Physical Properties of NERICA Compared to Indica and Japonica Types of Rice

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Abstract

In Africa, rice production has been increasing due to the contribution of NERICA rice. However, information on physical properties of NERICA is required for designing efficient equipment for its production and expansion. Consequently, the physical properties of NERICA were compared to the Indica and Japonica types of rice. The NERICA and Indica types indicated similarity in dimensions of rough rice and in physical properties of milled rice. This result suggested that technology used for processing Indica rice could be transferred and inserted in countries where NERICA production has been expanding.

Keywords: NERICA rice, Japonica rice, Indica rice, Moisture content, Thickness fraction, Physical properties

Introduction

Rice production in Sub-Saharan Africa has been increasing in recent decades due to the contribution of New Rice for Africa "NERICA" rice (Tollens *et al*., 2013). NERICA combines the high yields of the Asian parent (*Oryza sativa L.*) with the ability to grow in difficult environments of the African parent (*Oryza glaberrima Steud.*). This is the main reason for its widespread adoption among African rice producers (Fukuta *et al*., 2012). However, the deficiency of implements for rice farming and the high percentage of losses in the postharvest process are the biggest constraints to the rapid expansion of NERICA. Therefore, more detailed information is still required in order to overcome these limitations (Wiredu *et al*., 2014).

Both moisture content and thickness have been reported to affect the physical properties of rice. Moisture content principally affects rice's dimensions, volume, bulk density, and the coefficient of friction (Kunze *et al*., 2004; Bhattacharya, 2011b). Meanwhile, thickness influences drying, processing, and quality (Wadsworth *et al*., 1982), the head rice yield and degree of milling (Sun and Siebenmorgen, 1993), and the physical properties of rough and brown rice (Edenio *et al*., 2015).

Consequently, in this study, the physical properties of the NERICA type were compared to the Indica and Japonica types of rice considering different levels of moisture content of rough rice and different thickness fractions of milled rice.

Materials and Methods

Rice Samples

Five fresh-harvested rice varieties produced in 2014 were used to examine the effect of moisture content on physical properties of rough rice: NERICA varieties *NERICA-1* and *NERICA-4*; Indica varieties *IR-28*, *IR-50*; and Japonica variety *Yumepirika*.

Seven varieties of rice produced in 2013 were used to examine the effect of thickness fraction on the physical properties of milled rice: NERICA variety *NERICA-4*; Indica varieties *IR-28*, *IR-50* and IR-64; and Japonica varieties *Nanatsub-*

oshi, *Yumepirika* and *Oborozuki*.

NERICA and Indica varieties were produced in the Japan International Cooperation Agency (JICA) Tsukuba International Centre, Ibaraki Prefecture, Japan. Japonica varieties were produced at the Hokkaido University Farm, Sapporo, Hokkaido, Japan.

Rice Sample Preparation

Each of the fresh-harvested rice samples was dried to at least five moisture content levels, with moisture content decreasing by gradations of approximately 3%, using a laboratory grain test dryer (Shizuoka Seiki Co., Ltd, Japan). Meanwhile, each of the milled rice samples was divided into 3 thickness fractions using a laboratory thickness grader (SATAKE Engineering Co., Ltd, Japan).

Methods for Determining Physical Properties

Dimensional characteristics

Slenderness (ratio of kernel length to kernel width) Sl, was calculated using Equation 1 (Mohsenin, 1986). The volume of kernel Kv was calculated using Equation 2 (Jain and Bal, 1997). Both were determined as a function of length L, width W, and thickness T.

$Sl = L / W$ ....(1)

$Kv = 1 / 4\ [(\pi / 6)\ L\ (W + T)^2]$ ......(2)

Length L, width W, and thickness T, of the kernel, were determined by image-analysis software Grain Dimension version 1.6 (Shizuoka Seiki Co., Ltd, Japan).

Mass characteristics

Thousand-kernel weight TKW was determined by weighing 1,000 randomly drawn regular rice kernels in an electronic balance (Sartorius Lab Holding GmbH, Germany) and expressed in g (Bhattacharya, 2011a).

