Mechanical fracture characterization of rice kernel under milling process

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Abstract. Mechanical Fracture of rice kernel caused by milling process has not been studied completely yet. The objective of the research was to study the fracture of rice kernel under rubber-roll milling process. A long- grain rice variety (IR 64) and a-short-grain rice variety (IR42) with 14 % average moisture content (MC) were choices as the sample in this research Physical and mechanical properties of rice kernel were evaluated using micro Vickers hardness tester. Fractography of fracture surface using Scanning Electron Microscope (SEM) was used to observe the fracture surface. Gold coating on fracture surface was needed to become conductive. Stress analysis was also evaluated analytically in order to know the relationship between rice breakage force and pressure force induced roll rubber. The result shows that there is significant distinct of the hardness between IR 64 and IR 42 variety. Fractography of IR 42 and IR 64 show that modes of fracture are brittle. Cleavage of crack is clearer for IR 64 and initiate from the mid of part to outer part. Microcrack distributed along inert granules of endosperm zone. Force induced by roll with respect to paddy (Fn) is recommended smaller than the breakage force of paddy (Fp) in order to avoid fracture during milling process.

Keywords: *Mechanical properties fracture, microcracks, SEM, rubber roll.*

Introduction

Two modes of fractures on rice kernel are naturally fracture and mechanically fracture. Natural fracture occurred on rough rice. Natural fissure was caused by treatments after harvesting, whereas mechanical fracture, it was occurred during milling process. Both natural and mechanical fractures can decrease milling recovery of brown rice and head rice. Identification of mechanical fissure caused by milling process has not been studied completely yet.

Sieben Morgan (2004), explained that from 100 kg rough rice milled by rubber-roll milling machine result around 15 % broken rice. !5 % of broken part consist of naturally fracture and mechanical fracture. This research evaluated the broken part of rice kernel caused by milling process.

Zhang et-al., 2004 studied on understanding rice fissuring by SEM examination of fracture surface. The natural fracture surface of rice kernel at different drying duration was examined using SEM. Two distinct zones were identified and characterized. The phenomenon of different zoning on the natural fracture surface of rice was interpreted by the relative strength of the interfaces between cell walls and those between granules. This paper focused on the natural fracture, but for mechanical fracture during milling process has not been evaluated intensively.

Fracture behaviour of rice kernel has not been studied completely, especially for mechanical fracture. One of the important properties is fracture toughness of rice kernel also not studied yet.

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Fracture of rice kernel during milling process is strongly affected by pressure force induced by rubber roll. It is also affected by mechanical properties of rubber roll and gap distance of rolls.

Chandra,H., *et-al*. 2009, evaluated that pressure force induced by rubber rol is recommanded less than breakage force of rice kernel. Siebenmorgen, et-al (2004), also said that quality of rice milled is strongthly affected by breakage force distribution of rice kernel.

Zhang. *et-al*, (2005), studied the mechanism of failure of rice milled. Fracture energy, fracture strength, and modules of elastisity should be paid attention to reduce fracture.

Materials and Methods

The rough rice used in this research are a-long grain rough rice IR 64 with 9.73 mm average length and a-short grain rough rice IR 42 with 8.10 mm average length. The rough rice with 14% average moisture content (MC) was milled by two-pass rubber roll milling machine to become white rice.

The broken part of white rice IR 42 and IR 64 varieties were chosen as samples. Identification of fractography of fracture surface using scanning electron microscope is very important to use in this research. Prior to SEM examination, a thin layer of gold was sputtered onto the sample surface to make it conductive.

Evaluation of the mechanical properties of rice kernel was also tested to know its relationship with respect to mode of surface fracture. In this research micro Vickers hardness tester under 50gram load was subjected to get Vickers hardness number (VHN).

Stress analysis of rough rice during milling process was also analytically evaluated in order to optimize the milling process. There is relationship between rice hardness value and breakage force. Pressure force induced by rubber roll is recommended less than breakage force of rice kernel.

Results and Discussion

Fracture behaviour of rice kernel was studied for IR64 and IR42 varieties. Both varieties have a significant distinct in length and equivalent diameter as shown in Figure 1. IR 64 variety has 8.10 mm average length and 1.898 average diameter, whereas IR 42 variety has 9.728 mm average length and 2.104 average diameter.

