

Some Physical and Mechanical Properties of Pili (*Canarium ovatum* Engl. cv. Katutubo) Nut as a Function of Nut Moisture Content

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The physical and mechanical properties of pili (*Canarium ovatum* Engl. cv. Katutubo) nut were determined as a function of nut moisture content in the range of 10.72–24.97% wet basis (wb). The force, deformation and specific deformation required to initiate shell fracture were determined by compression at transverse and longitudinal loading orientations using a universal testing machine (UTM). The physical dimensions of the nuts and shell thickness were not significantly ($p < 0.05$) affected by moisture content while width, height, geometric mean diameter and weights varied directly with nut moisture content. The force required to initiate shell fracture generally decreased with an increase in nut moisture content. The deformation and specific deformation required for fracture did not differ significantly among moisture content levels under traverse and longitudinal loading. At all moisture content levels, longitudinal compression required significantly higher force (2.66–3.15 kN), deformation (8.37–8.57 mm) and specific deformation (0.14 mm mm^{-1}) for shell fracture compared with transverse compression (1.48–1.60 kN, 1.02–1.08 mm, 0.05 mm mm^{-1} , respectively). Longitudinal compression, regardless of nut moisture content level, readily freed the kernel from the shell and yielded the highest whole kernel recovery (97.8%).

Key Words: *Canarium ovatum* Engl., compressive failure characteristics, mechanical properties, physical properties, pili nut, pili nut sheller

Abbreviations: MC_{wb} – moisture content wet basis, UTM – Universal Testing Machine

INTRODUCTION

Pili (*Canarium ovatum* Engl.) is recognized as a potential export commodity and the Philippines dominates the world export market for pili nut products. In recent years, the Department of Agriculture identified pili as a crop worthy of more intensive research and development activities.

The pili fruit is technically a drupe which consists of a pulp (68% by weight), a shell (25% by weight), and a seed (7% by weight) (DA-RFU5 2010a). The seed is covered with a papery seedcoat or testa and is composed of two white cotyledons which are composed primarily of moisture (8%), protein (14.2% dry weight) and fat (68.5% dry weight) (Pili Technical Committee 1997).

The pili tree is valued primarily for its nuts, although the other parts offer other domestic and economic uses. The fibrous pulp is edible and is usually consumed as an appetizer or dessert. Researches from the Bicol

University demonstrated that pili pulp can also be used as chicken and animal feed (BURDC 2010). Pili pulp oil is comparable to coconut oil and can be used for cooking. It can also be used as fuel for lighting, and for the manufacture of soaps, perfumes and other cosmetic products (Pili Technical Committee 1997).

The shell of the pili nut is usually utilized as fuel and can be processed into charcoal. It serves well as a growing medium for orchids and anthuriums. When processed into activated carbon, it can be used for water purification. Powdered shells may serve as filters for resins, adhesives and paints. Abrasive grits from pili shells can be used as substitute for apricot hulls as sandblasting agents. In the Bicol Region, the shell is commonly used in making different handicrafts and furniture (DA-RFU5 2010b). The outer layer or peel of the pulp is also used as an animal feed and can also be a good source of dye. The testa or seed coat is also used as animal feed (Pili Technical Committee 1997).

The kernel is the most important part of the fruit, with a taste comparable to that of walnut and almond. The kernel can be processed into a wide variety of candies, confectionaries, pastries, cakes and other recipes. It contains about 70–75% oil which can be used for domestic and industrial purposes (DA-RFU5 2010a).

The Bicol Region of the Philippines ranks as the top producer of pili nuts [Bureau of Agricultural Statistics (BAS) 2012]. The increasing domestic and foreign demand for pili nut products poses challenges for the pili-based cottage industry. As of today, most of the production and postharvest operations are predominantly manual. Therefore, mechanization efforts could be extended to boost the volume of production especially in laborious operations. Mechanizing the postharvest operations for pili has been the subject of a number of initiatives from different researchers and institutions. However, insufficient understanding of the physical and mechanical properties of pili nut contributed to the low performance of existing machines used in postharvest operations.

