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BINDING FORCE AND MECHANICAL STRENGTH OF RICE GRAIN*

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A b s t r a c t. Strength properties of rice kernels related to losses of grain during combine harvesting and postharvest treatment were determined for seven varieties of rice cultivated in Italy. Compression tests using an Instron testing machine were conducted to determine: force of first failure F_1, force of rupture F_{max} of entire rice grains and energy required to damage the grain. Statistically significant differences in determined parameters were found among tested rice varieties.

An Instron load cell with appropriate attachment was used to measure the force to detach the kernel from the branch (binding force). Tests were conducted on one hundred grains of each of ten varieties of rice. Binding force was found in the range from 1.29±0.08 N to 2.37±0.06 N. Statistically significant differences in the values of binding force were found among tested rice varieties. A tendency of binding force to take higher values for the lower locations of the kernel on the branch was observed.

K e y w o r d s: rice, binding force, force at rupture

INTRODUCTION

The physical losses and quality deterioration of rice grain is related to mechanical properties of the plant and grain itself. The losses in harvesting include: shattering loss, lodging loss and standing crop loss. For threshing, loss components include: loose straw and chaff loss, scatter loss and unseparated grain loss. Qualitative losses include cracked kernels, damaged kernels, brokens and brewer's rice [5].

At present all rice production in Italy is combine harvested because the harvest must be completed within a short time. To retain its commercial value the paddy must not be broken or cleaved. The botanical characteristics of rice panicle strongly influence the design and work capacity of combine harvesters. The panicle carries single spikelets covered by glumes and floral glumes, sometimes bearing awns that must be removed without damage and breakage. Thus the accurate design and adjustment of the threshing group of the combine harvester for used rice is more important than in harvesters used for wheat or barley. The optimal function of the threshing group is to separate the paddy from the panicle and most of the paddy grains from the straw without damage, and with limited fragmentation of the straw. One of the deciding factors is the resistance to threshing which may be characterized by the force of separation of the grain from the rachilla. Too low resistance to threshing causes shattering and losses when cutting, too high resistance produces difficult grain separation and threshing losses [1,2].

The post-harvest processing of rough rice consists in cleaning, husking to obtain brown rice, then whitening and glazing to obtain the white rice. Generally from 100 kg of paddy produces 62 - 64 kg of white rice grains. During all these processes it is important to maintain the integrity of the caryopsis. According

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to Toquero and Duff [5] it is important to explore differences in varietal characteristics which lead to improved grain quality. These authors pointed to reduced to brokens and grain resistance to abrasive milling as major variables in the characterisation of grain quality. The genetic improvements which build in improved mechanical characteristics would greatly complement the efforts of engineers, and may be a necessity for overcoming post-harvest problems. Both seed breeding and the design of equipment need objective strength parameters of rice grain to evaluate the progress of work.

According to earlier investigations of Szot [4] performed on wheat, the binding force of grain is considered to reflect the threshing resistance and the characteristics of grain measured in compression test which, in turn, are considered to reflect the resistance of grain to mechanical damage in harvest and post-harvest treatment.

The objective of this study was: 1) to estimate the variation of mechanical properties of rice kernels and binding force resulting from genetical factors; 2) to deliver parameters useful for design of processing equipment.

MATERIAL AND METHODS

Determination of dimensions, porosity and mechanical characteristics of paddy grain was performed on seven rice varieties cultivated in Italy (Baldo, Cripto, Loto, Lido, Panda, Roma and Strella). An Instron testing machine was used to perform a compression test on 50 kernels of each variety. Typical compression curve recorded in force-deformation coordinate system is shown in Fig. 1. Kernels with long axis oriented horizontally were compressed between two parallel plates at constant speed of 20 mm/min. Maximal force F_{max} and force F_1 of initial rupture of grain structure were read from recorded characteristics. Energy E required to damage the kernel was also derived from the compression curve. The details of the procedure are given by Stępniewski and Woźniak [3].

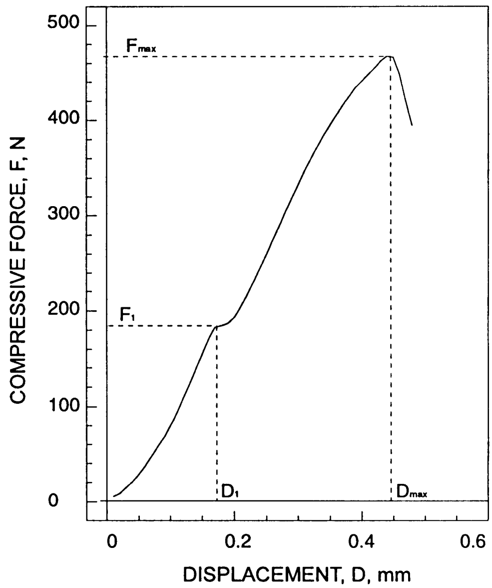

Fig. 1. Typical force-displacement characteristic for compression of rice kernel.

