Preliminary Investigation to Determine the Suitable Mixture Composition for Corn Starch Matrix

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Abstract. The use of natural fiber as reinforcement in polymeric composites has been seen a dramatically increase over the last decades. The surge in the interest of natural fiber composite or biodegradable composite is mainly due to the attractive cost of production, improved of hardness, better fatigue endurance and good thermal and mechanical resistivity. In this work, corn starch in the form of powder is utilized as the matrix of the composite. However, starch is brittle and has low strength make it inappropriate candidate for matrix binder. The main objective of this study is to modify the mechanical properties of pure corn starch by mixing it with water, glycerol and vinegar. The composition ratio of water is 60~80%, corn starch 10~35%, glycerol is 5~15% and vinegar is 0~5%, ten samples (A-J) have been manufactured and the best mixture composition is selected based on few selection criteria. The selection criteria are visual impaction, hardness and density. From the results, the samples without vinegar are not suitable to be used because of the fungus availability on the surface. Meanwhile the results from the samples with 5 ml vinegar have no fungus on their surface even has been exposed to the ambient air. While the sample C has shown the best sample based on the visual, hardness and density test.

1. Introduction

Composite materials are materials made from two or more constituent materials with significant different physical and chemical properties [1]. The combination of two different materials produces a new type of material that has different structural properties from the individual component [2]. The new material generated is generally preferred due to many reasons. One of the reasons is that the new material is generally has higher strength, lighter, and less expensive than the old one [1]. The use of natural fibers as reinforcement in polymeric composites has seen a dramatic increase over the last decades. The surge in the interest of natural fibers is mainly due to the attractive cost of production, improved of hardness, better fatigue endurance and good thermal and mechanical resistivity [3]. Apart from that, natural fibers are also considerably environmentally friendly [4]. In order to give the unique ability for the natural fibers, binder/matrix such as starch, epoxy and polypropylene are added to enhance the existing mechanical properties. During the ancient civilization, clay was reinforced by straw to build strong walls. The analogy is that the clay becomes the binder that holds the straw together resulting in stronger building structure.

Matrix or binder is an important component that should be thoroughly consider in order producing composite material. This consideration is needed due to the varying properties of the matrix such as the durability in various temperature, electricity conductivity, moisture sensitivity, weight, and ease of handling depending on the usage purpose of the matrix [5]. Besides that, the selection of matrix also will influenced by the fabrication method and the effect of matrix on the properties of reinforcement.
itself. However, the prime consideration is that the constituent should be chemically inert non-reactive. The matrix can be future classified into few categories, namely polymer matrix, metal matrix, ceramics matrix and graphic matrix materials. Even though the strength of the materials on the composites is basically due to the fiber reinforcement but, the function of the matrix cannot be underestimated as it also provides support for the fibers by helping to withstand the applied loads [6]. Moreover, the matrix also provides stability to the composite materials that is by holding the fibers together, and protects the fibers from the harsh environment. Distribution of even load between the fibers is achieved with the aid of the matrix. Due to all these reasons, the selection of matrix is critical as the mechanical properties of the composites such as the inter-laminar shear (bending loads) and the in plane shear (torsion loads) is heavily influenced by the type of matrix utilized.

In green category of composites materials, the matrix can be future classified into three types. The first type is named as partial biodegradable with non–biodegradable polymers matrix such as thermoplastic polymers (polypropylene, polyethylene) and thermoset polymers (epoxy, polyster). Meanwhile, the second type is named as fully biodegradable with biodegradable polymers matrix such as the renewable biopolymer matrix. The examples of this type are soy plastics, cellulosic plastics and starch plastic. The third type of matrix is defined as petro-based bio-degradable polymer matrix such as aliphatic co-polyster and polyesteramides [7, 8].

Starch matrix is classified under carbohydrate that is abundantly available in plants where it is stored in granule forms and acts as an energy reserve. The starch is composed of two types of polymers, which are named as amylose and amylopectin. The properties of hydrophilicity in the starch make the components incompatible with most of hydrophobic polymers. This incompatibility results to a condition where the molecules component of the starch is easily consumed by microorganism when it is exposed to soil. In order to improve the ductility of the starch, the addition of the glycerin can be performed as it lower down the transition and melting point temperature [9]. Besides that, starch has been the popular research subject for the past decade studied owing to the availability, biodegradability and low in cost of production. Starch can be easily found in corn, rice or potatoes. One unique characteristics of starch is that it becomes thermoplastic if water, glycerol or sorbitol is added as the plasticizer. However, several researchers reported that the main disadvantages of starch are poor of process ability, highly brittle, high water resistance and poor stability in the long term duration [10].

Previous study reported that starch has huge potential to be a good matrix or binder to produce a fully biodegradable composite [10]. However, the mechanical properties of the starch need to be improved through modification process. The improvement process starts with the determination of the composition of water, starch, glycerol and also vinegar. The best composition of the sample is then utilized in mechanical testing.
2. Methodology

In this work, corn starch in the form of powder is utilized as the matrix of the composite. However, starch is known to be brittle and has low strength that makes it inappropriate candidate for matrix binder [10]. Therefore, the strength properties of starch need to be enhanced. It is proposed in this paper that the enhancement of the starch structural properties can be enhanced by modifying its chemical composition. The modification of the chemical composition is conducted by adding water, glycerol and vinegar. Glycerol enhances the ductility of the corn starch while vinegar breaks the branched of amylopectin into straight chained amylose molecules. The composition volume of the mixture is depicted in Table 1. The powder form of starch is first mixed together with water, glycerol and vinegar. The combination of glycerol and water and vinegar results to liquidification of the starch powder. Then, the mixture is heated up so that the liquid form of starch, water and glycerol can be converted into a new form of liquid that has high viscosity. Next, this liquid is poured into a mould of which the solidification will take place.

The samples of the new starch are then prepared for mechanical testing. Two types of mechanical testing were performed, namely hardness and density test. The hardness test has been conducted using Hardness Shore Scale. The whole process of modification of the corn starch is presented in the flow chart depicted in Figure 1.

| Sample | Water (g) | Starch (SH) (g) | Glycerol (g) | Vinegar (g) |
|--------|-----------|-----------------|-------------|------------|
| A      | 60        | 25              | 10          | 5          |
| B      | 60        | 20              | 15          | 5          |
| C      | 70        | 20              | 5           | 5          |
| D      | 70        | 15              | 10          | 5          |
| E      | 60        | 35              | 5           | 0          |
| F      | 70        | 25              | 5           | 0          |
| G      | 75        | 15              | 10          | 0          |
| H      | 75        | 20              | 5           | 0          |
| I      | 80        | 10              | 10          | 0          |
| J      | 80        | 15              | 5           | 0          |
Figure 1. Flow chart of corn starch modification process
3. Results and Discussion

Figure 2 (Sample A up to D) and Figure 3 (Sample E up to J) below present ten samples after the completion of the cooling process. After doing the visual inspection of each sample, as seen in Figure 2, the surface of the samples from A-D are in good condition and have the same colour throughout the sample surface. On the other hand, samples E-J as presented in Figure 3 indicate that there is fungus on the surface. It clearly can be seen the dark area on the surface of each sample. Since the main difference in term of composition between samples A-D and samples E-J, is the availability or present of vinegar in the mixture composition is about 5ml. The present of vinegar as one of mixture components, it gives the acidic effect such as resisted of the fungus to be from and spreader throughout on the surface.

![Sample A](image1)
![Sample B](image2)
![Sample C](image3)
![Sample D](image4)

**Figure 2.** Sample of A to D (no fungus on surface)
Figure 3. Sample of E to J (with fungus on the surface)
Meanwhile Table 2 and Table 3 present the results of density and hardness tests respectively. For both tests, the tests have performed only for samples A, B, C and D since these samples have no fungus on their surface. The results in Table 2 show the density value of an average of five readings. Based on data collected, generally, the density values remain almost constant for A, B, C and D samples. This result indicates that the mixture composition has no significant effect on the density. Meanwhile from Table 3, sample C has the highest hardness number. As for the comparison purpose, the content of glycerol in sample C is the lowest with 5 gram. Thus, it is suggested that the content of glycerol significantly affects the sample hardness.

| No | Sample A | Sample B | Sample C | Sample D |
|----|----------|----------|----------|----------|
| 1  | 1.305    | 1.268    | 1.367    | 1.287    |
| 2  | 1.299    | 1.259    | 1.363    | 1.287    |
| 3  | 1.297    | 1.261    | 1.370    | 1.290    |
| 4  | 1.298    | 1.274    | 1.336    | 1.282    |
| 5  | 1.288    | 1.279    | 1.379    | 1.297    |
|    | Average  | 1.30     | 1.27     | 1.36     | 1.29     |

Table 2. Density Testing Results for Sample A-D (unit is in g/cm³)

| No | Sample A | Sample B | Sample C | Sample D |
|----|----------|----------|----------|----------|
| 1  | 9.5      | 3        | 8        | 1        |
| 2  | 8        | 4        | 6        | 2        |
| 3  | 6        | 3.5      | 10       | 1        |
| 4  | 8        | 5        | 11.5     | 0.5      |
| 5  | 3        | 1.5      | 17       | 1        |
| 6  | 4        | 4        | 14       | 1.5      |
| 7  | 6        | 1        | 13       | 0.5      |
| 8  | 8.5      | 3        | 5        | 0.5      |
| 9  | 9        | 1.5      | 11       | 0.5      |
| 10 | 6        | 1        | 7        | 1        |
| 11 | 4.5      | 4        | 18       | 0.5      |
| 12 | 9        | 1        | 6        | 1        |
|    | Average  | 6.79     | 2.71     | 10.54    | 0.92     |

Table 3. Hardness Testing Results for Sample A-D (dimensionless)
4. Conclusion

The process of modifying the mechanical properties of pure corn starch by mixing with water, glycerol and vinegar has been successfully demonstrated. It shows from the result that the sample without vinegar is prone to have fungus over some time. So that this samples with fungus on the surface is not suitable for future use. Apart from that, the hardness and density testing shows that Sample C has the best characteristics in terms of mechanical properties. Sample C has the composition of 70% water, 20% starch, 5% glycerol and 5% vinegar. Based on this result, it’s have generate potential to be used as matrix or binder with natural fibers to produce biodegradable composite. Therefore, further investigation is needed such as to obtain the best composition and orientation between the modified starch with the natural fiber to produce the best result of composite.

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