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Characteristics of Environmentally Friendly Food Container Composite Made From Sorghum Bagasse and Citric Acid

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Abstract

The common food container product was made from plastic such as polypropylene, polystyrene, etc which has slowed to degrade hence affected to the environmental pollution and health disorder. Therefore, environmentally friendly food container composite is developed from sustainable resources such as sorghum bagasse and citric acid. The effects of sorghum species, sorghum particles and citric acid content on the composite properties were investigated. Local species of sorghum was used as raw material such as Super 2 in the manufacturing of food packaging. The size and moisture content of the particles were passthrough on 40 mesh and 10%, respectively. The content of the particle was variated such as 10, 15, and 20% wt. Furthermore, citric acid was used as a binder with difference content such as 10, 20, and 30% wt. Those raw materials were mixed with tapioca starch, polyvinyl alcohol (PVA), and glutaraldehyde. The mixing material was hot pressed at 180 °C for 15 minutes. The composite dimension was 12 cm x 10 cm x 3 mm. The physical and mechanical properties of the composite were carried out. Considering the properties of the composite, sorghum bagasse and citric acid are suitable as raw material of food container composite.

INTRODUCTION

Food security is a priority issue in the world. Food distribution from one place to another become a problem due to distribution journey with long distance affected to the decreasing of food quality. Therefore, food packaging technology is developed massively in recent years. Commonly, raw materials of food packaging made from paper, carton paper, Styrofoam, glass, ceramic, metal, or composite metal-plastic. Each those raw material has benefit and weakness for the food packaging product. Unfortunately, most of the raw materials are obtained from unsustainable resources such as polypropylene, polystyrene, styrofoam, etc. In addition, those raw material contain toxic chemical which can transfer to the food and affected to the health disorder and affected to the environment pollution such as air pollution, soil pollution, and water pollution due to the raw materials couldn't degraded easily when it disposes to the environment.

Production of plastic food packaging increased when increasing of simple and cheap food packaging demand. According to Hana (2019) in 2019, the production of food packaging and drinking bottle growth up reach to 5-7%. Production of food packaging made from plastic and styrofoam is 14.000 tons/year, respectively (Indonesia, 2018). Massive production of the food packaging from plastic and Styrofoam affected the plastic waste population become uncontrolled. Therefore, development of environmentally friendly food packaging from sustainable material is required.

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Sorghum (*Sorghum bicolor*) is one of the top five cereal crops in the world. It also versatile crop characterized by very efficient photosynthesis, which can grow quickly (Patil et al., 2011; Belayachi et al., 1995) and has wide range adaptability. This biomass is renewable, cheap, and widely available. Moreover, sorghum produces a high yield of green biomass and a huge amount of ligno-cellulosic residue (Wu et al., 2010; Sipos et al., 2009). Bagasse Sorghum, the residue produced by juice extraction from the stalk, represents about 30% of the whole plant fresh weight (Thanapimmetha et al., 2011) and is used for non-food applications containing carbohydrate polymers (cellulose and hemicellulose) and lignin. Bakeer et al (2012) mentioned that the sorghum contains 41-45% of cellulose, 12-15% of cellulose, and 11-13% of lignin. In addition, the composition of ash, protein, fatty, C-H-O content were 1,1-2,2 %, 8-16%, 2-4%, 67-76%, respectively (Tassie, 2020, Shegro et al., 2013).

Citric Acid (CA) is an organic acid that could be found naturally from a variety of fruits and vegetables, particularly citrus fruits such as oranges, tangerines, lemons, limes, and pomelos which has formula $C_6H_8O_7$. Owing to the fact that the anion can be stabilized by intramolecular hydrogen-bonding from other protic groups on CA (Lee et al., 2020). In recent years, many emerging uses of CA have also been identified e.g., crosslinker, environmental remediation, and extracting agent (Ciriminna et al., 2017). A brief review regarding the application of CA as green binder to serve as a binding agent for lignocellulosic materials has been studied by Chayono and Syahidah, 2019. The performance of citric acid-modified starch has also been studied (Amini et al., 2020) includes the modification glutaraldehyde-modified starch using hot-pressing method to cure binder (Amini et al., 2013).

Therefore, in this research environmentally friendly food container composite is developed from sustainable resources such as sorghum bagasse and citric acid. The effects of sorghum species, sorghum particles and citric acid content on the composite properties were investigated.

