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Impact Damage Threshold of Young Coconut (Cocos nucifera L.)

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Abstract

Basic information on the bruising incidence of young coconut 'buko' was generated by establishing the threshold values for impact. Young coconut at two levels of maturity: 6--7 months (M1) and 7-8 months (M2) after pollination were subjected to impact at the cheek by actual dropping on two reference impact surfaces (ground and concrete) and by using a pendulum impactor that was locally fabricated. It was found that the drop heights, which bruised 10% of the fruits, were 20 cm and 22.50 cm for M1 and M2 nuts, respectively with reference to ground surface. For concrete, 10% bruising occurred at 5 cm and 7 cm for M1 and M2 nuts, respectively.

The study revealed that bruise volume and bruise depth increased with an increase in drop height for both levels of maturity. M1 nuts should never be dropped from heights greater than 38 cm above ground and not higher than 8 cm above concrete to limit depth of bruise below the critical depth of 1.435 cm. Similarly, drop heights for M2 nuts were noted to be lower than 60 cm and 8 cm for ground and concrete, respectively in order to avoid bruise reaching its critical depth of 1.299 cm. Correlation analysis revealed highly significant correlation between bruise volume and bruise depth and coefficient of restitution (e). Increase in e significantly decreased bruise volume and depth. On the other hand, absorbed energy (Eabs) was noted to have highly significant positive correlation with bruise volume and depth. As Eabs increased, bruise volume and depth also increased.

Prediction models were developed and validated relating magnitude of bruise to different parameters in the study.

***Keywords**:* Young Coconut, Maturity, Impact, Bruise Incidence, Absorbed Energy

1. Introduction

Coconut (Cocos nucifera L.) is widely cultivated in tropical and sub-tropical countries. In the Philippines, coconut farms represent 25% of the total agricultural land of the country with estimated land area of 3.56 million hectares (PCA, 2015). Sixty-eight (68) out of 79 provinces grow coconut as a major crop with more than 340 million coconut bearing trees planted nationwide. The recorded average annual production was 14.902 billion nuts or an equivalent yield of 2.26 million metric tons of copra (PCA, 2015). This makes the country second largest producer worldwide next to Indonesia. About 25 to 33% of the population was directly or indirectly dependent on the industry for their livelihood.

Major commercial products from coconut are copra or dried coconut meat, coconut oil, desiccated coconut and young coconut, known locally as "buko". Young coconut is one of the favorite commodities in the country. It is the immature, green nut that is prized for its nutritious refreshing juice. The meat is scooped from the split nut then eaten fresh together with the liquid endosperm or coconut water. It is used in tropical fruit salad preparations, made into pies and candies, or used as an ingredient in ice cream and sherbet (Hurtada and Raymundo, 1992). Besides being highly nutritious, young coconuts are also known to have medicinal effects against heart, liver, and kidney disorders.

Depending on consistency of the meat, coconut is sold in three different maturity stages namely: mucus-like stage, cooked-rice stage and leather-like stage (Gatchalian et al., 1994). Malauhog is a Tagalog term, literally meaning "mucos-like". The nut is 6-7 months old at this stage, and the meat is very soft and jelly-like and can easily be removed from the shell with a spoon or a specially designed and locally made knife (Bandian, 1989). The coconut is also sold at a mature stage (7-8 months) when the meat is of the consistency of hard-boiled rice called as "mala-kanin". This stage is primarily used in salad preparation and in making buko pie. The third stage (8-9 months) is when the meat is rather hard but not so hard as that of the mature nut. This stage is termed as "mala-katad", meaning "leather-like", which is usually used for making sweets, although some people prefer the "mala-kanin" stage (Bandian, 1989).

Young coconut is usually handled and marketed in fresh or minimally processed form. Minimally processed nuts may be partially or completely peeled to expose the softer underlying husk, as well as being carved into an esthetic shape to improve appearance. This is done for both local and export markets. To prevent enzymatic discoloration, trimmed nuts are immediately dipped in sodium metabisulfite solution (SMS), air dried, and wrapped individually in polyethylene plastic bags prior to storage and shipment abroad. Locally consumed nuts are not wrapped in plastic sheets. However, Yahia (2011) reported that sulfite treatment cannot eliminate browning of husk when young coconuts are subjected to impact.