Bulk density BD was determined using a grain volume-weight tester (Brauer type, Kiya Engineering, Tokyo, Japan) and expressed as g/L (Bhattacharya, 2011a).

Grain fluidity GF was determined using a grain fluidity tester and expressed as g/s (Kawamura, 2015).

Frictional characteristics

Static angle of repose θs was determined using a Perspex box (Bhattacharya, 2011a).

The static coefficient of friction was determined using an inclined plane (Bart-Plange and Baryeh, 2003). Rubber material used on the belt conveyor at a grain elevator in Japan was used as the test surface.

Moisture content

Moisture content was determined by the Japanese Society of Agricultural Machinery and Food Engineers (JSAM) standard method: about 10 g of whole grain rice was placed in a forced-air oven at 135°C for 24 h and computed on a wet basis.

Composition analysis

Components of milled rice (sound whole, broken, chalky, damaged, and discoloured kernels) were divided by human observation and expressed as a percentage of the weight (Japan Rice Millers Association, 1997).

Statistical analyses

Two-way analysis of variance (ANOVA) and Tukey's test with 99% of confidence were carried out to determine any significant differences among the means of physical properties by moisture content level among varieties and among moisture content levels within each variety.

One-way ANOVA and Tukey's test with 99% of confidence were carried out to determine any significant differences among the means of physical properties among thickness fractions within each variety.

Results

Effects of Moisture Content on Physical Properties of Rough Rice

In general, dimensional, mass,

Table 1 Average value of dimensions of rough kernel by level of moisture content

Variety	Moisture content %, w.b., 135°C n = 3	Length mm n = 200	Width mm n = 200	Thickness mm n = 200	Slenderness -[a] n = 200	Volume mm^3 n = 200
NERICA-1	10.3	8.70 b	2.98 c	2.06 c	2.92 a	29.2 c
	13.4	8.73 b	3.03 b	2.10 b	2.88 ab	30.2 b
	16.6	8.78 b	3.05 b	2.12 ab	2.88 b	30.9 b
	19.6	8.86 a	3.10 a	2.15 a	2.86 b	32.1 a
NERICA-4	10.2	8.98 d	2.93 b	2.08 c	3.07 b	29.6 d
	13.1	9.22 c	2.95 b	2.11 bc	3.13 a	31.0 c
	16.7	9.42 b	2.97 b	2.14 ab	3.18 a	32.3 b
	19.4	9.57 a	3.02 a	2.16 a	3.17 a	33.7 a
IR-28	10.4	9.42 b	2.80 b	2.08 c	3.37 a	29.4 c
	13.3	9.45 b	2.88 a	2.14 b	3.29 b	31.3 b
	16.4	9.52 ab	2.91 a	2.17 ab	3.28 b	32.2 a
	19.6	9.57 a	2.92 a	2.19 a	3.29 b	32.7 a
IR-50	10.5	8.64 b	2.49 d	1.90 d	3.49 a	21.9 d
	13.1	8.67 b	2.55 c	1.94 c	3.41 b	22.9 c
	16.3	8.75 a	2.60 b	1.98 b	3.38 bc	24.1 b
	19.3	8.78 a	2.65 a	2.02 a	3.31 c	25.1 a
Yumepirika	10.2	7.36 b	3.42 c	2.37 c	2.15 a	32.3 b
	13.4	7.45 ab	3.46 c	2.39 bc	2.16 a	33.3 b
	16.2	7.50 a	3.52 ab	2.41 b	2.14 a	34.7 a
	19.6	7.55 a	3.55 a	2.45 a	2.13 a	35.6 a

For each test, the mean followed by the same letter in the column within each type of rice do not differ statistically at 1% probability through the two-way ANOVA and Tukey's simple main effect. [a] – = non-dimensional and frictional characteristics decreased as moisture content decreased. Two-way ANOVA reported that such characteristics were highly affected by moisture content.

The NERICA varieties were closer in length, width, and thickness to Indica varieties (**Table 1**), and thus showed similar kernel volume. Two-way ANOVA did not report significant differences in volume among *NERICA-1*, *NERICA-4*, and *IR-28*. Moreover, *NERICA-4* shrank much more in length than it did in width with every decrease in moisture content level. As a result, its slenderness decreased as moisture content decreased (**Table 1**).

