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Andreas Wahyu Krisdiarto
Faculty of Agricultural Technology, Institut Pertanian Stiper (INSTIPER), Yogyakarta 55282, Indonesia, andre0402@yahoo.com

Lilik Sutiarso
Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

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Study on Oil Palm Fresh Fruit Bunch Bruise in Harvesting and Transportation to Quality

Andreas Wahyu Krisdiarto[1*] and Lilik Sutiarso[2]

1. Faculty of Agricultural Technology, Institut Pertanian Stiper (INSTIPER), Yogyakarta 55282, Indonesia
2. Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

[*]*e-mail: andre0402@yahoo.com*

Abstract

There are losses of production due to oil palm field's material handling. Activities that may raise the losses are harvesting and transportation, which may cause bruise and damage to fruit. This research was aimed to learn the bruise of fresh fruit bunch (FFB) phenomenon in harvesting and transportation. Method used in this research was measuring the bruise area resulted by FFB falling when harvested, loading (throwing up) FFB to truck bin, and transporting using truck. These data, coupled with weight of bruised fruit, were calculated to get FFB bruise index. Each FFB bruise index is related to potential free fatty acid (FFA) value. FFA is one of important quality indicator of crude palm oil. The harvesting was conducted at mineral land and peat land, and the loading and transportation was conducted using wooden board truck and dump (iron board) truck. There was a difference between bruise index and FFA of FFB fall on mineral and on peat land. FFA of mineral land harvesting was 2.19% while of peat land was 1.27%. It was obvious that fruit quality degradation was higher when FFB positioned at the bottom of bin truck layer rather than at the top. FFA of truck bin bottom layer was 2.79% while of top layer was 0.64%. It was found that there was a cumulative bruise on FFB within material handling, start from harvesting, loading up to truck bin, and transporting from field to loading ramp.

Abstrak

Dampak Hubungan antara Penyalur dan Produsen terhadap Kinerja Rantai Pasokan Industri Manufaktur di Indonesia. Kajian ini bertujuan untuk menggambarkan hubungan antara komitmen, komunikasi, kepuasan, kepercayaan, serta kualitas hubungan antara penyalur dan produsen dan kinerja rantai pasokan. Populasi di dalam penelitian ini adalah perusahaan-perusahaan manufaktur di Indonesia. Responden di dalam penelitian ini adalah pejabat-pejabat eksekutif tertinggi, sekretaris-sekretaris perusahaan, atau manajer-manajer yang ditunjuk dan terlibat di dalam proses pembuatan kebijakan strategis perusahaan. Sampel diambil menggunakan teknik sampel acak wilayah proporsional. Structural equation modeling (SEM) atau pemodelan persamaan struktural digunakan di dalam analisis. Hasil dari pemeriksaan langsung atau pun tidak langsung terhadap hipotesis-hipotesis menunjukkan bahwa dua hipotesis bersifat positif dan berdampak signifikan, sedangkan sembilan hipotesis bersifat positif tetapi berdampak tidak signifikan. Dua hipotesis yang bersifat positif dan berdampak signifikan itu adalah dampak langsung dari kepercayaan terhadap kinerja alur persediaan dan dampak langsung dari kualitas hubungan antara penyalur dan produsen terhadap kinerja alur persediaan.

Keywords: bruise index, free fatty acid, oil palm

1. Introduction

Indonesia has the largest oil palm plantations in the world. It has 7.3 M ha oil palm plantations, which produce 21.511 Mtons crude palm oil (CPO) in 2009. 15.5 Mtons of those productions were exported to many countries, such as China and India. The exported palm oil (CPO) value was about US$ 9.144 M/year [1]. Oil palm trees planted in tropical country like Indonesia have a potential yield of FFB 35.4 tons/ha/year. Referring to laboratory oil extraction rate, which is 30%, those potential FFB may be processed to 10.6 tons/ha/year crude palm oil. This output can be reached if there are best agricultural practices and material handling. The quality of FFB is important because it affects oil palm FFB processing. Low quality FFB requires higher effort in oil palm processing in attempting palm oil quality standard. The main parameter in palm oil quality is FFA content. The higher the FFA content, the worse the quality. Naturally, the FFA is in the fruit cell and will be released when cell wall is broken, i.e. during fruit maturity period. The FFA content of undamaged oil palm fruit is 0.2-0.7% before harvested, and it increases 0.1%/24 hours after it falls down to the ground [2]. Unfortunately, inappropriate fruit handling often bruises the fruit and damages the fruit cell wall. This results in increment of FFA content. The FFA content of bruised fruit may increase from 1% to 6% within 20 minutes [3]. On the other hand, FFB should has no more than 3% FFA when it comes to processing line, in order to get CPO with FFA content no more than 5%.

