STUDY OF IMPACT OF FRESH FRUIT BUNCH (FFB) OF PALM FRUITS ON DIFFERENT SURFACES

KAJIAN BENTURAN TANDAN BUAH SEGAR KELAPA SAWIT PADA PERMUKAAN-PERMUKAAN BENDA YANG BERBEDA

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ABSTRAK

Fenomena benturan TBS (tandan buah segar) kelapa sawit pada permukaan tanah, semen, kayu, metal dan TBS itu sendiri dikaji untuk menentukan ketahanan memar dan energi terserap minimum penyebab memar. Dengan menggunakan metode benturan benda jatuh bebas, hasil percobaan menunjukkan bahwa nilai ketahanan memar TBS yang dibenturkan pada permukaan tanah, semen, kayu, metal dan TBS itu sendiri masing-masing adalah 0,1175 J/mm^3, 0,0095 J/ mm^3, 0,0074 J/ mm^3, 0,0089 J/mm^3 dan 0,0077 J/mm^3. Energi terserap minimum penyebab memar dari TBS yang dibenturkan pada permukaan tanah, semen, kayu, metal dan TBS itu sendiri masing-masing adalah 334.46 J, 8.9671 J, 19.401 J, 17.553 J dan 9.5925 J. Terhadap pengaruh kematangan buah, nilai ketahanan memar berubah secara tidak menentu sedangkan nilai energi minimum penyebab memarnya menurun dengan semakin meningkatnya kematangan buah. Untuk menghindarkan kerusakan selama penanganan akibat benturan terhadap lima jenis permukaan tersebut, maka TBS harus dihindarkan dari terpaan energi lebih besar daripada nilai energi minimum penyebab memarnya.

Kata Kunci*:* benturan, ketahanan memar, buah kelapa sawit, permukaan berbeda

ABSTRACT

Phenomena of impact of oil palm's FFB against ground, concrete, wood, metal and FFB surfaces were studied to determine bruise resistance and minimum absorbed energy to cause bruising. Employing free fall and pendulum impact methods, results of the experiment indicated that the values of bruise resistances of FFBs impacted against ground, concrete, wood, metal and FFB surfaces were 0.1175 J/mm^3, 0.0095 J/mm^3, 0.0074 J/mm^3, 0.0089 J/mm^3 and 0.0077 J/mm^3, respectively. The values of minimum absorbed energies to cause bruising of FFBs impacted against ground, concrete, wood, metal and FFB surfaces were 334.46 J, 8.9671 J, 19.401 J, 17.553 J and 9.5925 J, respectively. In respect to fruit ripeness, the change of bruise resistance value followed an uncertain trend whereas the values of minimum absorbed energy to cause bruising decreased with the advance of fruit ripeness. In order to avoid bruising during handling due to impact against those five different surfaces, FFBs must be protected from suffering from energy greater than their minimum absorbed energies.

Keywords: impact, bruise resistance, palm fruit, surfaces

INTRODUCTION

Oil palm fruit (*Elaeis guineensis* Jacq) is one of significant commodities in Indonesia where in term of CPO production, now, this country is the biggest with 22.5 million tonnes (GAPKI, 2011). During harvesting and handling, oil palm fruit suffers numerous impacts. Impacts may commence when a fresh fruit bunch (FFB) falls down striking ground's surface during harvesting. Handling causes fruits (in or off bunch) subjects to impact of each others or impact between fruits and various surfaces of equipment and handling facilities resulting fruit damage in the form of bruising. Bruising due to impact is expected to be significant since a FFB can weigh between 10 to 40 kilograms. This mechanical incidence causes economical losses in two modes. Firstly, bruising allows the content of cells of the influenced tissues, which is mainly oil, to escape. So this is material loss. Secondly, when bruising occurs, the influenced tissues make contact to oxygen resulting in an increase in free fatty acid (FFA) which is the main criterion of crude palm oil (CPO). The higher fruit damage due to bruising, is the higher of the FFA content of CPO and the lower of the CPO quality. Quality threshold for FFA is 0.5% (Amir, 1999). Softer fruit tissues will be in risk of higher fruit damage due to impact. In order to eliminate or minimize damage caused by impact, impact phenomena of FFBs against different surfaces need to be studied.