The binding force was tested on one hundred kernels of each of ten rice varieties: Costituzione, Cripto, Europa, Lido, Loto, Miara, Moro, Panda, Strella and Vialone. The kernel was attached to a load cell with the holder while the branch was pulled down by hand. The force at the moment of breaking the pedicel was termed the binding force.

Measurements were conducted on dry rice with 8% moisture content of grain. Analysis of variance was performed on the data and means with 95% confidence intervals are presented on the following figures.

RESULTS

Dimensions and porosity

Length of grain was found in a range from 8.6±0.09 mm (Cripto) to 10.1±0.06 mm (Panda), width ranged from 2.43±0.01 (Panda) to 3.53±0.01 mm (Baldo), and thickness ranged from 1.88±0.01 mm (Panda) to 2.69±0.04 mm (Roma). Mean values of the parameters and 95% confidence intervals are shown in Fig. 2. Porosity of a layer of grain ranged from 68.5±0.1% (Lido) to 72.9±0.1%

(Strella). Significant differences in porosity were observed as shown in Fig. 3.

Strength parameters

Determined strength parameters showed considerable differentiation according to variety. There was no significant differences among forces of initial failure F_1 and forces at rupture point F_{max} within the group of the varieties Lido, Loto, Panda and Strella. Both forces for the variety Panda were significantly higher, while in the case of variety Cripto both F_1 and F_{max} were significantly lower than the values for the four varieties. F_1 was found in the range from 126±5 N to 231±11 N, while F_{max} ranged from 168±8 N to 439±21 N (see Fig. 4).

Energy required to damage the grain was found in a range from 26±3 mJ (Roma) to 130±16 mJ (Baldo) with considerable differentiation according to variety (see Fig. 5). Generally it was noted that the grain of the variety Panda showed the highest susceptibility to damage, while the grain of the variety Roma and Cripto showed the lowest susceptibility to damage. As may be seen from Figs 4

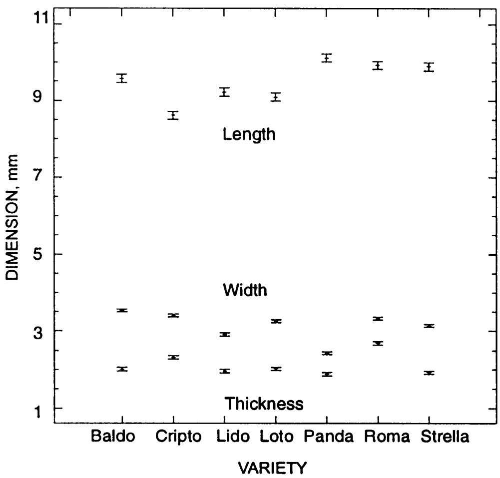

Fig. 2. Length, width and thickness of rice grain of seven varieties. Means and 95% confidence intervals.

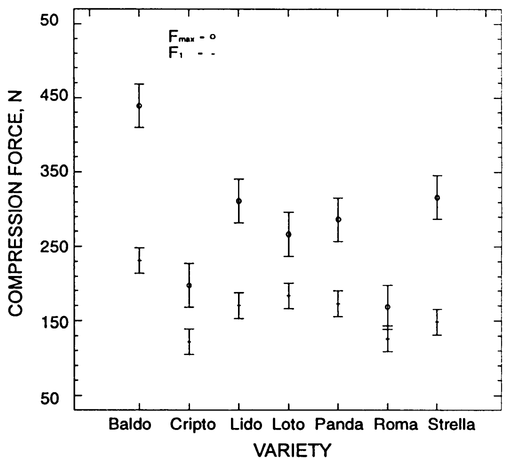

Fig. 4. Force of initial failure F_1 and force at rupture point F_{max} for rice grain of seven varieties. Means and 95% confidence intervals.