Some researchers have studied about oil palm FFB damage in the field [4-7], but there is a need to study the FFB bruise caused by each step during field material handling and its relationship to FFA content. The field's material handling that may raise the fruit losses are harvesting and transporting. These activities, which are full of physical work, are potential in injuring the fruit [4]. As the height of oil palm trees and heavy weight of FFB, FFB sometimes suffer high impact when harvested. Particularly on hard soil type or when there are rough materials below the tree, there is a risk for fruit to be bruised when falling down. During transportation, there is also a potential damage to the fruit. Throwing, loading, vibrating, and dropping of fruit may cause bruise/damage. Due to the significance of the fruit bruise to the palm oil raw materials quality, it is important to identify and study every work in FFB handling. This will guide oil palm planter in managing the harvesting and transporting activities in order to lessen FFA content of FFB.

2. Methods

This research was conducted in May-August 2013, and used oil palm fresh fruit bunch was used as a main object to be observed at PT. XXX, an oil palm plantation company in West Sulawesi. The FFB was harvested and transported from the field to the crude palm oil factory. The research observed bruise or damage of fruit at each harvest and post harvest step, i.e. harvesting, manual transportation form field to fruit collection point (FCP), and transportation from FCP to factory loading ramp. As research treatments, the harvesting was done for some variety in tree height, and on mineral soil as well as on peat soil.

Sample. Sample in this research was taken randomly, in harvested oil palm field. There were 20 data taken at each harvesting and transportation treatment.

Methods. Study on this research was done by applying two treatment of land, i.e mineral land and peat land. Oil palm tree height treatments were 2-4 m, 5-7 m, and 10-12 m three treatments of tree height, various heights of trees, various distance of block transportation, and two treatment of truck. Oil palm. Various distance of block transportation were 50, 100, 150, and 200 m. Treatment of transportation refers to position of FFB at truck bin layer, whether at top layer or bottom layer.

Data analysis. The data collected was analyzed statistically and graphically. The statistic method used was t-test. Graphical analysis was used to find correlation between independent factor, such as tree height and FFB weight, as well as level of bruise and FFA content. Level of bruise was calculated by measuring bruise area (cm^2) and fruitlets weight (g). The bruise index that can be related to FFA was classification and formula defined by Hadi [8]: A) sound fruits, no skin break, corresponding to bruise index (BI) of 1; B) minor bruised fruits, total bruise area of less than 1 cm, corresponding to BI of 2.5; C) moderate bruised fruits, total bruise area of 1–2 cm, corresponding to BI of 5.5; D). major bruised fruits, total bruised area of more than 2 cm, corresponding to BI of 10.

$$Bruise\ Index(BI) = \frac{1X_1 + 2.5X_2 + 5.5X_3 + 10X_4}{100}$$

Where X_1, X_2, X_3 and X_4 were the percentage weight of the fruits with no bruises (A), minor bruise (B), moderate bruise (C) and major bruise (D) respectively (see Figure 1). Bruise index was 1 if the whole lot consisted of unbruised fruits only, but it would be 10 if this lot was made up of fruits with major bruise.

The formulas used to predict FFA from bruise index were:

FFA (just ripe*) = 0.122 + 0.502 BI; (r = 0.823)
FFA (ripe**) = 0.76 + 1.287 BI; (r = 0.905)

* Just ripe FFB: 25–50% of its outer layer fruitlets loose from the FFB
** Ripe FFB: 50–75% of its outer layer fruitlets loose from the FFB. [9]

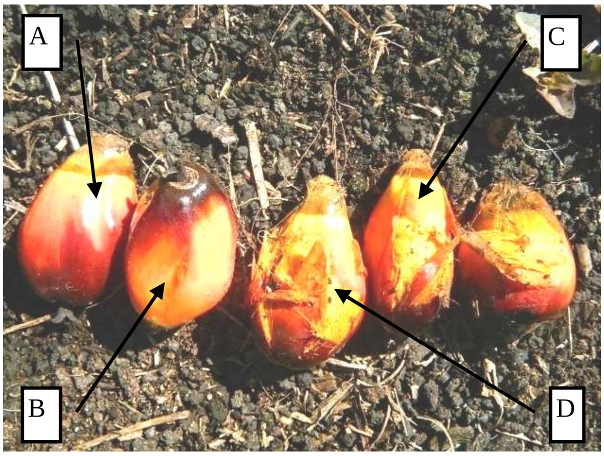

Figure 1. Fruitlets of Harvested FFB: A. No bruise, B. Minor Bruise, D. Major Bruise

