Mechanical Properties and Melt Flow Index of Poly (butylene succinate) Blended with a Small Amount of Natural Rubber Compound

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Abstract. Natural rubber compound (NRC) was blended with biodegradable poly(butylene succinate) (PBS) with PBS/NRC weight ratios of 100/0, 97/3, 94/6 and 90/10. The PBS/NRC blends were melt mixed using an internal mixer at 145°C. Mechanical properties and melt flow index of the blends were investigated. The results showed that the percentage elongation at break and impact strength of the blends improved when NRC was added. On the other hand, the Young's modulus and tensile strength of the blends decreased with an increase in the amount of NRC. The melt flow index of the blends continuously decreased with an increase in NRC content. This implied that NRC increased the viscosity of the blends. Moreover, the fractured surface morphology of PBS/NRC blends showed a good dispersion of NRC particles in PBS matrix. The average particle size of NRC was 2-5 µm.

1. Introduction
Many researchers are concerned with the current ever increasing environmental pollution hence, the development of green or environmental-friendly materials has attracted attention; for example the research on bioplastic materials [1-5]. Bioplastics have attracted a considerable interest to study because they are made from renewable resources such as cellulose, casein, collagen, soy protein, corn. The use of bioplastics is the best way to decrease plastic pollution because they can degrade and decompose in the natural environment. Examples of bioplastics are polycaprolactone [6], poly (lactic acid) (PLA) [2-3], and poly (butylene succinate) (PBS) [4-5]. The most popular material in the bioplastic industry is PLA. However, it is a brittle material and difficult to process. On the other hand, PBS has good mechanical properties and is easy to process. PBS is synthesized from the condensation reaction between 1,4-butanediol and succinic acid. It has a polyester and linear structure. It has thermal stability up to 200°C. After use, PBS degrades into carbon dioxide and water. However, it is still an expensive cost. Hence, there have been many attempts to increase the ability application of PBS i.e. polymer blend [4-5, 7] and/or composites materials [8-9].

Natural rubber (NR) is a bio-based elastomer which has a high elasticity and good tear strength. There have been many attempts to improve the toughness of polymeric matrix by natural rubber [2-5].
Examples of some of the reported studies are in polystyrene [10], poly (lactic acid) [2-3], poly (butylene succinate) [4-5].

This study examined the effect of NRC content on the mechanical properties and melt flow index of biodegradable PBS and natural rubber compound (NRC) blend which were melt blended in an internal mixer.

2. Materials and method

2.1. Materials
Natural rubber (NR, STR 5L), stearic acid, zinc oxide (ZnO), sulphur (S), and N-cyclohexyl-2-benzothiazole sulfenamide CBS (CZ) were used to prepare natural rubber compound (NRC). All chemicals used in preparing the rubber compounds were purchased from Chareon Tut Co., Ltd., Thailand. Biodegradable poly (butylene succinate) (PBS), BioPBSTM FZ71PM grade, was supplied by PTT MCC Biochem company limited.

2.2. Natural rubber compound preparation
Natural rubber (NR) and chemicals were mixed on a two-roll mill (Chareon Tut co., ltd., ML-D6L12-INV) with a roller speed ratio between front roll and back roll of 1:1.4 for 35 min in order to make NRC. The order of reagents is shown in Table 1. After being mixed, NRC was kept in room temperature for a night before being blended.

| Raw materials | Composition, phr | Mixing time, min |
|---------------|------------------|------------------|
| 1. Natural rubber | 100              | 15               |
| 2. Stearic acid | 2                | 5                |
| 3. ZnO         | 4                | 5                |
| 4. Sulphur     | 3                | 5                |
| 5. CZ          | 0.7              | 5                |

2.3. Poly (butylene succinate)/natural rubber compound blend
PBS was dried in an oven at 50°C for 24 h before use. NRC and dried PBS were mixed in an internal mixer (Chareon Tut co., ltd., MX500-D75L90) with a rotor speed of 50 rpm at 145°C for 15 min. The ratio of PBS/NRC were 100/0, 97/3, 94/6 and 90/10. The total weight of each batch was 270 g. After completely mixing, the PBS/NRC blend was cooled to room temperature and ground with a grinder.

