JMES The International Journal of
Mechanical Engineering and Sciences
https://iptek.its.ac.id/index.php/jmes
e-ISSN 2580-7471

# The Effect of Rice Husk as Additive in Injection Molding Process

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*Received: 19 August 2022, Revised: 4 September 2022, Accepted: 12 September 2022*

**Abstract**

This study investigated the moldability and the mechanical properties of bio-composite with rice husk as natural reinforcement. Natural materials that are abundant in nature can be used as reinforcement for polymer materials. Natural materials as reinforcement in plastic materials were used to obtain alternative materials in an injection molding process. With rice husk, polypropylene, and MAPP, four compositions of bio-composite materials were made and used as raw material injection molding process. The moldability from this material was observed through visualization of the product. The mechanical properties of the materials were observed by the tensile strength and impact test on the injection molding product. The result showed that these materials could be injected to form ASTM D638-03 Type V tensile test and ASTM D256-04 impact test specimens. Visually, the more rice husk on the bio-composite material, the darker the product color. The differences in tensile strength values decreased along with increased rice husk content. All bio-composite materials had roughly the same tensile strength value and were lower than polypropylene, except RH-5%. The impact value of bio-composites was lower than polypropylene impact value and tended to decline along with the increase in the rice husk content. Scanning electron microscope (SEM) analyzes were done on the fracture side of the impact specimen. Microscale voids decreased and were rarely found by adding rice husk to the material bio-composite. On the other hand, rice husk breakage and pullout phenomenon on bio-composite material were found

**Keywords: Polypropylene, rice husk, MAPP, bio-composite, injection molding process**

## 1. Introduction

Recently, research on alternative materials has become popular and widely performed. Researchers are competing to look for new alternative materials with various criteria according to needs and desired material properties. Bio-composite is one of the alternative materials that have been widely developed. Bio-composite is a composite material that uses reinforcement derived from natural materials, such as plants and animals. Examples of natural reinforcement derived from animals are wool, secretion (silk), fish scale, animal horn, etc. While natural reinforcement derived from plants are bamboo, kenaf, sisal, cotton, grain, etc [1]. Synthetic fiber materials commonly used as reinforcement to make composite are less environmentally friendly and expensive Therefore, other environmentally friendly and inexpensive materials, such as natural fibers derived from plants, are needed. Many researchers have started using natural reinforcement as filler in the composite. One example of a natural reinforcement that is often used is rice husk. In 2014, Shu-Kai Yeh et al. [2] studied the manufacture of bio-composite materials from rice husk. Rice husk fibers can be utilized as filler in bio-composite to maximize products. Rice husk is a byproduct of rice milling that has not yet been exploited to its full economic potential. Rice husk is a natural, cheap material that can be used to strengthen polymer bio-composites [3]. Due to the lack of information about rice husk's mechanical properties, the final results of research on rice husk as a filler in bio-composites depended on several factors, such as how the machine was made, the coupling agent, and how the rice husk was oriented.

In manufacturing industries, injection molding machines are widely used to produce products in mass production. The molded products of this machine have dimensions that conform with the design and can be produced in a short time. Generally, these machines make products from plastic or polymer as raw materials. However, many bio-composites are currently processed using injection molding machines. KC et al. [4] did injection molding using pellets from sisal fiber and polypropylene. Srebrenkoska et al. [5] recycled polymer processing with kenaf fiber and rice husk printed using an injection mold-

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ing machine.

Every material has its characteristics, such as mechanics, thermal, etc. Moldability is the ability of the material to be molded into a product. Moldability is different for each type of material because of different material properties [6]. Moldability of the material can be seen from the defect-free products when it is used as a raw material of process. In addition, the mechanical properties of the resulting product, namely tensile strength and impact value, also need to be considered. Subasinghe et al. analyzed the fiber length retention capacity of extrusion and injection molding processes for short and long kenaf fiber-reinforced polypropylene composite. Raw materials from polypropylene (PP), maleic anhydride grafted polypropylene (MAPP), and kenaf fiber were used. The result showed that although the fiber length obtained was below the critical fiber length under high shear processing (twin-screw compounding and injection molding), effective fiber dispersion, orientation, and opening led to significantly improved mechanical performance of the PP/kenaf composites, irrespective of the initial fiber length [7]. Using rice husk and high-density polyethylene (HDPE) as a material, Rahman et al. [8] explored the injection molding processability of a bio-composite by analyzing the melt flow behavior. The melt flow rate of rice husk/HDPE (RHPE) reduced as the rice husk composition increased, but apparent viscosity increased with composition for all filler sizes. The injection molding method was discovered with a minimum melt flow rate requirement of 4 g/10 min. The impact strength decreased with decreasing filler size and increasing filler content.