Bruising is associated with extensive damage to tissue due to cell bursting (Holt and Schoorl, 1982). A bruise can be detected from the

**Penulis untuk korespondensi*

softening and brown colour of the affected tissue. According to Ruiz *et al.* (1989), softening is caused by degradation of the cellular walls and the middle lamellae by different enzymes, while browning is known to be due to oxidation of polyphenols, in the presence of the enzymes polyphenoloxydases (PPO). Furthermore, they noted that although oxygen exists primarily in the intercellular spaces, it is still doubtful concerning the actual site where the oxidative reaction occurs.

Mechanically, bruising begins when the shear stress reaches a certain value (Mohsenin, 1986). Because of this, the critical shear stress may be defined as the current bruising strength (Holt and Schoorl, 1982). For any material, there will be limits to normal and shear stresses which can withstand, and these will correspond to bruising strengths. Shear failure (bruising) is dependent on the maximum difference in normal stress, and independent of the absolute value of the normal stresses. Within the failure diagram for solid materials, for a rising load, as the stresses on the material increase, the mode of failure will be determined by which strength boundary is encountered first (Mohsenin, 1986). If the size of the Mohr's circles increases due to increasing differences in stress and reaches a boundary on the shear stress exist first, bruising occurs (Holt and Schoorl, 1982).

There have been a large number of studies on the incidence of bruising using static and dynamic tests. Dynamic tests have been performed by employing various impact devices. The most common modes are freely falling samples (Klein, 1987; Yuwana and Duprat 1996; Yuwana and Duprat, 1997), a pendulum drop test (Topping and Luton, 1986), driving indenter or projectile (Holt and Schoorl, 1977) and a falling mass which impacts the sample (Chen and Sun, 1981; Salveit, 1987).

It has been demonstrated that biological materials exhibit viscoelastic behaviour and are therefore sensitive to loading rate (Mohsenin, 1986). For example, at the same impact energy, fruit (apples) experienced more severe damage under slow loading (Holt and Schoorl, 1977). Holt and Schoorl (1977) found that there was strong correlation between bruise volume and absorbed energy for both impact and slow compression of apples. Furthermore, Schoorl and Holt (1980) introduced the bruise susceptibility coefficient with unit mL/J, determined by dropping fruits on to a flat surface of material. They claimed that the bruise susceptibility coefficient was effective in predicting bruise damage and in the evaluation of packaging, handling and distribution systems for the fruits they studied. On the other hand, bruise resistance was also popularly utilized by researchers. Bruise resistance is the slope of graph obtained from the relationship between absorbed energy and bruise volume, in which bruise volume as X-axis and absorbed energy as Y-axis. Intercept of the graph with Y-axis represents minimum absorbed energy to cause bruising.

This research studies the phenomena of FFB impacting to different surfaces (ground, concrete, wood, metal and other FFB) with the objectives to determine bruise resistances and minimum absorbed energies bruising, and to explore the effect of fruit ripeness on the values of these two parameters.

MATERIALS AND METHOD

Material

Ripe fresh fruit bunchs (FFBs) of oil palm fruit, Tenera cultivar harvested from the same field were used in the experiments. The fruit fractions were identified according to the classification standard (Naibaho and Taniputra, 1986) presented in Table 1. As indicated by the table that ripe fruits were fruits of fraction1, 2 and 3.

Method

The experiments consisted of three series, i.e. impact of FFBs against field's ground, impact of FFBs against concrete, wooden and metal surfaces, and impact between FFBs.

Impact FFBs Against Ground

Apparatus to produce impact consisted of two parallel pillars, 1 m separated and 13 m high, jointed with horizontal beam on the upper sides. A roller bearing installed in the center of the beam was used to raise a strong nylon string tied to a FFB at its lower end, so that the FFB was raised when the upper end of the string was dragged. One of the pillars was equipped with two scales: one scale to adjust drop height of FFB and the other scale to help measuring the rebound height of FFB.