NERICA-4 also indicated the highest thousand-kernel weight and bulk density (**Figs. 1** and **2**). Additionally, two-way ANOVA did not report a significant difference between *IR-28* and *Yumepirika* in thousand-kernel weight (**Fig. 1**), and between *NERICA-1* and *Yumepirika* varieties in bulk density (**Fig. 2**).

The NERICA varieties showed the highest static angle of repose and static coefficient of friction (**Figs. 3** and **4**). Moreover, two-way ANOVA did not report significant difference among *IR-28*, *IR-50*, and *Yumepirika* in the static angle of repose (**Fig. 3**), and among varieties in static coefficient of friction (**Fig. 4**).

Effect of Thickness Fraction on Physical Properties of Milled Rice

In thickness distribution, the NERICA variety was closer to the Indica varieties. Japonica varieties indicated the thickest kernels and showed the biggest differences in thickness (0.10 mm each) between thickness fractions. By contrast, Indica and NERICA varieties indicated thinner kernels and showed smaller differences in thickness (0.05 mm each) between thickness fractions (**Fig. 5**).

Composition Analysis

In general, the highest thickness fraction within each variety contained a higher percentage of sound whole kernels and a lower percentage of broken, chalky, discoloured and damaged kernels, and hence contained higher quality samples. The quality of the NERICA variety was similar to the Indica varieties. Meanwhile, the Japonica type showed the highest quality, and also showed the smaller difference in the