This research was conducted to determine the effect of rice husks on the mechanical properties of products made by injection molding. Four compositions of plastic and rice husks mixtures were made and injected as materials to form a tensile and impact test specimen. In addition, the quality of the printed product was also observed by cross-sectional observation.

## 2. Experimental Method

### 2.1. Materials

The constituent materials were polypropylene (PP) as the main matrix, rice husk as filler, and Maleic Anhydride Polypropylene (MAPP) as adhesive. Rice husk was used from agricultural waste from Bojonegoro, East Java, Indonesia, with a melting temperature of 18°C. The PP and MAPP had melting temperatures of 163°C and 190°C respectively. Four bio-composite materials composition was made with composition as shown in Table 1. After mixing and extruding, the materials were made in the form of pellets, as shown in Figure 1.

### 2.2. Equipment

HAITIAN-MA900/260e injection molding machine was used to make the product in this research. Standard ASTM D638-03 type V tensile and ASTM D256-04 impact test specimens were employed in the sample preparation. In addition, these sample items were subjected to a tensile and impact test. Tensile strength measurement used AUTOGRAPH AG-10TE, and impact test used a small impact tester, Charpy type, with capacity 0.5 – 22 Joule. Scanning electron microscope (SEM) examination was held on the cross-section fracture of the impact test specimen. The analysis used 500x magnification and focused on the void and rice husk position.

**Table 1.** Bio-composite materials composition.

| Item | Bio-composite | Polypropylene | Rice Husk | MAPP | Melting Point (°C) [9] |
|---|---|---|---|---|---|
| a | RH-5% | 90% | 5% | 5% | 163.6 |
| b | RH-10% | 85% | 10% | 5% | 164.2 |
| c | RH-15% | 80% | 15% | 5% | 163.3 |
| d | RH-20% | 75% | 20% | 5% | 163.1 |


**Figure 1.** Bio-composite materials.

### 2.3. Experimental Procedure

The injection machine's performance, the mold's design, the process parameter, and the raw materials directly affected the quality of the injection molding product [10, 11]. Therefore, it was necessary to determine the relevant parameters before manufacturing the product. A molding window was used to describe the setup parameter area of injection molding, indicating that a good sample lacked visual defects, such as short shots and flashes, as shown in Figure 2. In Figure 3, the molding window was represented by a set of boundaries that define a window-like shape, with injection pressure and melt temperature serving as process parameters. Molded items outside the illustrated process window were unacceptable due to sink, flash, or short shot. [12, 13].

Several conditions of the product, such as short shot, flash, and no defect, were shown in Figure 2. The molding window experiment utilized melt temperature and injection pressure as setup parameters in this study. Low melt temperature resulted in insufficient material melting, whereas high melt temperature resulted in over-melting and material deterioration. Low injection pressure resulted in a short shot or unfilled cavity, and high injection pressure resulted in a flash. Figure 3 showed the result of the molding window experiment. According to Figure 3, the suitable melt temperature was between 200 and 220°C, and the injection molding pressure was between 50 and 60 bar. Furthermore, the selected setting parameter of injection molding was shown in Table 2.

