Investigation of Oil Palm Empty Fruit Bunch (OPEFB) Embedded with Artocarpus Odorattisimus Mechanical Behaviour as an Alternative Replacement for Raw Material in Wood Industry

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Abstract. This paper presented the investigation of Oil Palm Empty Fruit Bunch (OPEFB) reinforced with Artocarpus Odorattisimus (Mahang/Tarap) board in which fabricated manually using hand lay method and hot pressed in order to determine a suitable alternative fiber board as a replacement for the usage of woods as raw materials in various types of industry. The idea of conducting this research came due to the worldwide community attention on major deforestation which may lead to natural disaster throughout the world. The effects of adding Artocarpus Odorattisimus (Mahang/Tarap) to the oil palm empty fruit bunch (OPEFB) on certain dry weight ratios are being studied and the main objective of this research is to determine certain mechanical properties of the board especially tensile strength to be compared to the pure oil palm empty fruit bunch (OPEFB) board (4.712 N/mm²)[22]. The experimental process is carried out in accordance to test standard of ASTM D3039/3039m-17. Morphological structure study by using Scanning Electron Microscope (SEM) also conducted on the tested samples to further understand the board properties. Practically, aluminium swarf (chips) collected from an automotive production line is less likely to have any contaminants once the lubricants are removed. In theory, metals do not degrade in value and can be used infinitely.

1. Introduction
Forest has been one of precious source of woods since decades ago in which woods has become main raw materials various construction and much more. As the world became more advance in terms of technology, the demands of woods as raw material has arisen to critical level where it gives a big impact on major deforestation. This matter has come into worldwide community attention in which it gives a lot of negatives impact to the world stability. Based on United Nation Foods and Agriculture Organisation (FAO), the global forest reserve worldwide in 1990 is 4128 million ha while in 2015 worldwide forest reserve has decreased to 3999 million ha in which shows a change in percentage from 31.6% to 30.6% throughout stated time period [1]. As for that, an alternative resources are needed to replace woods as main raw materials needed by the global industries while on the same time continuously supporting the technological advancement momentum. Oil Palm Empty Fruit Bunch (OPEFB) board is one of alternative sources that can be introduced as a replacement for woods and throughout time there are lot of experiments carried out using Oil Palm Empty Fruit Bunch (OPEFB) in order to acquire its properties [2-11]. Malaysia alone produced about 30 million tons annually of palm oil biomass in which included fronds, trunks and also empty fruit bunches. On the other hand, the
utilization of the oil palm processing scrap such as empty fruit bunch will gives benefits to the nation [12].

In Malaysia, production of alternatives board as an alternative replacement for woods has been done such as the fabrication of Medium Density Board (MDF) built from Oil Palm Empty Fruit Bunch (OPEFB) incorporated with rubber woods, rice husk, waste paper and much more, but up until now there is no hybridization from Oil Palm Empty Fruit Bunch (OPEFB) incorporated with Artocarpus Odorattisimus been done [13]. [22] in her research titled“ Developing and prototyping new high density board” found out the pure Oil Palm Empty Fruit Bunch (OPEFB) board has a tensile strength of (4.712 Nmm-2) while comparing it with Oil Palm Empty Fruit Bunch (OPEFB) that embedded with waste paper. While tarap/mahang or known as Artocarpus Odorattisimus in which belong to Moraceae plant family where it can be found either growing in wild or been planted in various region in Borneo include Sabah and Sarawak [14]. The fruit has become more popular nowadays as it said to be rich with anti-oxidants sand possess other benefits when consumed [15]. A low density, non-abrasiveness and bio-degradability are among the advantages gained from using oil palm fibres. Hybrid composites which very often combined with natural fibers as Oil Palm Empty Fruit Bunch (OPEFB) usually demonstrates a good mechanical properties [16].