Table 1. Ripening standard criteria for bunch of oil palm fruit

Ripening Level	Fraction	Fruitlet off bunch	Criterion
Unripe	00	No fruit	Cat eye
	0	1-12.5% outer layer fruits	Unripe
Ripe	1	12.5-25% outer layer fruits	Ripe
	2	25-50% outer layer fruits	Ripe 1
	3	50-75% outer layer fruits	Ripe 2
Overripe	4	75-100% outer layer fruits	Overripe 1
	5	Several inner layer fruits	Overripe 2

During operation, the FFB was raised to a chosen drop height by dragging the string up, and was then dropped striking the ground by releasing the string. A video camera was prepared to record the impact of FFB against the ground in order to determine the rebound height made by the FFB by replying the recorded video. Impact energy and absorbed energy were calculated using formula as follow:

Impact Energy (J) : $E_i = wh_1$ …………………. (1)
Absorbed Energy (J) : $E_a = w(h_1-h_2)$ ………..... (2)

where w = weight of sample, w = m.g., m = mass of sample, g = gravity constant, h_1 = drop height (m), h_2 = rebound height (m).

To determine representative bruise volume and minimum absorbed energy to cause bruising, 22 FFBs were prepared and dropped from 2-12 heights, with 1 m interval and 2 FFBs. On the other hand, the effect of fruit ripeness on the values of bruise resistance and minimum absorbed energy were studied by preparing 11 FFBs of fraction 1 and 11 FFBs of fraction 3, and were also dropped by using the same techniques. All impacts were recorded and then the recorded videos were replied in a computer to determine the rebound heights.

Impact of FFBs Against Concrete, Wooden and Metal Surfaces

A pendulum impact method was employed in this experiment. A FFB hung to the wall with a string functioned as pendulum. The string was very light but strong so that its weight was neglected. The wall was equipped with a circular scale so that the impact angle of FFB could be controlled. By using that scale, the rebound angle of FFB was also identified after impact incidence was recorded. A concrete block having 10 cm thickness, 2 cm thickness of wooden surface, and 3 mm thickness of metal plate were prepared as impacted surfaces. During operation, one type of surface was placed firmly on the wall on which the FFB would strike. The pendulum was set at certain drop angle and then released to strike the surface on the equatorial part of the FFB. The impact was recorded to determine the rebound angle later on. Impact and absorbed energies were calculated as follow:

$E_i = m.g.R\,(1-\cos\alpha)$ …................................ (3)

$E_r = m.g.R.(1-\cos\alpha_1)$ .... (4)

$E_a = E_i - E_r$ .... (5)

where E_i = impact energy (J), E_r = rebound (J), E_a = absorbed energy (J), R = length of string (4 m), α = impact angle (º) and α_1 = rebound angle (º).

Numbers of FFB samples used in this experiment in respect to the impact angles chosen and surfaces were presented in Table 2.

Impact Between FFBs

A pendulum drop test was also utilized to carry out impact between FFBs. Two FFBs (FFB1 and FFB2) were freely hung using two strings on a horizontal beam situated at 2.5 m height. The beam was equipped with a circular scale where the center of this scale was fitted exactly at the upper ends of those two strings. This scale was used to adjust impact angle and to help in recording rebound angle. During operation FFB2 was dropped from predetermined impact angle struck FFB1. Fruit setting was made so that collision occurred on the equatorial parts of two FFBs. Rebound angle demonstrated by string of FFB1 run a long the scale was recorded by using video camera. Impact energy was calculated from equation (3) by using mass of FFB2 while rebound energy was calculated from equation (4) by using mass of FFB1. Here, length of string depended on each impact setting in respect to the variation of fruit sizes. Number of FFBs sample used in this experiment in associated with the impact angles chosen and surfaces was presented in Table 3