Hardness Test

The result of hardness test using micro Vickers hardness tester showed that the average hardness of IR64 variety was higher than IR 42 variety. The hardness of IR 64 variety is VHN 6.78, whereas IR 42 variety is VHN 5.96.

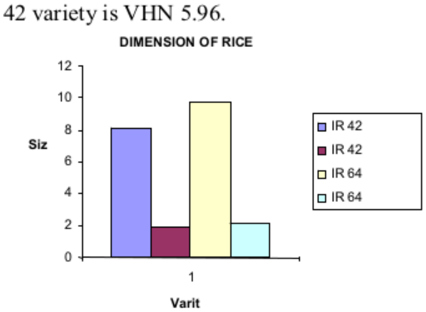

Figure 1. Physical size of rice kernel

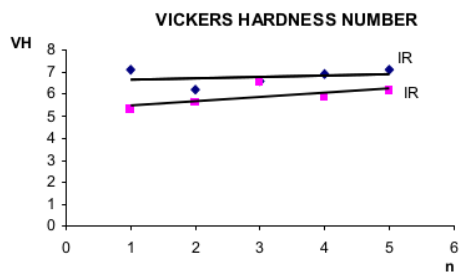

Figure 2. Hardness value of rice kernel

Inspection Using Scanning Electron Microscope

Identification of fractography of rice kernel was conducted to study further the behaviour of fracture surface of rice kernel. Visualization and scanning electron microscopy were subjected to rice kernel. The fracture pattern, crack initiation, and crack propagation phenomena were studied in this research. There are three stages of fracture are crack initiation stage, crack propagation stage, and final fracture. Crack initiation always begin on a weakest zone of rice kernel. Crack propagates stably for ductile material and unstably for brittle material like rice kernel. Fracture toughness of rice kernel is very low, because rice kernel is belonging to brittle material. Endosperm zone consist

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of granules has susceptibility to crack. Endosperm zone whole is covered by bran layer, it is reasonable that crack initiates from centre portion because the centre portion of rice kernel is weaker than outer portion.

Fractography of IR 42 and IR 64 varieties using SEM appeared to be significantly distinct. The fracture surface appeared as shown on Figure 3 and Figure 4.

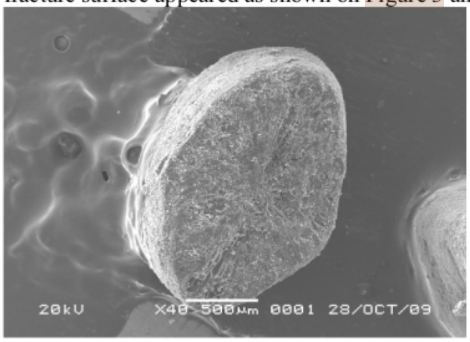

Figure 3. Scanning electron micrograph of fracture surface IR 42 variety.

Figure 4. Scanning electron micrograph of fracture surface IR 64 variety.

Fracture mode of rice kernel tend to appear a brittle fracture. Cleavage crack appear clearly on fracture surface IR 64. Crack initiated from centre portion and propagated interannually to outer portion. Endosperm zone of rice is covered by bran layer. SEM Fracture surface appearance by SEM show that endosperm zone is more brittle than bran layer. It because crack begin from centre portion and propagate to outer zone. Microcracks distributed on fracture surface of IR 42 and IR 64 varieties. The crack growth of microcracks is very strongly affected by moisture content and treatment after harvesting. The growth of microcracks would be integrated to become large crack as shown on Figure 5 and Figure 6.

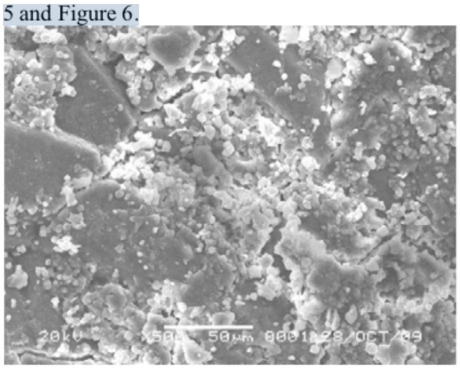

Figure 5. Scanning electron micrograph of IR 42 variety (x 500).

