Dents Occurrence, Potential Energy and Weight Loss of Dropped Hog Plum (*Spondias Mombin* L.) Fruits

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ABSTRACT

This study investigated the impact of bruise damage on the physiological response of hog plum during short-term storage, examining susceptibility at various ripening stages and impact forces on different platforms (metal, foam, and paper). Results indicated that hog plums are highly sensitive to bruising based on ripeness and platform material. Bruising probability was highest in ripe fruits and significantly lower in unripe ones, with bruise severity increasing with drop height and impact energy, especially on hard surfaces like metal. Over five days of storage, cumulative weight loss (CWL) was notably higher in ripe fruits dropped from greater heights, with ambient conditions exacerbating this effect compared to refrigerated storage. The findings emphasize impact energy as a critical factor in bruise susceptibility, suggesting that minimizing impacts during harvest and handling could reduce damage.

Keywords: Hog plum, postharvest, bruise susceptibility, weight loss, polynomial, drop-height

INTRODUCTION

The hog plum (*Spondias mombin* L.) is a fruit-bearing tree within the Anacardiaceae family and the genus of flowering plants. Indigenous to the lowland rainforests of the Amazon, it is primarily cultivated in the tropical regions of the Americas, the West Indies, and Nigeria (Esua et al., 2016). Hog plum is a rich source of vitamins A and C, as well as essential minerals like potassium and phosphorus, alongside various health-promoting phytochemicals (Mishra *et al.*, 2017). The fruit has a leathery outer skin and a thin layer of edible pulp, commonly consumed fresh or processed into juice, concentrates, jellies, and sherbets (Olaoye *et al.*, 2021). Although the fresh fruit has a naturally astringent taste, initially limiting its appeal, research has increasingly highlighted its health benefits, enhancing its acceptability (Carvalho & Nascimento, 2020).

During harvesting and transportation, hogplum often encounter both static and dynamic forces that create pressure, potentially leading to mechanical damage and accelerating metabolic processes that ultimately cause fruit deterioration (Polat *et al.*, 2012; Sun *et al.*, 2023). Bruising, the most prevalent type of mechanical damage, primarily arises from impact and vibration (Al-Hadrami et al., 2023; Hou et al., 2024; Opara & Pathare, 2014). This damage affects the subcutaneous tissue, compromising the internal structure with or without breaking the fruit's skin (Guan et al., 2023; Opara & Pathare, 2014). Bruise damage can occur from various factors, including fruit falling onto other fruits or branches, contact with hard, un-cushioned surfaces on machinery, careless handling, inadequate packaging, and poorly designed equipment (Fu et al., 2023; Hussein et al., 2019). Bruised fruits suffer economically, as the damage reduces their market appeal, causes moisture loss, decreases weight and vital nutrients, and increases metabolism, hastening senescence and spoilage (Fu et al., 2023; Htike et al., 2023; Hussein et al., 2019).

Laboratory simulations of fruit bruising are essential for understanding the mechanical damage that occurs during harvesting and handling. Mohammad Shafie et al. (2015) demonstrated that various test methods can effectively replicate the dynamic loading conditions fruits experience in real-world scenarios. For instance, Sun *et al.* (2023) observed that in bruised peaches, respiration rates increased significantly with the severity of damage. Similarly, Scherrer-Montero *et al.* (2011) reported a 66% increase in respiration rates in bruised citrus fruits. These findings align with the general understanding that mechanical damage, such as bruising, accelerates metabolic processes, leading to increased respiration rates and faster deterioration. While extensive research has documented the effects of bruising on respiration rates in various fruits, there is a notable gap concerning hog plum. Understanding how bruising affects the physiological responses of hog plum, particularly its respiration rate, is crucial for developing effective post-harvest handling and storage strategies. Therefore, this study aimed to evaluate the impact of mechanical damage from bruising, varying impact forces, and storage conditions on the physiological responses of hog plum at different ripening stages.

MATERIALS AND METHODS

Fruit Selection and Classification

Fresh hog plum fruits were harvested from the University of Ibadan, Nigeria (Latitude 7.423713° N, Longitude 3.934891° E). Fruits were visually classified into three ripeness stages: ripe, about-to-ripe, and unripe. Only fruits weighing between 5 and 12 grams and free from visible defects such as cracks, sunburn, or husk scald were selected for the study (Plate 1).

Experimental Design

Based on preliminary experiments, specific drop heights and platform types were selected to simulate realistic handling conditions. Drop heights of 0.1, 0.2, 0.3, 0.4, and 0.6 meters were chosen to represent typical handling scenarios (Fig 1). Three platform materials were used: metal (hard surface), paper (moderate surface), and foam (soft surface), corresponding to surfaces commonly encountered during harvesting and transportation. Each fruit was subjected to a single drop from the specified heights onto the designated platforms. Post-impact, fruits were stored under two temperature conditions to assess weight loss: ambient temperature (25 ± 2°C) and refrigerated temperature (5 ± 1°C). Weight measurements were taken at 0, 1, 3, and 5 days of storage to monitor weight loss over time.