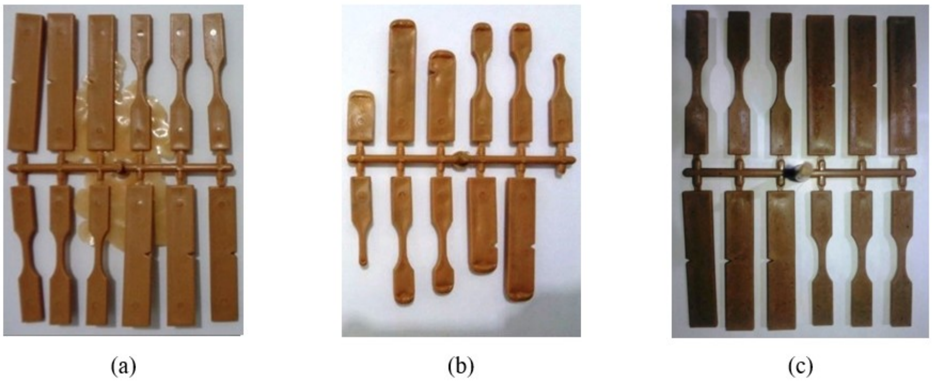


**Figure 2.** Several condition of (a) flash product, (b) short shot product, and (c) no defect product.

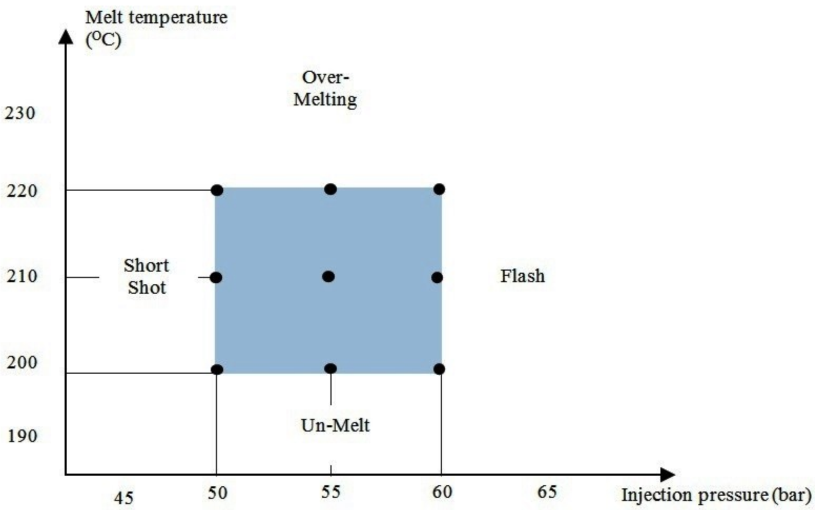


**Figure 3.** Molding window result.

**Table 2.** Injection molding setting parameter.

| Holding Pressure | Injection Pressure | Nozzle-Hopper Temp. | Injection Time | Holding Time | Cooling Time |
|---|---|---|---|---|---|
| 40 bar | 55 bar | 210 OC | 0.65 second | 15 second | 8 second |

## 3. Results and Discussion

### 3.1. Product of Injection Molding Process

RH-5% had the brightest brown color, and RH-20% had the darkest brown color, as shown in Figures 4 and 5. More rice husk on the bio-composite material made the product's color darker. While melting bio-composite materials in the injection machine barrel, the burned rice husk made the product dark

From visual observations, there were shrinkage defects or contractions on specimens, as shown in Figure 6. The largest shrinkage was on the RH-5% specimen, and the smallest shrinkage was on the RH-20% specimen. Shrinkage could be seen based on the hollow profile in the RH-5% composite specimen, especially on the thick part. The shrinkage made the product or specimen incompatible with the existing geometry specification. This condition happened because of the plastic content inside bio-composite material. Plastic content inside the product tended to form shrinkage if the setting parameter was not set properly, as shown in the RH-5% specimen that contained the highest plastic content inside. Improvements were needed to optimize the injection process by making shrinkage the main parameter.