3. Results and Discussion

Oil Palm is a plant that gives relatively high output per ha per time. Its fruit is arranged in a bunch that can reach 45 kg in weight. The first harvesting fruit (i.e. of 3 years old plant) may be processed in palm oil factory, and the FFB weight is about 3 kg. In an optimum cultivated land, the yield of 15 years old tree is about 2 - 2.25 tones/ha/month. Generally oil palm plantation is divided into blocks with 30-40 ha width that consists of about 4080-5400 trees. That bulky yield needs good material handling in order to keep the quality of fruit as a palm oil raw materials. The heavier the FFB is, the more likely for impact or friction to occur. The bruises or injuries of fruit speed up FFA content, which is a restriction of palm oil quality.

FFB quality degradation due to bruise in harvesting. Harvesting experiment was conducted for various tree heights, i.e. 2-10 m. Data collected showed that FFB bruise caused by harvesting fall was different for mineral land and peat land (ρ=0.015 on t-test). The average FFA of on-mineral harvested FFB was 2.31% while on-peat land harvested FFB was 1.34%. On mineral land, the FFB bruise area caused by falling down when harvesting was larger. The percentage of moderate and major bruise was higher, which gave rise to higher bruise index. Generally, mineral land is harder than peat land. This potentially caused larger bruise on FFB harvested. FFB average weight of 8 year-old oil palm trees was about 15 kg. As this tree height was about 7 m, the falling force was 1030 N. The impact resulted was higher when FFB fall down on mineral soil, which is harder than peat land. Peat land has sponge like characteristic, which can reduce force impact.

The number of bruised fruitlets was higher when there were fruitlets that prolapsed by FFB. These fruitlets dropped itself due to maturity or separated from FFB when it was harvested.

This research also observed the effect of tree height to fruitlets bruise level. The observation was done to FFB harvesting at various oil palm tree height on mineral land, from 2-10 m. The relationship can be depicted by equation: y=1.585x+11.62.

Data collected showed that there was Bunch Average Weight (BAW) increase for taller trees (Figure 2). Naturally, the older the trees, the higher they were. Oil palm tree has bigger and heavier bunch when it is older. It may have 3 kg FFB when it is 3 years old, to 35 kg FFB when it is 15 years old [10]. This different height potentially causes different impact on FFB. The fruitlets bruised area will be wider when they hit by bigger impact. Moreover, according to Hadi [8], wider bruise means higher bruise index, and it would relate to higher content of FFA. Graph in Figure 3 showed that FFA content resulted by bruise was higher for taller trees. The fruitlets suffered more bruises if FFB fell on trunk. This sometimes happened when the trunk is crooked. Many fruitlets or even FFB were damaged when the FFB dropped to the trunk or other hard material such as stone, oil palm stem, or stump. Therefore, it is important to keep oil palm field free of these materials and to attempt to straighten the trees growth. The straight growth of oil palm tree was one of important issues in planting oil palm on peat soil, due to its low supporting capacity. Normally, the fruit bruise of FFB harvested on peat land was smaller than on mineral land.

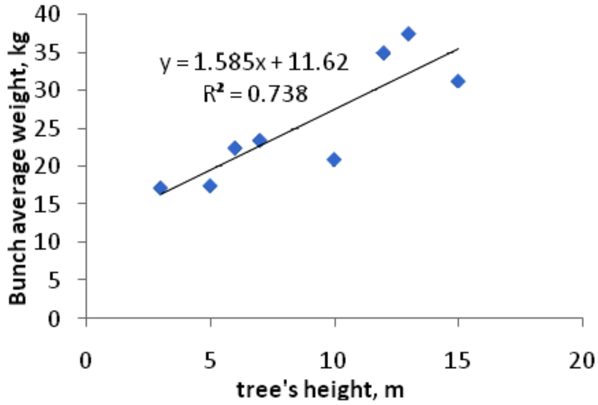

Figure 2. Bunch Average Weight (BAW) on Different Harvested Oil Palm Tree's Height