Table 2. Numbers of FFBs corresponding to impact angles chosen and surfaces

Surface	Impact angle (°)	Number of FFBs		
		Fraction 1	Fraction 2	Fraction 3
Concrete	10	1	1	1
	20	1	1	1
	30	1	1	1
	40	1	1	1
	50	1	1	1
Wood	10	1	1	1
	20	1	1	1
	30	1	1	1
	40	1	1	1
	50	1	1	1
Metal	10	1	1	1
	20	1	1	1
	30	1	1	1
	40	1	1	1
	50	1	1	1

Table 3. Number of FFBs respecting impact angle and impact combination between fractions

Impact Angle (°)	Number of FFBs					
	Impact Combination 1		Impact Combination 2		Impact Combination 3	
	Impacted Fraction Fraction1	Impacting Fraction Fraction 1	Impacted Fraction Fraction1	Impacting Fraction Fraction 2	Impacted Fraction Fraction1	Impacting Fraction Fraction 3
15	1	1	1	1	1	1
30	1	1	1	1	1	1
45	1	1	1	1	1	1
60	1	1	1	1	1	1
75	1	1	1	1	1	1

Every impact was recorded to measure its rebound angle. All impacts were used to determine the representative bruise resistance and minimum absorbed energy to cause bruising, and then impacts of FFBs fraction1 versus fraction1 and impact of FFBs fraction1 versus fraction2 were analyzed separately to investigate the effect of impact of different fruit ripeness.

Resulted bruises of every impact for all experiments were quantified from bruise of individual fruitlet collected from the bruised part of FFB. The formula utilized in calculation was:

$$V = (1/6)\ (\pi\ d^2 t) \qquad (6)$$

where V bruise volume (mm^3), d and t were bruise diameter and bruise depth, respectively, in mm.

RESULTS AND DISCUSSION

Figure 1 presents the relation of bruise volume and absorbed energy of impacting FFBs against field's ground, indicating that bruise resistance and minimum absorbed energies to cause bruising were 0.1175 J/mm^3 and 334.46 J, respectively.

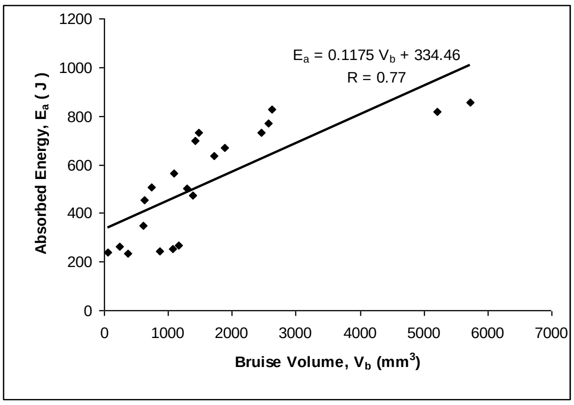

Figure 1. Relation of bruise volume and absorbed energy of impacting FFBs against field's ground

Figure 2 indicates that fruit ripeness influenced the values of these two parameters. The value of bruise resistance increased from 0.1127 J/mm^3 to 0.1265 J/mm^3 whereas the value of minimum absorbed energy to cause bruising decreased from 373.58 J to 286.11 J when fruit ripeness changed from fraction 1 to fraction 3.

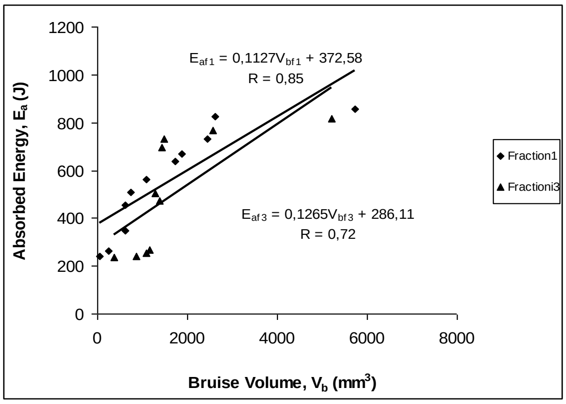

Figure 2. Relation of bruise volume and absorbed energy of impacting FFBs against field's ground in respect to different fruit ripeness

Figure 3 shows the relation of bruise volume and absorbed resulted from impacting FFBs against concrete, wooden and metal surfaces. The relations produced values of bruise resistance for concrete, wood and metal 0.0095, 0.0074 and 0.0089 J/mm^3, respectively while the corresponding values of minimum absorbed energy to cause bruising were 8.967, 19.404 and 17.553 J, respectively. The changes of these values because of the change in fruit ripeness from fraction 2 to fraction 3 were demonstrated by Figures 4, 5 and 6, and described as follows.