**Figure 4.** ASTM D638 tensile test specimen products of (a) RH-5%, (b) RH-10%, (c) RH-15% and (d) RH-20%.

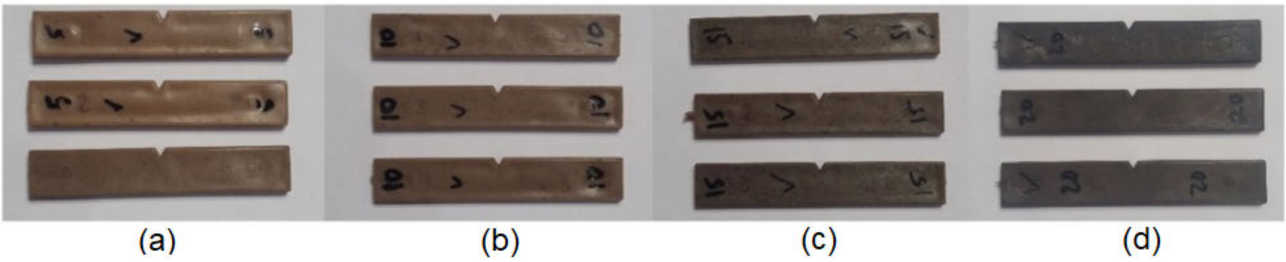


**Figure 5.** ASTM D256-04 impact test specimen products of (a) RH-5%, (b) RH-10%, (c) RH-15% and (d) RH-20%.


**Figure 6.** Shrinkage on the product.

### 3.2. Tensile Strength Test Result

Every bio-composite material had a variation in tensile strength value and elongation percentage, as shown in Figure 7. The difference in tensile strength values was insignificant. The tensile strength value decreased along with the increase in the rice husk content. All bio-composite materials had roughly the same tensile strength value and were lower than polypropylene, except RH-5%. RH-5% had tensile strength slightly higher than polypropylene, caused by the mixture being not homogeneous when stirred and the rice husk as only filling material (filler), not as reinforcement. A similar result was shown by the Burgstaller study [14]. Adding rice husk up to 50% into polypropylene composition could not increase tensile strength because rice husk had only a few cellulose layers, making it easy to crack. Therefore, it was unable to withstand mechanical loads [15]. Moreover, the deficiencies of stress transfer due to the lack of MAPP concentration on bio-composite material made the formation of the phase interface between PP and rice husk not go well. The elongation also decreased with increasing rice husk percentage. Figure 7 also depicts the elongation value which decreases with the increase in the percentage of rice husks. The elongation value describes the deformation of the material that occurs before fracture when the material is stretched. The lower elongation value indicates the material is slightly deformed before fracture. This condition means that RH-20% is the most brittle material compared to other materials.

### 3.3. Impact Test Result

The impact value of bio-composites was lower than polypropylene impact value and tended to decline along with the increase in the rice husk content, as shown in Figure 8. RH-5% had the highest impact value, while RH-10%, RH-15%, and RH-20% had the same value. The impact value decreased rapidly as rice husks were added to the main polypropylene matrix. It happened because the rice husk could not absorb the impact energy that was given well.

On the specimen fracture side, the residual fracture surface shape of RH-5% and RH-10% had a smooth fracture. While RH-15% and RH-20% had a rough fracture with fibrous on the edge of the fracture side, as shown in Figure 9. This was due to delamination, where local separation occurred on bonding material from the surface and caused a decrease in tensile strength. The remains of the fracture showed that RH-5% and RH-10% were ductile material, while RH-15% and RH-20% were brittle material. Furthermore, RH-5% and RH-10% did not have