Determination of Bruise Area, Volume and Susceptibility

The probability of bruise occurrence was determined following the method described by Hussein *et al.* (2019), with minor modifications. Briefly, each fruit was dropped from various heights (0.1, 0.2, 0.3, 0.4, and 0.6 m) onto rigid surfaces (metal, paper, and foam). Samples were then categorized based on visible and non-visible bruises, with equation 1 applied to calculate the probability of bruise occurrence (PBO). Visible bruises (as shown in **Plate 2**) were marked, and bruise characteristics—such as depth, major, and minor axes—were measured using a digital caliper with an accuracy of ±0.02 mm. Equations 1 to 5 were used to quantify the probability of bruise occurrence, bruise area, bruise volume, bruise susceptibility and specific bruise susceptibility respectively.

$$PBO = {}^{N_b}\!/_{N_s} \qquad (1)$$

$$BA = \left(\frac{\pi}{4}\right) \mathrm{L} * \mathrm{b} \qquad (2)$$

$$BV = \frac{\pi d}{24}\left(3\mathrm{Lb} + 4d^2\right) \qquad (3)$$

$$BS = \frac{BV}{E} \qquad (4)$$

$$SBS = \frac{BS}{m} \qquad (5)$$

where;

PBO - probability of bruise occurrence

Nb - the number of fruits sustained visible and measurable bruises,

Ns - the number of replications of the same treatment.

BA – bruise area (mm^2)

BV – bruise volume (m^3)

BS – bruise susceptibility (m^3mJ^{-1})

d – depth (mm)

L – major axis (mm)

b – minor axis (mm)

SBS – Specific bruise susceptibility ($m^3mJ^{-1}g^{-1}$)

Potential Energy in the Dropped Fruits

The potential energy of the harvested fruits was determined by dropping each fruit on rigid surfaces (metal, paper and foam) at different heights (0.1, 0.2, 0.3, 0.4 and 0.6m). A mean of 10 replicates were recorded as obtained data. Equation 6 was used to calculation of the potential energy.

$$E\,(J) = m * g * h \qquad (6)$$

Where E – impact energy (mJ)

m is the mass (g) of each individual hog plum fruit, g (m/s^2) is the gravitational constant, and h (m) is the drop height.

Determination of Weight Loss

Hog plums of different ripening stages (ripe, about to ripe, unripe) were bruised by drop impact test at 0.1m, 0.2m, 0.3m, 0.4m and 0.6m drop heights using previously described procedures. Bruised fruits were stored at refrigerated (5 ± 2°C, 90 ± 2% RH) and room temperature (27 ± 2°C, 75 ± 3% RH) conditions for 5 days while non-bruised fruits were used as control. The samples were numbered, and weight was measured daily throughout 5days storage duration using an electronic scale (0.0001g accuracy). Equation 7 gave weight loss in percentage.

Where;

$$WL = \frac{(Mi - Mf)}{Mi} x100 \qquad (7)$$

WL – weight loss (%)

Mi is initial weight (g) of the fruit at the beginning of storage; and *Mf* is the weight (g) of the fruit at the time of sampling during storage.

Statistical Analysis

Means of triplicate determination were recorded and subjected to statistical analysis. The data were subjected to analysis of variance (ANOVA) using Statistical Packages for Social Science (SPSS) to analyze the variance among accessions. Tukey post hoc statistical significance test was also performed ($p<0.05$).

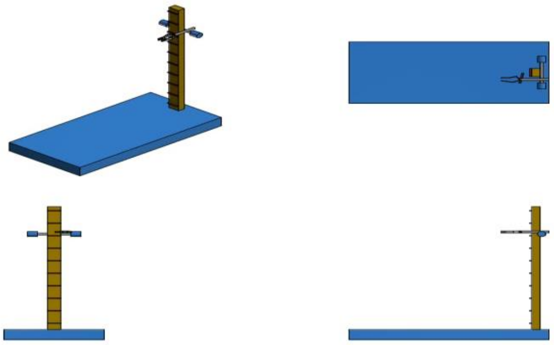

Fig. 1. Isometric view of the laboratory equipment used for bruising

Plate 1A Plate 1B Plate 1C

Plate 1: Picture of “Unripe”, “About to ripe” and “Ripe” hog plum fruits

Plate 2: Picture of the ripe bruised hog plum sample after24 hours

RESULTS AND DISCUSSION

Probability of bruise occurrence

Table 1 presents the probability of bruise occurrence in hog plums at various ripening stages when subjected to different drop heights. Ripe fruits exhibited a bruise probability of 1.0 across all drop heights from 0.1 m to 0.6 m, indicating consistent bruising upon impact. Fruits classified as "about-to-ripe" showed bruise probabilities ranging from 0.4 to 0.8 within the same drop height range. Unripe fruits first exhibited bruising at a probability of 0.2 when dropped from heights of 0.3 m and 0.4 m, with the highest bruise probability of 0.4 observed at a 0.6 m drop height after 24 hours. The lower incidence of bruising in unripe fruits may be attributed to their firmer cuticle, which provides greater resistance to impact energy (Al-Hadrami *et al.*, 2023; Guan *et al.*, 2023). The high rate of bruises seen in the ripened fruits is likely due to the softer skin and increase in moisture content of the fruits and the hard surface of the metal platform in which it was dropped (Hou et al., 2024; Sun et al., 2023). The probability of bruises observed using foam of 15mm thickness was highest at 0.6m for ripened fruit which means an impact energy is less than or equal to the energy that can get the fruit bruised. The fruits dropped on the paper platform has an impact energy capable of causing bruises at 45.21mJ for ripe fruit and an impact energy of 56.51mJ is less than or equal to the energy needed to cause bruises in unripe fruit (data not shown). The overall view of the results shows that the probability of the bruise damage is higher in ripe fruit dropped on the metal platform and this suggests that fruit harvested and dropped on a metal container are likely to undergo postharvest losses more than those dropped on padded containers such as paper or packaging padded with foam of about 15mm.