MATERIALS AND METHODS

Materials

Sorghum (*Sorghum bicolor*) baggase Super 2 from LIPI sorghum plantation, Cibinong, Indonesia was used as raw material with the particle size throughout 40 mesh of sieving. Polyvinyl alcohol (PVA) technical grade for industrial use was obtained from Chang Chun Chemical (Jiangsu) Co., Ltd., China. Citric Acid Anhydrous technical grade (CAS No. 77-92-9) from Weifang Ensign Industrial Co., Ltd., China, Glutaraldehyde from Merck CAS 8.20603.1000 as cross linker agent, and commercial tapioca starch (Cap Pak Tani) was used to be mixed.

Methods

The Sorghum particles were dried by oven drying at 80 ^{0}C to reach moisture content (MC) around 10%. Then, the particles were mixed polyvinyl alcohol (PVA) and 20% concentration of starch. The concentration of sorghum bagasse particles in the mixed materials were variated become 10, 15, and 20% of composite weight. In addition, citric acid was added into mixed material with the variation concentration such as 0, 10, 20, and 30% of the composite weight. Moreover, glutaraldehyde was added into the mixed material with the concentration of 4 % from PVA weight. All materials were mixed properly for 5 minutes. The mixed material was moulded with the size 12 x 10 x 3 (mm), then it was hot pressed at 180^{0}C for 15 minutes. Physical and mechanical properties of the composite such as moisture content (MC), density, water absorption (WA), thickness swelling (TS), and flexural strength were tested after 6 days conditioning of the composite sample at room temperature ($\pm$ 27^{0}C). All the testing samples were repeated by 3 times. The mechanical property of the composite was evaluated according to the ASTM D 790-2000 standard and used Universal Testing Machine (UTM) Shimadzu AG-IS 50kN.

RESULTS AND DISCUSSION

Physical and mechanical properties

Physical properties of food packaging composite show in Table 2.The densities of food packaging composites were about 0,3-0,48 gram/cm^3 as shown in Table 2. These densities were lower than food packaging density from carton paper (0,3-0,8 gram/cm^3) but higher than Styrofoam food packaging (0,01-0,05 gram/cm^3) (Goyal, 2020). The MC of food packaging composite was around 7-10%. Thickness swelling of the composite with contains 10 and 20% of citric acid (5,1-14,6 %) is almost similar with the previous

Table 2. Physical properties of food packaging composite made from sorghum (fiber) in each variation.

Type	Citric acid content (%)	Fiber content (%)	Density (g/cm^3)	Moisture Content (%)	Water Absorption (%)	Thickness Swelling (%)
A	0	10	0.25	4.99	302.63	16.05
B	0	15	0.42	0.88	198.75	25.34
C	0	20	0.28	2.45	244.40	13.73
D	10	10	0.34	7.82	133.3	7.8
E	10	15	0.42	9.99	142.9	10.2
F	10	20	0.41	5.54	127.6	8.5
G	20	10	0.48	7.15	104.9	8.9
H	20	15	0.47	7.90	109.0	14.6
I	20	20	0.32	7.75	107.3	5.1
J	30	10	0.32	1.47	296.25	18.25
K	30	15	0.46	7.31	120.32	11.26
L	30	20	0.52	0.78	126.58	16.49