For concrete, the bruise resistance increased from 0.007 to 0.009 J/mm^3 whereas the minimum absorbed energy to cause bruising decreased from 15.01 to 9.997 J. For wood, the bruise resistance decreased from 0.0075 to 0.0069 J/mm^3 whereas the minimum absorbed energy increased from 12.25 to 15.391 J. For metal, the bruise resistance increased from 0.0074 to 0.0083 J/mm^3 whereas the minimum absorbed energy to cause bruising decreased from 26.708 to 0.9157 J.

The relation between bruise volume and absorbed energy for the impact between FFBs was shown in Figure 7. This figure indicates that the values of bruise resistance and minimum absorbed energy to cause bruising were 0.0077 J/mm^3 and 9.5925 J, respectively. The bruise resistance and minimum absorbed energy to cause bruising of FFBs fraction1 impacted against FFBs fraction 1 were higher than those of FFBs fraction 2 impacted against FFBs fraction1 as demonstrated by Figure 8.

The results suggested that, in general, the values of bruise resistance and minimum absorbed energy to cause bruising were varied among the surfaces. In respect to fruit ripeness, the change of bruise resistance value followed an uncertain trend whereas the values of minimum absorbed energy to cause bruising decreased with the advance of fruit ripeness.

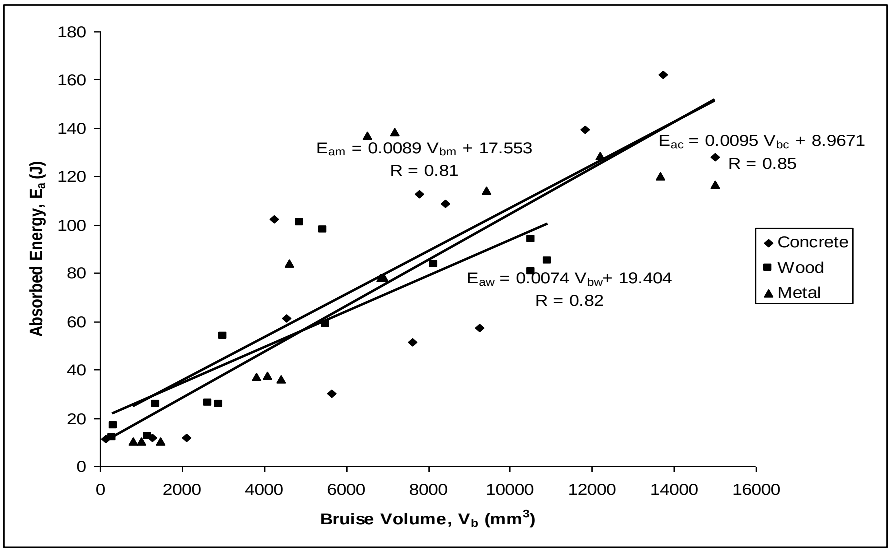

Figure 3. Relation of bruise volume and absorbed resulted from impacting FFBs against concrete, wooden and metal surfaces

