	2	24	26	92

Table 2 . Effects of tempering on fissuring of brown rice (cv. Drew).

Air temp. (ºC)	Initial MC (%)	Fissure % without tempering	Fissure % with tempering
45	18.5	16.5 (5.5)	5 (4.3)
50	18.5	46 (5.7)	27 (4.7)
55	18.6	58 (3.8)	34 (3.8)
60	18.5	94 (2.6)	51 (3.2)

Values inside parentheses are standard deviations of the mean.
MC = moisture content.

drying and tempering process. Kernels were observed for a 24-hour period after drying to see if one or multiple fissures occurred. The time and kernel location of fissure initiation were observed.

RESULTS AND DISCUSSION

The fissuring characteristics of the three rice cultivars were compared. Table 1 and Fig. 2 show that Cypress was more resistant to fissuring when dried at lower temperatures than were the other two cultivars. Drying air temperatures at and above 50°C caused Bengal and Drew to fissure substantially more than Cypress until drying air temperature of 60°C, in which fissuring for all three cultivars was essentially similar, with practically all kernels fissuring. It was found that fissuring response was not significantly different at lower temperatures (37 to 45°C) for Bengal and Drew; however, Cypress fissured significantly less than Bengal and Drew ($P = 0.05$).

Table 2 shows the percentage of kernels that developed fissures with tempering after drying with and without tempering at the various drying temperatures. The data clearly show that the tempering process reduced the amount of fissured kernels. The effects of temperature on fissuring were similar in tempered rice and non-tempered rice (Fig. 3).

Viewing fissures while they occurred provided two observations. First, a fissure begins from inside of the kernel and progress to the surface of the kernel. Second, rice kernels fissure nearly instantaneously. This process is visually similar to a piece of ice being dropped into a glass of warm water. In both cases, fissures begin rapidly inside and propagate across the cross-section of the kernel or ice cube.

The observation that Cypress was more resistant to fissuring than the other two cultivars could have a big impact on the industry. If this observation is verified, it could result in processors requiring this cultivar for its superior fissure resistance. Plant breeders could also use this information in the development of new rice cultivars.

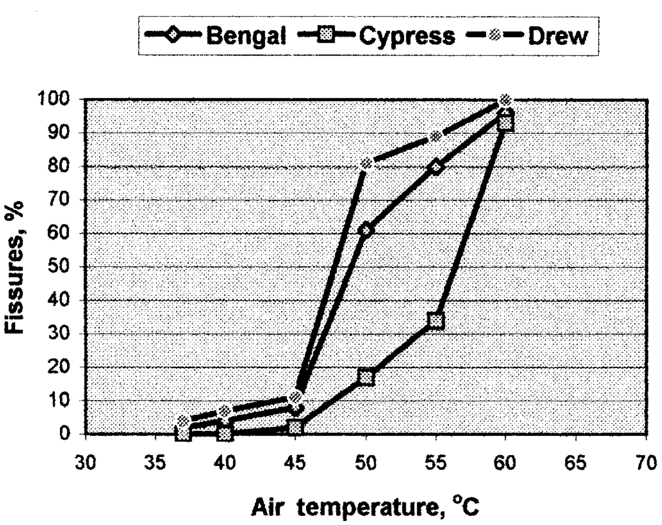


Fig. 2. Effects of drying air temperature on fissuring of three rice cultivars without tempering.

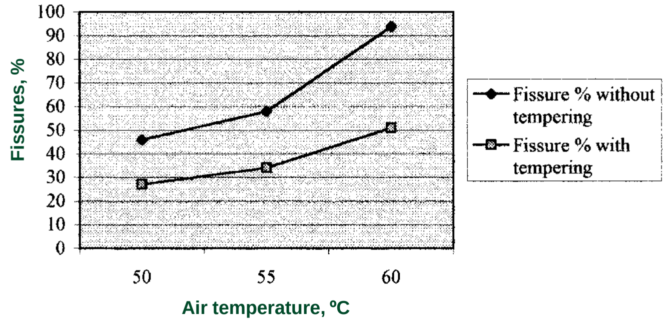


Fig. 3. Effects of tempering on fissure formation in brown rice (var. Drew) after drying kernels to 12.5% moisture content with the indicated drying air temperature.

LITERATURE CITED

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