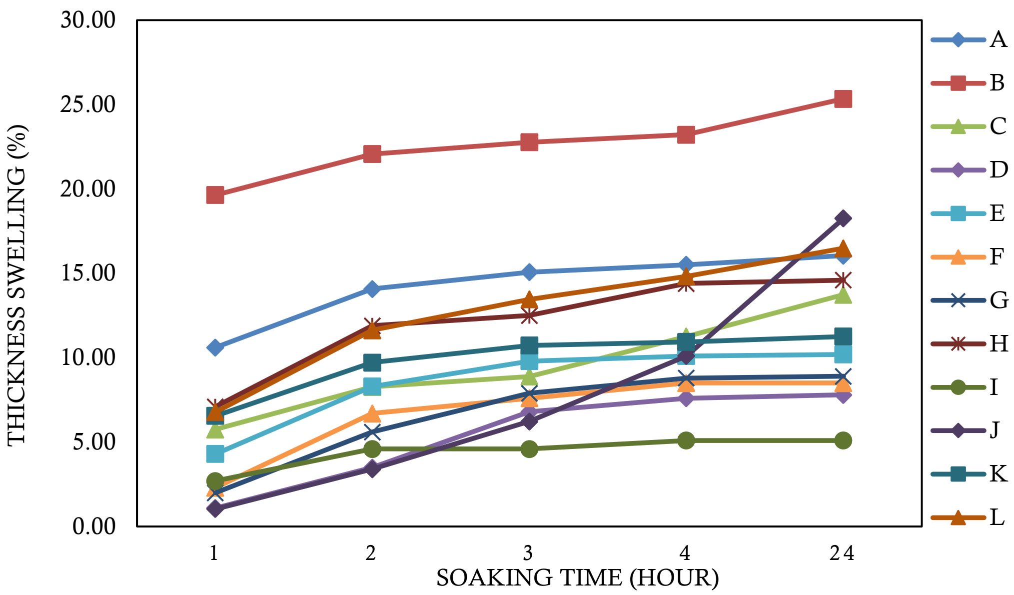


Figure 1. Thickness Swelling (%) of the food packaging composite made from sorghum bagasse related to soaking time.

studied about composite board made from sorghum bonded with citric acid and sucrose (11-12%) (Kusumah et al., 2017). It is similar too with the results of Syamani et al (2020) in sugarcane bagasse-citric acid composite (4.43-11.47%). But, the composites with zero of citric acid and contains 30% of citric acid have higher thickness swelling value. Water absorption of the composite decreased with decreasing fiber content in 10% of citric acid. The composite type with 20% of citric acid had lower thickness swelling than thus of the composite with 10% of citric acid. The value of water absorption of composite with no addition of citric acid higher than composite with contains citric acid.

Thickness Swelling (TS) of all the food packaging composites was lower than 8% at 1 h soaking time and increased sharply from 1 to 2 h soaking time as shown in Figure 1. Moreover, TS of all composites are almost stable after 2 h soaking time. The type A composite had highest TS in each soaking time. In the other hand, the type F composite had lowest TS in 3 until 24 h soaking time. Previously, Widyorini et al 2017 (Widyorini et al., 2017) stated that the reaction between starch and citric acid affected to the good dimensional stability of the composite. In addition, carboxyl group of citric acid react with hydroxyl group of lignocellulose material to form ester linkages hence hygroscopicity of the lignocellulose material was

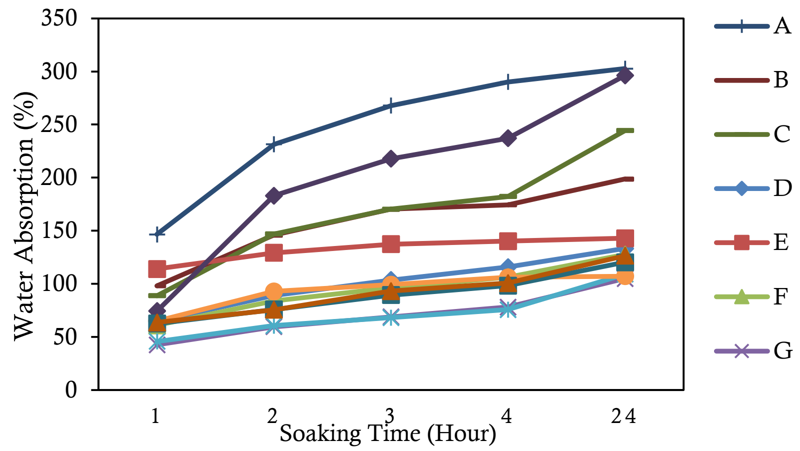


Figure 2. Water absorption (%) of the food packaging composite made from sorghum bagasse related to soaking time.

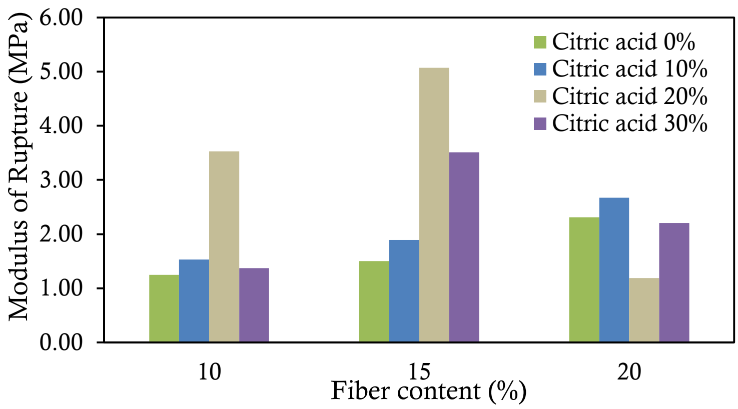


Figure 3. MOR of the food packaging composite in each fiber and citric acid content.

