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The Real-Time Analysis for the Mechanical Properties of Red Bean Grains

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Abstract. Data on the physical and mechanical properties of seeds have significantly importance for most machinery and process equipment design. These properties include breaking force, deformation and stress-strain as well. This study was conducted to investigate the real-time mechanical properties of red bean grains via our design of the pneumatic mechanical tools (PnMT). The significant data revealed that the red bean grains mostly contained with moisture content of 20% w.b.. The average length, width and thickness were 6.2, 5.4 and 5.1 mm respectively. The results showed that breaking force, deformation and stress-strain were different in both features and values in most different applied force directions. In addition, we observed there were the relationship between strain and time. This followed the significant power law in all different force directions.

1. Introduction

The mechanical properties of agricultural materials such as applies force, deformation and stress-strain are important for the prediction of their load-deformation behavior [1, 2]. Investigating these technological characteristics can aid in the design of processing machineries and other post-harvest operations. The advantage of these mechanical properties may be used by manufacturers in order to design harvesting machines or other mechanical devices such as sorting and separating machines. However, in the previous studies [3], the mechanical strengths of red bean grains were typically reported as average values, or based on limited experimental data from the instrument and/or a few good kernels, which would hardly reflect the significant variations in physical and mechanical properties especially in terms of real-time deformation and dynamics. Our research has been conducted to propose the Real-time Pneumatic Mechanical Tools [1] for investigating the mechanical properties such as breaking forces and stress-strain properties of red bean grains. In addition, we were investigated the characteristic of these properties in the different force directions.

2. Materials and Methods

2.1 Sample preparation

The red bean grain used in this study was obtained from a local market in Bangkok, a central province in Thailand (shown in **Fig. 1**). The grains were cleaned manually and the foreign matter, as stones, straw and dirt were removed. Initial moisture content (MC) of samples was determined by drying them in an oven according to ASAE [4]. Initial MC of red bean grains were approximately

20% (w.b.). The red bean grain samples were finally sealed in double plastic bags and stored at approximately 4°C before conducting the experiments.

2.2 Real-time Pneumatic Mechanical Tools

The schematic of our system was shown in **Fig. 1**. The mechanical stress-strain measurements were supported by force, rotation and pressure sensor. The deformation rate was set at 0.2 mm/s. This system corresponds to the compression test of food materials of convex shape [5].

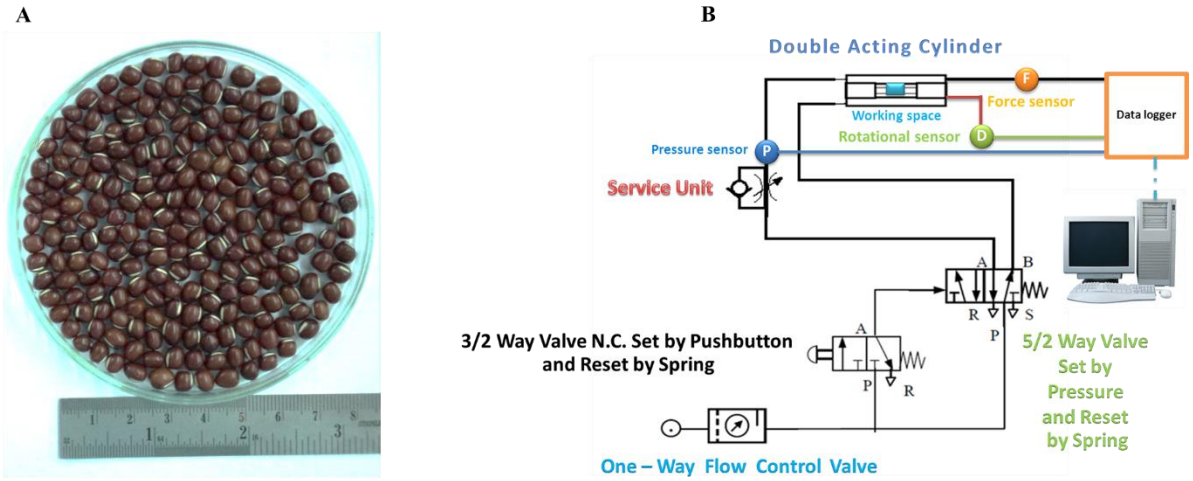
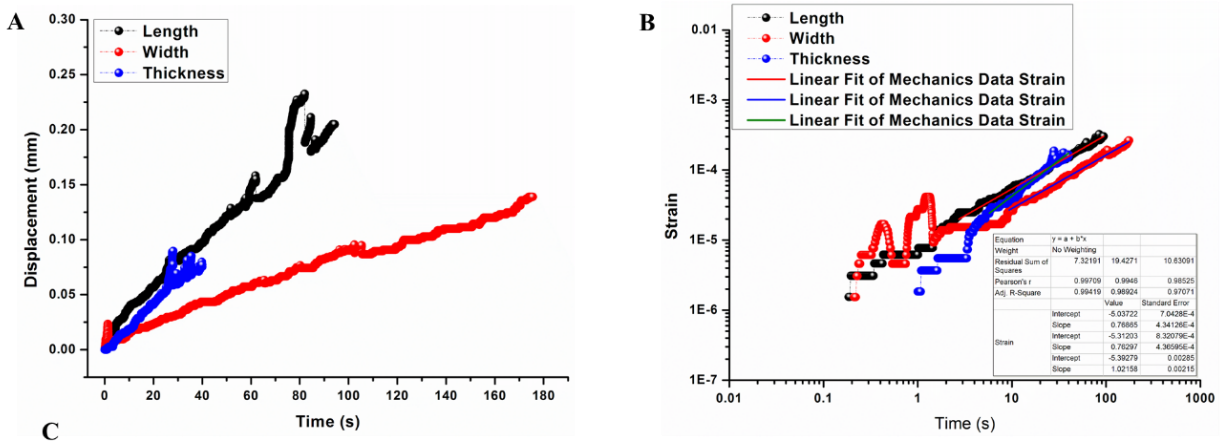


