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The Effect of Liquid Smoke Treatment on Physical Stability and Impact Toughness Chicken Feather Fibre (CFF) as Reinforcement in Composites

(Kesan Rawatan Asap Cecair terhadap Kestabilan Fizikal dan Keliatan Impak Gentian Bulu Ayam (CFF) sebagai Pengukuhan dalam Komposit)

MUKHLIS MUSLIMIN[1,*], SALEH[2], AHMAD SENG[1], WILLY ARTHA WIRAWAN[3], MOHAMMAD MUZNI HARBELUBUN[1], SANDI RAIS[1] & MUHAMMAD ALFAJRI ISHAM[4]

[1]*Mechanical Engineering Department, Universitas Khairun, Yusuf Abdurrahman Street, Ternate 97719, Indonesia*
[2]*Department of Chemistry, Universitas Khairun, Yusuf Abdurrahman Street, Ternate 97719, Indonesia*
[3]*Indonesian Railway Polytechnic, Tirta Raya Street, Madiun 63161, Indonesia*
[4]*Student of Mechanical Engineering Department, Universitas Khairun, Yusuf Abdurrahman Street, Ternate 97719 Indonesia*

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ABSTRACT

The objective of this study was to determine the effect of liquid smoke treatment on chicken feather fibres (CFF) on the morphology and impact toughness of composites reinforced with CFF. The experiment was carried out by measuring the density of CFF, followed by immersion in liquid smoke for 1, 2, and 3 hours. All of the fibers, including one without the immersion treatment, were then inserted into the oven at a temperature of 40 °C for 30 min. The morphological assessments were done using a scanning electron microscope (SEM) and the impact test according to the ASTM D5942-96 standard on the Charpy method impact tester. The SEM results showed that the fibers without immersion had a multitude of impurities at the surface, while with immersion treatment, the fibers had a more clean and rough surface. Impact test results showed that the fiber-reinforced composite without treatment was 61,583 Kj/m^2, while the fiber-reinforced composite with immersion treatment for 1, 2, and 3 hours increased by 63,894 Kj/m^2, 71,061 Kj/m^2, and 80,538 Kj/m^2. Treatment for 3 hours significantly increased the strength of the composite by 30.78%.

Keywords: CFF; composite; impact toughness; liquid; morphology

ABSTRAK

Objektif kajian ini adalah untuk menentukan kesan rawatan asap cecair ke atas gentian bulu ayam (CFF) terhadap morfologi dan keliatan impak komposit yang diperkuat dengan CFF. Uji kaji dijalankan dengan mengukur ketumpatan CFF, diikuti dengan rendaman dalam asap cecair selama 1, 2 dan 3 jam. Semua gentian, termasuk satu tanpa rawatan rendaman dimasukkan ke dalam relau pada suhu 40 °C selama 30 minit. Penilaian morfologi dilakukan menggunakan mikroskop elektron pengimbasan (SEM) dan ujian impak mengikut piawaian ASTM D5942-96 pada penguji impak kaedah Charpy. Keputusan SEM menunjukkan bahawa gentian tanpa rendaman mempunyai banyak kekotoran pada permukaan, manakala dengan rawatan rendaman, gentian mempunyai permukaan yang lebih bersih dan kasar. Keputusan ujian impak menunjukkan komposit bertetulang gentian tanpa rawatan ialah 61,583 Kj/m^2, manakala komposit bertetulang gentian dengan rawatan rendaman selama 1, 2 dan 3 jam meningkat sebanyak 63,894 Kj/m^2, 71,061 Kj/m^2 dan 80,538 Kj/m^2. Rawatan selama tiga jam dengan ketara meningkatkan kekuatan komposit sebanyak 30.78%.

Kata kunci: Cecair; CFF; keliatan kesan; komposit; morfologi

INTRODUCTION

The development of composite materials in engineering is increasingly popular. This is due to its characteristics that superior to conventional materials, such as high ratio between strength and density, rigid, abundant materials, simple manufacturing, as well as resistant to corrosion and fatigue loads (Prabangkara et al. 2022; Rajole, Ravishankar & Kulkarni 2020), Composite materials are being reintroduced using synthetic fibers combined with polymeric materials as the matrix. The aim is to obtain high strength and stiffness. However, in practice, synthetic fibers have caused environmental impacts due to their non-recyclable waste (Kamarudin et al. 2022). Therefore, natural fibers are gaining more attention as reinforcement materials for polymer composites (Wirawan et al. 2022). The purpose of creating composites is to improve certain mechanical or specific properties, facilitate difficult designs in manufacturing, provide flexibility in shape or design that can reduce production costs, and make materials lighter (Akil et al. 2011).

Composite reinforcement materials in the form of fibers have been reported by several investigations. The sago frond fiber with liquid smoke treatment improves tensile strength and fiber morphology (Mukhlis et al. 2019a). The sago frond fiber with liquid smoke treatment can alter the texture of the fiber so that fiber-matrix compatibility occurs (Mukhlis et al. 2019b). Soaking king pineapple fiber with liquid smoke can change the morphology, tensile strength, crystalline properties, and functional groups of the fiber (Palungan & Muslimin 2022). Fiber-matrix bonding occurs after the fiber is treated with liquid smoke (Muslimin, Kamil & Wardana 2021). Liquid smoke has an effect on increasing tensile strength, changing morphology, crystalline properties, and functional groups of banana stem fibers (Muslimin et al. 2022). The physical properties and thermal stability were affected by chemical treatments of NaOH Silane (Wirawan et al. 2023). The fiber soaked in liquid smoke could be an alternative to improve the mechanical properties of Coconut Fiber (Mukhlis, Hardi & Mustafa 2021).

From several previous studies, many natural fibers have been studied but chicken feather fibers derived from chicken processing waste have not been studied, chickens have a very large population so the remaining processed feathers can be developed into composite reinforcement materials and converting this waste into useful products (Acda 2010; Tesfaye, Sithole & Ramjugernath 2017; Tesfaye et al. 2018).

Chicken feather waste will likely become an environmental problem in the future because it is not easily degradable and will lead to air pollution that can interfere with health (Choudary et al. 2019). Lack of landfills and processing makes this waste disposed of carelessly. Carelessly disposed of chicken feathers make this waste vulnerable to contamination with microbial biomass which makes this waste hazardous waste (Cheng et al. 2009). Chicken feather waste contains ~91% keratin protein thus, the potential of feathers can be utilized into high-value compounds or products because they consist of keratin protein or keratin fibers (Tesfaye et al. 2018). Feathers disposal in landfills leads to environmental pollution and results in the wastage of 90% of protein raw material (Ramakrishnan et al. 2018). Chicken feather fiber also has a unique structure and properties that other fibers do not have. Although chicken feather fiber (CFF) cannot be spun like wool, and cotton (Bansal & Singh 2016; Reddy & Yang 2007).

Prior to the use of fiber as reinforcement in the manufacture of composites, an environmentally friendly method is needed that can change the morphological properties of fiber, because fiber morphology greatly affects the strength of the interface bond and the matrix, several previous studies have stated that fiber morphology can change with liquid smoke treatment, where liquid smoke will react with the fiber so that the impurity layer and lignin in the fiber will decompose and cause porosity on the surface of the fiber, porosity occurs in the fiber will cause the interaction process and the matrix to be better (Muslimin et al. 2022, 2019b; Palungan & Muslimin 2022).

Therefore, in this study, the effect of liquid smoke on morphology and impact toughness with chicken feather fiber base material will be tested to determine whether the effect of liquid smoke treatment has an effect on chicken feather fiber and the effect of liquid smoke treatment on the composite blend of fiber materials on chicken feathers is stronger than the base material in general.

Materials and Methods

MATERIAL AND TREATMENT METHODS

The materials used include broilers' chicken feather fiber (CFF) obtained from the waste of several chicken slaughtering industries in Ternate City, yukalac 157 polyester resin, Mepoxe catalyst, and distilled water purchased at a chemical shop in Ternate City. The method in this research is the experimental method. The picture is as follows (Figure 1).

The fiber collection is done by taking chicken feather waste from the processing of chicken slaughtering then chicken feathers are cleaned using clean water until the fiber is completely clean and the chicken feathers are dried in the sun to dry, after the chicken feathers are dry, the fiber is taken by cutting at the edge of the chicken feathers with a size of 10 mm.

The treatment method consists of two methods, including the treatment of fiber immersion with grade three liquid smoke by various immersion times that is 1,2,3 h, and without treatment. After that, the fiber was dried in a memmert oven UN 55 Cap 53L at 40 °C for 30 min (Table 1).

Two stages of fiber treatment were conducted namely immersion and heating process. The immersion process of fiber with liquid smoke is a compounding process between the lignin compounds in the fiber and the acid in the liquid smoke so that liquid smoke fiber compounds are formed. The next stage is the heating process for 30 min at a temperature of 40 °C to facilitate the decomposition of lignin compounds and the degradation of H_2O compounds.

The reaction process above causes an increase in the tensile strength of the fiber and the morphological properties of the fiber become coarser and more porous. Changes in these properties are needed for the use of fiber in composite reinforcement because new fibers can be used as composites not only to be strong but also to have coarse, porous, and morphology. These changes in properties will make CFF a reliable and environmentally friendly composite reinforcement.

MOLECULAR STRUCTURE

From chemical point of view, CFF is an elongated aliphatic chain with one alpha and one beta helix, respectively (Figure 2). Numerous active sites composed by amines, which are categorized as polar amino acids, and hydroxyl groups can be found all throughout this chain. The liquid smoke, which mostly consisted of Methanol, Formic acid, Furfural, Phenol, and Methyl-Pentadecanoate Methyl Ester (Figure 4) (Rizal et al. 2020), eventually established a link with these groups via either nucleophiles or electrophiles. This interaction produced a surface (matrix) with phorous-like properties that serves as an anchor during the mixing process with resin and increases the tensile strength of the CFF-resin. This phenomena can be seen via SEM analysis as presented in Figure 3.

FIGURE 1. Chicken feather fiber, (a) Raw materials for chicken feathers (b) CFF separation process, and (c) pure CFF

TABLE 1. Treatment notation on CFF

No	Notation	Code	Treatment
1	Without treatment	TP	Without
2	1-h treatment	P1J	Liquid smoke grade (III)
3	2-h treatment	P2J	Liquid smoke grade (III)
4	3-h treatment	P3J	Liquid smoke grade (III)

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TESTING AND OBSERVATION

For morphological observations, the coating process was carried out and then observed with the JEOL JCM 6000 SEM tool. Before testing the specimen was made according to ASTM D5942-96 standard and tested with Composite Impact Toughness.

Impact strength calculation:

$$a = \frac{W}{h \; x \; b} \tag{1}$$

where α is the impact toughness; W is the energy absorbed by the specimen; H is the thickness of the specimen that has been impact tested; b is the width of the fracture point in the specimen.

SEM OBSERVATION

The scanning electron microscope (SEM) observations test was to see the morphology of the coated test material by placing the specimen on the preparation. The SEM test equipment was then operated and observed until the surface of the specimen was visible, then photographed and stored.

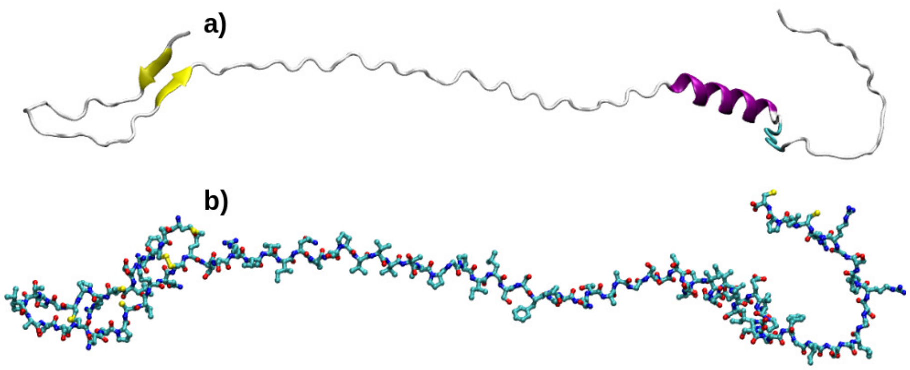


FIGURE 2. Snapshots of CFF molecular structure. a) secondary structure representation. b) ball-stick representation

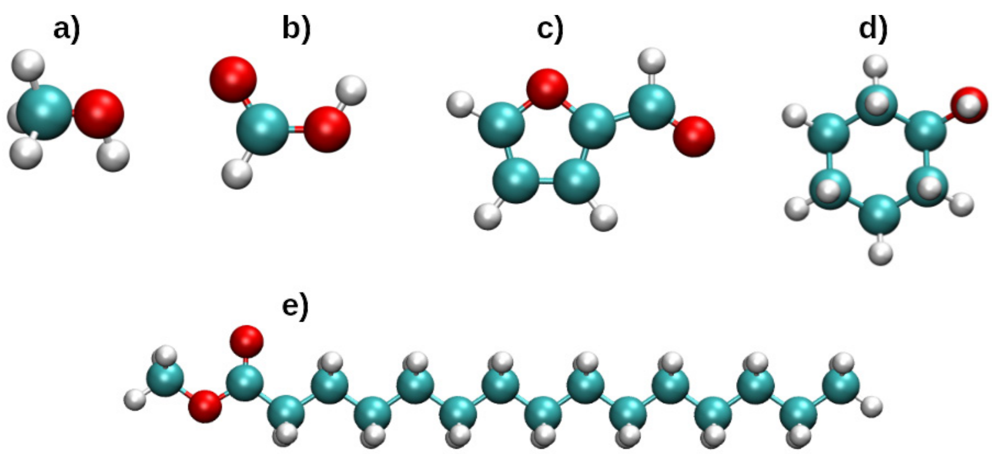


FIGURE 3. Molecular structure of liquid smoke. a) Methanol, b) Formic acid, c) Furfural, d) Phenol, (e) Methyl-pentadecanoate methyl ester

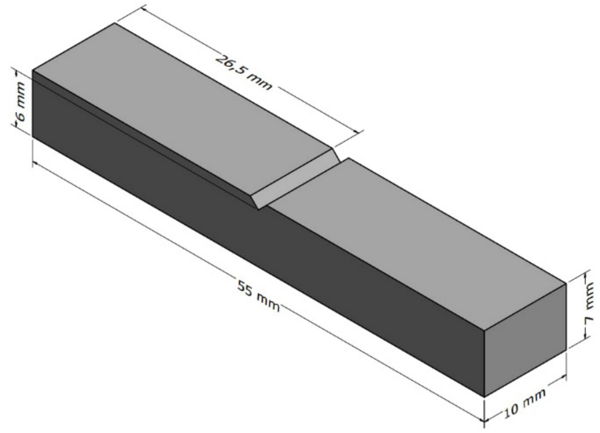


FIGURE 4. Standard ASTM D5942-96

COMPOSITE IMPACT TEST

The composite molding process by first preparing untreated fibers and fibers that have been soaked for 1, 2, 3 h, then weighing the fibers so that the weight of the fibers that will be molded into composites has the same size, then mix 70% yukalac 157 resin plus 1% catalyst then the resin catalyst that has been mixed is poured partially into a mold containing 30% CFF, close the mold and apply pressure so that the composite in the mold becomes flat and is allowed to stand for 48 h, after the mold has been left for 48 h it is opened and the dried composite is released from the mold, then the specimen making process will be carried out. Making impact test specimens is done by cutting the composite according to the standard size of ASTM D5942-96 impact testing.

RESULTS AND DISCUSSION

EFFECT OF LIQUID SMOKE TREATMENT ON CFF MORPHOLOGY

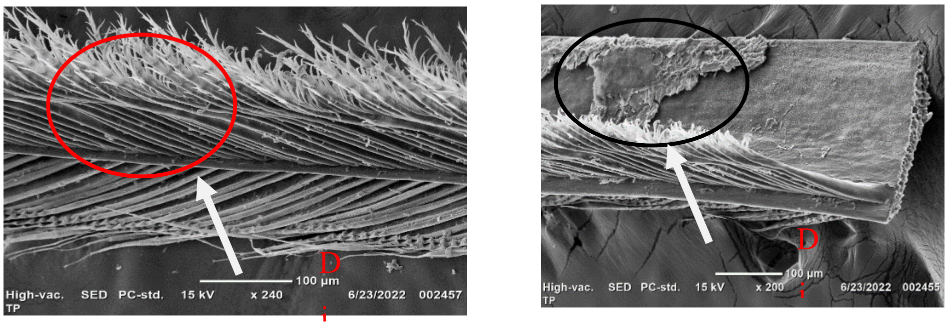
The morphological observations show a difference in the shape of the fiber surface, where the untreated fiber looks branched and has a lot of dirt on the surface of the fiber branches compared to the fibers that have been soaked using liquid smoke, which look cleaner from impurities. The fiber gaps are clearly visible so that the potential for resin to enter the gap is greater and will increase the adhesion between the matrix and CFF, as in Figure 5.

The picture also shows the difference in the ends of different fiber cross-sections, where it can be seen that the untreated fiber has a branch tip pattern that looks like small hairs covered with lignin and messy, resulting in the fiber surface not being able to bond properly, the surface covered with lignin can also prevent bonding bonds from being maximized so that the union of the resin with the fiber is hampered (Wirawan 2017). While in the treatment of 1, 2, and 3 h, the fiber surface looks cleaner than the lignin layer, and looks rough, so this also affects the union of resin and fiber. When making composites with CFF reinforcement, it will be easier for bonding to occur, so that the mechanical properties of the composite will be stronger.

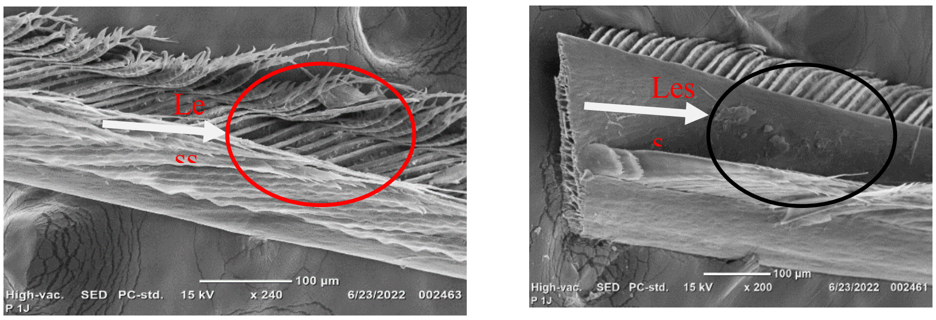
The morphological results of liquid smoke-treated fibers have also been confirmed based on Image analysis using ImageJ as shown in Figure 6. It can be seen that lignin and other impurities on the surface disappear and there appears to be uniformity. With this configuration, the binding force of the feather fiber with the synthetic matrix becomes better, allowing an increase in mechanical properties (Wirawan et al. 2020).

The results of imageJ imaging in Figure 6 clearly show that the surface of the untreated fiber is covered by lignin and other impurities in the chicken feather fiber. This of course if made into a composite will have a negative impact on the interfacial bounding of the composite (Sepe et al. 2018). Poor interfacial bounding results in a weak decrease in mechanical properties (Zhang et al. 2021). When compared with liquid smoke treated fibers, it is clear that there is a reduction in impurities such as lignin and clear fiber surface pores appear to be open evenly. Fiber pores can open due to impurities that are lost due to treatment. So that this pore will be filled by the matrix so that it is possible to increase the toughness of the composite.

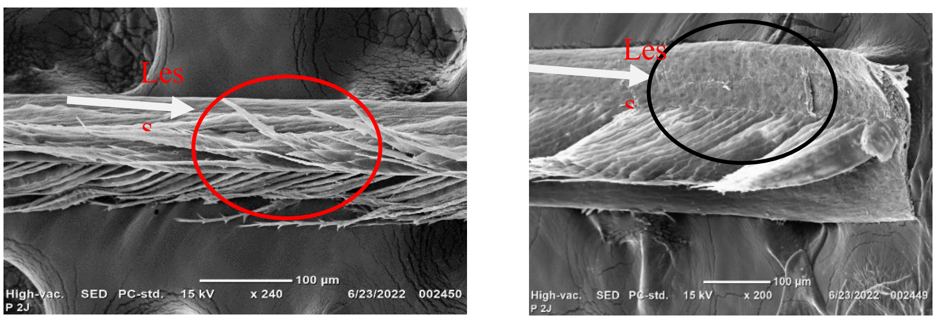
a. Without treatment



b. 1 h treatment



c. 2 h treatment



d. 3 h treatment

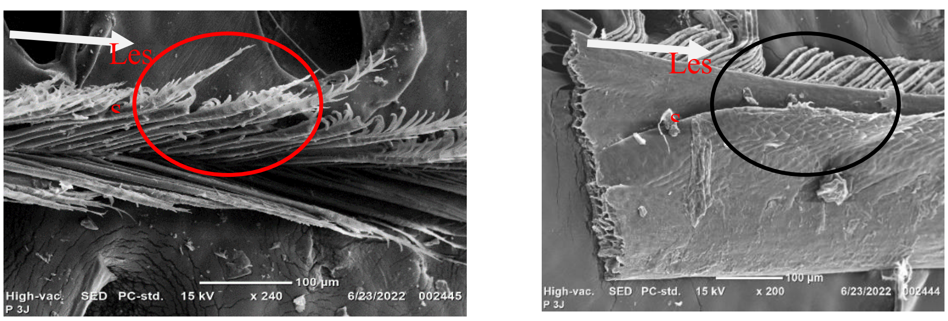


FIGURE 5. Fiber structure seen from SEM observation

EFFECT OF LIQUID SMOKE TREATMENT ON IMPACT TOUGHNESS

The impact load test results using the Charpy method, composites using yukalac 157 resin as a matrix and CFF as reinforcement, with each variation of treatment with liquid smoke for 1, 2, and 3 h compared to untreated fibers, the impact test results show different results where composites with untreated fiber reinforcement have smaller toughness compared to composites with treated fiber reinforcement, data on the difference in impact toughness can be seen in Table 2 and Figure 7.

This test results show that CFF without treatment has a toughness of 61,583 Kj/m2 with a visible fiber surface that looks irregularly branched and dirty, after soaking for 1 h, the toughness properties of CFF tend to increase by 63,894 Kj/m2 an increase occurs due to impurities that have begun to come out of the fiber so that the interaction of the CFF fiber surface with the resin experiences a

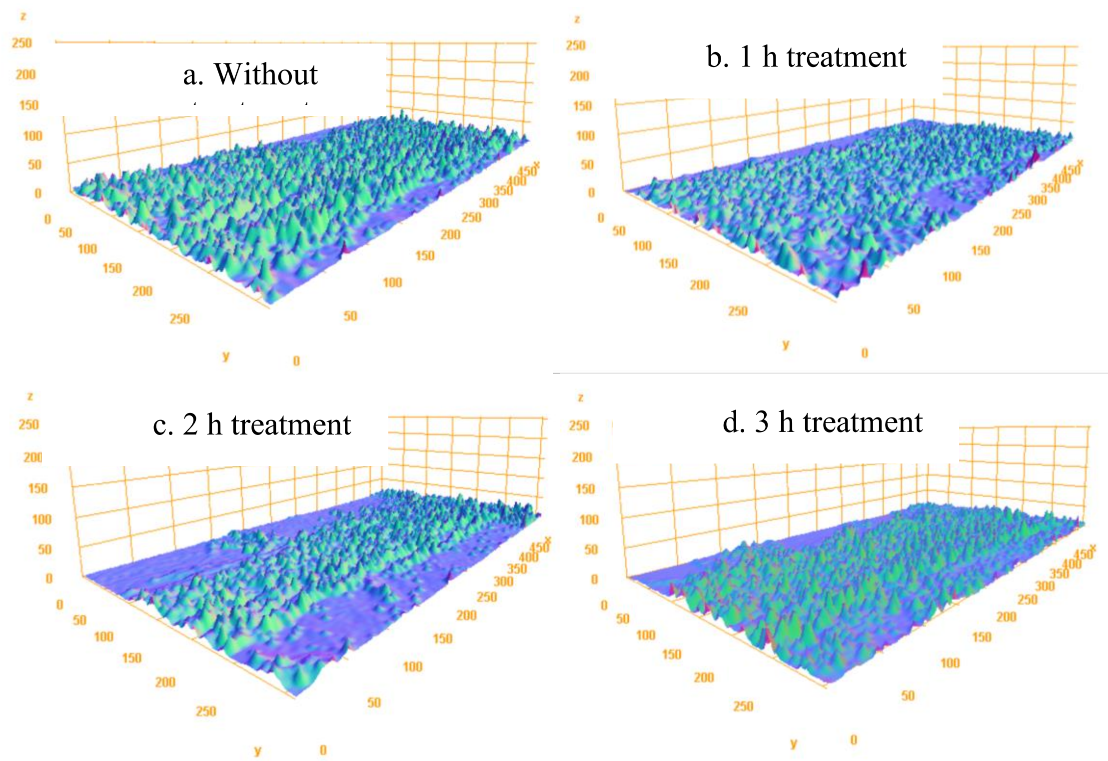


FIGURE 6. Results of photo image analysis using ImageJ

TABLE 2. Impact strength changes of composites with CFF reinforcement

No	Treatment	Average impact strength (Kj/m^2)	Changes (%)
1	TP	61.583	0.000%
2	PIJ	63.894	3.753%
3	P2J	71.061	15.391%
4	P3J	80.538	30.780%

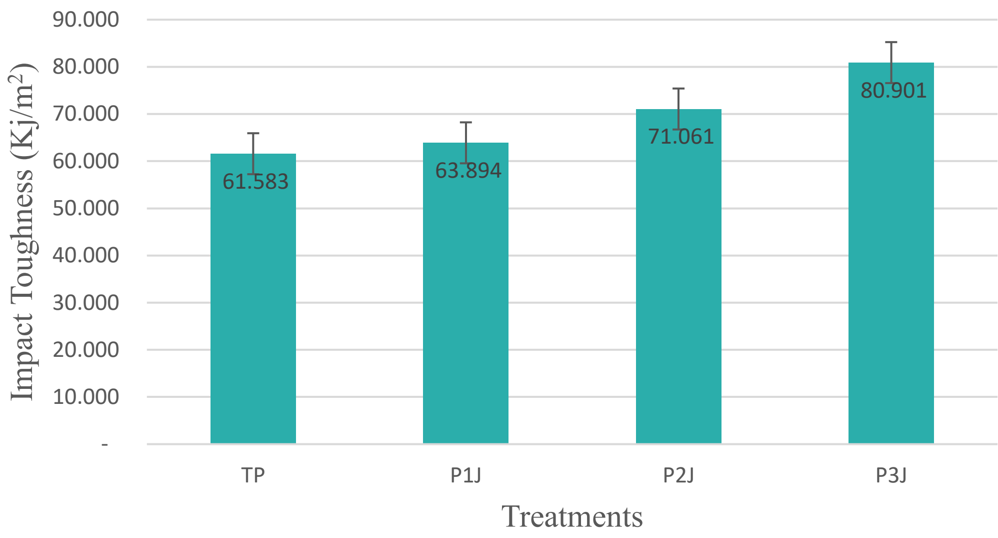


FIGURE 7. Relation between TP, P1J, P2J, and P3J and impact strength

deinterface which will cause the CFF bond with the resin to strengthen, while in immersion 2 and 3 h has experienced a significant increase with mechanical properties on impact toughness at 2 h of immersion of 71.061 Kj/m2 and 3 h the mechanical properties increased with an impact toughness of 80.538 , this is because the fiber has undergone a process of cleaning dirt and the fiber gaps are wide open so that the resin enters the fiber gaps this has been confirmed in the SEM test results, resulting in increased adhesion between the resin and CFF. The graph above shows that the immersion of CFF using liquid smoke can increase the mechanical properties of impact toughness. The percentage change in impact toughness is shown in Table 2.

The table shows the percentage change in impact strength due to the treatment of CFF with liquid smoke, where when compared to CFF composites without treatment with CFF composites, there is a percentage increase in strength change at P1J of 3.753%, while at P2J there is an increase in impact strength of 15.391% and the most significant increase in strength occurs at P3J of 30.780%. This shows that the longer the treatment will increase the impact strength of CFF composites and the longer the immersion time, the better the bonding of CFF with resin, so liquid smoke can be recommended as a treatment material to improve the mechanical properties of CFF reinforced composites.

Conclusion

Based on the results of SEM observations, it can be concluded that the effect of liquid smoke fiber treatment can change the morphology of CFF to be rougher, cleaner, and away from impurities in the treatment of 1, 2, and 3 h compared to without treatment where without treatment has a branched fiber surface pattern and has many newspapers. While the effect of liquid smoke treatment on impact toughness can be concluded that the longer the immersion using liquid smoke, the greater the toughness value in impact testing with a percentage increase in impact toughness occurs in the 3-h treatment of 30.780%. SEM confirmation results show that liquid smoke treatment is very effective in removing impurities and lignin on the surface of CFF fibers. The pores of the fiber can be opened evenly after treatment, this pore configuration can be filled by the synthetic matrix so that better mechanical bounding occurs. The result of good mechanical bounding has an impact-on-impact toughness.

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*Corresponding author; email: mukhlis@unkhair.ac.id