In shelling operation, for example, most machines simulated the manual shelling method of applying impact to the shell to initiate cracking. Impact shelling using a bolo was observed to be effective when manually done. However, the success of this method was not replicated in mechanical pili nut shellers. Even though it is widely adopted for pili shelling, the use of the impact method for cracking was not fully investigated and, therefore, designers were not fully guided during the design of different sheller components. It was observed that impact shelling induces a high degree of damage to the kernels which significantly reduces their marketability (Malinis et al. 2003).

The design of different machines for pili postharvest operations requires the determination of the physical and mechanical properties of the nuts, the kernels and the shells. The physical and mechanical properties of nuts such as macadamia (Braga et al. 1999), walnut (Koyunco et al. 2004), almond (Aydin 2003), filbert nut (Pliestic et al. 2006), pine nut (Vursavus and Ozguven 2005), hazel nut (Guner et al. 2003), peanut (Aydin 2007) and cashew (Balasubramanian 2001; Bart-Plange et al. 2012) had been determined and reported. Similar investigations had been conducted for shea nut (Olaniyan and Oje 2002), sunflower (Gupta and Das 2000), bambara groundnuts (Baryeh 2001), apricot pit (Vursavus and Ozguven 2004), jatropha (Karaj and Muller 2010), conophor (Aviara and Ajikashile 2011), dika nut (Ogunsina et al. 2008), palm nut (Gbadam et al. 2009) and *Mucuna flagellipes* nut (Aviara et al. 2012). These studies recognized the significant effects of moisture content, among others, on the physical and mechanical properties of such commodities.

Little information appears to be available on the physical and mechanical properties of pili nut. This study aimed to determine the physical and mechanical properties of pili nut as a function of nut moisture content. As pili has many varieties, the 'Katutubo' variety was selected. This variety is recognized for its large fruits and other promising fruit characteristics and is a good subject of investigation on the properties of pili.

MATERIALS AND METHODS

Sample Preparation and Moisture Conditioning

The experiments were conducted in January 2011 in the laboratories of the College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños.

Five hundred (500) mature fruits of 'Katutubo' pili variety were gathered from the Pili Drive of the University of the Philippines Los Baños. The pili fruits were depulped using the retting method (Pili Technical Committee 1997), i. e., the fruits were soaked in tap water for 2 d to soften the epicarp and the mesocarp. The epicarp and mesocarp layers were manually removed and the nuts were washed and cleaned with water. All nuts that floated in water were removed as these are considered immature or devoid of kernel (Pili Technical Committee 1997). Nuts were then air-dried for 1 h to remove excess moisture.

The drying curve of the nuts was first established to determine the moisture levels to be used. The nuts were dried in a laboratory dryer at 50 °C for 10 h. This temperature was chosen in an attempt to simulate sundrying conditions, the most common way of drying pili nuts in the field. The equation describing the drying curve was used to determine the required drying time to vary the moisture content of the nuts. To vary the moisture content, the newly depulped nuts were first divided into three lots. The first lot was set to have the highest moisture level which is equal to the moisture content of the newly depulped nuts. The second lot was oven-dried for 10 h at 50 °C to obtain an intermediate moisture level. The third lot, which was set to have the lowest moisture level, approximated the moisture content of the nuts during shelling operation. Moisture content was obtained by oven drying the third lot at 50 °C for 24 h.

In the absence of a standard method of determining moisture content for pili nuts, the procedure was patterned after ASAE S410.1 DEC1982 (R2008) Moisture Measurement – Peanuts (ASABE 2008b). In this procedure, the nut moisture content is the sum of the weighted moisture contents of the kernel and the shell. In each replicate, the nuts were carefully cracked to separate the kernels and from the shells. To determine the