Most traders prefer handling and shipping young fresh coconut as whole green fruit. Not much consideration is given to any damage that the fruit may incur during handling. Rough handling of young nuts often results in impact, compression, and vibration damages. Damage area of nut when trimmed turns brown quickly and becoming unsightly which presents marketing problem (Tongdee et al., 1991). Thus, maintaining the quality of young coconut through the reduction of mechanical damage sustained in the postharvest handling chain will increase the profitability and marketability of the product.

During harvesting and sorting, fruits are frequently dropped to hard surfaces or each other resulting in impact bruises (Hilton, 1993). Stronger impact of young coconut causes a deeper bruising and may cause cracking of the shell (Yahia, 2011). Her study also indicates that a fall of only 5 cm on a hard surface causes a light brown brusing at a depth of 2 cm, while falling a greater distance causes more intense browning. Over-packing in rigid containers lead to compression damage while related damages are usually incurred during transport, with severity determined by the intensity and duration of vibration (Mohsenin, 1986). Careful handling during harvesting, sorting, storage, and transport must be employed to young coconut to minimize bruise damages due to impact, compression, and vibration. Impact and vibration tests were done mostly for pears, apples and potatoes (Kang et al, 1995; Mathew and Hyde, 1997; Baritelle and Hyde, 1999), wheat and other cylindrical samples (ASAE, 1988), and mango (Valerio et al., 1999). In young coconut, Tongdee et al. (1991) evaluated only the rupture force of trimmed nuts.

Improper harvesting and handling practices subject fruits to excessive impact stress. This produces mechanical damage accompanied by a reduction in quality. Bruising in young coconut occurs when fruits are dropped onto hard surfaces or collide with each other. Internal bruises become visible when nuts are peeled during minimal processing. Dipping in SMS does not improve the color of the bruised area. Bruises are difficult to identify because they are not visible immediately, but appear only after enzymatic browning in the injured tissue has occurred. Even small bruises detract from the overall appearance of the fruit and reduce its visual quality. This makes it more difficult to market the nuts, since consumers are more particular about quality today. It is very important to consider the factors influencing these damages on young coconut so that problems in handling will be better understood and recommendations can be made. The aim of the work reported in this paper was to measure the bruise severity of young coconut by establishing the threshold values for impact.

2. Body of the Article

Preliminary tests showed that drop heights ranging from 15 cm to 120 cm onto ground and concrete surfaces were sufficient to produce bruises on young coconut. It was observed that the apical end of the fruit is highly resistant to impact bruises even with higher drop heights compared with the stem end or cheek. The stem end, on the other hand, is very susceptible to impact bruises even at lower heights. Hence, the cheek of the samples was selected to be the contact area for impact testing.

It was found that the moisture contents of husk for M1 and M2 nuts were 84.26% and 83.44% wet basis, respectively, using oven method. The firmness of husk was also measured using the Instron Universal Testing Machine. The Instron gave a mean force of 251.67 N (25.65 kgs) with a standard deviation of 24.29 N for M1 nut and 237.34 N (24.19 kgs) with a standard deviation of 17.81 N for M2 nut. These means were compared using t-test of independent samples and were found to be significantly different from each other at 95% level of confidence. The result is in consonance with the study of Terdwongworakul et al. (2009) that the rupture force of marketable young coconut ranges 200-400 N.

Effect of Drop Height on Bruising Incidence

Mathew and Hyde (1997) and Schulte et al. (1992) used statistical thresholding to determine the bruise threshold for potato and apple, respectively. The method involves dropping specimens at various heights with respect to different impact surfaces and locating the height that gave the 10% bruising incidence. Using the method and setting the same bruise threshold value for young coconut, Figures 1 and 2 show the incidence of bruising with respect to drop height, maturity, and impact surface for ground and concrete, respectively. The intersection of the dotted horizontal line at 10% bruise with each of the maturity stage lines indicates the 10% bruising threshold drop height for that maturity. For ground surface, the 10% bruise threshold for *M1* and *M2 nuts* were approximately 20.00 and 22.50 cm, respectively.