2. Materials and Methods

2.1. Materials

Oil Palm empty fruit bunch (OPEFB) was supplied by Makmal Konkrit, Fakulti Kejuruteraan, Universiti Malaysia Sabah. Artocarpus Odorattisimus (Mahang/Tarap) gathered from Kg. Tagasan Tani, Semporna, Sabah. Urea Formaldehyde that been used as a binder in this research supplied by Sepanggar Chemicals Sdn. Bhd (Sabah, Malaysia).

| Properties              | OPEFB Fibre |
|-------------------------|-------------|
| Density (g/cm3)         | 0.7 - 1.55  |
| Tensile strength (MPa)  | 0.1 - 0.4   |
| Young’s Modulus (GPa)   | 1 – 9       |
| Elongation at break (%) | 8 – 18      |
| Cellulose content (%)   | 49.6        |
| Lignin content (%)      | 21.2        |

Sources: Bismarck A. Mishra S, Lample T. Plant fibers as reinforcement for green composites.
Table 2. Properties of Urea Formaldehyde

| Property                  | Value   |
|---------------------------|---------|
| Viscosity / 30°C          | 164 cps |
| Specific Gravity / 30°C   | 1.1935  |
| pH value                  | 7.6     |
| Free Formaldehyde         | 1.20%   |
| Pot Life                  | 75 Min  |
| Solid Content             | 51.4%   |

Sources: Sepanggar Chemicals Sdn. Bhd, Kota Kinabalu, Sabah, Malaysia.

2.2. Methodology

2.2.1. Specimen Fabrication

Empty fruit bunch as a solid waste from oil palm processing procedure was taken from oil palm mill in a single strands shape and then shredded in order to acquire size ranged from 10mm to 15mm. The fiber, then, was treated by using a mixture of detergent powder in a boiled oil to remove impurities for about approximately 10 minutes. After that, the fibers being rinsed using potable water to remove the detergent and then kept in air tight container in order to avoid additional increase of humidity to the fibers. A branches of Artocarpus Odorattisimus (Mahang/Tarap) tree in age of approximately 10 to 15 years was taken and the chopped by using a chainsaw. The chip as a results from chain sawing process of the Mahang branches in sizes of 10mm to 15mm are collected and then are kept under air tight container to avoid additional moisture to the chip.

A cast iron mould in size of 150mm x 150mm x 150mm selected to fabricate the specimen using hot press method. The empty fruit bunch and Artocarpus oddorattisimus are mixed together in 4 dry weight ratios that is 100:0, 93.3:6.7, 86.6:13.4, 66.7:33.3 (empty fruit bunch : arto) where in total the combination of each ratios will results 100 gram each. The mixture then added with 50 gram Urea Formaldehyde (UF) and blended together so that the Urea Formaldehyde (UF) will able to reach every part of the mixture. The mixture then placed in the hot cast iron mould in which the mould was heated for 24 hours in an oven until it reach 200 °C and then pressed using KENCO compressive strength machine under 300KN load to produce a fibre board in size of 150mm x 150mm x 5mm. The board the reshaped into size of 150mm x 25mm x 5mm in accordance to ASTM D3039/3039m-17. For each type of mixture, there will be 3 specimens prepared.
2.2.2. Specimen Testing
The fabricated specimen of 150mm x 150mm will be reshaped into a size of 150mm x 25mm using universal cutting machine in accordance with ASTM requirements. The reshaped specimen then are tested to gain its mechanical properties using universal testing machine (Tensile). The machine that been used in this experiment is GOTECH/AI-7000M.

After the specimen tested for its tensile properties, the cracked specimen then are brought to Scanning Electron Microscope (SEM) machine in order to investigate the morphological structure of the specimen especially on the cracked area. In this research, ZEISS EVO MA 10 Scanning Electron Microscope (SEM) are used to conduct the image sampling.
3. Result & Analysis

Table 3. Results of Tensile strength Test

| No | Specimen Ratio | Max Load (N) | Tensile Strength (N/mm²) | Elongation (mm) |
|----|----------------|--------------|--------------------------|-----------------|
| 1  | Specimen A     | 579.35       | 3.84                     | 2.89            |
|    | (100g OPEFB: 0g ARTO) |            |                          |                 |
| 2  | Specimen B     | 731.00       | 5.98                     | 1.80            |
|    | (93.3g OPEFB: 6.7g ARTO) |        |                          |                 |
| 3  | Specimen C     | 774.74       | 5.17                     | 2.21            |
|    | (86.6g OPEFB: 13.7g ARTO) |       |                          |                 |
| 4  | Specimen D     | 954.52       | 7.61                     | 2.26            |
|    | (66.7g OPEFB: 33.3g ARTO) |        |                          |                 |