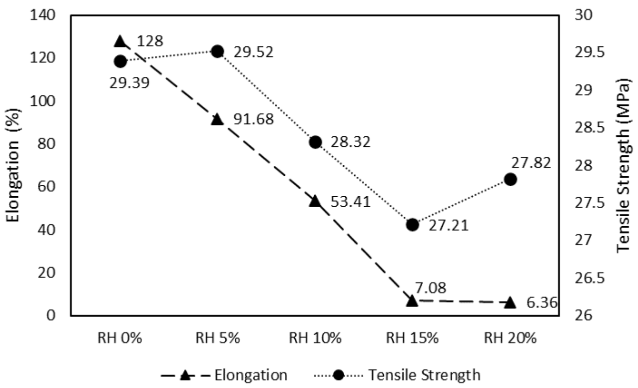


**Figure 7.** Bio-composites tensile strength and elongation percentage value.

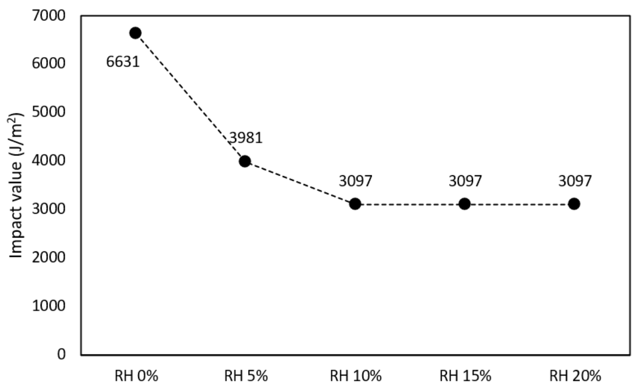


**Figure 8.** Bio-composites impact test value.

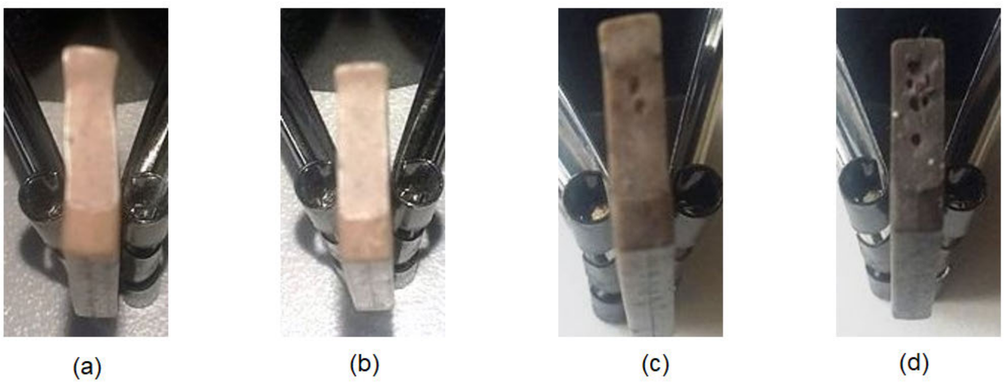


**Figure 9.** Sighting fracture of impact specimens of (a) RH-5%, (b) RH-10%, (c) RH-15% and (d) RH-20%.

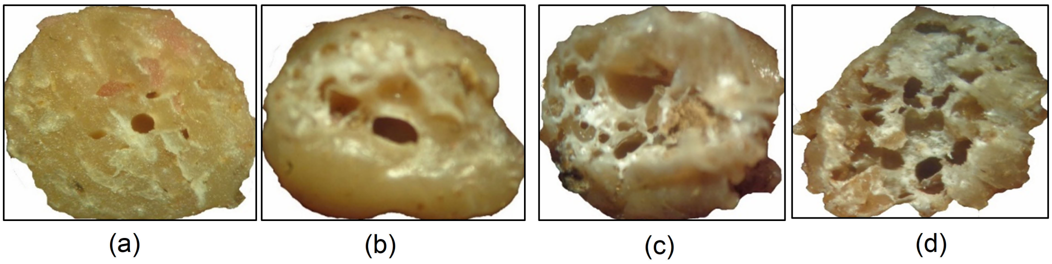


**Figure 10.** The cross-section of pellet with 40x magnification by using microscope of (a) RH-5%, (b) RH-10%, (c) RH-15% and (d) RH-20%.

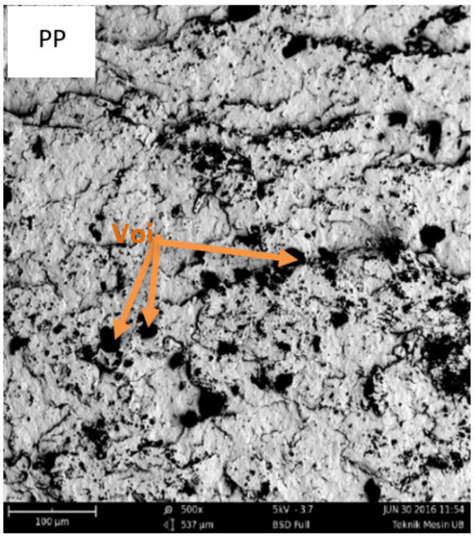


**Figure 11.** SEM result of polypropylene.

holes on the fracture side, in contrast to RH-15% and RH-20%. RH-15% had a few holes. RH-20% had more holes as it had a higher rice husk percentage. These holes were related to the injection molding process. These holes may be caused in material preparation, especially in the drying material process. Before molding, the drying material process reduced the content of air trapped inside the material. Moreover, the quality of the pellet also influenced this condition. The raw materials cross-section could be seen in Figure 10. The raw materials had many voids that caused holes in the product.

### 3.4. Scanning Electron Microscope (SEM) Result

SEM analyses were done on the fracture side of the impact specimen. The SEM result of polypropylene were shown in Figure 11. The SEM results of the bio-composite impact specimen were shown in Figure 12. In Figure 11, polypropylene had microscale voids and a raggy fracture surface. This rough surface was ductile material characteristics. When an impact test was conducted, some area of the fracture surface was pulled off, forming a wavy surface. In Figure 12, microscale voids decreased and nearly never occurred in bio-composite materials. RH-5% had a little void on the specimen fracture side, while RH-10%, RH-15%, and RH-20% hardly had a micro-scale void.