Fig. 1 The red bean grain and the pneumatic mechanical tools (PnMT) in this study. **(A)** The red bean grains in this study. **(B)** The schematic of Real-time Pneumatic Mechanical Tools.

3. Results and Discussion

The relation of kernel deformation and strain with respect to time for 3 applied forces (along length, width and thickness) as shown in **Fig. 2.** These results shown that the difference of applied force direction shown the characteristic time scale dynamics of red bean deformation. We could be led to distinguish the responsibility of red bean on the applied force directions by using the breaking time and breaking force. Moreover, we found that the slopes of Strain-time relation showed to be 0.77±4.34E-04 s^{-1}, 0.76±4.37E-04 s^{-1} and 1.02±0.00215 s^{-1} for the force direction along length, width and thickness, respectively, indicating a more strain rate for the thickness of red bean kernels. This is the first time for the reported results of mechanical properties including breaking time, breaking force, and slopes of Strain-time relation, which study in the red bean kernels that were found to compare with the results obtained in this study. However, these mechanical properties of the different agricultural materials are close to those reported by Bargale and Irudayaraj (1995) for barley kernels, Burubai et al. (2008) for African nutmeg (*Monodora myristica*), Baryeh (2000) for Avocado pear and Zhang et al. (2005) for rice [6-9].



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	Breaking Time (s)	Breaking Time SD	Breaking Force (N)	Breaking Force SD	Strain-Time Slope (s^{-1})	Strain-Time Slope SD
Length	94.37	34.79	24.80	17.68	0.77	4.34E-04
Width	175.57	18.07	80.30	14.21	0.76	4.37E-04
Thickness	40.08	11.74	15.70	13.48	1.02	0.00215

Fig. 2 The time evolution of red bean kernels in terms of deformation and strain with 3 force directions **(A)** Displacement and time relation of red bean kernels that presented along length, width and thickness. **(B)** Strain-time relation of red bean kernels that calculated from (A). **(C)** Table mechanical parameters include breaking time, breaking force, and strain-time slope.

In addition, the modulus of red bean grains that applied the different force directions as shown in **Fig. 3**. We found that the transition point for changing to rupture behavior reflected the different acquiring energy for damage kernels. These results indicated that thickness has high strain energy for a red bean kernel undergoes fracture.

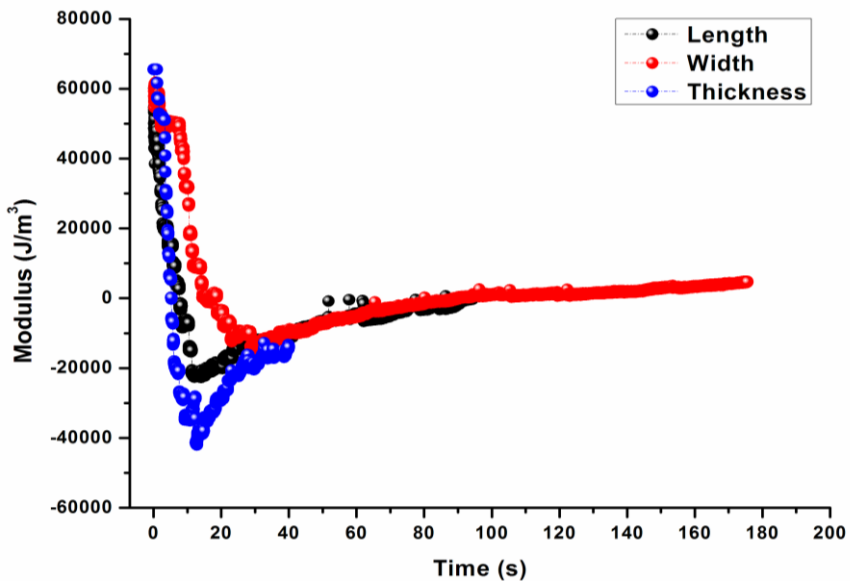

Fig. 3 The modulus-time relation of red bean kernels in terms of deformation and strain with 3 force directions which presented along length, width and thickness.

4. Summary and Conclusion

The real-time Pneumatic Mechanical Tools could be appropriated to study the mechanical properties of red bean grain especially the real-time dynamics. We were measured these properties in terms of average breaking force, breaking time, and stress-strain. Deformations and stress-strain properties of red bean grains generally differenced in the different applied force direction.

5. Acknowledgements

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