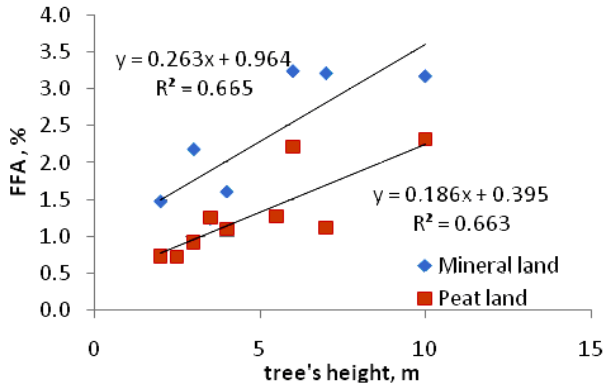

Figure 3. FFB's FFA Content in Relation with Oil Palm Tree Height, and Comparation between on Mineral Land Harvesting and on Peat Land Harvesting

However, if there were many crooked trunks, and FFB fell down on the trunk, the possibility of fruit damage was higher. The fruit surface bruise was cell wall damage, which free the free fatty acid. Naturally, this FFA would release from cell when the fruit was overripe. The relationship between FFA and tree's height can be illustrated by equations; y=0.263x+0.964 for mineral land and y=0.186x+0.395 for peat land.

FFB quality degradation due to bruise within field handling. After harvested, FFB was carried to FCP using rickshaw. This lifting and dropping activities sometimes contributed to fruit bruise, due to the drop impact, friction among FFB, and friction between FFB and rickshaw. Figure 4 shows the relationship of block transportation and quality degradation. There was no clear bruise index increment when tree-FCP distance increased, which had almost same FFA content. As the oil palm plantation block width was generally 300m x 1000m, the in-block FFB transportation could be 500 m. Nevertheless, graph in Figure 4 suggests that in-block transportation should be handled carefully in order to minimize fruit damage, particularly when there were bumpy path. Overload rickshaw also contributed to fruit bruise, because there was more load to FFB in rickshaw's undercoat, which resulted in higher friction and impact.

Observation of fruit bruise on FFB dropping from rickshaw to FCP showed that there was no significance correlation between bunch weight and bruise index and FFA content. It means that the bruise caused by FFB dropping from rickshaw was relatively the same, whether the FFB was heavy or light. More bruise potentially occurred in fruit handling at FCP, i.e. when harvester arrange FFB sequential lineup. In this activity harvester might lift, drag, and drop the FFB. Probability of dragging and dropping is higher for heavier FFB, due to the difficulty in lifting the FFB (Figure 5).

FFB quality degradation due to bruise in transportation. The activity that has high possibility to damage fruitlets is FFB loading to truck bin from FCP. Although there are some oil palm plantation companies that use net and bin system to avoid FFB throwing, today, the majority of FFB loading system in Indonesia is throwing FFB manually to the truck bin. The FFB, which has 5-40 kg weight, is thrown to the truck bin, which has about 1.9 m height. The FFB drops to truck bin base or FFB layer. The impact of this drop is suffered by fruitlets surface. The impact is highest for the first layer thrown, because FFB falls to truck bin base, which is made from wood or iron/steel (Figure 6). The impact on upper layer thrown may be lower due to the FFB fall on previous thrown FFB.

Graph in Figure 7 shows that fruit quality degradation, which can be identified by FFA content, at truck bin bottom layer was higher than at top layer. This indicated that fruitlets suffered higher impact when thrown to first

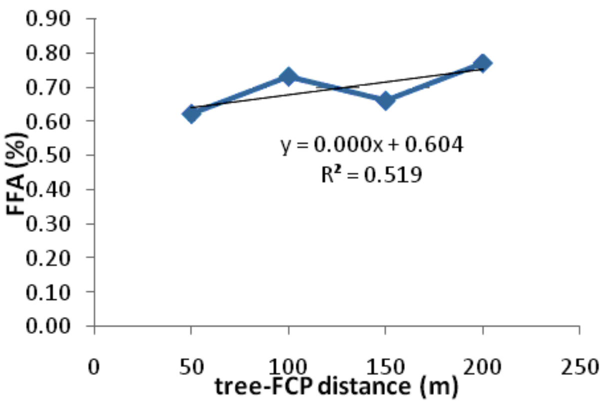

Figure 4. FFA Content of Fruit that Transported from Tree to Fruit Collection Point (FCP/*TPH*)

Figure 5. Dropping the FFB at FCP/*TPH*

Figure 6. Manually Loading FFB to Truck Bin (Throwing Up)