Bruise susceptibility, bruise area and bruise volume

Bruise Susceptibility quantifies the potential for bruise damage per unit of impact energy and provides a general measure of how likely the fruit is to bruise under a given impact. The effect of drop height, ripeness and surface type on the bruise susceptibility of the hog plum fruits were shown in **Table 2**. As expected, bruise susceptibility is directly proportional to the drop height, i.e. the higher the drop height, the higher the bruise susceptibility. Fruits dropped from 0.1m displayed lower susceptibility than those dropped from 0.6m. Furthermore, bruise susceptibility was higher in ripened fruits compared to unripe ones. A significant difference ($p < .05$) was observed between fruits dropped on the metal surface and those on the foam platform, with the metal surface producing the highest bruise susceptibility. Among all factors considered (ripeness, drop height, and platform type), ripened fruits dropped from 0.6 m on the metal platform were most susceptible to bruising, with a bruise susceptibility value of 8.59 $m^3\ mJ^{-1}$. The foam platform yielded a maximum susceptibility of 1.96 $m^3\ mJ^{-1}$ for ripe fruits at the same height, while the paper platform exhibited values ranging from 0.27 to 2.44 $m^3\ mJ^{-1}$

Bruise area (**Table 3**) and bruise volume (**Table 4**) of the samples at different drop heights and different platforms. The bruised area of the ripe sample dropped on the metal surface also ranges from 77.56 to 177.43m^2, about to ripe samples range from 24.2 to 155.47m^2 and the unripe samples range from 11.63 to 13.22m^2 with the first occurring at 0.3m drop height. The bruised area for paper ranges from 27.04 to 105.86 m^2 for ripe samples, 16.21 to 88.94 m^2 for about to ripe, and 15.57 to 15.97 m^2. The result shows a significant difference from the samples (ripe, about to ripe and unripe) when dropped on different experimental platforms. The bruise volume increases with an increase in drop height from 95.6 to 162.9 m^3 for “ripe” hog plum, and 28.58 to 154.1 m^3 for “about to ripe”. The unripe samples when dropped on the metal platform only have bruise volume from 0.3m^3 to 0.6m^3. The samples dropped on the foam and paper platforms also showed the same progression of increase, but none of the unripe samples underwent bruising when dropped on the foam platform until a drop height of 0.4m. The progression of bruise volume on the platform increased from foam to paper and then metal platform. As expected, the hard surface of the metal platform contributed to the high values of bruise area and bruise volume. Samples dropped on paper platforms show no significant difference from a drop height of 0.1m to 0.4m but a significant difference exists between the bruise volume at 0.6m for ripe, about to ripe and the unripe samples. The bruised area shows a significant difference in the samples from 0.1m to 0.4m but has no significance difference at 0.6m when dropped on metal surface. Significant differences exist on the samples when dropped on the paper platform at 0.4m and 0.6m, while no significant difference exists between the samples dropped on the foam surface. Overall, the results align with findings by Hussein et al. (2019) and Htike et al. (2023) who reported similar increases in bruise volume and bruise area in pomegranate cultivars and guava, respectively. In a report by Tabatabaekoloor (2013), it was suggested increase in bruise area is associated with the higher potential energy that accelerates the intensity of fruit fall. Hog plum fruit is featured by natural irregularities both in shape, peel thickness, and degree of ripeness, which might affect the fruit properties such as the radius of curvature, an important property that affects fruit-to-surface impact (Ahmadi et al., 2013; Ekrami-Rad et al., 2011). The observed disparities in bruising between the studied hog plum fruits could also be attributed to differences in the mechanical and physico-morphological attributes such as firmness, peel thickness, moisture content, degree of ripeness, and fruit’s radius of curvature (the equatorial diameter) (Hussein *et al.*, 2015; Mohammad Shafie *et al.*, 2017). Differences in susceptibility to bruising of fruit at different surface platforms and degree of ripeness subjected to the same impact loading conditions can also be associated with their differences in mechanical properties (Aliasgarian et al., 2015; Van linden et al., 2006).