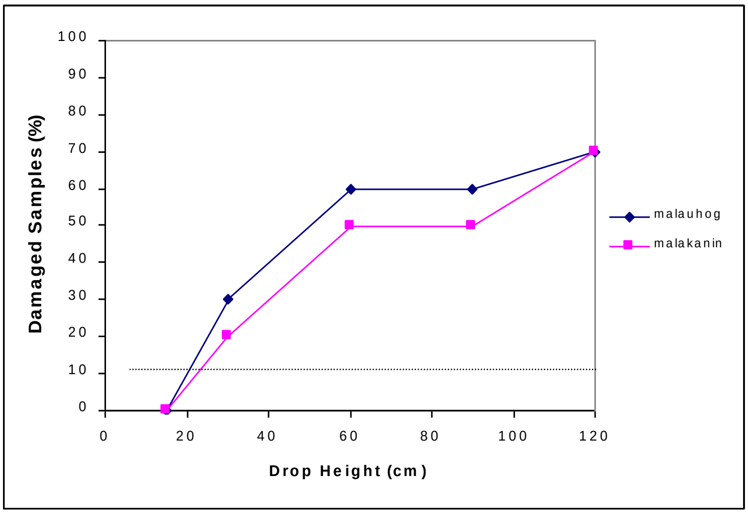

Figure 1. Young coconut bruise threshold on ground.

Incidence of bruising was directly related to drop height (with r^2 of 0.870 and 0.938 for M1 and M2 nuts, respectively) with higher incidence at greater drop heights. Young coconut was more susceptible to bruising when dropped on concrete. Incidence was 100% starting from height of 15 cm or more. The threshold of 10% was reached at 5 cm and 7cm drop heights for M1 and M2, respectively.

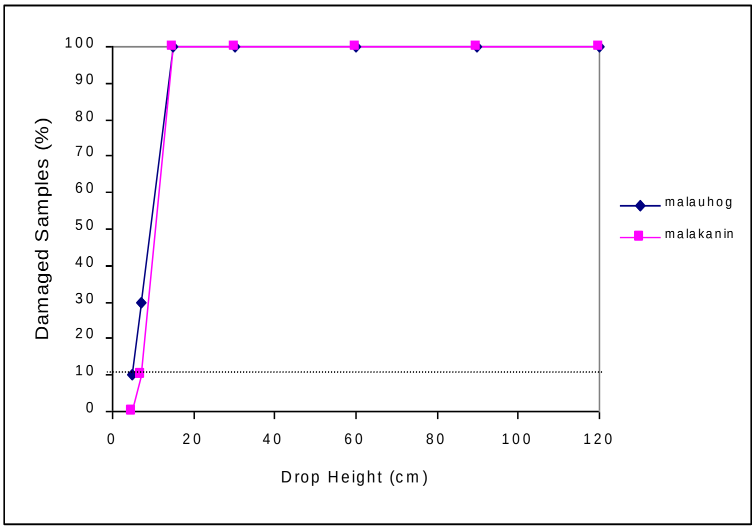

Figure 2. Young coconut bruise threshold on concrete.

Effect of Maturity, Drop Height and Impact Surface on Bruise Severity

The bruise of young coconut when dropped on either ground or concrete surface is not visible immediately after impact, either on the peel surface or in the underlying mesocarp. However, a brown discoloration is evident in the mesocarp about 24 hours after impact. This is a result of enzymatic browning that occurred when the injured or crushed tissue was exposed to air (Mohsenin, 1980). The shape of the bruise approximates that of an ellipse.

Simple linear regression analysis was done to determine the relationship of bruise depth and drop height for each maturity and impact surface and to establish prediction models for bruise volume using drop height as the predictor variable. The summary of predicting equations and r squares for bruise depth under each maturity and impact surface is presented in Table 1. Results of simple regression analysis reveal that the relationship between drop height and depth of bruise is linear and positive. For ground, r^2 are 0.983 and 0.979 for M1 and M2 nuts; respectively; while for concrete, r^2 are 0.931 and 0.976 for M1 and M2 nuts, respectively. These indicate that there is a corresponding increase in the depth of bruise in young coconut for both levels of maturity under each impact surface as drop height increases. The prediction models for bruise depth are also presented in Table 1.

Table 1. Prediction models for bruise depth

IMPACT SURFACE	M_1	M_2
Ground	$y_o = -0.123 + 0.0116\ x_i$	$y_o = -0.142 + 0.0087\ x_i$
Concrete	$y_o = 1.731 + 0.0044\ x_i$	$y_o = 1.690 + 0.0065\ x_i$

Legend:

M_1 = Malauhog y_o = Predicted, bruise depth (cm)

M_2 = Malakanin x_i = Predictor, drop height (cm)

Depth of bruise has significant implications in relation to handling of young coconut for export. Fruits must be free from internal damage when processed to produce a visually attractive commodity. Hence, it was important to determine the usual thickness of removed husk from shaved young coconut, since it defines the maximum allowable depth of bruise.