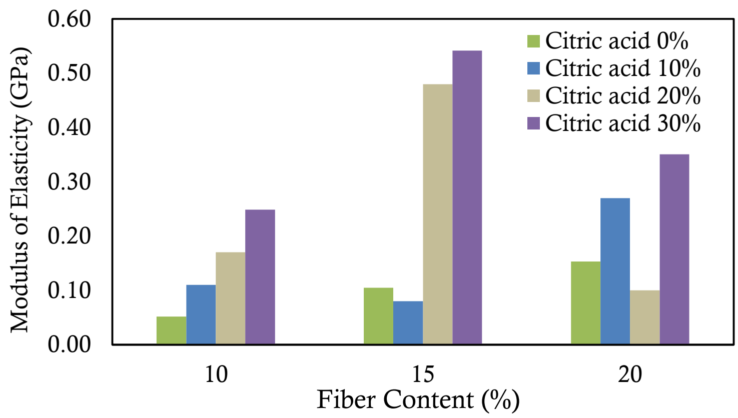


Figure 4. MOE of the food packaging composite in each fiber and citric acid content.

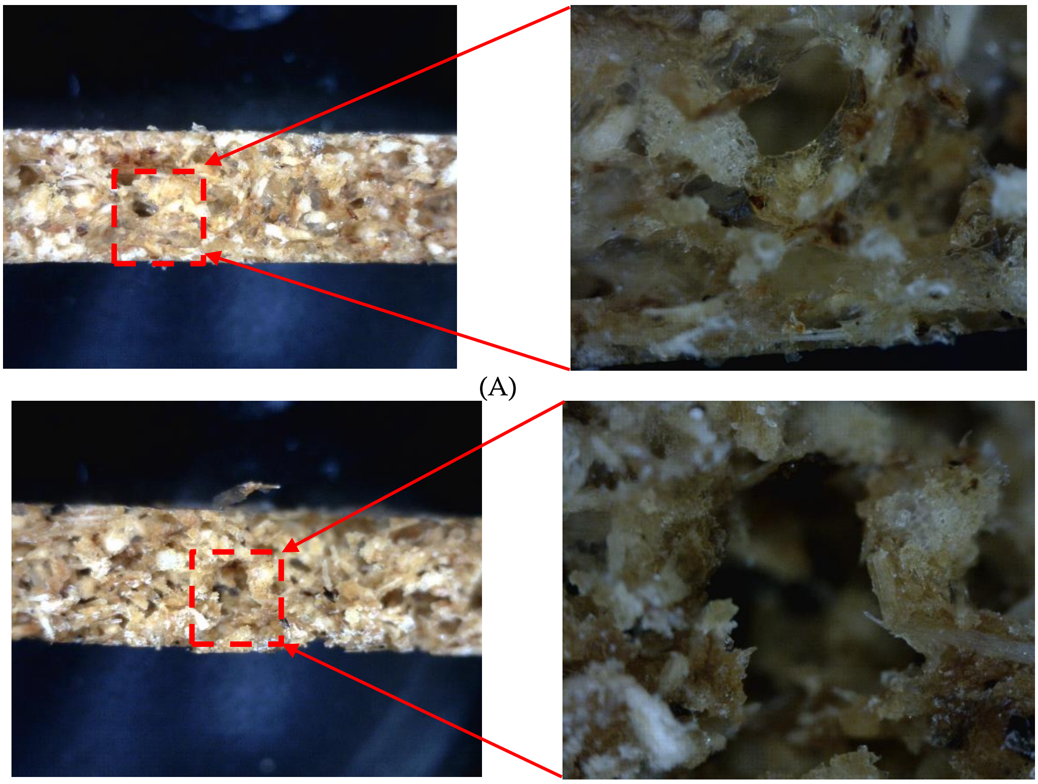
reduced and improve the dimensional stability of the composite (Widyorini et al., 2017). Besides that, starch contained amylase which has straight chain that important to create the linkages hence improve the water resistance of the composite (Widyorini et al., 2017, Thiebaud et al., 1997).

Water absorption (WA) of all composite type inclined in each soaking time and have WA value less than 80% except for type B composite at 1 h soaking time as shown in Figure 2. High WA value of all composite type because of many pore forms in the composite to obtain low density of the food packaging composite.

Figure 3 and 4 show Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of the composite. MOR of the composite increased with increasing fiber content when 10% of citric acid content was added. However, MOR of the composite with 20% of citric acid content increased from 10 to 15% and decreased at 20% of fiber content. The composite composed with 15% of fiber content and 20% of citric acid content has highest MOR (5.07 MPa). Decreasing of MOR at the composite with 20% of fiber and 20% of citric acid content because of decreasing the compatibility between starch, fiber, and PVA as shown in Figure 3. Differences of the material compatibility lead the materials could not mixed properly, hence fiber and polymer are not evenly distributed.

Morphology analysis of the food packaging composite

The cross-sectional image of the composite was shown in Figure 5. The left section of the cross-sectional image is the image with 50-time magnification and the right section is the image with 220-time magnification. The images show that there are some lumens was formed in the composite hence the composite has low density. Moreover, the composite has high WA. Furthermore, low density of the composite affected to the low MOR and MOE values. Domination of sorghum fiber was shown in the image of the composite with 15% fiber content and 20% citric acid content at 220-time magnification of image, therefore this composite has higher MOR and MOE than those of the other content of fiber and citric acid addition on the composite. As mentioned in the previous study that the addition of the fiber increased viscosity of the mixed material hence the material has low expanded properties, and it reduced the lumens which is formed in the composite (Shogren et al., 1998). Structure material with the big size of the lumen and high porosity will produce the composite with low density and compression strength. Commonly, the lumen which is formed in the composite has thin wall hence easy to deform when the compression is applied. In addition, high porosity of the composite affect to the high absorption of the water hence the WA of the composite tend to increase (Soykeabkaew et al., 2004).



(A)

(B)

Figure 5. Morphology of the food packaging composite by dyno lite microscope imaging with the 50 and 220 times of magnification.; (A)10% FC, 0% CA; (B) 15% FC,0% CA; (C) 20% FC, 0% CA; (D)10% FC, 10% CA; (E) 15% FC, 10%CA; (F) 20% FC, 10% CA; (G) 10% FC, 20% CA; (H) 15% FC, 20% CA; (I) 20% FC, 20% CA; (J) 10% FC, 30% CA; (K) 15% FC, 30% CA; (L) 20% FC, 30% CA.

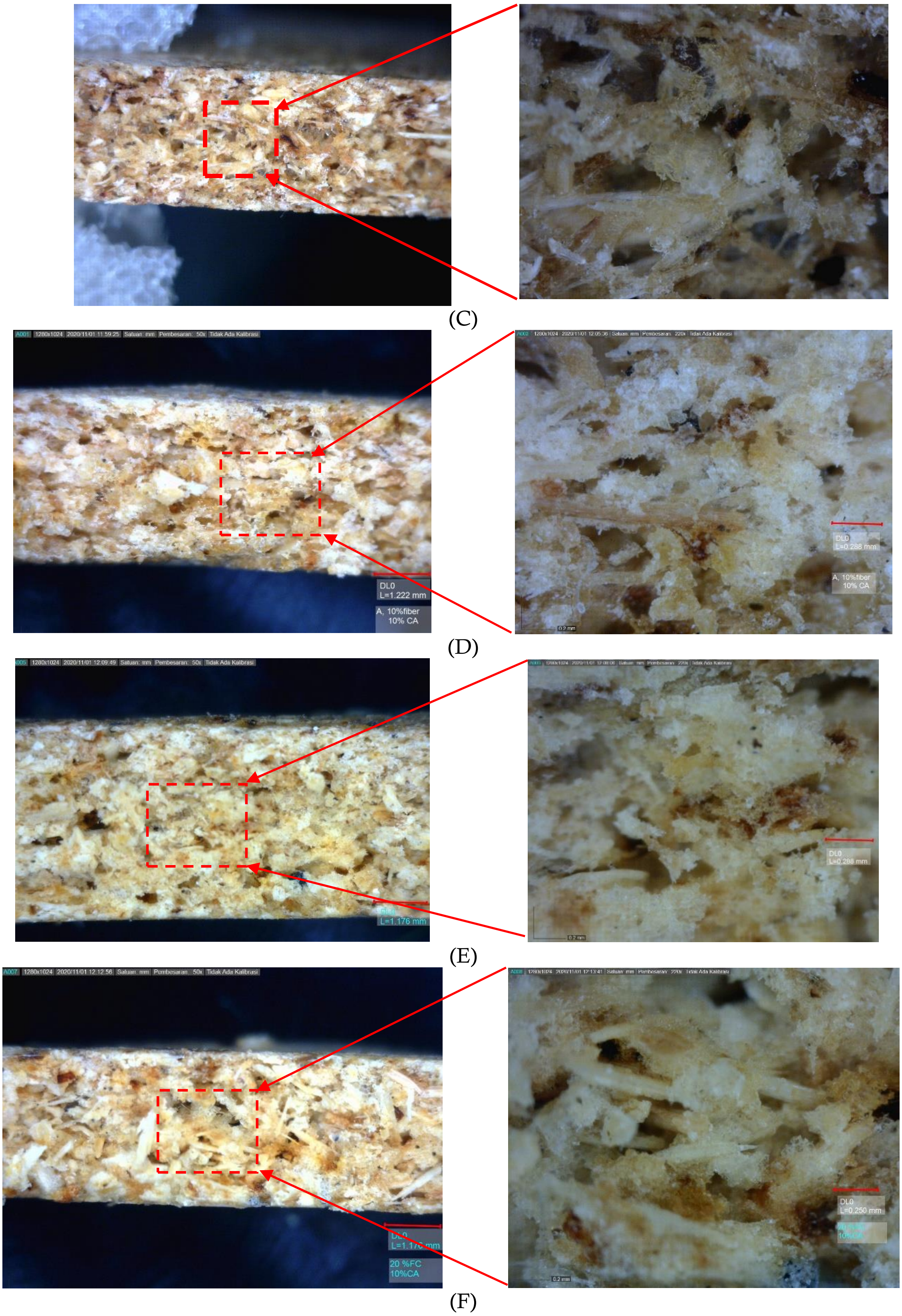
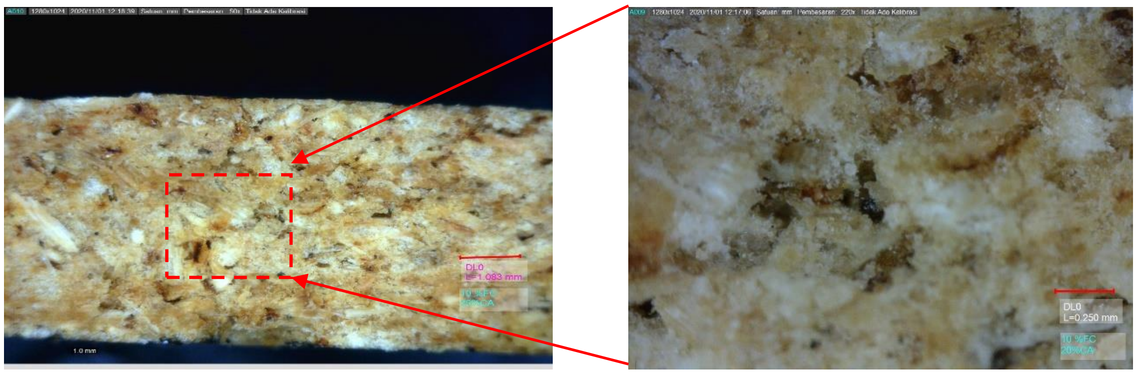
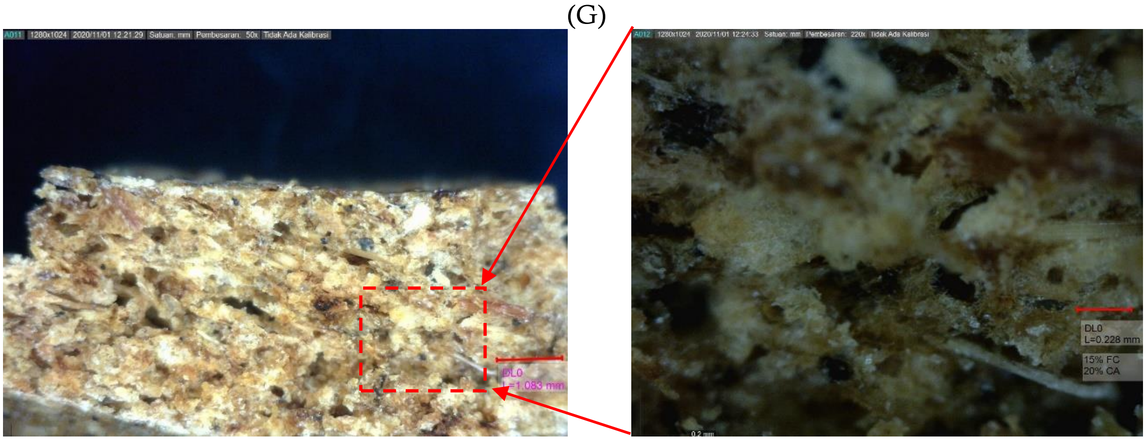