In Figure 12, rice husk breakage and pullout occurred on RH-10%, RH-15%, and RH-20%. RH pullout was caused by insufficient adhesion between rice husk and PP. Thus, the rice husk pulled when the specimen was under tension. This condition results in holes in the fault zone. RH breakage occurred if the adhesion between rice husk and PP was sufficient. These conditions did not occur on RH-5%. The Rice husk pulling phenomenon absorbed more energy during impact testing than RH fracture [16]. This phenomenon was influenced by the primary matrix's interaction with the filler. Strong interfaces created bio-composites with high strength and stiffness but also brittleness. This brittleness caused by fracture propagation from the matrix to the fiber or filler occurred easily. A weak interface lowered the load transfer efficiency from the matrix to the filler. Consequently, bio-composite materials had low strength and stiffness. At this low interface situation, the transversal crack movement traveled to the interface of matrix and filler, causing filler pullout from the filler's fracture mechanism, resulting from a strong interface. The coupling agent could create a strong interaction between the matrix and the filler.

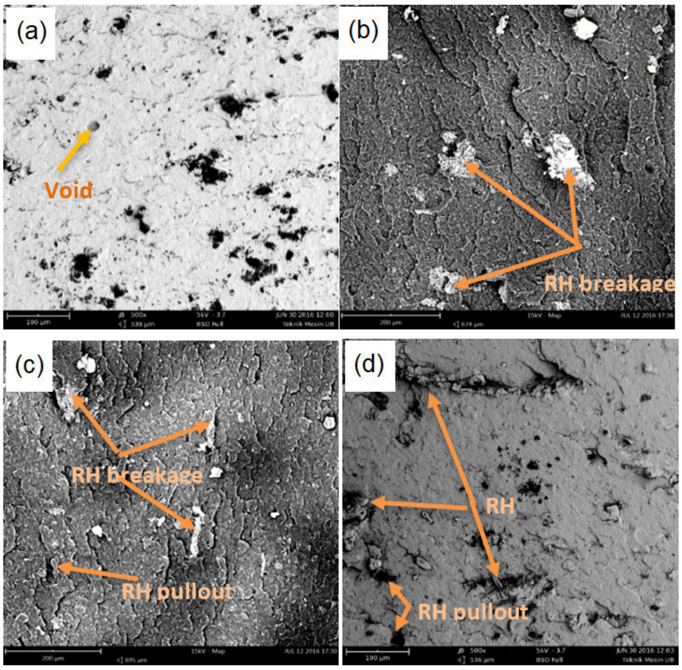


**Figure 12.** SEM result with RH pullout and RH breakage on the (a) RH-5%, (b) RH-10%, (c) RH-15%, and (d) RH-20%.

## 4. Conclusion

The result showed that the bio-composite materials could be injected to form ASTM D638-03 type V tensile test and ASTM D256-04 impact test specimens. However, it was found that shrinkage defects or contractions occurred on the specimens. Visually, the more rice husk on the bio-composite material, the darker the product color. Tensile strength and impact test after injection molding were evaluated. The difference in tensile strength values was insignificant and decreased along with the increase in the rice husk content. All bio-composite materials had roughly the same tensile strength value and were lower than polypropylene, except RH-5%. RH-5% had tensile strength slightly higher than polypropylene. RH-5% had an average impact value of 3981 J/m$^2$, and others had an impact value of 3097 J/m$^2$. The impact value decreased rapidly as rice husks were added to the main polypropylene matrix. It happened because the rice husk could not absorb the impact energy that was given well. The remains of the fracture showed that materials RH-5% and RH-10% were ductile, and materials RH-15% and RH-20% were brittle. Furthermore, SEM results showed rice husk breakage and pullout phenomenon on RH-10%, RH-15%, and RH-20%. Further research was needed to optimize the injection molding process using bio-composite materials to get the best product. In addition, shrinkage testing needed to be carried out on these specimens.

## Acknowledgments

The authors thank the Ministry of Research, Tech., and Higher Education of the Republic of Indonesia and the Mechanical Engineering Department of Institut Teknologi Sepuluh Nopember Surabaya for supporting this research and paper through The Grant 2022.

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