It was found that the average thickness of husk removed from trimming were 1.435 cm and 1.299 cm for M1 and M2 nuts, respectively. The thickness of trimming was more or less determined by the judgment of the trimmer. These values were considered as the critical depths of bruise: cd-m1 for M1 and cd-m2 for M2 represented by broken horizontal lines as shown in Figs. 3 and 4. For samples dropped on the ground, the corresponding drop heights were 38 cm and 60 cm for

M1 and M2 nuts, respectively. For samples dropped on concrete, the critical drop heights for M1 and M2 nuts were both about 8 cm.

In Fig. 3, the prediction models for M1 and M2 nuts under ground surface tend to under estimate the actual bruise depth. This fact might also be associated with the changes on the characteristics of ground surface where drop test was performed as previously discussed. For concrete, models for both levels of maturity had closer estimate of actual bruise depth compared with the models for ground surface as shown in Fig. 4. Regardless of impact surface, M1 nuts sustained deeper bruise than M2 nuts. Similarly, deeper bruise was also noted for fruits impacted on concrete than on ground.

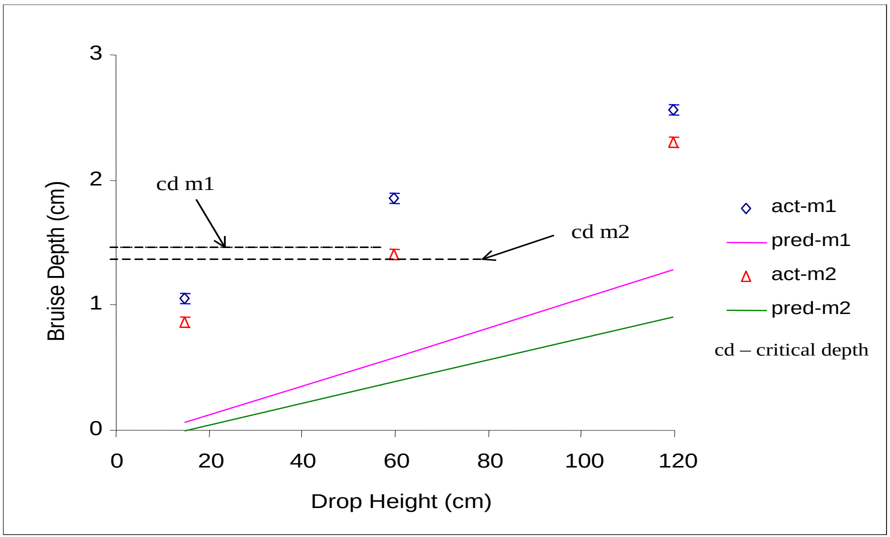

Figure 3. Effect of drop height on bruise depth for ground surface

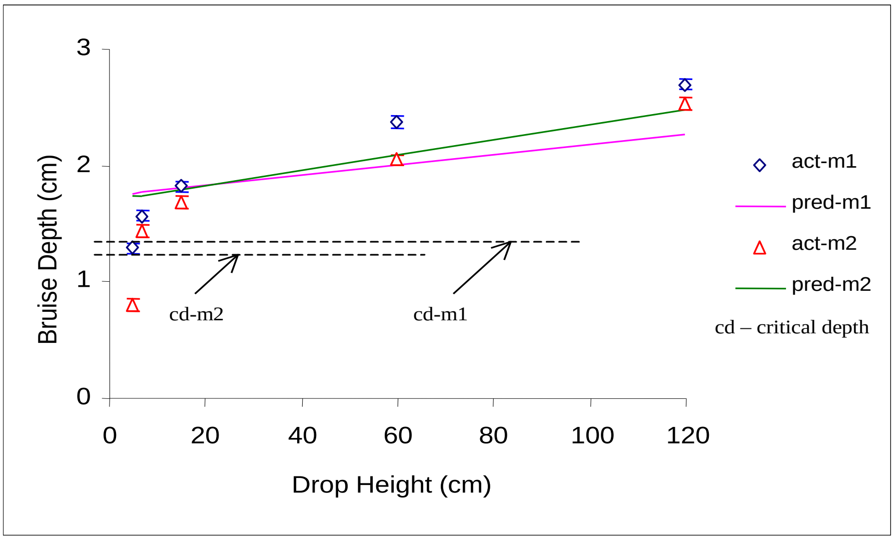

Figure 4. Effect of drop height on bruise depth for concrete surface

Pendulum Test

The relationship of bruise volume and bruise depth to physical parameters such as drop height, coefficient of restitution, total energy, and absorbed energy for the two levels of maturity was investigated.