Figure 5. Morphology of the food packaging composite by dyno lite microscope imaging with the 50 and 220 times of magnification (Cont.)



(G)



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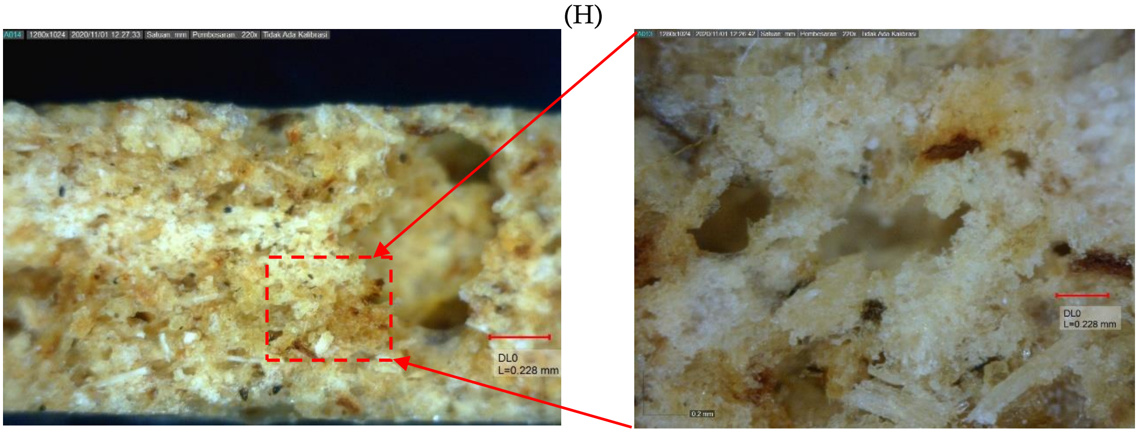
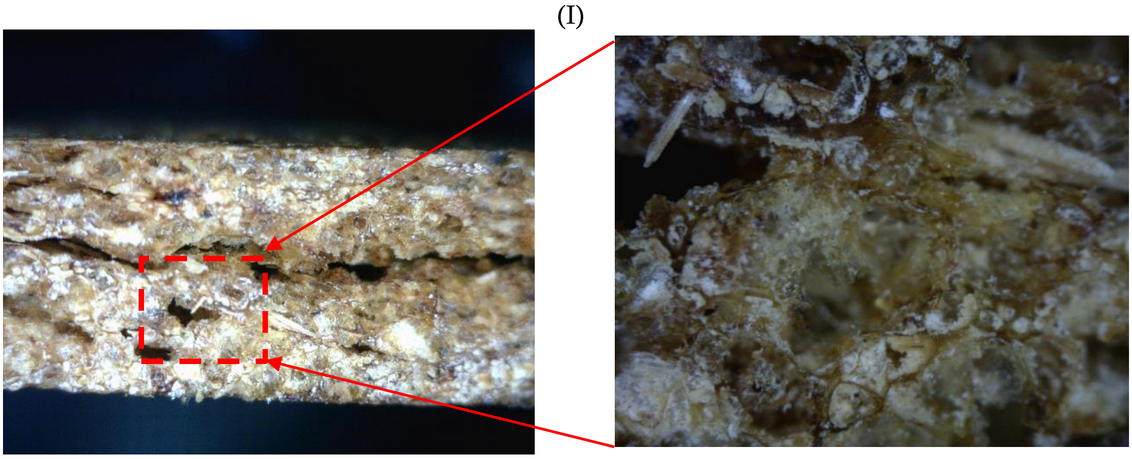
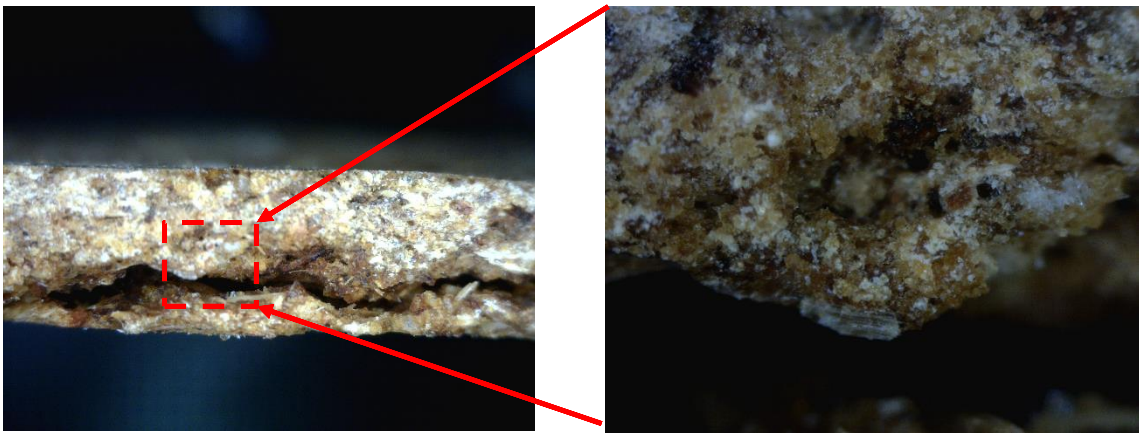


(I)

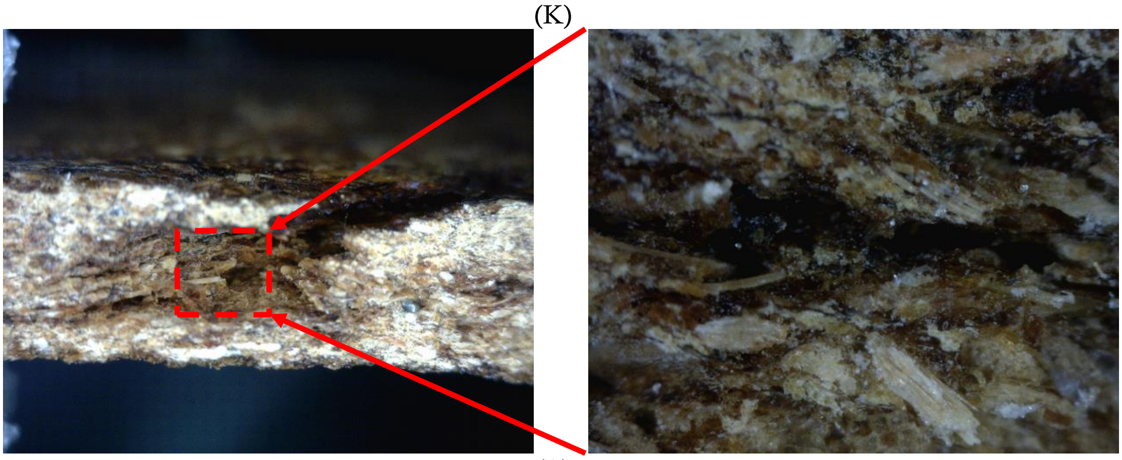


(J)

Figure 5. Morphology of the food packaging composite by dyno lite microscope imaging with the 50 and 220 times of magnification (Cont.)



(K)



(L)

Figure 5. Morphology of the food packaging composite by dyno lite microscope imaging with the 50 and 220 times of magnification (Cont.)

CONCLUSION

Eco-friendly food container composite was made from Sorghum bagasse and citric which has good density property. The composite with no addition of citric acid content has lower density than the other composites. The water adsorption of the composite decreased with addition of the fiber and citric acid. The MOR and MOE of the composite increased with increasing fiber content when 10% of citric acid was added. However, the highest MOR of the composite was reached when 20% of citric acid and 15% of fiber was added. Then the composite with 30% of citric acid content and 15% fiber content has highest value of MOE.

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