Specific Bruise Susceptibility (SBS) offers a more detailed assessment by expressing the potential for damage per unit mass of the fruit. SBS accounts for variations in fruit size and weight, providing a more precise evaluation of bruise susceptibility. Ripe fruits consistently exhibited higher SBS across all drop heights and platform types compared to about-to-ripe and unripe fruits. For instance, at a 0.6 m drop height onto a metal platform, ripe fruits had an SBS of 0.76 $m^3mJ^{-1}g^{-1}$, whereas about-to-ripe and unripe fruits recorded 0.37 $m^3mJ^{-1}g^{-1}$and 0.02 $m^3mJ^{-1}g^{-1}$, respectively (**Table 5**). This trend aligns with existing literature, which suggests that as fruits ripen, their tissue softens, making them more prone to mechanical damage. Opara and Pathare (2014) noted that the softening of fruit tissues during ripening increases susceptibility to bruising due to reduced structural integrity. The interplay between ripeness, drop height, and platform type was evident in the SBS outcomes. Ripe fruits dropped from greater heights onto metal exhibited the highest SBS values. This finding underscores the importance of careful handling of ripe fruits, especially when they are subjected to higher drop heights and harder surfaces during postharvest operations. Implementing cushioning materials and minimizing drop heights can mitigate bruise damage, as suggested by Opara and Pathare (2014).

Polynomial relationship between the drop height and the impact energy

Polynomial relationship was obtained between the impact energy and the drop height of the hog plum fruits at different ripening stages and dropped platforms. **Fig.2** shows the correlations for ripe fruits. The R^2 values obtained were quite promising as the values were 0.991, 0.981, and 0.990 for fruits dropped on metal, paper, and foam respectively. Similarly, the R^2 of fruits that were about-to-ripe, and that of unripe fruits were 0.981, 0.981, and 0.963 (**Fig. 3**), 0.993, 0.974, and 0.997 (**Fig.4**). This high R^2 shows a high accuracy for bruise prediction based on the dropped platforms and the degree of ripeness of hog plum fruits. Many researchers have used linear regression to predict the bruising properties of fruits such as tomatoes, guava, and kiwifruits (Ahmadi, 2012; Htike *et al.*, 2023). However, this research used a polynomial equation to predict bruise damage properties of hog plum fruits at different ripening stages and dropped platforms.

Effect of temperature on the weight of Hog plum during short-time storage

Cumulative weight loss (CWL) in the percentage of hog plum fruits during five days of storage after bruising at different drop platforms was shown in **Fig. 5**. The current study revealed that at ambient (20 °C) temperature, change in fruit weight was significantly ($p < 0.05$) affected by both bruising and bruise intensity. After 5 days of storage at ambient conditions, the highest % CWL was observed in fruit dropped at 0.6 m. The highest weight loss was measured in ripe samples at 0.6m with 73% followed by the “about to ripe” with 65% at 0.3m and 0.4m drop height respectively. The trend of increase in weight loss with bruise severity was also observed in cold (5 °C) stored ripe fruit, in which the highest %CWL of 5% for the control sample followed by 4.5% observed at 0.6m drop height of about to ripe samples stored at refrigerated temperature. Overall, the effect of low-temperature storage reduced weight loss by more than 8-fold than ambient stored fruits. The reduction in weight loss by reduced temperature is higher than that reported by Hussein (2019) on pomegranate. The most crucial observation is that low-temperature storage significantly reduced the moisture loss of bruised fruit for all samples. This could be attributed to a reduced rate of the metabolic process at a low temperature (Fawole & Opara, 2013; Scherrer-Montero et al., 2011), even for bruised fruit. Weight loss in hog plum fruit during storage is promoted by the high porosity of its peel which enables free vapor movement, a property that has been ascribed to the fruit’s high sensitivity to moisture loss (Ambaw *et al.*, 2017). Bruise damage increased the weight loss as revealed in the current study. Bruising results in the modification of tissue permeability and the resulting small cracks connecting both the internal and external atmospheres permit the interchange of atmospheric gases, particularly water vapour (Martínez-Romero *et al.*, 2003).

Table 1 Effects of drop height, ripeness, and surface type on probability of bruise occurrence.

	Platform			
Height	**Degree of Ripeness**	**Metal**	**Foam**	**Paper**
0.1m	Ripe	1	0.2	0.2

	About to Ripe	0.4	0	0
	Unripe	0	0	0
0.2m	Ripe	1	0.2	0.4
	About to Ripe	0.4	0	0.2
	Unripe	0	0	0
0.3m	Ripe	1	0.6	0.6
	About to Ripe	0.6	0.2	0.2
	Unripe	0.2	0	0
0.4m	Ripe	1	0.4	1
	About to Ripe	1	0.4	0.4
	Unripe	0.2	0	0.2
0.6m	Ripe	1	0.6	1
	About to Ripe	0.8	0.4	1
	Unripe	0.4	0	0.4

Table 2 Effects of drop height, ripeness, and surface type on bruise susceptibility (m^{3}mJ^{-1}).

		Platform		
Height	**Degree of Ripeness**	**Metal**	**Foam**	**Paper**
0.1m	Ripe	2.13±0.38^{c}	0.21±0.06^{a}	1.35±0.02^{b}
	About to Ripe	1.55±0.80	ND	ND
	Unripe	ND	ND	ND
0.2m	Ripe	3.83±0.78^{c}	0.43±0.09^{a}	2.38±0.27^{b}
	About to Ripe	1.80±0.66^{b}	0.19±0.24^{a}	0.87±0.45^{b}
	Unripe	ND	ND	ND
0.3m	Ripe	3.81±1.24^{b}	0.83±0.3^{a}	2.43±0.23^{b}
	About to Ripe	2.19±0.46^{c}	0.34±0.06^{a}	0.66±0.28^{ab}
	Unripe	0.33±0.04^{b}	0.02±0.01^{a}	ND
0.4m	Ripe	5.34±1.64^{c}	1.44±0.66^{a}	2.44±0.45^{ab}
	About to Ripe	3.12±1.27^{c}	0.4±0.09^{b}	1.11±0.07^{ab}
	Unripe	0.36±0.80^{b}	0.06±0.01^{a}	0.38±0.08^{b}
0.6m	Ripe	8.59±2.90^{b}	1.96±0.82^{a}	2.26±0.64^{a}