*OPEFB: Oil Palm Empty Fruit Bunch, ARTO: Artocarpus Odorattisimus

3.1. Tensile Test

Based from the plotted graph, the highest tensile strength of the mixture of oil palm empty fruit bunch (OPEFB) and artocarpus odorattisimus (ARTO) gained at specimen D in which the mixture ratios of 66.7% OPEFB to 33.3% ARTO, this followed by specimen B (93.3% OPEFB to 6.7% ARTO), specimen C (86.6% OPEFB to 13.4% ARTO) and lastly is specimen D in which made from pure OPEFB (no addition of ARTO). The results shows that the addition of artocarpus odorattisimus (ARTO) gives significance improvement in terms of tensile strength to the fabricated board. The pure OPEFB board only possess 3.84 Nmm⁻² of tensile strength value while addition of ARTO into the board shows that an increased value of tensile strength on all types of ratios which is Specimen B tensile strength value is 5.98 Nmm⁻², Specimen C tensile value is 5.17 Nmm⁻² and Specimen D tensile value is 7.61 Nmm⁻². This matter of situation also been discussed by H Ku et al. in which said that addition of fiber to composites matrices will improve the tensile strength due to the stiffness value and higher strength of the fibers [17-19].

![Graph of Tensile Strength (N/mm²) against Type of Specimen](image)

Figure 12. Graph of Tensile strength (N/mm-2) against Type of Specimen

By comparing the tensile strength value between the ratios of OPEFB and ARTO (excluding pure OPEFB), it is determined that the more addition of ARTO into the mixture will gives an increase to the tensile strength value of the fabricated board. The results shows that the highest tensile strength value obtained from the specimen in which contain 33.3% of ARTO (Specimen D) that is 7.61 Nmm-2 while the other specimen (specimen B (6.7% ARTO) and specimen C (13.4% ARTO)) although shows an
increase amount of tensile strength compared to pure OPEFB board, still possess lower tensile strength value if compared to specimen D. This matter shows that the addition of artocarpus odorattsisimus into oil palm empty fruit bunch board improve inter locking bonding between materials thus improve its tensile strength [17].

Figure 13. Graph of Load (N) against Type of Specimen

Figure 13 shows the maximum load needed to be applied until the tested specimen reach crack propagation. Based on the chart, it shows the highest maximum load need to be applied is at specimen D (66.7% OPEFB and 33.3% ARTO) that is 954.52 N and followed by specimen C (86.6% OPEFB and 13.4% ARTO) 774.74N, specimen B (93.3% OPEFB and 6.7% ARTO) 731.00N and lastly specimen A (pure OPEFB) 579.35N. From the gathered data, it can be said that the addition of ARTO into the specimen will increase the inter bonding relation within the materials as the maximum load applied keep on increasing as the portion of ARTO increased in the specimen. Irina M.M.W et al [20] stated that hybrid composites has the ability to increase stiffness, reduced weight an also balancing up modulus properties and thus explaining the increasing of applied forces needed to break the specimen.

Figure 14. Graph of Displacement (mm) versus type of Specimen

Figure 14 represents the elongation (displacement) for each type of specimen before break when pulled with certain of forces during tensile testing procedure. Based on the data obtained, specimen A in which made from 100% pure OPEFB gives the longest elongation that is 2.89 mm before the specimen
started to break, this followed by specimen D (66.7% OPEFB and 33.3% ARTO) have an elongation of 2.26 mm before breaking, specimen C (86.6% OPEFB and 13.4% ARTO) 2.21 mm and lastly specimen B (93.3% OPEFB and 6.7% ARTO) which gives the lowest elongation among all the tested specimen that is 1.8 mm. According to the data, it is clear that the addition of artocarpus odorattisimus to the empty fruit bunch board will decrease the ductility of the board while on the same time increase the brittleness of the fabricated board. But as the ratio of artocarpus odorattisimus portion increased in the specimen mixture, the ductility of the fabricated board can be seen increased even the value of the ductility still below the ductility value of the pure OPEFB board. G. Jordi et al stated that the addition of any filler to composites will lead to decrease of elongation at yield and break [21].