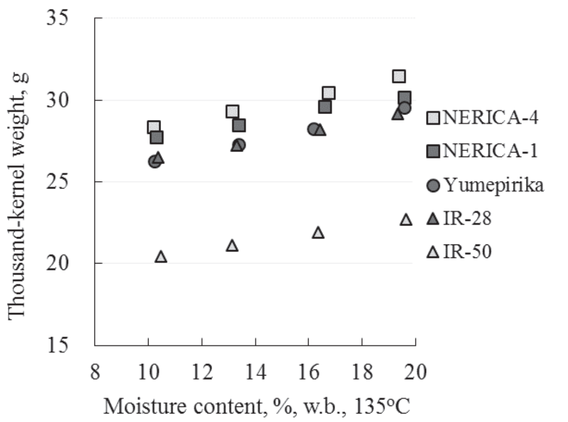

Fig. 1 Dependency of thousand-kernel weight of rough rice on moisture content

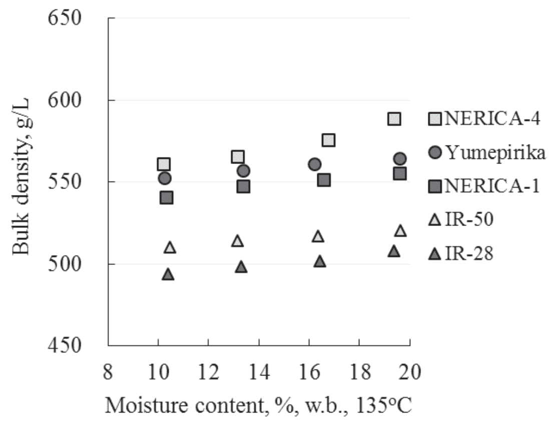

Fig. 2 Dependency of bulk density of rough rice on moisture content

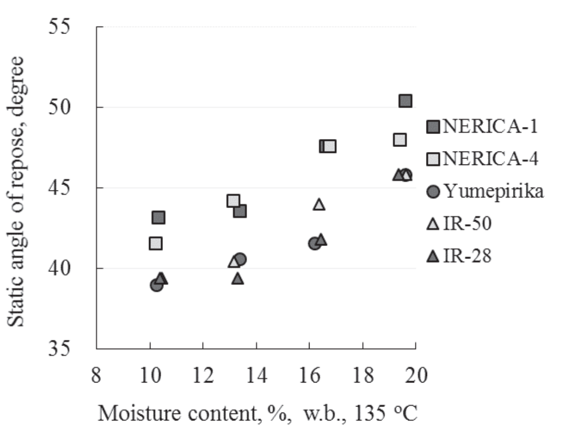

Fig. 3 Dependency of static angle of repose of rough rice on moisture content

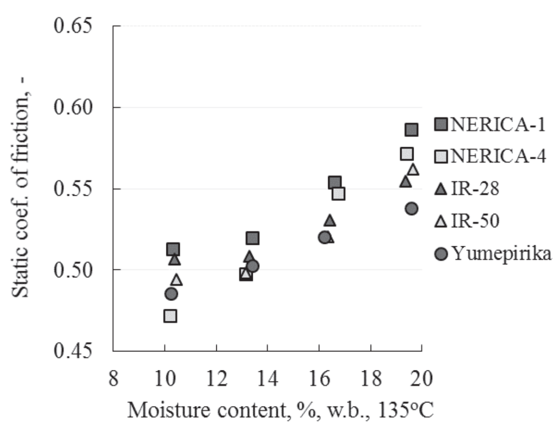

Fig. 4 Dependency of static coefficient of friction of rough rice on moisture content

percentage of sound whole kernel among varieties and thickness fractions (**Fig. 6**).

Dimensional, Mass, Frictional Characteristics of Milled Rice

In general, dimensional, mass, and frictional characteristics increased as thickness increased. One-way ANOVA reported that such characteristics were highly affected by kernel thickness.

The NERICA variety was closer in length, width, and thickness to Indica varieties. The two types of rice thus showed similar slenderness and volume of kernel of milled rice (**Table 2**). Moreover, the behavior shown by thickness distribution was caused by the similarity in kernel dimensions among NERICA and Indica varieties. Consequently, NERICA and Indica varieties were classified as long and medium classes of grain, as their average length was within the range of 6.6-7.5 mm, and their slenderness within the range of 2.1-3.0. The Japonica type was classified as short and round, as its length was 5.5 mm or less and its slenderness was less than 2.0 (Bhattacharya 2011b).

The NERICA variety was closer in weight, density, and fluidity to Indica varieties. However, Japonica varieties were heavier, denser, and flowed faster in volume (**Figs. 7** and **8**). Additionally, one-way ANOVA reported a significant difference in thousand-kernel weight among thickness fractions within each variety (**Fig. 7**). Meanwhile, in grain