	About to Ripe	3.74±0.59^{c}	0.61±0.37^{a}	2.09±0.06^{b}
	Unripe	0.61±0.37^{c}	0.04±0.05^{a}	0.27±0.06^{b}

Mean values are presented as mean±standard deviation and significant difference at $p<0.05$ in the same column.

Table 3 Effects of drop height, ripeness, and surface type on susceptibility area (mm^{2}).

	Platform			
Height	**Degree of Ripeness**	**Metal**	**Foam**	**Paper**
0.1m	Ripe	77.56±20.77^{c}	12.34±2.71^{a}	27.04±6.29^{ab}
	About to Ripe	24.2±33.6	ND	ND
	Unripe	ND	ND	ND
0.2m	Ripe	90.67±18.38^{c}	15.66±6.42^{a}	37.71±6.50^{b}
	About to Ripe	36.14±53.51^{b}	10.86±4.98^{a}	16.21±48^{a}
	Unripe	ND	ND	ND
0.3m	Ripe	95.35±19.73^{c}	17.9±7.35^{a}	44.29±4.67^{b}
	About to Ripe	43.62±40.46^{b}	15.16±3.39^{a}	18.94±6.67^{a}
	Unripe	11.63±4.9	ND	ND
0.4m	Ripe	105.1±30.35^{b}	20.6±6.05^{a}	87.48±9.31^{b}
	About to Ripe	69.99±18.38^{c}	15.61±3.96^{a}	36.77±1.58^{b}
	Unripe	13.22±9.7^{ab}	10.21±6.4^{a}	15.57±4.81^{b}
0.6m	Ripe	177.43±42.5^{c}	23.91±8.46^{a}	105.86±38.6^{b}
	About to Ripe	155.47±27.37^{c}	16.84±5.77^{a}	88.94±15.56^{b}
	Unripe	32.3±7.1^{b}	12.88±3.63^{a}	15.97±5.71^{a}

Mean values are presented as mean±standard deviation and significant difference at $p<0.05$ in the same column.

Table 4 Effects of drop height, ripeness, and surface type on bruise volume (m^{3}).

	Platform			
Height	**Degree of Ripeness**	**Metal**	**Foam**	**Paper**
0.1m	Ripe	95.6±22.3^{c}	2.71±1.5^{a}	11.76±6.29^{b}
	About to Ripe	28.58±12.21	ND	ND
	Unripe	ND	ND	ND

0.2m	Ripe	117.8±27.3^{c}	6.99±5.65^{a}	46.06±6.20^{b}
	About to Ripe	59.59±54.70^{b}	12.59±3.47^{a}	15.57±4.81^{a}
	Unripe	ND	ND	ND
0.3m	Ripe	118.1±33.7^{b}	38.66±5.83^{a}	59.77±5.03^{a}
	About to Ripe	64.51±62.43^{b}	20.6±6.05^{a}	20.87±6.67^{a}
	Unripe	6.8±1.39	ND	ND
0.4m	Ripe	139.4±33.6^{b}	49.99±60.7^{a}	107.71±10.2^{b}
	About to Ripe	90.56±3.3^{c}	17.9±7.35^{a}	45.53±7.58^{b}
	Unripe	15.8±5.2^{a}	14.81±6.21^{a}	15.07±3.39^{a}
0.6m	Ripe	162.9±24.5^{b}	126.5±15.5^{a}	149.42±53.3^{ab}
	About to Ripe	154.1±33.8^{c}	23.91±8.46^{a}	120.6±15.6^{bc}
	Unripe	27.3±6.9^{b}	14.44±2.45^{a}	16.45±6.77^{a}

Mean values are presented as mean±standard deviation and significant difference at $p<0.05$ in the same column.

Table 5 Effects of drop height, ripeness, and surface type on SBS ($m^{3}mJ^{-1}g^{-1}$).

	Platform			
Height	**Degree of Ripeness**	**Metal**	**Foam**	**Paper**
0.1m	Ripe	0.23±0.06^{b}	0.02±0.0^{a}	0.15±0.03^{b}
	About to Ripe	0.16±0.15	ND	ND
	Unripe	ND	ND	ND
0.2m	Ripe	0.36±0.08^{b}	0.05±0.00^{a}	0.24±0.04^{b}
	About to Ripe	0.16±0.01^{b}	0.02±0.03^{a}	0.06±0.01^{a}
	Unripe	ND	ND	ND
0.3m	Ripe	0.37±0.15^{c}	0.12±0.01^{a}	0.29±0.02^{b}
	About to Ripe	0.22±0.03^{c}	0.01±0.05^{a}	0.10±0.01^{b}
	Unripe	0.04±0.01	ND	ND
0.4m	Ripe	0.44±0.02^{b}	0.17±0.02^{a}	0.32±0.08^{b}
	About to Ripe	0.34±0.07^{b}	0.07±0.01^{a}	0.11±0.02^{a}
	Unripe	0.05±0.02^{b}	0.04±0.03^{a}	0.04±0.01^{a}
0.6m	Ripe	0.76±0.26^{c}	0.18±0.05^{a}	0.39±0.05^{b}

	About to Ripe	0.37 ± 0.10^c	0.06 ± 0.01b	0.22 ± 0.06^b
	Unripe	0.02 ± 0.01^b	0.005 ± 0.0^a	0.03 ± 0.05^b

Mean values are presented as mean±standard deviation and significant difference at $p<0.05$ in the same column.