**Figure 15.** Cumulative graph of Load (N) against Displacement (mm) of Specimen

Figure 15 shows the graph of Load (N) against Displacement (mm) of all 4 specimen that been combined in one graph. Based from Graph 4, it can be seen that Specimen D (66.7% OPEFB: 33.3% ARTO) possess the highest maximum load during the tensile test, followed by Specimen C (86.6% OPEFB and 13.4% ARTO), Specimen B (93.3% OPEFB and 6.7% ARTO) and then Specimen A (100% OPEFB). The graph also show that Specimen A (pure OPEFB) reach its maximum load faster than other specimen. This was followed by Specimen B, Specimen D and Specimen C. But in contrast of that, the displacement of specimen before break indicates that pure OPEFB has the longest displacement, followed by Specimen D, Specimen C and lastly Specimen B. Form the graph, it can be said that addition of ARTO to OPEFB board will increase the maximum load of the specimen and in terms of displacement even though the addition of ARTO to OPEFB will decrease the displacement before break but as the portion of ARTO increase in OPEFB, the displacement also can be seen improving. Scanning Electron Microscope (SEM) used to further understand the mechanical behavior of the tested specimen. All 4 types of specimen with different ratios of Oil Palm Empty Fruit Bunch (OPEFB) and artocarpus odorattisimus (ARTO) which is (100:0, 93.3:6.7, 86.6:13.4, and 66.7:33.3) are scanned using SEM to determine their morphological structure.

**Figure 16 show** the results from Scanning Electron Microscope (SEM) of Specimen A (100% OPEFB) under 25X magnification and also 80X magnification. Based on the picture we can see that there are several dimple and voids consists within the materials. Small crack growth appeared as on picture 12(a) on the surface and edge of the materials. Delamination also can be seen as a results from tension during the testing session. Picture 12(c) shows that the existence of voids within the fiber. It can be seen that, the occurrence of voids within the fabricated specimen (pure OPEFB) are much likely to occur even when the matrix and the fiber are trying to hold up against another. The matrix will transfer the stresses to the fiber at the fiber-matrix interface by shear stresses that possibly causes the delamination within the materials and resulting the strong stiffness and tensile strength but has a low fracture toughness within the composites [23].
Figure 16. Scanning Electron Microscope (SEM) of Specimen A - pure (100% OPEFB)

Picture 17 show the morphology structure of Specimen B (93.3% OPEFB and 6.7% ARTO) under 80X magnification. Based on the picture, it can be seen that the occurrence of fiber bridging within the specimen as in picture 13(a). The addition of artocarpus oddorattisimus into OPEFB resulting the bridging scenario within the materials. This can be seen to strengthen the tensile strength of the fabricated materials as bridging fiber tends to slow the crack propagation. [24] Porosity also can be seen on the fabricated specimen as the addition of fibers to the specimen. Addition of artocarpus oddorattisimus into the specimen has reduce the gap between the matrix and fibers. Delamination still can be seen as a result from tension during testing process as in picture 13(c). Several fiber pull out (picture 13(d)) still can be seen on the specimen but on a lesser amount if compared to specimen A.

Figure 17. Scanning Electron Microscope (SEM) of Specimen B - (93.3% OPEFB; 6.7% ARTO)
Figure 18 shows the morphological structure of specimen C in which fabricated using 86.6% OPEFB and 13.4% ARTO under 80X magnification. According to the picture 14, much lesser voids can be seen on the microstructure. Picture 14(b) shows that the addition of higher portion of fiber (artocarpus oddorattisimus) has increased the fibers bridging within the materials structure. Formation of fine dimple as in picture 14(d) occur near the crack propagation. The existence of lesser voids within the specimen microstructure shows that the specimen C are much tougher to crack if compared to specimen A and specimen B.

![Figure 18. Scanning Electron Microscope (SEM) of Specimen C - (86.6% OPEFB; 13.4% ARTO)](image)

Figure 19 show the morphological structure of specimen D in which fabricated from 66.7% OPEFB and 33.3% ARTO. Based on the picture, it can be seen that the formation of micro buckling and ply splitting as in picture 15(a). This situation occur due to the intensity amount of fiber (artocarpus oddorattisimus) that added to the structures. But still much lesser voids can be seen and the amount of fiber bridging within the structures also increased. The fiber bridging that occurred near the crack initiation will slows the crack progress thus the materials has the ability to withstand much higher stress.
4. Conclusion

Oil palm empty fruit bunch board has become one of suitable candidate in order to replace the usage of conventional woods in nowadays industry. There are various experiment conducted such as hybridization of OPEFB with paper, rice husk, bamboo and much more in order to determine the best board properties to be introduced to the industry especially on its mechanical properties. The addition of artocarpus odorattisimus (Mahang/Tarap) into OPEFB board has shown an improvement in terms of its mechanical properties especially on tensile strength value and this value keep on increasing as the portion of artocarpus odorattisimus added to the mixture. While on the same time the ductility of the fabricated board with addition of ARTO decreased if compared to pure OPEFB board, but as the portion of ARTO increased in the mixture, the ductility of the materials slowly increase but still below the ductility of pure OPEFB.

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