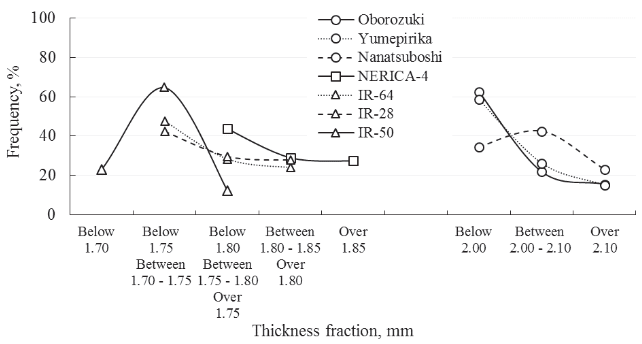

Fig. 5 Frequency distribution of milled rice by thickness fraction

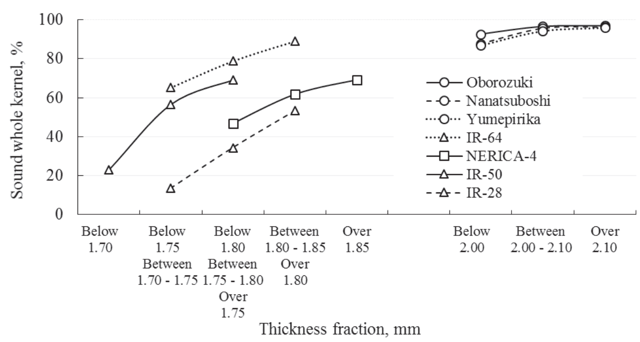

Fig. 6 Sound whole kernel of milled rice by thickness fraction

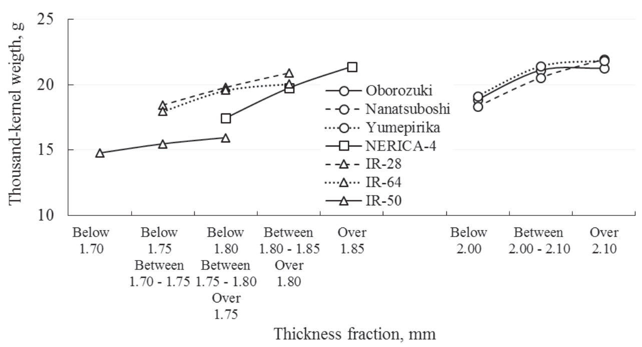

Fig. 7 Thousand-kernel weight of milled rice by thickness fraction

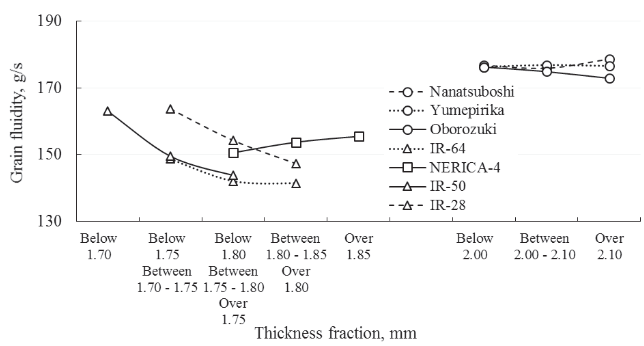

Fig. 8 Fluidity of milled rice by thickness fraction

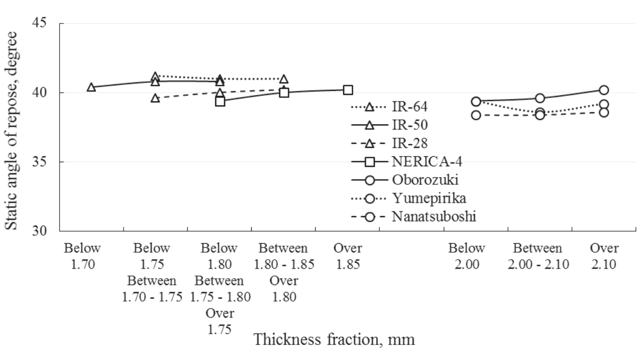

Fig. 9 Static angle of repose of milled rice by thickness fraction

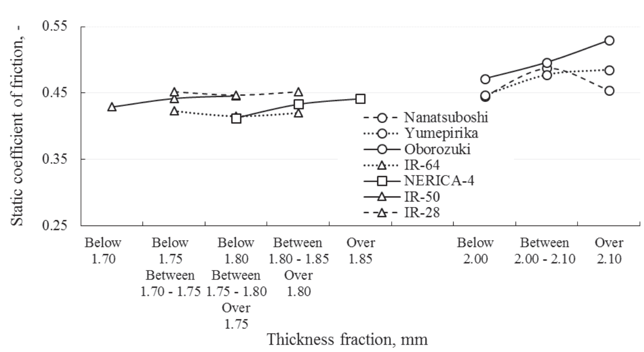

Fig. 10 Static coefficient of friction of milled rice by thickness fraction

fluidity, significant differences were reported among thickness fractions within each Indica variety (**Fig. 8**).

In angle of repose and coefficient of friction, the NERICA variety was closer to Indica varieties. However, Japonica varieties indicated the lower angle of repose and higher coefficient of friction (**Fig. 9** and **10**). Moreover, one-way ANOVA did not report a significant difference in static angle of repose among thickness fractions within each variety (**Fig. 9**). Meanwhile, in static coefficient of friction, significant differences were reported among thickness fractions within each Japonica variety (**Fig. 10**).

Discussion

Rough rice kernel of NERICA varieties apparently had a lower void space between the outer husk and the inner caryopsis compared to other varieties, and hence was heavier in mass despite not being higher in kernel volume. Moreover, rough rice of NERICA varieties indicated higher bulk density because the proportion of empty space in a bulk was lower due to their slenderness. However, the behaviour of the slenderness of NERICA varieties during drying affected the degree of packing of the kernel in bulk; they thus stood higher when piled and needed a greater force to initiate movement on a rubber surface.