Effect of the Different Parameters on Bruise Volume and Bruise Depth

Results of ANOVA reveal that only drop height had a significant effect on bruise volume and depth. The effect of maturity and its interaction with drop height were insignificant. Generally, there was a dramatic increase in bruise depth as drop height (angle of drop) increased.

Coefficient of Restitution (e)

Figures 5 and 6 show the relationship of *e* with bruise volume and bruise depth, respectively. Coefficient of restitution had highly significant negative correlation with bruise volume, r^2 are –0.846 and –0.910 for M1 and M2 nuts, respectively. Highly significant correlation was also noted for bruise depth, r^2 are –0.968 and –0.984 for M1 and M2 nuts, respectively. The results indicate that there was a corresponding decrease in bruise volume or depth as *e* increased for both levels of maturity. The curves reveal non-linear relationships between parameters; hence non-linear models were developed for each level of maturity.

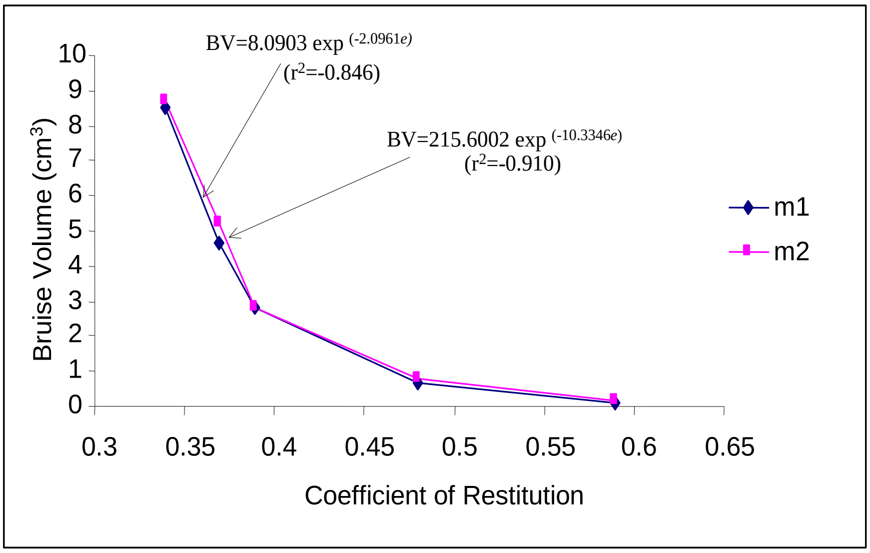

Figure 5. Relationship between coefficient of restitution and bruise volume

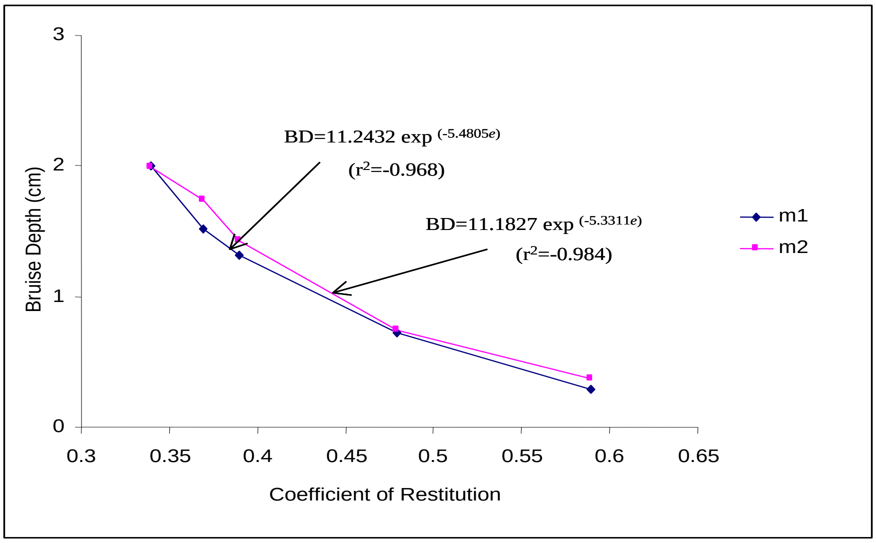

Figure 6. Relationship between coefficient of restitution and bruise depth

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Energy Absorbed (E_{abs})