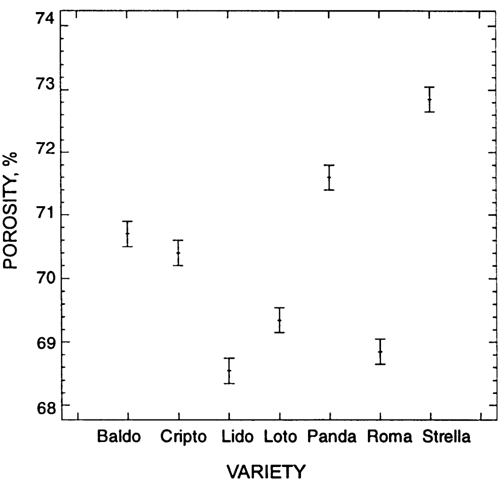

Fig. 3. Porosity of rice of seven varieties. Means and 95% confidence intervals.

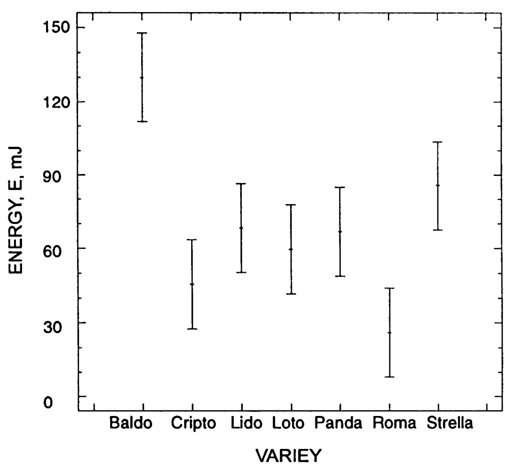

Fig. 5. Energy E absorbed at rupture point for rice grain of seven varieties. Means and 95% confidence intervals.

and 5 the courses of relations of strength parameters compared to varieties are very similar to another one. Thus only one of them may be used to characterise the strength of grain. The force at rupture point F_{max} being the easiest to determine may be recommended as a single parameter for comparative studies.

Binding force

Considerable differentiation of binding force of grain to the branch was found within the group of ten varieties. The binding force of 2.37±0.06 N found for the variety Strella was the highest of all determined, while the lowest value of 1.29±0.08 N was found for the variety Panda. Mean values of binding force as compared to variety are presented on Fig. 6 together with 95% confidence intervals. Examination of an influence of location of grain on the branch on the binding force was performed. Binding force was determined for four rice varieties (Cripto, Europa, Lido and Panda) and for one hundred grains of each of: low, middle and high location of grain on the branch. In the case of three of the four tested varieties, binding force of grains located on the lower part of the branch was significantly higher than the force for grains located on the upper part of the branch. The highest ratio of the binding force for low to high location of grain equal to 1.2 was observed in the case of the variety Cripto.

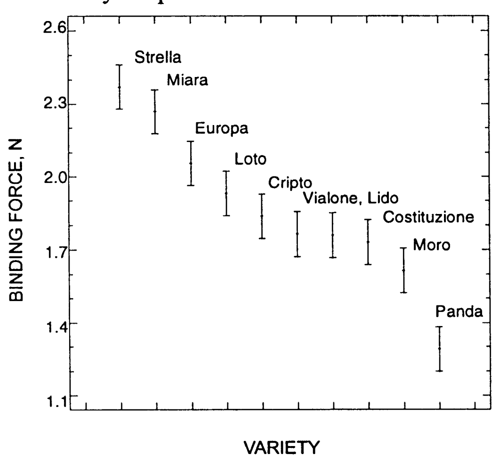

Fig. 6. Binding force of grain to the branch for ten rice varieties. Means and 95% confidence intervals.

CONCLUSIONS

Considerable differentiation of determined parameters of grain occurred among investigated varieties of rice. The differences in the mean values were statistically significant among groups of varieties. High degree of variability of geometric and strength parameters of rice grain should be accounted for in the design of harvesting and processing equipment.

Force of initial failure of grain F_1 was found in the range from 126±5 N to 231±11 N, while force at rupture point F_{max} ranged from 168±8 N to 439±21 N. Energy required to damage the grain was found in a range from 26±3 mJ to 130±16 mJ. The order of all strength parameters as compared to varieties appeared almost identical. This means that the parameters are equivalent. The force at rupture point F_{max} being direct, and easy accessible, may be recommended as a single parameter for comparison of the strength of grain.

Binding force of rice kernel to the branch was found in the range from 1.3±0.1 N to 2.4±0.6 N. Binding force tended to take higher values for the lower locations of the kernel on the branch. For three of four tested varieties of rice, binding force of grains located on the lower part of the branch was significantly higher than the force for grains located on the upper part of the branch.

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