Milled rice of the NERICA variety showed similar physical properties to those of the Indica type. Consequently, both types flowed in volume, stood when piled, and needed force to initiate movement on a rubber surface in the same way.

Information obtained in this study could be useful for technology development. Dimensional properties can be used for designing cleaning process, pneumatic conveying systems, fluidized bed dryers, and aeration systems in the drying process (Sablani and Ramaswamy, 2003). Mass characteristics can be useful for determining the diameter of tube conveyors: pneumatic and chute (Bucklin *et al*., 2007). Frictional characteristics can be useful for determining the horsepower required to drive belt conveyors (Wimberly, 1983), and the design of hopper at the bottom of a bin (Kunze *et al*., 2004).

Furthermore, because the NERICA and Indica types indicated similarity in kernel dimensions of rough rice and in dimensional, mass and frictional characteristics of milled rice, the technology used in the post-harvest processing of Indica varieties could be transferred and inserted in those countries where NERICA production has been expanding. Consequently, postharvest losses would be reduced and rice quality improved.

Table 2 Average value of milled kernel dimensions by thickness fraction

Variety	Thickness fraction mm	Length mm n = 200	Width mm n = 200	Thickness mm n = 200	Slenderness -[a] n = 200	Volume mm^3 n = 200
NERICA-4	Below 1.80	6.16 c	2.34 c	1.74 c	2.64 b	13.5 c
	Between 1.80-1.85	6.33 b	2.37 b	1.82 b	2.68 b	14.6 b
	Over 1.85	6.60 a	2.40 a	1.95 a	2.75 a	16.4 a
IR-28	Below 1.75	6.45 c	2.37 a	1.76 c	2.73 b	14.4 c
	Between 1.75-1.80	6.56 b	2.38 a	1.78 b	2.77 ab	14.8 b
	Over 1.80	6.68 a	2.40 a	1.93 a	2.79 a	16.3 a
IR-50	Below 1.70	6.22 c	2.07 c	1.67 c	3.00 a	11.4 c
	Between 1.70-1.75	6.38 b	2.10 b	1.73 b	3.04 a	12.3 b
	Over 1.75	6.44 a	2.12 a	1.77 a	3.04 a	12.8 a
IR-64	Below 1.75	6.74 c	2.16 a	1.72 c	3.13 b	13.3 b
	Between 1.75-1.80	6.91 b	2.17 a	1.76 b	3.19 a	13.9 c
	Over 1.80	7.03 a	2.18 a	1.83 a	3.23 a	14.8 a
Nanatsu-boshi	Below 2.00	4.68 c	2.83 c	1.95 c	1.66 a	14.0 c
	Between 2.00-2.10	4.80 b	2.89 b	2.10 b	1.66 a	15.7 b
	Over 2.10	4.99 a	3.00 a	2.32 a	1.66 a	18.6 a
Yumepirika	Below 2.00	4.92 b	2.96 c	1.95 c	1.67 a	15.0 c
	Between 2.00-2.10	4.99 a	3.00 a	2.01 b	1.67 a	16.5 b
	Over 2.10	5.04 a	3.06 b	2.12 a	1.66 a	17.8 a
Oborozuki	Below 2.00	4.91 c	2.86 c	1.98 b	1.72 a	15.1 c
	Between 2.00-2.10	5.09 b	3.01 b	2.02 b	1.71 a	17.1 b
	Over 2.10	5.21 a	3.07 a	2.12 a	1.70 a	18.7 a

For each test, the mean followed by the same letter in the column within each type of rice do not differ statistically at 1% probability through the one-way ANOVA and Tukey's simple main effect. [a] – = non-dimensional

Conclusions

Physical properties of rice were highly affected by moisture content and thickness. The NERICA and Indica varieties reported similar kernel dimensions of rough rice and dimensional, mass and frictional characteristics of milled rice. Information obtained in this study could be helpful in designing equipment required to improve the efficiency of postharvest processes and in developing a technology-transfer strategy. Consequently, such information could help to relieve the constraints to NERICA expansion, increase its production and improve the quality of the grain.

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