Results of correlation analysis revealed highly significant correlations between E_{abs} and bruise volume or bruise depth at each level of maturity. Absorbed energy significantly affected the magnitude of bruise volume and bruise depth for both levels of maturity. It can be seen in Figs. 7 and 8 that as E_{abs} increased, bruise volume or bruise depth also increased. Both figures show non-linear relationships, hence non-linear prediction models were developed relating magnitude of bruise with E_{abs}.

It was observed that M1 and M2 do not considerably vary with each other, which indicates that the effect of energy absorbed by the fruit on the magnitude of bruise volume or bruise depth was more or less similar at the two levels of maturity.

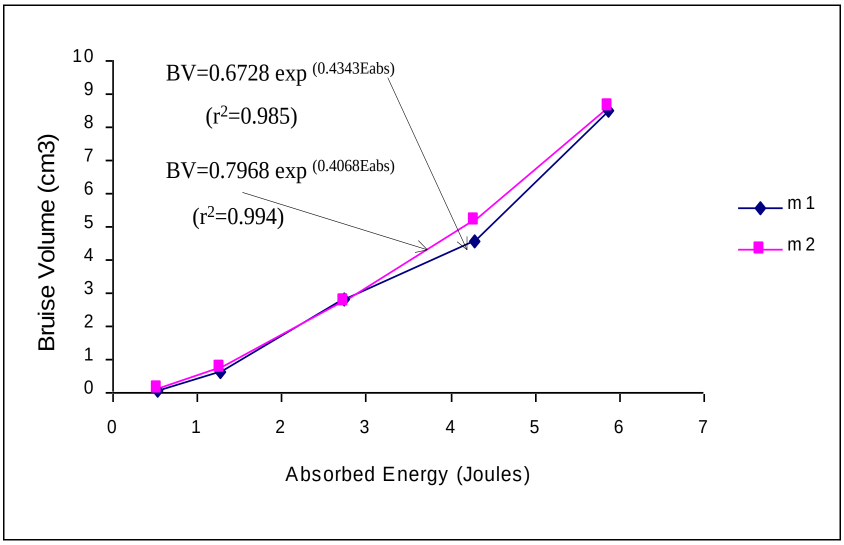

Figure 7. Relationship of bruise volume and absorbed energy

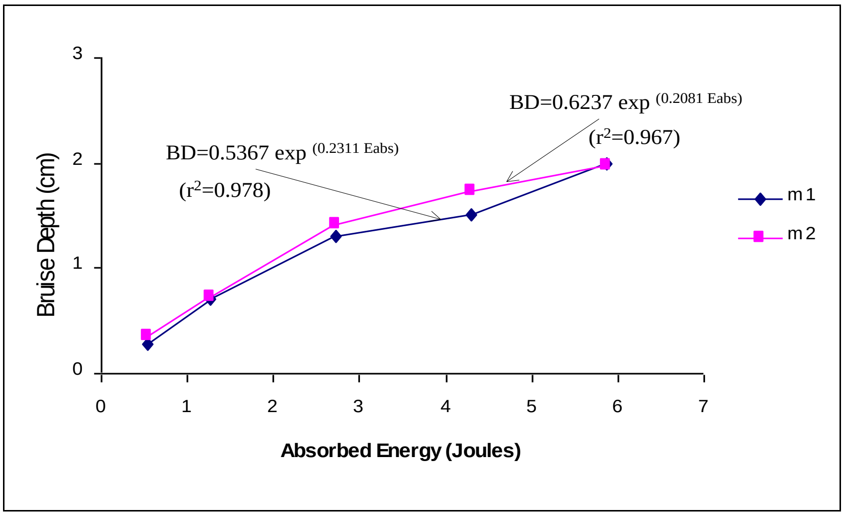

Figure 8. Relationship of bruise depth and absorbed energy

Relationship of Bruise Volume and Bruise Depth to the Different Parameters

Stepwise multiple regression analysis was performed to determine the relationship of bruise volume and bruise depth to the different physical parameters: drop height, coefficient of restitution, absorbed energy, and total energy. Results revealed some relationships that maybe used in predicting the magnitude of bruise volume and bruise depth at the two levels of maturity. All variables that were significant at α=0.10 were included in the model.