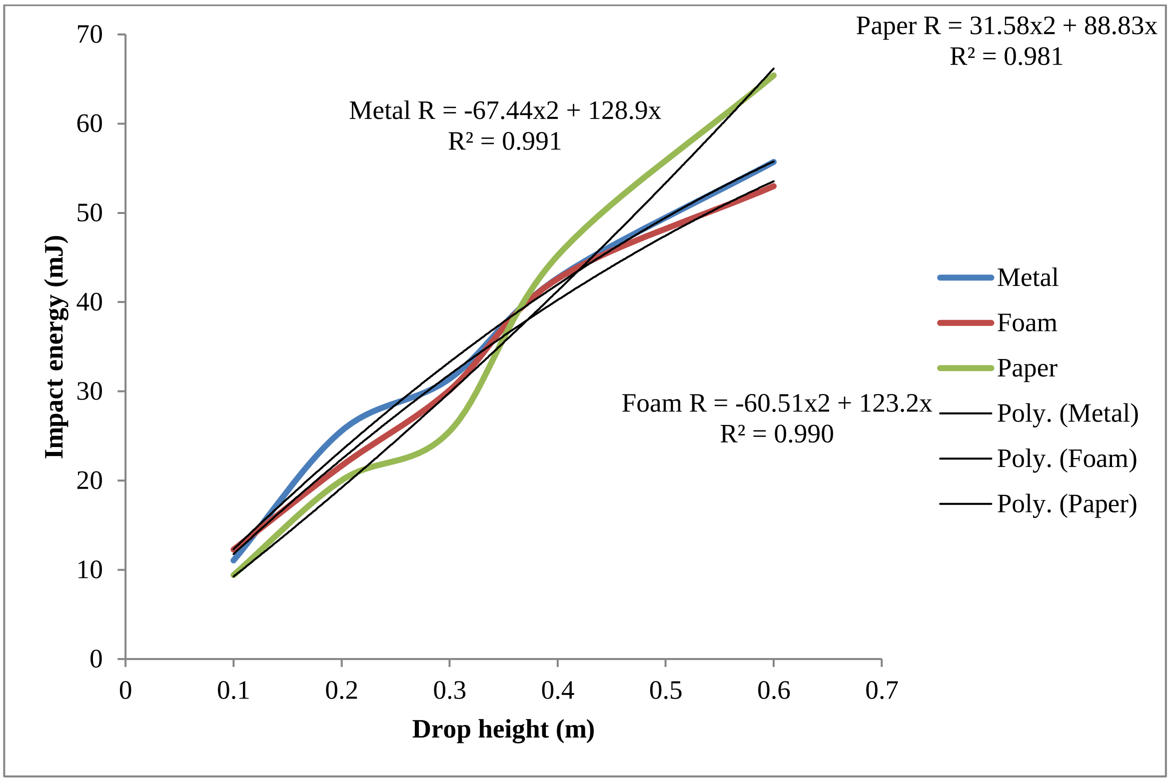

Fig. 2. Effects of drop height and surface type on impact energy on ripe hog plum.