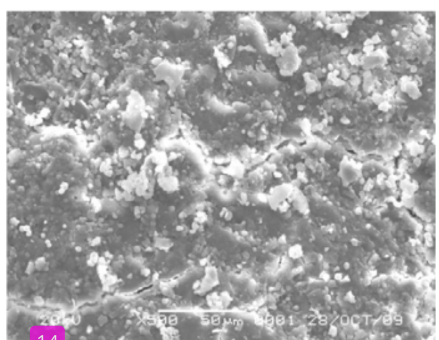

Figure 6. Scanning electron micrograph of IR 64 variety (x 500)

Analysis of Friction Force

Interaction between paddy and rubber roll during milling process should be evaluated in order to reduce milling failure. The failure of milling process would decrease milling recovery. Pressure force induced by rubber roll is very important to evaluate in order to get good contact between rubber roll and paddy as shown on Figure 7.

(a) (b)

Figure 7. milling process (a), free body diagram of friction force (b)

Dehulling force

F = Ft - Ff+ (m.g) ....(1)
Ft = tangential force
Ff = friction force

W = m.g = paddy weight
F = Ft – (μ . Fn) + (m.g)................................(2)
Where Ft = T/2D..(3)
T = Torsi/puntiran
D = Diameter rol

T = (P (1).60)/2. π . n(1).................................(4)
thus Ft = (P(1).60)/4.π.D.n(1).....................(5)

(5) substitute to (1)
F = (P.60)/4π.D.n(1) – (μk .Fn)+(m.g)...........(6)
Fn is function of paddy and rubber roll strength

Summary

The fractograph of IR 42 and IR 64 varities tend to appear a brittle fracture. The hardness of IR 64 is higher than IR 42 varity. Macro crack initiate from center portion and propagate to outer portion. Macrocracks propagate transgranuly. Whereas microcrack as multiple cracks distributed intergranuly. Pressure force induced by rubber roll is recommanded smaller than breakage force of rice kernel.

Acknowledgments

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References

[1] Bekki, E., Rustiko C. 1996. Behaviour of fissure caused by moisture adsorption in brown rice. Bull. Fac. Agric. Hirosaki Univ, Japan.
[2] Hardjosentono,M.,Wijato. 1978. Mesin-mesin pertanian, PT Bumi Aksara. Jakarta, Indonesia.
[3] Q.Zhang.,W.Yang.,Z.Sun.,T.J.Siebenmorgen. 2002. A study of rice kernel fracture under three- point bending test.. Dept of food science, Univ. of Arkansas, 2650 N. Young Ave., Fayetteville, AR 72704.
[4] Siebenmorgan, J., G Qin. 2005. Relating rice kernel breaking force distribution to milling quality. ASABE, St. Joseph, Michigan.
[5] Sun,Z.,W Yang., T.J. Siebenmorgen., A.M. Stelwagen., C. Jia., and A.G. Cnossen. 2002. Using dynamic shrinkage tests to study fissure propagation in rice kernels. Technical note, Trans ASAE.

IOP Conf. Series: Journal of Physics: Conf. Series **1198** (2019) 042011 doi:10.1088/1742-6596/1198/4/042011

[6] W,Yang.,Q.Zhang.C.,C.Zhia. 2005. Understanding rice breakage through internal work, fracture energy, and glass transition individual kernels. ASAE.
[7] Zhang,Q., Yang,W., T.J. Siembenmorgen, Z.Sun, and A.G. Cnossen. 2001. Understanding rice fissuring by SEM examination of fracture surface. AACC Annual conference, Charlotte,NC.
[8] Zhang,Q., W Yang., Z. Sun, and T.J.Siebenmorgen. 2005. Mechanical properties of sound and fissured rice kernels and their implications for rice breakage ASABE, St.Joseph, Michigan.
[9] Zhang,Q., W Yang.,Z Shun (2003). Tracing fissure information by scanning electron microscope characterization of naturally fissured surfaces rice kernels. Trans of ASAE.

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