2.4. Hot-compression process
The ground PBS/NRC blends were dried in an oven at 50°C for 24 h before hot-compression process. In the sample prepared for mechanical test, a hot-compression machine (Chareon Tut co., ltd., PR2D-W300L350 PM-WCL-HMI) was used at a temperature of 145°C and pressure of 1500 psi. The pre-heat time, pressing time and cooling time were 5, 5, and 3 min, respectively. The samples were prepared according to ASTM D638 for tensile test and ASTM D256 for impact test.

2.5. Testing and characterization
2.5.1. Mechanical testing. For tensile test, universal testing machine (UTM, LLOYD INSTRUMENT, LR10K plus) with a crosshead speed of 50 mm/min was used at room temperature. At least five samples were tested and evaluated. For impact test, the notched Izod impact type was conducted according to ASTM D256 at room temperature by impact tester machine (INSTRON, Ceast 9050). At least ten samples were tested and evaluated.
2.5.2. **Morphological study.** The fractured surface from tested impact sample was investigated by using scanning electron microscope (Phenom-world holding B.V., Phenom pro).

2.5.3. **Melt flow index testing.** Melt flow index (MFI) was investigated according to ASTM D1238. The ground PBS/NRC blends were dried in an oven at 50°C for 24 h before being measured.

### 3. Result and discussion

#### 3.1. Mechanical testing.

The impact strength of PBS/NRC blends is shown in Fig 1. The results showed that the impact strength of the PBS/NRC blends in the ratio of 100/0, 97/3, 94/6 and 90/10 were 3.09 ± 0.85, 3.71 ± 0.28, 4.95 ± 0.84 and 5.150 ± 0.57 kJ/m², respectively. For the blends containing 3, 6 and 10 %wt of NRC, their impact strength were higher than that of the neat PBS. The highest impact strength of the blends showed in the ratio of 90/10 which improved from 3.09 to 5.15 kJ/m² (around 1.7 times). The reason for this improvement was that NRC which presented as a rubbery particle in the PBS matrix acted as stress absorber in the polymeric matrix. It is a toughened polymer matrix similar with a previous report, which improved toughness of PBS by the blending of the elastomeric acrylonitrile butadiene rubber (NBR) [7].

The tensile properties are illustrated in Fig 2. The elongation at break of PBS/NRC blends showed that NRC contributed to improve this value (Fig 2a). The highest elongation at break of the blends was 20.05 ± 0.03 percentage in the ratio of 90/10. This is due to the elastic property of NRC that is similar to the polymer-rubber system i.e. PBS/NBR blend [7], PBS/NR blend or PBS/epoxidized NR [5]. On the other hand, the incorporation of NRC significantly decreased the tensile strength and Young’s modulus of PBS as shown in Fig 2(b) and (c), respectively. As expected, these values decreased with an increase in the amount of NRC due to the rubber particles being a weak point or stress concentration in the system.

![Figure 1](image-url)  
*Figure 1. Impact strength of poly (butylene succinate)/natural rubber compound (PBS/NRC) blends*
Figure 2. Tensile properties of PBS/NRC blends; (a) elongation at break, (b) tensile strength and (c) Young’s modulus

3.2 Morphological property
Figure 3 illustrates the SEM micrographs of the fractured surface from impact test of PBS/NRC blends with various blend ratios. The result showed that the coarse surface of pure PBS could be observed as shown in Fig. 3(a). All blends illustrated dispersed NRC particles in the PBS matrix (Fig. 3(b)-(d)). The distribution of NRC particle size was approximately 2-5 µm as shown in Fig. 3(b)-(d). These morphologies were involved with the mechanical properties as previously discussed.

![SEM micrographs](image)

**Figure 3.** Morphology of PBS/NRC blends with a weight ratio of; (a) 100/0, (b) 97/3, (c) 94/6, and (d) 90/10. The arrows mark NRC particles.

3.3. *Melt flow index*

Figure 4 shows the melt flow index (MFI) as a function of NRC content. The result showed that the MFI was decreased with an increase in the amount of NRC. This implies that the viscosity of the blend increased with an increase of NRC content.
4. Conclusions
PBS/NRC blends with various weight ratios of 100/0, 97/3, 94/6 and 90/10 were prepared via an internal mixer. The amount of NRC had an effect on the mechanical properties, melt flow index and morphology of the blends. The highest impact strength and percentage elongation at break were achieved at 10 wt% of NRC. The tensile strength and Young’s modulus monotonically decreased with an increase in NRC content. In addition, the melt flow index of the blends decreased. Finally, NRC might be used to enhance toughness of other brittle polymer matrix or increase viscosity of other polymers.

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