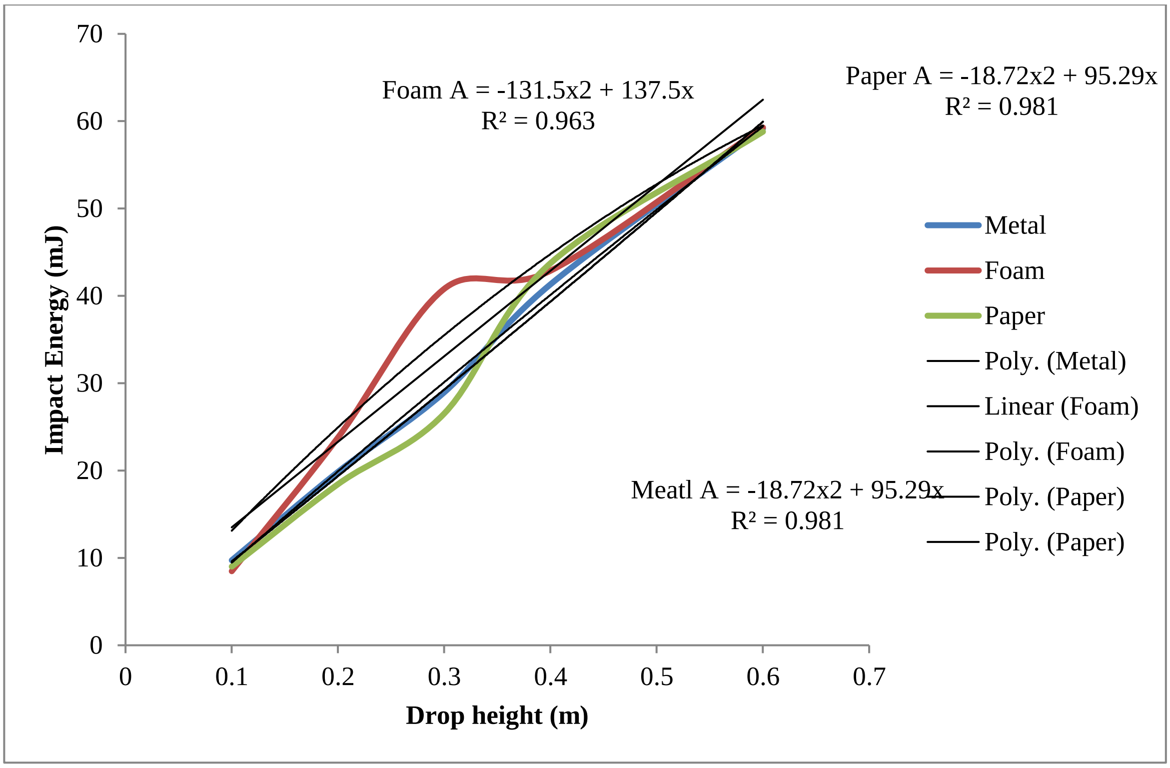

Fig.3. Effects of drop height and surface type on impact energy on about to ripe hog plum.

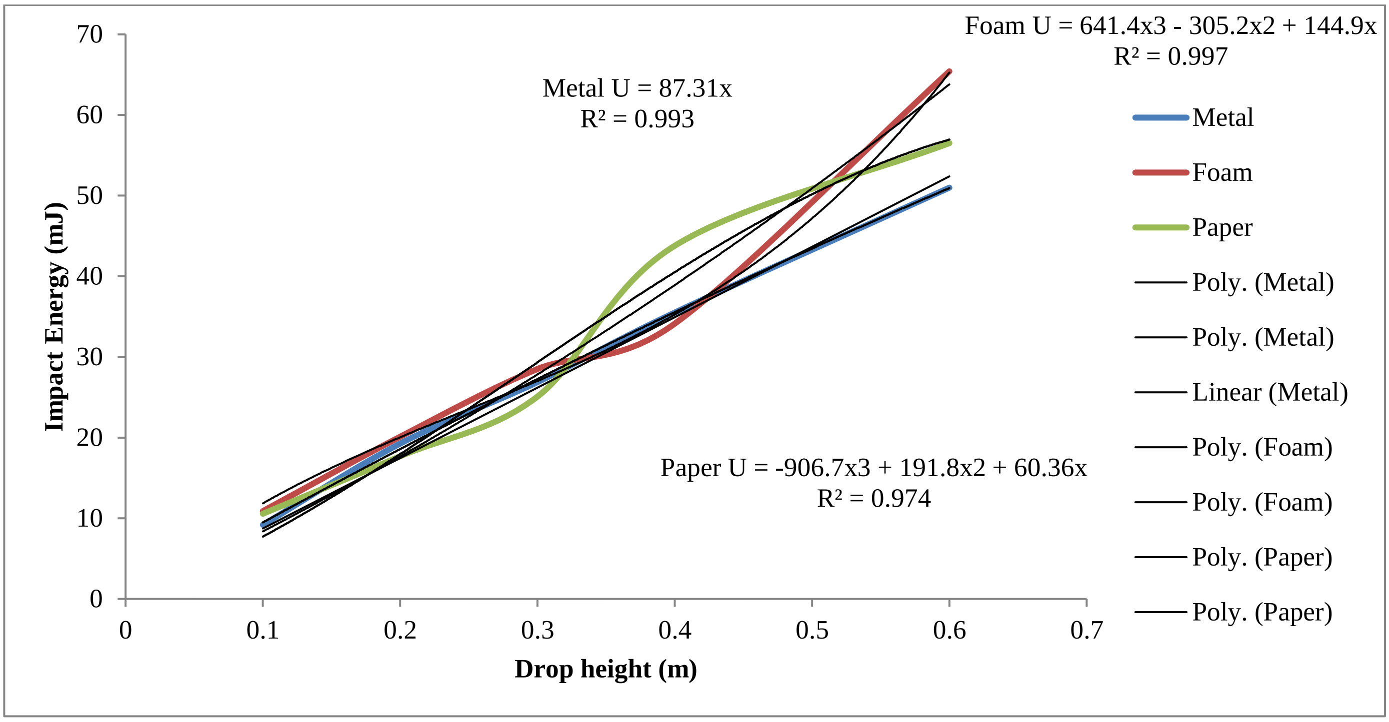

Fig. 4. Effects of drop height and surface type on impact energy on unripe hogplum.