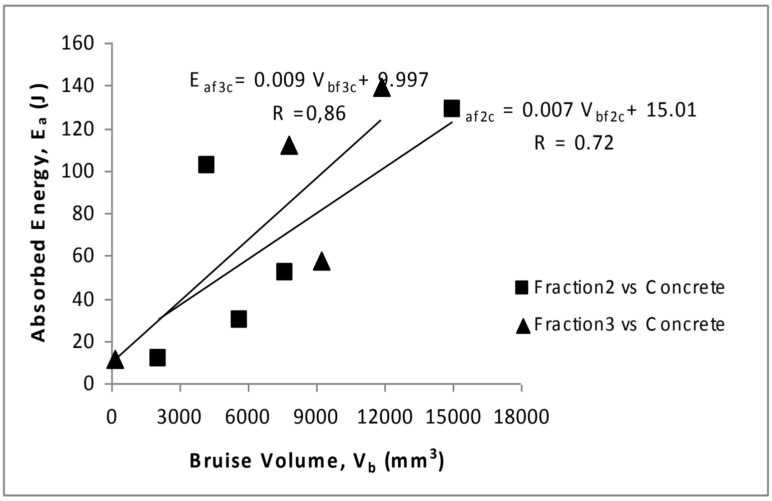

Figure 4. Relation of bruise volume and absorbed resulted from impacting FFBs against concrete surface in respect to different fruit ripeness

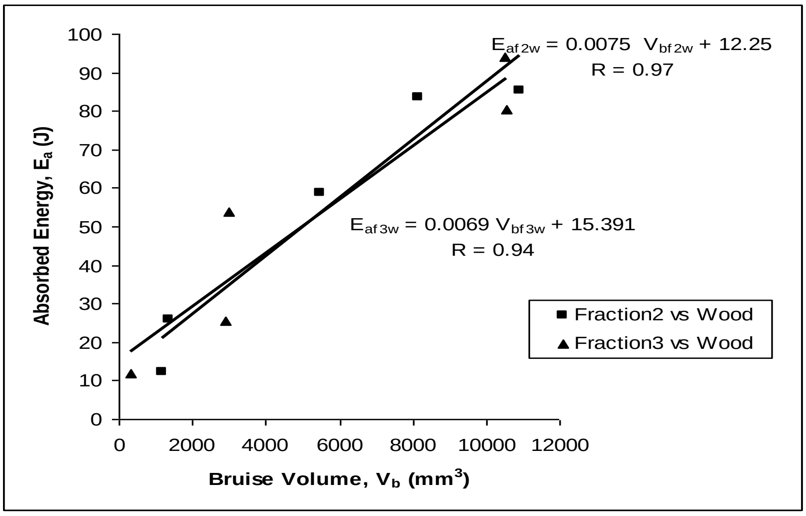

Figure 5. Relation of bruise volume and absorbed resulted from impacting FFBs against wooden surface in respect to different fruit ripeness

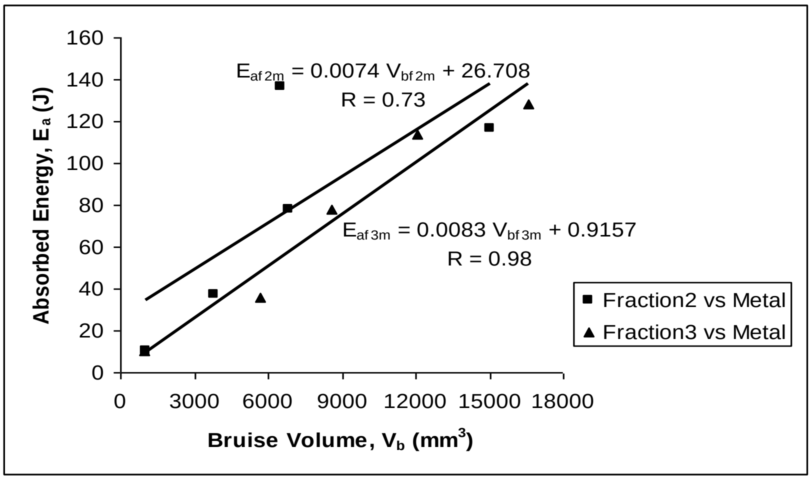

Figure 6. Relation of bruise volume and absorbed resulted from impacting FFBs against metal surface in respect to different fruit ripeness

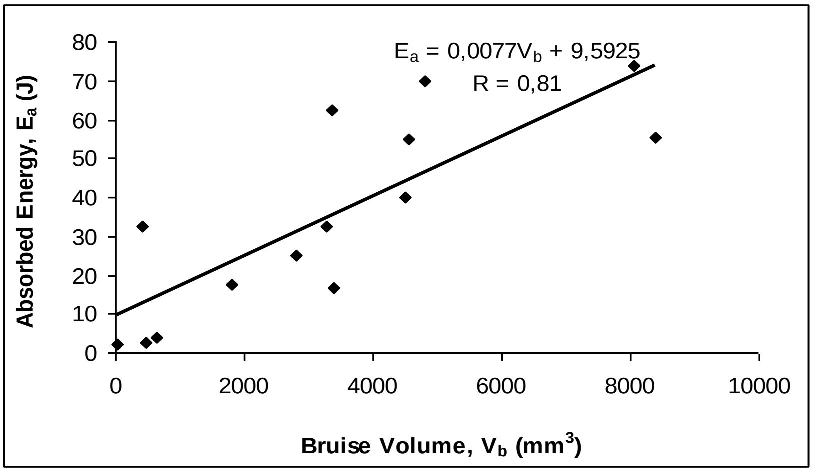

Figure 7. Relation between bruise volume and absorbed energy for the impact between FFBs

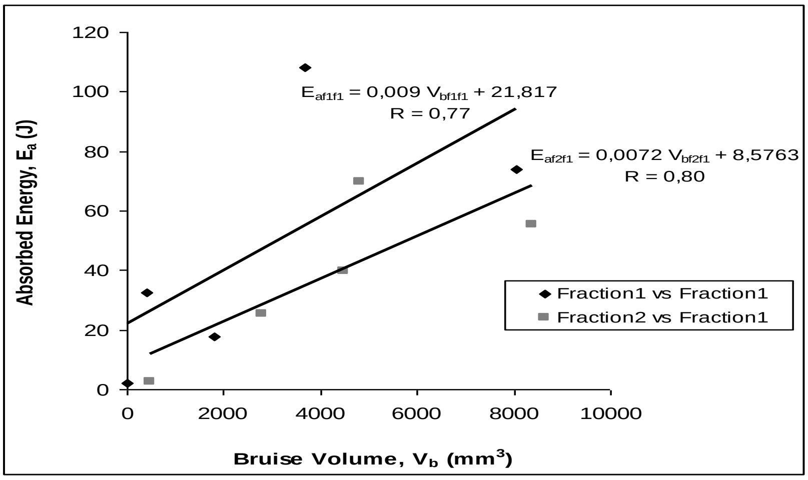

Figure 8. Relation between bruise volume and absorbed energy for the impact between FFBs in respect to different fruit ripeness

CONCLUSIONS AND RECOMMENDATION

Conclusions

Based on the above results, conclusions can be formulated as follows: (a) The values of bruise resistance of FFBs impacted against ground, concrete, wood, metal and FFB surfaces were 0.1175 J/mm^3, 0.0095 J/mm^3, 0.0074 J/mm^3, 0.0089 J/mm^3 and 0.0077 J/mm^3, respectively; (b) The values of minimum absorbed energy to cause bruising of FFBs impacted against ground, concrete, wood, metal and FFB surfaces were 334.46 J, 8.9671 J, 19.401 J, 17.553 J and 9.5925 J, respectively; and (c) In respect to fruit ripeness the change of bruise resistance value followed an uncertain trend whereas the values of minimum absorbed energy to cause bruising decreased with the advance of fruit ripeness.

Recommendation

It is recommended that to avoid bruising on palm fruit during handling due to impact against ground, concrete, wood, metal and FFB surfaces; the fruit must be protected from suffering energies of 334.46 J, 8.9671 J, 19.401 J, 17.553 J and 9.5925 J, respectively.

ACKNOWLEDGEMENTS

Acknowledgment addresses to Directorate of Research and Community Services Affairs, Directorate General of Higher Education, National Education Department, the Government of Indonesia.

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