Bruise volume. For *malauhog* stage, bruise volume is a function of absorbed energy and coefficient of restitution (BV = -4.254 + 1.593E_{abs} + 4.630*e*). Energy absorbed and coefficient of restitution also determine bruise volume for *malakanin* stage (BV = -3.305 + 1.736E_{abs} + 3.951*e*). This may be due to the fact that correlations of bruise volume with energy absorb and coefficient of restitution for both levels of maturity are significant at α=5%.

Bruise depth. For *malauhog* stage, bruise depth is a function of drop height, coefficient of restitution and energy absorbed (BD = 1.053 + 0.01905DH – 1.562*e* – 0.140E_{abs}). For *malakanin* stage, bruise depth is also determined by the coefficient of restitution, drop height and energy absorb (BD = 1.592 + 0.03344DH – 2.572*e* – 0.458E_{abs}). The inclusion of the three parameters in the equations may be due to the fact that they are significantly correlated with the depth of bruise for both levels of maturity.

4. Conclusion

The mechanical properties of young coconut 'buko' were determined by establishing the threshold values for impact. Sensitivity of young coconut to impact bruising was investigated using two separate impact tests: actual drop and using a pendulum impactor. These tests were performed to locate the threshold drop height for young coconut and to determine the effects of different factors (maturity, drop height, and impacting surface) on bruise volume and depth. It was found that the drop heights, which bruised 10% of the fruits, were 20 cm and 22.50 cm for M1 and 2 nuts, respectively with reference to ground surface. For concrete, 10% bruising occurred at 5 cm and 7 cm for malauhog and malakanin, respectively.

Results revealed that bruise volume and bruise depth increased with the level of drop height. Young coconut samples sustained severe damages at higher drop heights especially those impacted on concrete. The threshold drop height for the maximum allowable bruise depth was established. Young coconut at M1 stage should never be dropped at heights greater than 38 cm above ground and 8 cm above concrete to avoid depth of bruise exceed the critical value of 1.435 cm. Similarly, the critical heights for nuts at M2 stage were established at 60 cm and 8 cm for ground and concrete, respectively. Heights greater than the critical would mean exceeding the critical depth of bruise of 1.299 cm for M2 nuts. Exceeding critical bruise depths means significantly affecting the marketability of young coconut for export. Regardless of impact surface, it was noted that magnitude of bruise was not significantly affected by fruit maturity.

Coefficient of restitution influenced bruise volume and bruise depth at both levels of maturity. Results indicated a negative but highly significant correlation between coefficient of restitution and bruise volume or bruise depth. The coefficient also decreased with drop height. It was further found that total energy prior to impact and energy absorbed by the fruit at impact significantly increased with level of drop height. Positive and highly significant correlation was also noted between total energy or absorbed energy with bruise volume or bruise depth. Prediction models were developed through simple and stepwise regression analysis that showed the relationship between different parameters and the magnitude of bruise.

The models were validated by comparing the predicted and actual magnitudes of bruise. Some models were found to closely predict actual values of bruise. Other models under predict bruises.

Even just the threshold values of drop height for different levels of maturity, would be useful practical information in handling young coconut. It is recommended that maximum allowable drop heights must always be observed during handling operations to limit bruise damage below the critical values.

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A Brief Author Biography

Alexander M. Pascua, Ph. D. – A graduate of the University of the Philippines Los Banos Laguna in the degree of Master of Science in Agricultural Engineering the University of the Philippines Los Baños under the CHED Post-Baccalaureate Scholarship Program for College Faculty Members from Underserved Islands Off Luzon in the year 2004. He was also a recipient of the Faculty Scholarship Program under the AGRITECH (Australia-Philippines) Project to take up Master of Agricultural Science and Technology Major in Agricultural Engineering at Cavite State University and finished the degree also in 2004. In 2007, he pursued Doctor of Philosophy in Agricultural Engineering under the CHED Higher Education Development Project-Faculty Development Program and finished the degree in October, 2011. His researches include development of postharvest machineries and equipment. Currently, he is an Associate Professor III and the Dean of the School of Agriculture and Natural Sciences of Marinduque State College.