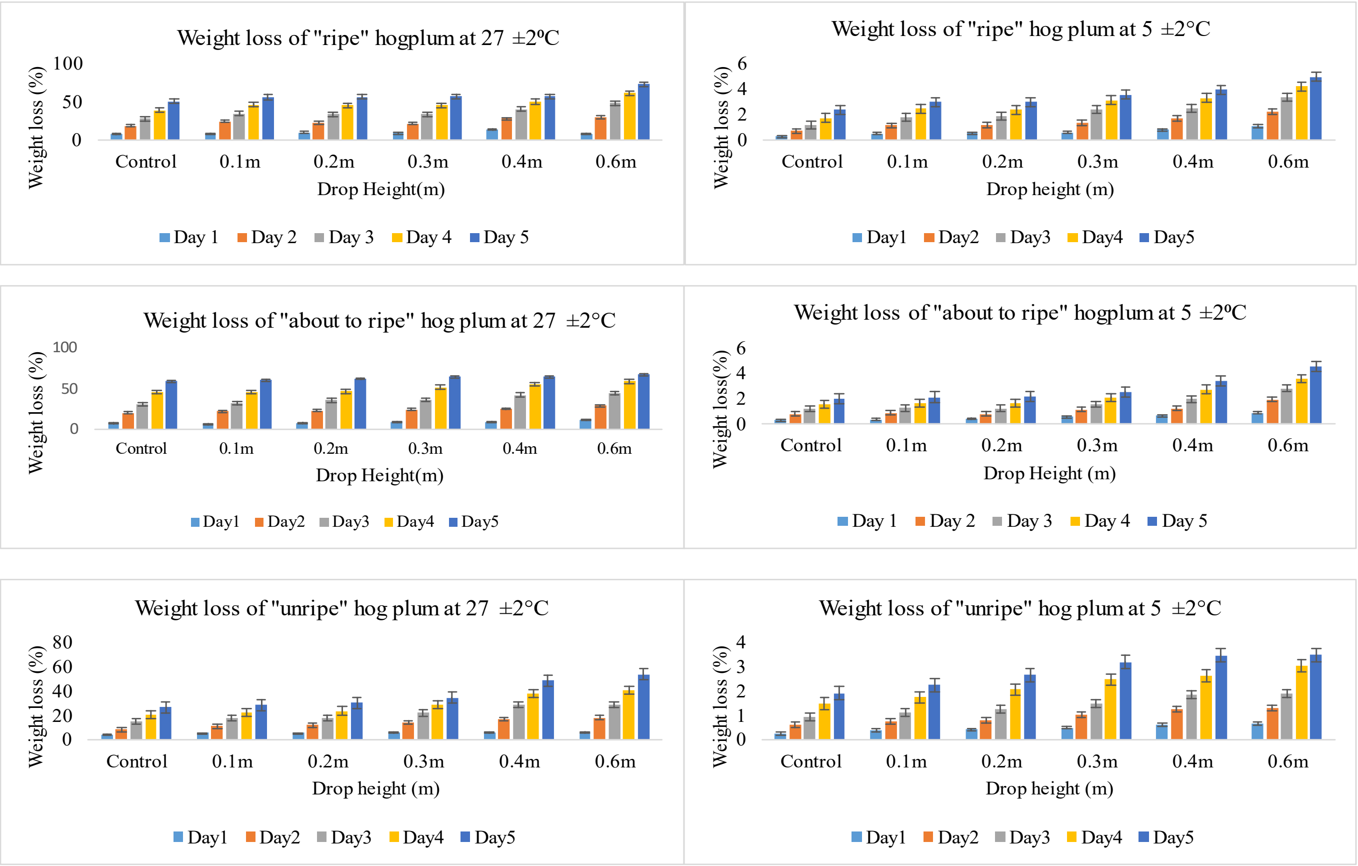

Fig.5**.** Percentage of cumulative weight loss (CWL) in hog plum fruits over a five-day storage period

CONCLUSIONS

This study provided information about the bruise damage susceptibility of Hog plum fruit at impact levels at different ripening stages and drop platforms. The findings revealed that impact energy is the main parameter in the bruise damage potential of hog plum at different ripening stages on metal, foam and paper platforms. The increase in drop impact level (or impact energy) increased the potential for bruise damage to occur on the fruit. Therefore, the first step to reducing bruise damage incidence could be to minimize impacts during fruit harvesting and postharvest handling. Based on the bruise damage size (bruise volume and bruise area) which is the most reported measure of the amount of bruise damage, 'ripe fruit on a metallic platform was the most susceptible to bruising which was attributed to the hardness of the surface, and the softness of the skin than 'about to ripe' and unripe samples. The bruise damage was also higher on metal platform, than on paper and paper is higher than that on foam of 15mm thickness. This finding suggests that when hog plum is to be harvested, a padded container of about 15mm thickness of foam can protect against bruises that can accelerate postharvest losses. An increase in these physiological responses was influenced by impact levels which had a crucial effect on bruise intensity and the fruit temperature. The effects of bruising on the metabolic responses were more pronounced in fruit stored at ambient temperature (27± °C) than those stored at cold (5 ±2°C) temperature. Overall, this study has provided new evidence on the bruise damage susceptibility of hog plum fruits to assist in better postharvest handling practices to reduce fruit losses due to mechanical damage. It can be recommended that further research of the bruise susceptibility on other tropical fruits such as almond, African star apple and African mango be carried out to see the effect of drop height and various postharvest physiological responses thus reducing post-harvest losses on tropical regions.

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