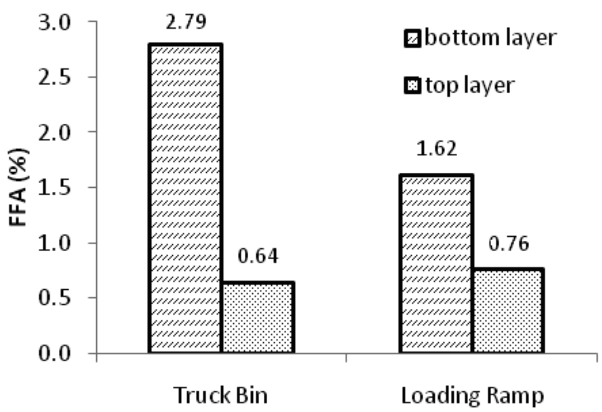

Figure 7. FFA, as a Result of FFB Bruise, Observed in Truck Bin and in Loading Ramp

layer and fall down to truck bin base. The upper and top layers had 'cushion', i.e. previous FFB layer. The lower layer of FFB functioned as dampers, which reduced damaging impact or vibration. This was because every agricultural product has spring properties [11-12]. This result was also in accordance with Yuwana research [7], which found that impact energy and absorbed energy have linear correlation with fruit damage volume.

Comparison of fruit bruise between in truck bin and in loading ramp indicated that the FFB bruise in loading ramp was lower than in truck bin (ρ value of t-test = 0.036). Fruit bruise between the two conditions of top layer FFB was almost the same (ρ value of t-test = 0.095). This fact means fruit damage caused by throwing was higher than vibration on transporting FFB from FCP to loading ramp.

Observation on activity series, i.e. from harvesting to FFB unloading on loading ramp, showed that there was an obvious increase of fruit bruise, which was related to FFA content. Bruise at harvesting was due to dropping impact of FFB on land. The quality degradation, which was indicated by FFA content, increased significantly in series activities from collecting at FCP, loading to truck, and unloading on loading ramp at palm oil factory. It means that quality degradation in prior activity affects the next. Accordingly, it is recommended that FFB should be handled carefully in order to resist quality reduction. The harvester and fruit loader should avoid high impact when dropping and throwing the fruit. The fruit collector and transporter should try to lessen the friction and bump among the fruit. In order to get good quality palm oil, it is required that FFB's FFA content at loading ramp to be no more than 3%. As seen in Figure 8, the bruise index of FFB at loading ramp may reach 2.6, which may be related to FFA content as much as 1.5%.

The related research conducted by Krisdiarto [13] indicated that a quantity of leftover FFB on field can be affected by plantation road quality. The worse the road

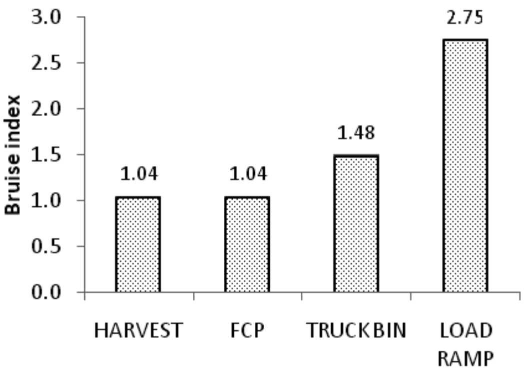

Figure 8. Bruise Index of FFB (Accumulation) from Harvesting to Unloading on Loading Ramp

condition is, the more leftover FFB there is. The leftover FFB would then be processed next time/day. Budiyanto *et al.* [14] found that the delayed processing of FFB may increase FFA content of the fruit. Budiyanto *et al.* [14] stated that the significant increase of FFA occurred during 16 to 24 hour delayed processing of FFB. This suggests the planter to handle the FFB attentively from the early harvesting, collecting, and transporting activities, as well as maintaining the road to always be in good condition.

4. Conclusions

There was different bruise area between mineral land harvested FFB and peat land harvested FFB. This resulted in higher FFA content of FFB harvested on mineral land rather than on peat land. The average FFA of on-mineral harvested FFB was 2.19%, while on-peat land harvested FFB was 1.27%. The taller the oil palm tree, the bigger the bunch average weight. FFA of FFB also tend to be higher at taller tree harvesting. Bruise index and FFA content did not clearly increase as tree-FCP distance increase, and there was no significance correlation between bunch weight and bruise index. In loading process, fruit quality degradation of bottom layer truck bin positioned fruit was higher than of top layer. The FFA content of bottom layer fruit was 2.79% while of top layer was 0.64%. Fruit damage caused by throwing to truck bin was higher than by vibration on transporting, i.e. 2.79%, compared to 1.62%. The quality degradation noticeably increased in series activities from harvesting, collecting at FCP, loading to truck bin, and unloading on loading ramp.

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