Development of super-tough polylactic acid by the combining plasticization and rubber toughening techniques.

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INTRODUCTION:

The population of the world has increased several times. There is a lot of plastic waste and "non-biodegradable". The most popular biodegradable plastic is polylactic acid (PLA).

Polylactic Acid:

- Derived from renewable resources
- A thermoplastic polymer
- Biodegradable property
- Processability

Brittleness
- Low toughness
- Low Impact Strength

Properties improvement of toughness of polylactic acid

Additives

- Toughening agent
- Plasticizer

- Used to improve mechanical properties such as toughness and impact strength.
- Used as a plasticizer of plastic to increase plastic flexibility, softness and compatibility.
Objective:

- This study aims to develop the toughness of polylactic acid with addition toughening agents and plasticizer.

The benefits expected to be received:

- To enhance the toughness and reinforced plastic condition for poly (lactic acid).
- Molded products can be easily squeeze bottle of sauce with biodegradable properties.
Materials:

- PLA
- Core Shell Rubber (CSR)
- Tributyrin

- PLA:
  - Acrylic or PMMA ingredients with excellent compatibility with matrix resin which helps the even distribution of impact modifiers.

- CSR:
  - Composed of rubber, Absorbs impact energy from the outside.
  - Core Shell Rubber (CSR) act as toughening agent and Impact modifier to plastic.
  - Used as a plasticizer of plastic to increase plastic flexibility and Compatibility.

- Tributyrin:

![Chemical structure of PLA](image1)

![Chemical structure of Tributyrin](image2)
Table Formulations of PLA, CSR and TBR:

<table>
<thead>
<tr>
<th>Formulation Code</th>
<th>PLA content (wt%)</th>
<th>Core shell Rubber content (Wt%)</th>
<th>Tributyrin (TBR) (wt%)</th>
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<tr>
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Additives overall 15%wt. 10%wt. 5%wt.

<table>
<thead>
<tr>
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6 STEPS
OF EXPERIMENT FOR OUR SQUEEZE SAUCE BOTTLE

STEP 1
MIXING
PLA+CSR

Dry mixing PLA/CSR according to different ratio and compounding by twin screw extruder and cut into the pill.

STEP 2
COMPOUNDING
PLA/CSR + TBR

Dry mixing PLA/CSR with TBR according to different ratio and compounding by twin screw extruder and cut into the pill.

STEP 3
COMPOUNDING

STEP 4
INJECTION MOLDING

Injection molded PLA/CSR/TBR according to different ratio into dumbbell for testing.

STEP 5
TESTINGS

Test thermal properties of PLA/CSR/TBR pill according to different ratio by Differential Scanning Calorimeters (DSC).

STEP 6
EXTRUSION BLOW MOLDING

Dumbbell parts were taken mechanical properties test, tensile strength, impact strength, morphology and melt flow index test.

Choose the best recipe to make a bottle of easy squeeze sauce with extrusion blow molding machine.
## Result and Discussion:

### Melt Flow Index

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## Result and Discussion:

### Thermal property

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<th>Tg (°C)</th>
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- **Heating**
  - PLA80CSR15TBR5
  - PLA80CSR10TBR10
  - PLA80CSR5TBR15
  - PLA85CSR10TBR5
  - PLA85CSR7.5TBR7.5
  - PLA85CSRSTBR10
  - PLA90CSR7.5TBR2.5
  - PLA90CSRSTBR5
  - PLA90CSR2.5TBR7.5
  - PLA95CSR3.5TBR1.5
  - PLA95CSR2.5TBR2.5
  - PLA95CSR1.5TBR3.5
  - neat PLA

- **Cooling**
  - PLA80CSR15TBR5
  - PLA80CSR10TBR10
  - PLA80CSR5TBR15
  - PLA85CSR10TBR5
  - PLA85CSR7.5TBR7.5
  - PLA85CSRSTBR10
  - PLA90CSR7.5TBR2.5
  - PLA90CSRSTBR5
  - PLA90CSR2.5TBR7.5
  - PLA95CSR3.5TBR1.5
  - PLA95CSR2.5TBR2.5
  - PLA95CSR1.5TBR3.5
  - neat PLA
Result and Discussion:

<table>
<thead>
<tr>
<th>PLA:CSR:TBR</th>
<th>Modulus (GPa)</th>
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<tbody>
<tr>
<td>neat PLA</td>
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</table>

Fig. A overall additive 5%wt

<table>
<thead>
<tr>
<th>PLA:CSR:TBR</th>
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<tbody>
<tr>
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Fig. B overall additive 10%wt

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<th>Modulus (GPa)</th>
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Fig. C overall additive 15%wt

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Fig. D overall additive 20%wt
Result and Discussion:

**Tensile Strength**

**Fig. A overall additive 5%wt**

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**Fig. B overall additive 10%wt**

<table>
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**Fig. C overall additive 15%wt**

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**Fig. D overall additive 20%wt**

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Result and Discussion:

Fig. A Overall additive 5% wt

- neat PLA
- PLA95CSR1.5TBR3.5
- PLA95CSR2.5TBR2.5
- PLA95CSR3.5TBR1.5

% Elongation at break

Fig. B Overall additive 10% wt

- neat PLA
- PLA90CSR2.5TBR7.5
- PLA90CSR5TBR5
- PLA90CSR7.5TBR2.5

Fig. C Overall additive 15% wt

- neat PLA
- PLA85CSR5TBR10
- PLA85CSR7.5TBR7.5
- PLA85CSR10TBR5

Fig. D Overall additive 20% wt

- neat PLA
- PLA80CSR5TBR15
- PLA80CSR10TBR10
- PLA80CSR15TBR5
Result and Discussion:

- **Fig. A overall additive 5%wt**
- **Fig. B overall additive 10%wt**
- **Fig. C overall additive 15%wt**
- **Fig. D overall additive 20%wt**

Impact Strength

<table>
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<tr>
<th>CSR:TBR</th>
<th>Impact strength (J/m)</th>
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Conclusion:

The effect of addition toughening agents and plasticizer into polylactic acid by Core shell rubber (CSR) and Tributyrin (TBR) it can be development the toughness of polylactic acid on mechanical properties of PLA/CSR/TBR blends was elucidated.

Tensile modulus and tensile strength of PLA/CSR/TBR blends decreased while increasing the amount of tributyrin additives. The impact strength and the %elongation at break of the PLA/CSR/TBR blends were improved significantly.
Acknowledgment:

The authors would like to acknowledge the research grant supported by Faculty of Agricultural Product Innovation and Technology, Srinakharinwirot University. Thanks are extended to Asst. Prof. Nawadon Petchwattana for the preliminary study of this research.

References:


