PRODUCTION AND CHARACTERIZATION OF POLYMER BLEND FROM LDPE AND STARCH

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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering.

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STUDENT’S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been dully acknowledged. The thesis has not been accepted for any degree and is not concurrently for award of other degree.

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ABSTRACT

Polymer blend is an alternative polymer to substitute a common polymer used in industrial. It acts same as the others polymer. The resource to make polymer blend is from the natural polymer. The combination of natural polymer and other polymer is called polymer blend. In this study, tapioca starch and low-density polyethylene (LDPE) had been used to form the polymer blend. A compatibilizer is required in order to allow starch and LDPE to get mixed. Citric acid is one of the most readily applicable agents Function of the compatibilizer is to fragment the bond of the combination polymer due to the acidity of citric acid is propitious and the ensuing dissolution of the tapioca starch granules. The objectives of this study are to improve production of polymer blend and optimum polymer composition. Formulation that had been set are from 5, 10, 15, 20 and 25% value of starch based on LDPE. The samples first undergo extrusion process that make the samples form into pellet size. Then, the pellet had been gone through molding process which is injection molding. The pellet been shaped into dumbbell shape for testing purpose. Characteristic that had been done are like tensile strength, density and water absorption. The result expected is to show the certain formulation gives high response in the area of testing and the optimum polymer blend composition is determined.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Polymer blend from renewable resources have attracted all attention over the last twenty five years because of due to two major factors: firstly environmental issues, and secondly the realization that the petroleum resources are finite (Yu *et al*., 2006). The polymer blend is alternative materials that have been produced with desirable properties based on available polymers rather than to design and synthesize a new polymer. For these reasons, the demands for polymer blend are really high in the market.

Polymer blend have attributed many functions to industrials sector and gain popularity through it. Many goods are made from polymer blends and it is usually cheaper and less time-consuming (He *et al*., 2004). The application of polymer blend is use in numerous sectors such as; adhesion, colloidal stability, and design of composite and biocompatible materials (Lipatov, 2002). Basically, polymer blend are produced by combining polymers and changing the blend composition of product that have been use.

Material that normally been used to produced polymer blend is belong to polysaccharides group which are cellulose, pectin, gums, caragreenan and starch. From all the materials, starch is a potential material since its inherent biodegradability, overwhelming abundance and its annual renewal compare to the others. However, the pure starch needs to add plasticizer due to solve water soluble, difficult to process and brittle problems (Yu *et al*., 2006).

The common method to convert raw starch into polymer blend is by using reactive extrusion. The reactive extrusion is take place in batch or continuous stirred tank reactors. The reactive extrusion process can be simply described as gelatinization then results in disruption follow by formation and end with modification process. The material which is starch undergoes gelatinization in hot water for certain temperature resulting in disruption of starch granule and formation of homogenous solution based on the starch. Finally, the substance goes through modification process at relatively low reaction temperature and with high salt and water concentrations. For this process, temperature and composition of water and starch influence the process which causes the poor and good reaction selectivity (Moad, 2010).

1.2 Identification of Problem

Polymer blend is an alternative polymer to substitute a common polymer used in industrial. It acts same as the others polymer. The advantage using the polymer blend is because it is inherently biodegradable. Currently, whole world-wide have concern how important the environmental issues. By using the polymer blend, means that it can control the environment furthermore can create new applications from it (Yu *et al.*, 2006).

The low costing for making the polymer blend have make it more preferable to be used. They represent one of the most rapidly factors in polymer science material. However, the polymer blend also have it disadvantages are their dominant hydrophilic character, fast degradation rate and unsatisfied mechanical properties (Yu *et al.*, 2006). But compare to the synthetic polymer which are not degradable, have environmental problem and limited resources, clearly the needed for other alternative is high. Based on that statement, a proposal on a new production and characterization of polymer blend by knowing the addictives that been used to improve their process ability and properties in term of mechanical strength to determine the best polymer compositions have been clarified.

1.3 Statement of Objectives

The main objectives of this study to improve the production of polymer blend via injection molding, to perform characterization of polymer blend and to determine the optimum polymer composition via mechanical testing.

1.4 Research Scopes

The research scopes for this study are:

i. To improve the productions of polymer blends at fix composition of plasticizer and different composition of LDPE and starch.
ii. To perform the characterization of polymer blends in terms of mechanical properties of the polymer blends such as tensile strength, and elongation.
iii. To determine optimum polymer blend production based on the composition of LDPE and starch, where measure in terms of mechanical properties.

1.5 Rationale and Significance of Study

Polymer blend basically a combination of two or more polymers produce by blends them together to make a new product with unique properties. A study shown over 30% of polymers that have been used world-wide are from polymer blends (Alam *et al.*, 2005) and it suggest that the demand for polymer blends is currently rising. From this perspective, the polymer blend is a promising alternative because of several advantages; it is renewable, biodegradable, and less-consuming. The production of polymer blend from starch are really suitable to be make as Malaysia have many sources of starch such as tapioca, potato and corn. The polymer blend that will be produce should have different properties although the products for blending have different properties.

The costing for production of polymer blend is lower compares to production of new polymer. Therefore, the demands of polymer blend in plastic sector rising because of its properties. It also proved that polymer blending is one of simple and efficient in developing high performance of composite system (Pinchuk *et al.*, 2003). For this purpose, the production of polymer blend can be use world-wide especially in Malaysia since the source of natural polymer like starch can be obtains. By commercially using polymer blend, it also can save the environment since it is a biodegradable product.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Polymer Blend

For the development of new polymeric materials, polymer blending is a convenient route for this goal and it produce polymer blend. Compare to the individual components properties, the process able to yield materials with properties profiles superior than the components. In addition, this process is usually cheaper and less time-consuming for the production of polymer materials with new properties than the development of new monomers or new polymerization routes. Polymer blend’s advantage is that the properties of the materials can be altered by combining component polymers and changing the blend composition (He *et al.*, 2004).

There are three different types of polymer blend can be categorized: firstly is completely miscible blends, secondly partially miscible blends and lastly fully immiscible blends. Miscible can be defined as where the two or more liquid can be mixed together. Besides that, polymer blends are either exists in homogeneous or heterogeneous state. In homogeneous blends, the average properties of the blend components are the final properties which means the properties is divided equally. Meanwhile in heterogeneous blends, the properties of all blend components are present (Yu *et al.*, 2006 & He *et al.*, 2004).

2.2 Polymer Blend Production

The process to produce polymer blend is by polymer blending. This method is combination of two or more polymer by blending it together. The properties obtain from new material usually have different properties from the original properties. Normally the polymer blend use sources like natural polymer. This is because the natural polymer is easy to get, totally biodegradable and inexpensive. Examples of natural starch have been shown in Figure 2.1. For this study, starch has show potential as the natural polymer due to its ability and desirable properties.

Table 2.1: List of natural polymer (Yu *et al.*, 2006)

Natural polymer
Polysaccharides • Plant/algal: cellulose, pectin, konjac, alginate, starch, caragreenan, gums • Animal: hyluronic acid • Fungal: pulluan, elsinan, scleroglucan • Bacterial: chitin, chitosan, levan, xanthan, polygalactosamine, curdlan, gellan, dextran
Proteins Soy, zein, wheat gluten, casein, serum, albumin, collagen/gelatin, silks, resilin, polylysine, polyamino acids, poly(γ-glutamic acid), elastin, polyarginyl-polyaspartic acid
Lipids/surfactants Acetoglycerides, waxes, surfactants, emulsan
Speciality polymers Lignin, shellac, natural rubber

One of the main disadvantages of biodegradable polymers obtained from renewable sources is their dominant hydrophilic character, fast degradation rate and, in some cases, unsatisfactory mechanical properties, particularly under wet environments. In principle, the properties of natural polymers can be significantly improved by blending with synthetic polymers for example is polyethylene.

Polymer blending is a well-used technique whenever modification of properties is required, because it uses conventional technology at low cost. However, in the production of polymer blend there are several problem might occurs; water soluble, difficult to process and brittle. Therefore to solve the problems is to add plasticizer to the blend (Yu *et al.*, 2006). By embedding themselves between the chains of polymers, and spacing them apart is how the plasticizer works.

2.2.1 Melt Processed Blends

Starch is one of the most promising natural polymers because of its inherent biodegradability, overwhelming abundance and its annual renewal. However, by itself, pure starch is not a good choice to replace petrochemical-based plastics. It is mostly water soluble, difficult to process and brittle when used without the addition of a plasticizer. In addition, its mechanical properties are very sensitive to moisture content. Blending two or more chemically and physically dissimilar natural polymers has shown potential to overcome these difficulties.

2.2.2 Aqueous Blends

Many natural polymers cannot be melt processed, either because they degrade on or before melting (softening) or because they are designed to incorporate substances that do not stand high temperature (proteins, drugs, etc.). For these examples, aqueous blending is the preferred technology, particularly in biomedical applications.

Natural polymers are usually biocompatible and non-cytotoxic due to their similarity with living tissues. Biopolymers are an important source of material with a high chemical versatility and with high potential to be used in a range of biomedical applications. A great variety of materials derived from natural sources have been studied and proposed for different biomedical uses, namely polysaccharides (starch, alginate, chitin/chitosan) or protein (soy, collagen, fibrin gel) and, as reinforcement, a variety of biofibers such as lignocellulosic natural fibers. Starch-based polymers present enormous potential for wide used in the biomedical field, as these natural polymers are totally biodegradable and inexpensive when compared to other biodegradable polymers available. Aqueous blends of soluble starch and cellulose acetate have been studied intensively because these blends have a range of properties that make them suitable for use in a wide array of biomedical applications, ranging from bone replacement to engineering of tissue scaffolds and drug-delivery systems.

2.3 Starch

Starch is a polysaccharide carbohydrate and a complex carbohydrate. The chemical formula for starch is $(C_6H_{10}O_5)_n$. It is consisting of amylose (linear chain of glucose) and amylopectic (branched chain of glucose). Starch is a polysaccharide produced by mostly higher order plants as a means of storing energy. Most commercially available starches are isolated from grains such as corn, rice and wheat, and from tubers such as potato and tapioca (Liu *et al.*, 2009 & Dona *et al.*, 2010).

Tapioca starch is very cheap and readily available in Malaysia which has made this product chosen among different kinds of starch. Starch also as an old source of food for human and animals has been known for centuries (Abolhasani *et al.*, 2010). Composition of the tapioca root is moisture (70%), starch (24%), fiber (2%), protein (1%) and other substances including minerals (3%). The starch composition in tapioca is quite higher compare to the other sources (Liu *et al.*, 2009).

Tapioca starch has been used world-wide and the in industrial application such as textiles, paper, detergent soap, and as well used as adhesive and glue (Matzinos *et al.*, 2002). Since the tapioca starch has been used and many usage can be gain from it, the tapioca starch have exploited and been used to produce polymer based products.

2.3.1 Starch Composition and Structure of Component

Starch is a polymeric carbohydrate consisting of anhydroglucose units linked together primarily through α-d-(1→4) glucosidic bonds. Although the detailed microstructures of different starches are still being elucidated, it has generally been established that starch is a heterogeneous material containing two microstructures linear is amylose and branched is amylopectin (Le *et al.*, 2009 & Liu *et al.*, 2009).

Amylose is essentially a linear structure of α-1,4 linked glucose units, and amylopectin is a highly branched structure of short α-1,4 chains linked by α-1,6 bonds. Figure 2.1 shows the chemical structure and a schematic representation of amylose and amylopectin starches. The linear structure of amylose makes its behavior more closely resemble that of conventional synthetic polymers (Tester *et al.*, 2003, Moad, 2011 & Liu *et al.*, 2009).

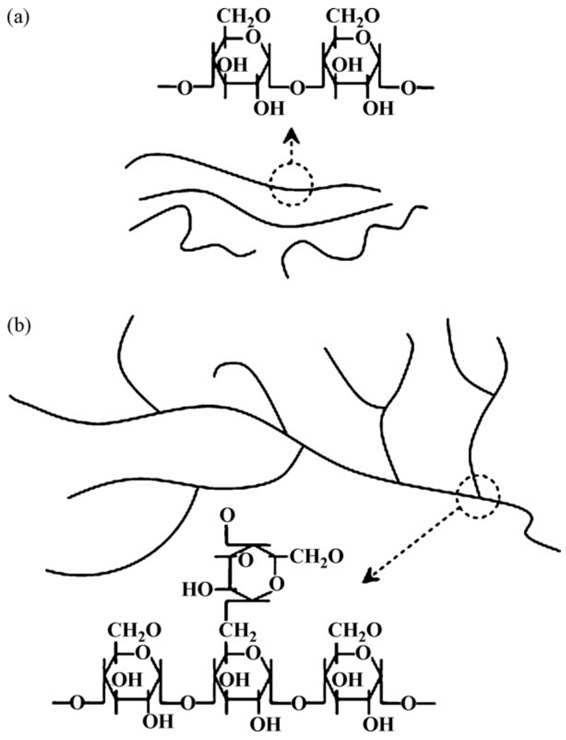

Figure 2.1: Chemical structures and physical schematic representation of (a) amylose starch and (b) amylopectin starch. (Liu *et al.*, 2009)

Amylopectin, on the other hand, is a branched polymer and its molecular weight is much greater than amylose, with light-scattering measurements indicating molecular weights in the millions. The high molecular weight and branched structure of amylopectin reduce the mobility of the polymer chains, and interfere with any tendency for them to become oriented closely enough to permit significant levels of hydrogen bonding. Between the linear amylose and short-branched amylopectin, a long-branched structure has been detected and it can be seen in tapioca starch (Tester *et al.*, 2003, Moad, 2011 & Liu *et al.*, 2009).

2.4 Polyethylene (PE)

Polyethylene is a type of polymer that is classified as a thermoplastic, meaning that it can be melted to a liquid and remolded as it returns to a solid state. As the name implies, polyethylene is chemically synthesized from molecules that contain long chains of ethylene, a monomer that provides the ability to double bond with other carbon-based monomers to form polymers. Polyethylene is known by other, non-official names, such as polythene in the United Kingdom. In addition, it is sometimes spelled as polyethylyne, or abbreviated to simply PE.

The first laboratory creation of polyethylene occurred in 1898 by accident at the hands of Hans von Pechmann while applying heat to another compound the German chemist previously discovered; diazomethane. Ironically, the synthesis of polyethylene via extreme heat and pressure in an industrial setting was again made by accident, but 35 years later. A few years later, another chemist employed by the same England-based chemical company devised a method to consistently produce polyethylene under the same conditions. As a result, polyethylene became the primary source of low-density polyethylene (LDPE) production in 1939 (Sailaja & Seetharamu, 2007).

2.4.1 Low Density Polyethylene (LDPE)

Low density polyethylene (LDPE) is one of thermoplastic type plastic. Generally, it produces from petroleum at high temperature process. LDPE exists in solid particle form, with a density of 0.93 g/cm3 and a melt index of 2.5 g/min. LDPE contains the saturated C–C and C–H bonds, and shows the properties of nonpolarity, low surface energy and poor hydrophilic (Yang *et al.*, 2008). LDPE is from synthetic polymer group and plays important roles in polymer blend production as compatibilizer (Sailaja & Seetharamu, 2007).

2.4.2 High Density Polyethylene (HDPE)

HDPE is the high density version of PE plastic. It is harder, stronger and a little heavier than LDPE, but less ductile. HDPE is lighter than water, and can be molded, machined, and joined together using welding (difficult to glue). The appearance is wax-like, lustreless and opaque. The use of UV-stabilizators (carbon black) improves its weather resistance but turns it black. Some types can be used in contact with food (Yang *et al.*, 2008).

2.5 LDPE and Starch Combination

Through blending process, LDPE and starch could be mix together to form a new polymer blend. However, LDPE and starch itself cannot mix easily due to water soluble matter. Therefore, plasticizers and addictives such as glycerol, citric acid and stearic acid can be used to solve the matters (Liu *et al.*, 2009 & Chillo *et al.*, 2008). The addictives and compatibilizer help the molecule to attach to each others. To produce this process starch based material, such as extrusion, injection molding and film casting, are similar to those widely used in the processing of traditional petroleum based material. The processing of starch, however, is much more complicated and different to control. This is because the unsatisfactory processing properties as a result of its unique phase transitions, high viscosity, water evaporation and fast retrogradation (Liu *et al.*, 2009). To solve this problem, proper formulation development and suitable processing conditions need to be done. The formulation development include: adding appropriate plasticizers, adding appropriate lubricants, using modified starch and using copolymers of starch graft hydrophobic polymer (Matzinoz *et al.*, 2002).

2.6 Effect of Addictives and Plasticizer

A starch-based polymer cannot be thermally processed without a plasticizer or gelatinization agent, since its decomposition temperature is lower than its melting temperature before gelatinization. Various plasticizers and additives have been evaluated and developed to gelatinize starch during thermal processing. Water is the most popular plasticizer used in the thermal processing of starch-based polymers, indeed cooking starches with water has been practiced for hundreds of years. Various other plasticizers to improve the processing properties and product performance of thermoplastic starch have been evaluated, and various polyols have been widely used, e.g. glycerol glycol and sorbitol (Liu *et al.*, 2009). LDPE was utilized as the backbone in binder formulation. A compatibilizer is required in order to allow the thermoplastic and LDPE to get mixed. Citric acid is one of the most readily applicable agents (Abolhasani *et al.*, 2010).

2.6.1 Glycerol

The function of glycerol attend in the thermoplastic starch are because it can result in a reduction in apparent viscosity. In addition, a reduction in K has been attributed to the plasticizing effect of glycerol (Sailaja & Seetharamu, 2007 & Liu *et al.*, 2009).

2.6.2 Citric Acid

To mix between starch and LDPE, the citric acid must be used. This is because the acidity of citric acid is propitious to fragmentation and the ensuing dissolution of the tapioca starch granules deteriorates the chain entanglements in the starch and weakens the interactions between the starch molecules, which in turn facilitates the slipping movement among starch molecule (Liu *et al.*, 2009).

2.6.3 Stearic Acid

It also necessary for stearic to be add to polymer blend production from LDPE and starch. The stearic acid acts as a surfactant agent to bridge between binder and metal powder. It has shown that the stiffness of the binder at room temperature was reasonably acceptable that would ensure the polymer blend strength (Abolhasani *et al.,* 2010).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Material and Solvent

Citric acid was procured from Sigma-Aldrich will be used as additives for polymer production. Glycerol solution will be used as plasticizer in the blending solution. In extrusion reaction, the feedstock are LDPE pellet and starch powder are been used. Water also will be used in blending process for thermal purposes.

3.2 Apparatus

The apparatus that will be used in this experiment are extruder and hot press machine. Detail explanations are provided in Section 3.2.1, and 3.2.2.

3.2.1 Extruder

Extruder as illustrated in Figure 3.1 is the equipment that will be used in this research for blending process. The extruder is for the extrusion process. It designed to produce long continuous products such as tubing, wire covering, and tire threads. The extruder generally consists of the material feed hopper, basic extruder, the extrusion die, the calibration units, the haul-off, cutting device, and finally the devices for treatment final finishing and handling. The basic extruder type usually use is screws, however in some extruder the type is different such as drive or gearbox.

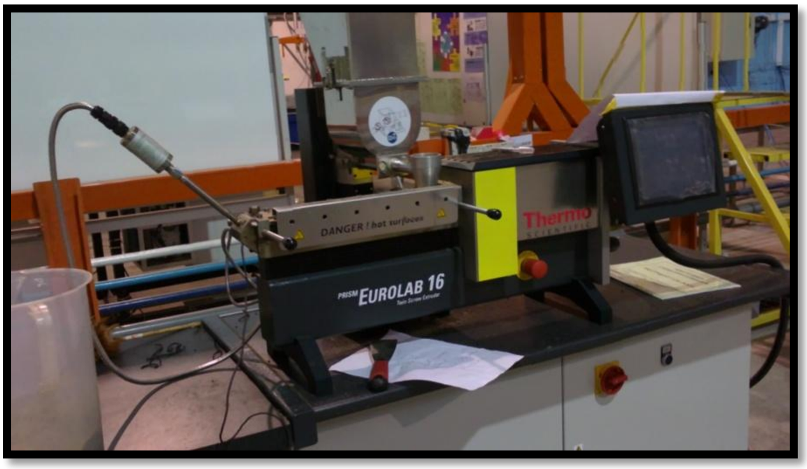

Figure 3.1: Extruder machine

3.2.2 Hot Press Machine

Hot press machine is a machine use to forming object according to mold that been used by using press method. The machine use pressure that will press the two plate which are in high temperature. Thus to forming a dumbbell shape for testing analysis can be achieve by heat and pressure supply by the machine. The heat will melt the polymer so that it can form shape according to the mold. The hot press machine is illustrated in Figure 3.2.

Figure 3.2: Hot press machine

3.3 Experimental Work

3.3.1 Sample Preparation

Based on Table 3.1, the material are been weight according to the right weight. It is 5 sample after all the material been weight and been mixed. The sample had been categorized based on starch weight percentages.

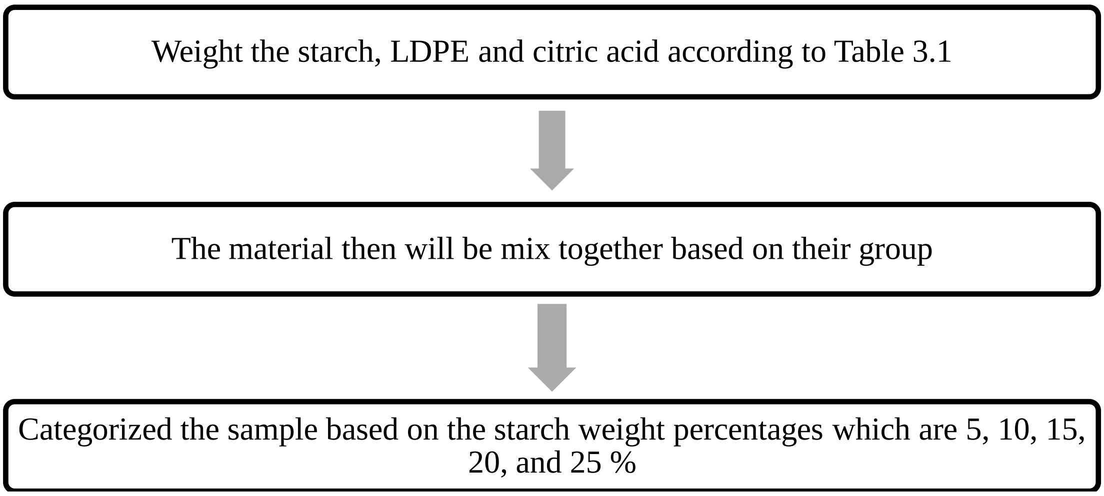

Figure 3.3: The flow chart for sample preparation

Table 3.1: Ratio of LDPE, starch and citric acid that want to be study

LDPE Basic Weight (g)	Starch (wt%)	Citric acid (wt%)
300	5	3
300	10	3
300	15	3
300	20	3
300	25	3

3.3.2 Extrusion Process

In this work, a blend of starch, distilled water, citric acid and glycerol will be mix, and then be heat in the extruder machine to make a yellow transparent fluid, which could be considered as thermoplastic starch. At the extruder machine, six value of temperature should be set which are for zone 2, zone 3, zone 4, zone 5, zone 6 and die. All the temperatures are different starting from zone 2 until die sections which are 140, 145, 150, 155, 145 and 140°C. The excess water content in the mixing will be evaporates due to the working point temperature. The temperatures that had been set will ensure combination of LDPE and starch to melt. The screw rotation speed for extruder will be set about 70 rpm. Lastly, the continuous pallet will be form.

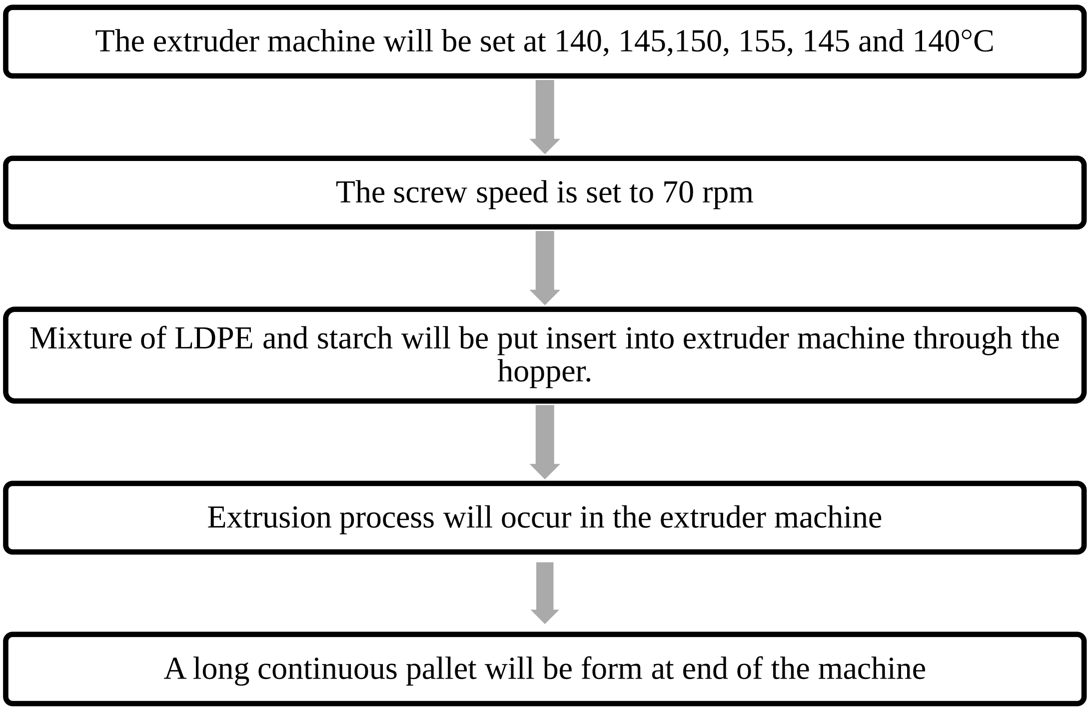

Figure 3.4: The flow chart of extrusion process

3.3.2 Palletizing

After long continuous long pallet had been formed, the polymer then will be palletizing to form a small shape of polymer blend. This must be done because it will be easier for the next step where the molding process occurs. By referring to

3.3.3 Hot Pressing

The pallets that form from extrusion method then will be going through a molding process which could form a shape. For this research, require shape is the dumb bell shape because of the analysis will conduct based on the shape. The steps is to insert the pallet into the dumbbell shape mold, that been on the plate, then set the temperature to 150°C. After that, the mold will be put on the plate at the hot press machine. Wait about 5 minute, so that the polymer can melt, then compress the mold and wait another 2 minutes. Lastly, by open the mold the polymer blend will be obtained as a dumb bell shape.

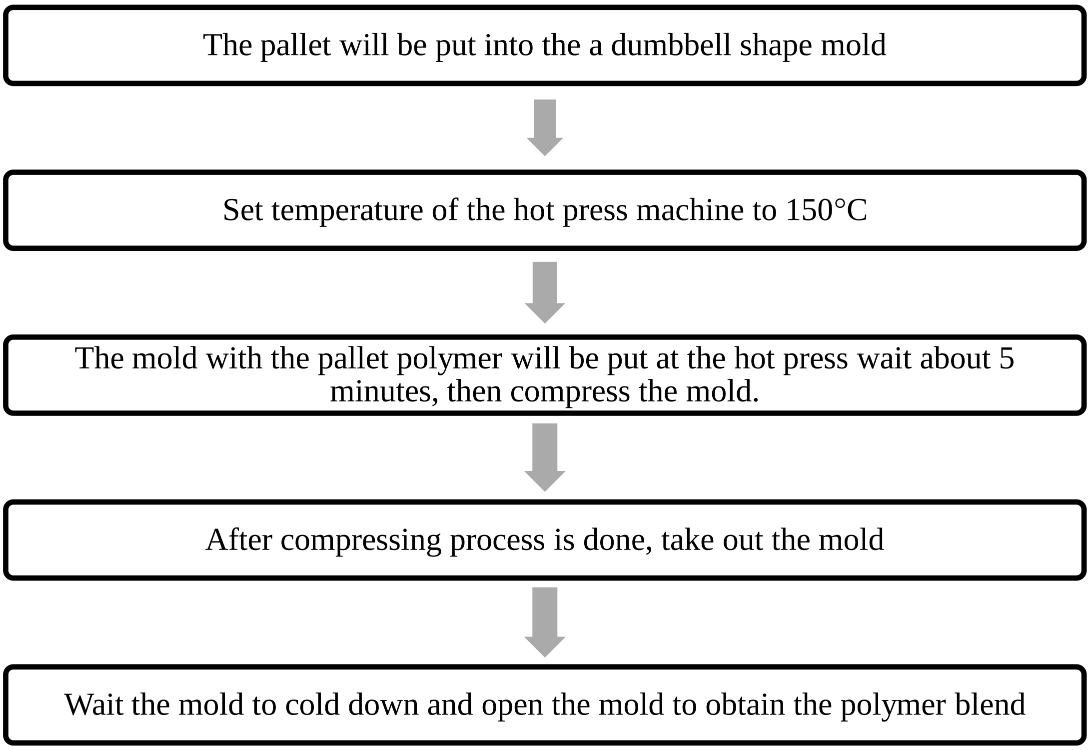

Figure 3.6: The flow chart of processing step in extruder

3.4 Analysis Method

3.4.1 Mechanical Properties

The universal testing machine will be used to analysis the mechanical properties on the polymer blend. The machine operates by put the polymer blend at the test place. Then by using computer, all the data can be gather. The machine can be used to test the tensile strength, elongation, stress-strain and etc for the particular polymer blend. The data that will be obtained then must be comparing to select the best composition for the polymer blend. The universal testing machine can be seen in Figure 3.6.

Figure 3.7: Universal testing machine

3.4.2 Density

To determine the density of polymer blend, the method used is by using traditional method. The traditional method using water dispersion, where the volume of the polymer blend can be determined, first the weight of the polymer blend that cut into preferred dimension is weight as the density is mass per unit volume. From that the volume is determine by water dispersion and density can be calculated. The increasing value of volume after the polymer is been disperse in water can determine the polymer volume. The volume after polymer is dispersed minus the initial volume of water. To disperse the polymer in to the water, block of high density is used.

3.4.3 Water Absorption

The testing is about to determine the water that can be absorbed by the polymer blend that been produced. The experiment is been conducted in 15 days, and value of the water been taken by 5 hour repeatedly. For percentages of the water absorb is determine by finding the different weight after been in water with initial weight then divide the initial weight and convert to percentage form. Average of the sample weight is done first before find the percentages in order to minimize the error.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Tensile Strength

Table 4.1 shows the summary for the sample for LDPE and combination of starch according to the weight percentages. The tensile strength of the material can be obtained after plotting graph of stress versus strain, by referring the curve peak. Thus, the tensile strength is the maximum amount of stress been put on the polymer blend. From the table, it show the higher tensile strength is the LDPE itself follow by LDPE with 5% starch, 10% starch, 15% starch, 20% starch and 25% starch. Between 5% and 15% starch, the tensile strength value are close which around 6 to 7 MPa. For comparison, the pure LDPE have value of tensile strength which is 10 MPa. The tensile values are slightly decreased from the original. But for the LDPE with 20 and 25% of starch, the tensile are 3.3 and 2.0 MPa respectively. The value is quite differ and not in the pattern of previous mixture. It could be said that addition of starch above than 20% could decrease the tensile strength of polymer blend. A possible explanation for the decrease in tensile strength after the addition of starch to LDPE, could be the low interfacial interaction between the components of the blend, which would lead to mechanical rupture at the blend interface.

Table 4.1: Data for tensile strength

Starch Composition (wt%)	Tensile Strength (MPa)
0	10.0431
5	6.8809
10	6.6603
15	6.3416
20	3.2780
25	2.0282

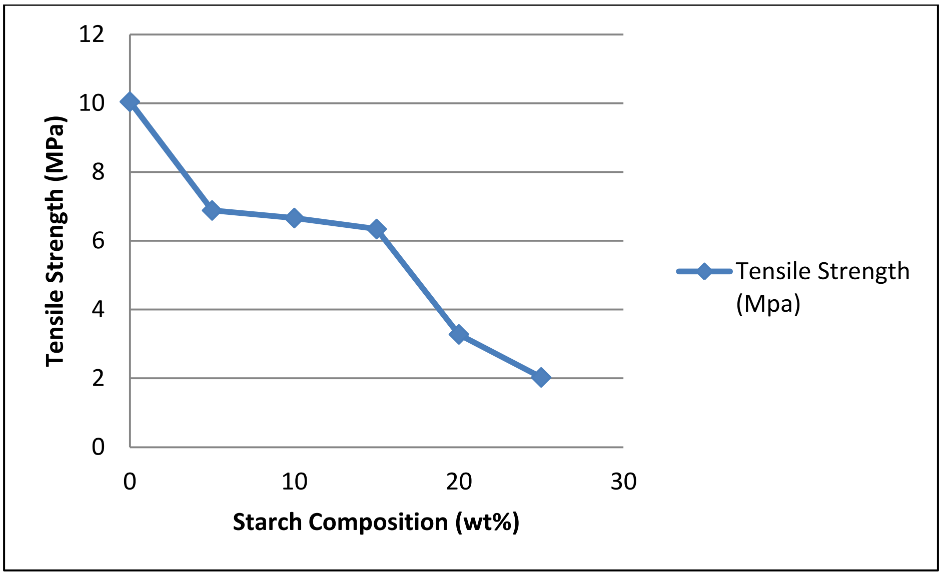

Figure 4.1: Graph of tensile strength

4.2 Modulus of Elasticity

Modulus of elasticity or Young's modulus data can be seen in Figure 4.1. The figure shows the highest value for modulus of elasticity is LDPE while the lowest is the LDPE with 25% starch. For LDPE with 5, 10, 15% starch, the modulus of elasticity is quite the same except there are about 0.1 MPa different. It could say that the value is same and properties of elastic must slightly different. From the chart also it be say that the starch percentages from 5 to 15% is not affect the modulus of elasticity but starting with 20 and 25%, the modulus of elasticity start to drop. So that the mixture best after starch addition is on range between 5 to 15% of starch. When starch was added to LDPE, the Young modulus showed low standard deviations expected of materials in which the heterogeneity of the specimens is higher than that of the monodisperse materials.

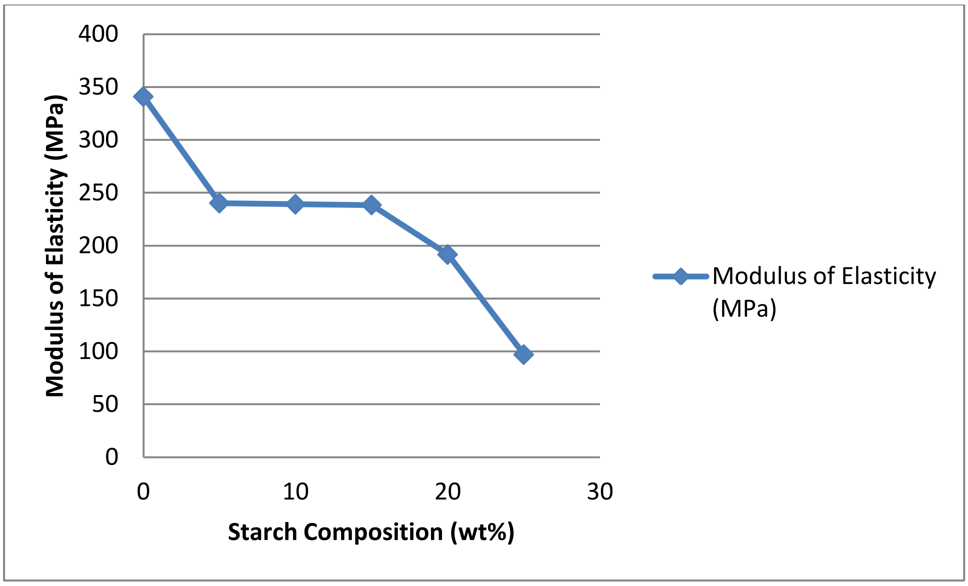

Figure 4.2: Graph for modulus of elasticity

4.3 Elongation at Break

From Figure 4.2, the elongation at break pattern for combination LDPE and starch can be seen through the graph. The elongation at break is calculation about length of polymer after been put stress per initial length times 100%. The equation for elongation at break can be seen by referring Equation 4.1 The graph show the decreasing value of elongation percentages from 5% of starch and 25 % starch. It shows that the amount of starch percentages in LDPE influence the polymer blend performance as the elongation percentages decreasing from low value of starch percent to high value of starch. The addition of starch granules to LDPE produced the general trend for filler effects on polymer properties.

$$\mathrm{EL\%} = \left(\frac{l_f - l_o}{l_o}\right) \times 100\% \qquad \textbf{Equation 4.1}$$

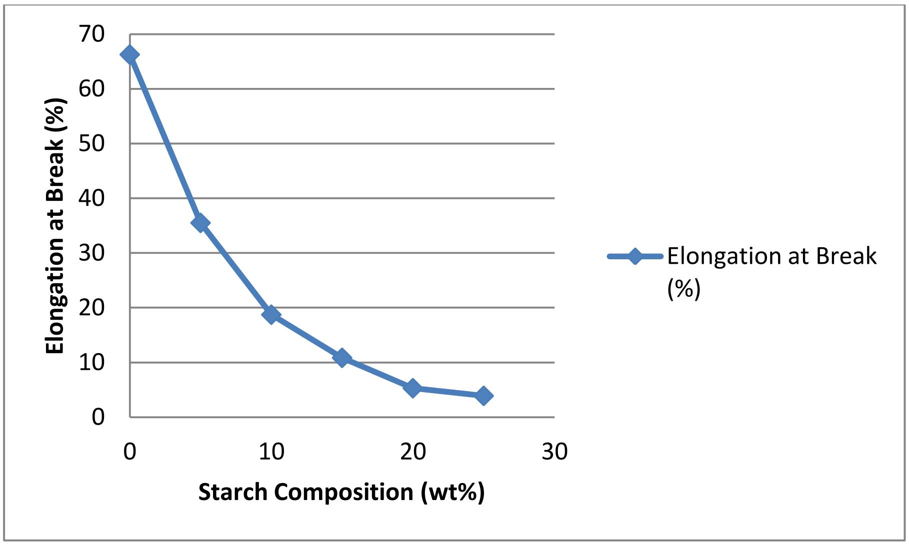

Figure 4.3: Graph of elongation at break

4.4 Density

Density can defined as mass per unit volume. For this testing, the density of the polymer blend was determined as for 0, 5, 10, 15, 20 and 25 of weight percentages. Figure 4.4 show the trend of the density of the polymer blend. From the graph it shows the value increase as the weight percentages of starch increase. For this, it can be say that the compound of the polymer blend increases as the mass of polymer per unit volume. The higher density is starch composition of 25 wt percentages followed by 20, 15, 10, 5 and 0. The lowest value of density is the LDPE itself with no starch. It is obviously show that starch addition has increase the density of the polymer blends.

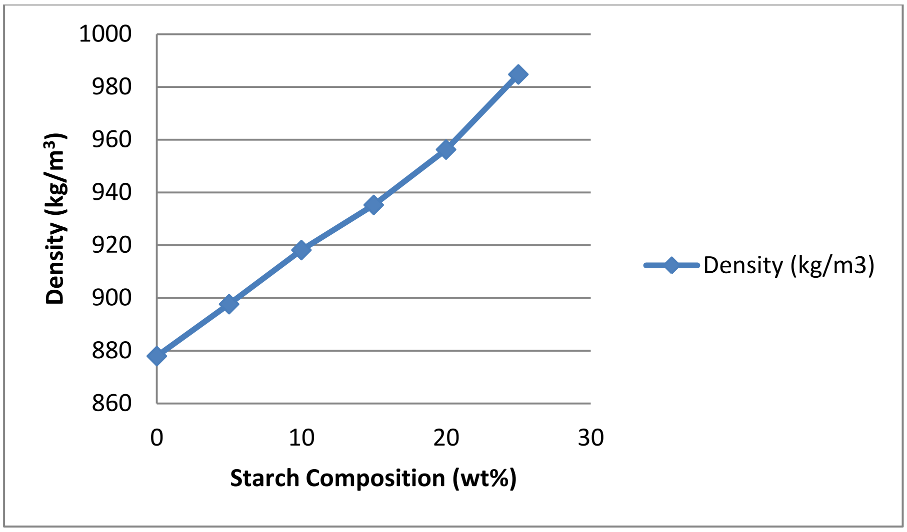

Figure 4.4: Graph of density

4.5 Water Absorption

The water absorption of the polymer blend has done for 15 days. The point of the testing to determine the percentages of water absorption by the polymer blend by starch composition. The graph shows that the higher starch weight percentages, the higher value of the percentages of water can be absorb. It follows by the 20, 15, 10, 5 and 0 of starch weight percentages. For the pure LDPE which is the no contain of starch, the graph is just flat and no water absorption after 15 day of experiment. From that, it directly suggests that the LDPE itself cannot absorb water compare to other formulation that contains starch. As the starch weight percentages is increase, the water percentages also increase. Therefore, the higher the starches contain in the formulation, the polymer blend became biodegradable.

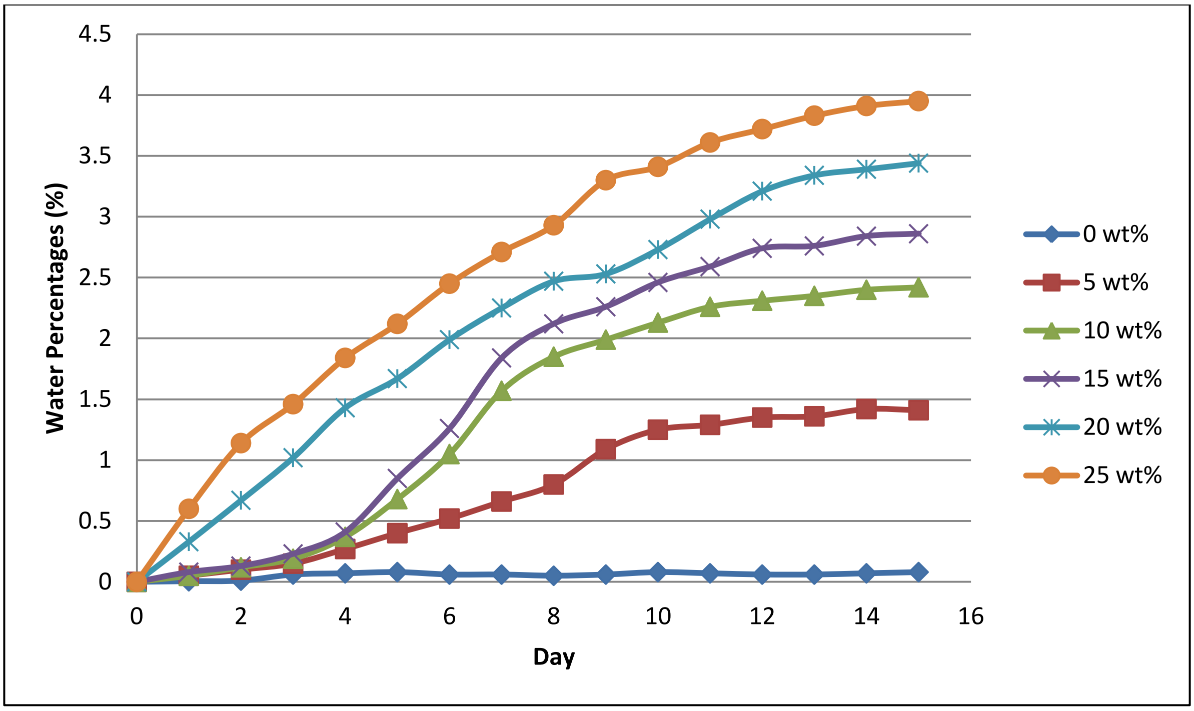

Figure 4.5: Graph of water absorption

4.6 Optimum Percentages Starch Selection

Based on Table 4.2, the summary for characterization of mechanical properties of polymer blend can be seen. The mechanical properties of LDPE mix with starch can be say decreasing mean the starch addition to LDPE influences the mechanical properties. From the table the best formulation of starch is the 15% of starch where the LDPE have contain of more starch which is the natural polymer and stills have good characterization of mechanical properties. If the more starch were used mean that the LDPE is more biodegradable logically based on the natural polymer. It can show from the water absorption testing as more starch is add the more water can be absorbed. Although the 15 % starch formulation have value for tensile strength, modulus of elasticity and elongation percentages, but still the mechanical properties slightly different from the previous starch formulation.

Table 4.2: Summary data of mechanical properties

Starch Composition (wt %)	Tensile Strength (MPa)	Modulus of Elasticity (MPa)	Elongation at Break (%)
0	10.0431	340.923	66.2585
5	6.8809	240.224	35.4958
10	6.6603	239.150	18.7191
15	6.3416	238.432	10.8462
20	3.2780	191.582	5.28595
25	2.0282	96.9466	3.89433

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

By using extrusion and injection molding, the production of polymer blend will be successfully done. Therefore, the alternative polymer which is polymer blend can be used instead of synthetic polymer. Environment can be preserved and nature could be balance. For the composition of polymer blend production also can be determined and the optimum composition for the best characterization properties also can be determined. For this research the best optimum composition is mixture of LDPE with 15% starch.

The addition of starch to LDPE reduces the tensile strength, Young's Modulus, and elongation of break whereas the water absorption percentages and density increase. Thus, the use of more starch had significant effect on the tensile strength of blends, modulus of elasticity, and elongation at break, density and water absorption, making this polymer a suitable substitute for the virgin LDPE.

5.2 Recommendations

For this research, the recommendations that must be done to improve the research for future is instead of using the hot press method, it is better to use the injection molding method to get a good mould product. The good mould product will affect the testing especially the mechanical testing. This is because the bubble will not form in the injection molding method as when bubble is appear in the molded polymer, the break will occurs that point.

Next is to added plasticizer to the polymer blend to increase mechanical properties. By the addition of the plasticizer, the pattern of mechanical properties can be maintained and can be altered easily. Lastly is to do testing about degradability of polymer blend to determine rate of degradable. The testing will help in determine the rate of the polymer to degradable based on the starch composition and how it is effect to environment if been throw.

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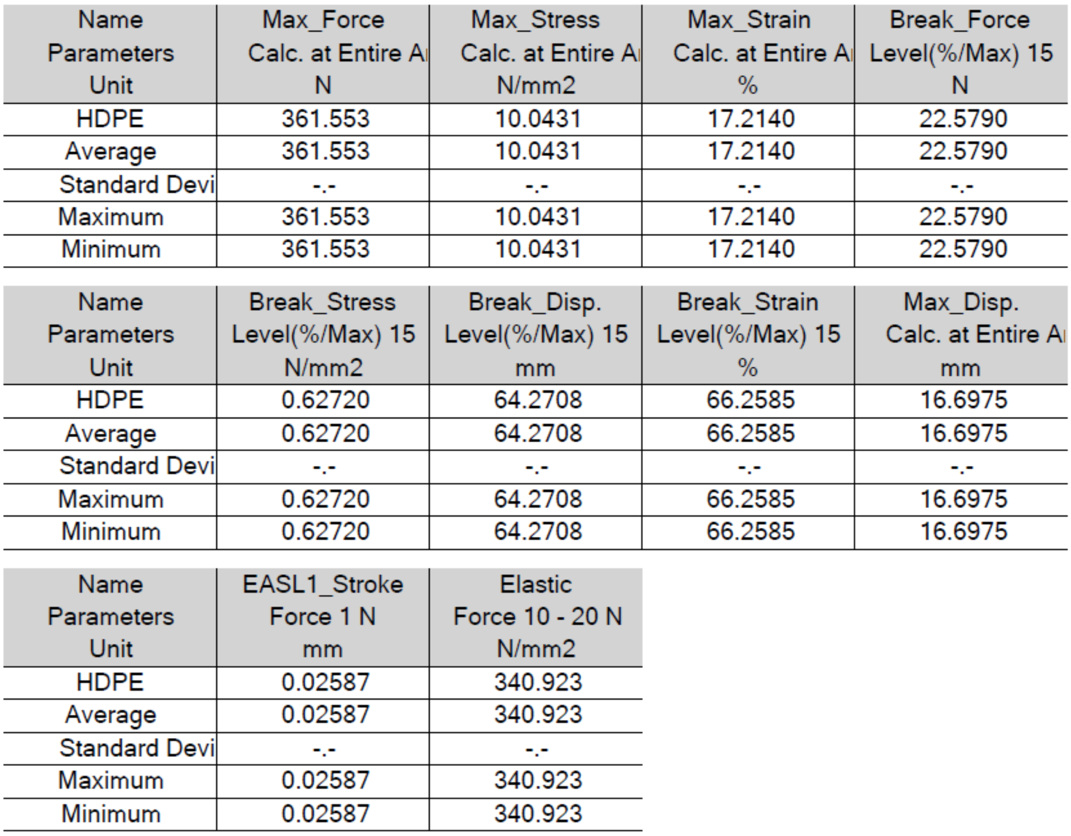
APPENDIX A

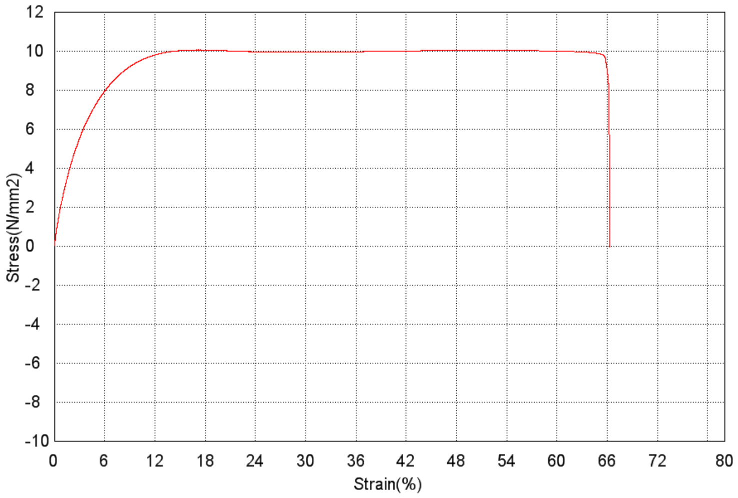
0 wt % starch composition



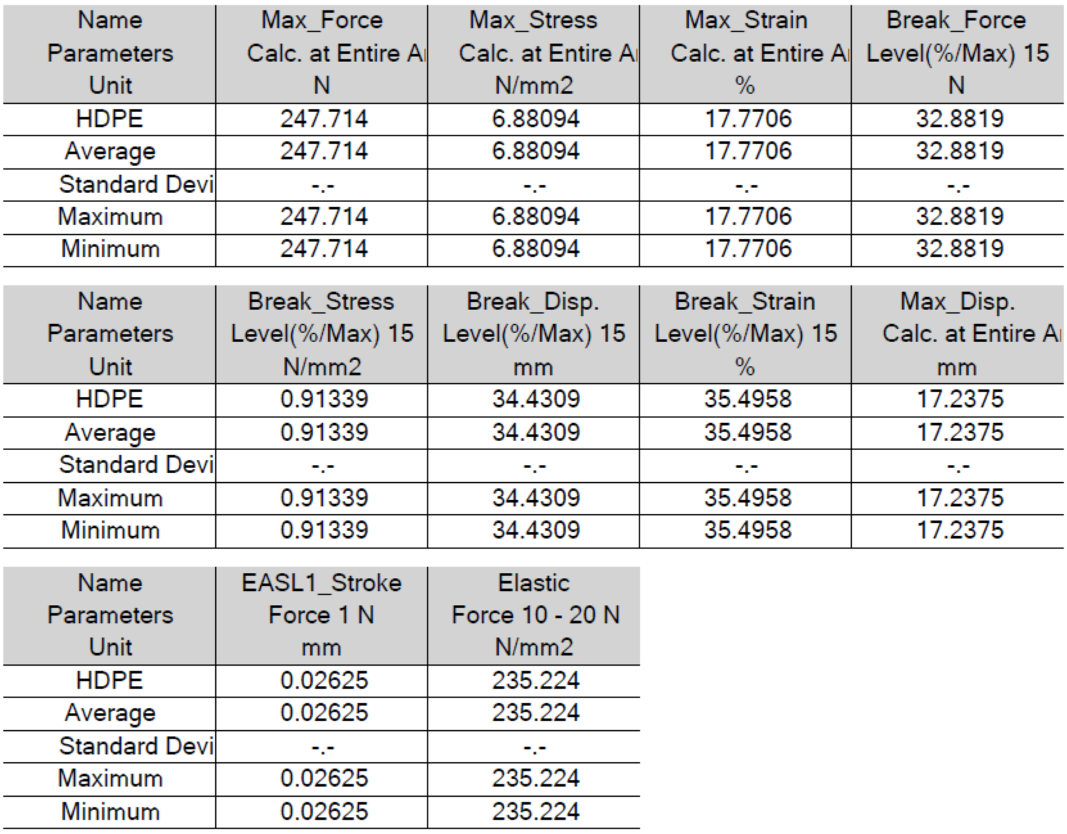
Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	361.553	10.0431	17.2140	22.5790
Average	361.553	10.0431	17.2140	22.5790
Standard Devi	-.-	-.-	-.-	-.-
Maximum	361.553	10.0431	17.2140	22.5790
Minimum	361.553	10.0431	17.2140	22.5790

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.62720	64.2708	66.2585	16.6975
Average	0.62720	64.2708	66.2585	16.6975
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.62720	64.2708	66.2585	16.6975
Minimum	0.62720	64.2708	66.2585	16.6975

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02587	340.923
Average	0.02587	340.923
Standard Devi	-.-	-.-
Maximum	0.02587	340.923
Minimum	0.02587	340.923



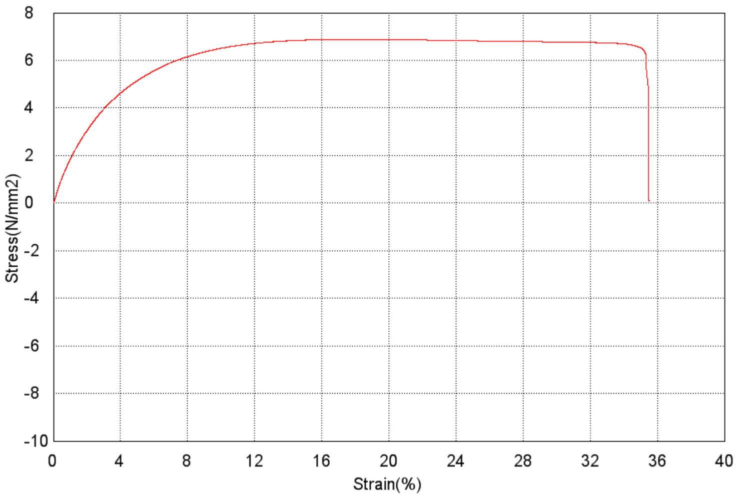
5 wt % starch composition



Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	247.714	6.88094	17.7706	32.8819
Average	247.714	6.88094	17.7706	32.8819
Standard Devi	-.-	-.-	-.-	-.-
Maximum	247.714	6.88094	17.7706	32.8819
Minimum	247.714	6.88094	17.7706	32.8819

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.91339	34.4309	35.4958	17.2375
Average	0.91339	34.4309	35.4958	17.2375
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.91339	34.4309	35.4958	17.2375
Minimum	0.91339	34.4309	35.4958	17.2375

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02625	235.224
Average	0.02625	235.224
Standard Devi	-.-	-.-
Maximum	0.02625	235.224
Minimum	0.02625	235.224

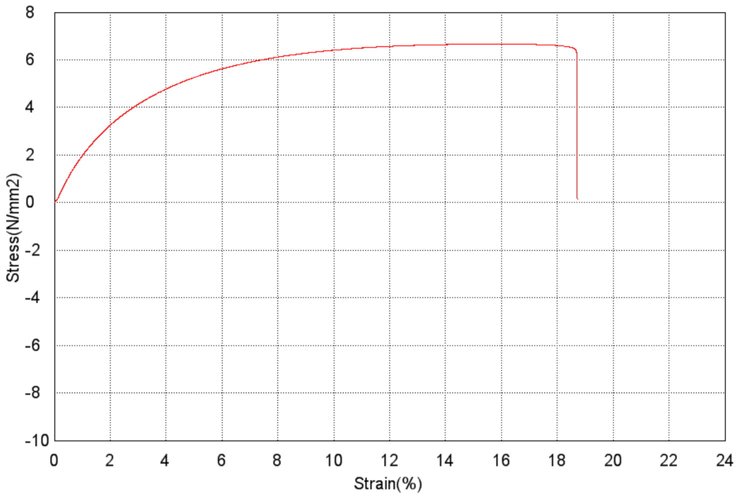


10 wt % starch composition

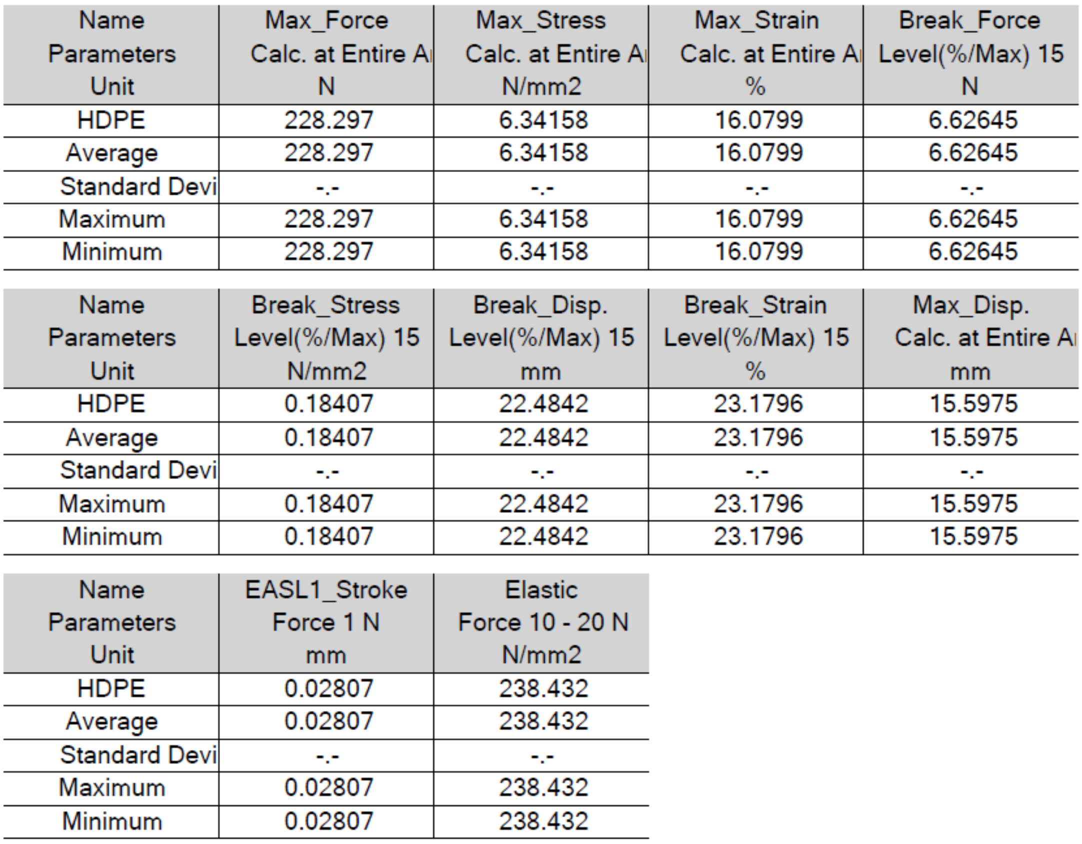
Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	239.771	6.66031	15.7636	7.12474
Average	239.771	6.66031	15.7636	7.12474
Standard Devi	-.-	-.-	-.-	-.-
Maximum	239.771	6.66031	15.7636	7.12474
Minimum	239.771	6.66031	15.7636	7.12474

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.19791	18.1575	18.7191	15.2907
Average	0.19791	18.1575	18.7191	15.2907
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.19791	18.1575	18.7191	15.2907
Minimum	0.19791	18.1575	18.7191	15.2907

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02432	239.150
Average	0.02432	239.150
Standard Devi	-.-	-.-
Maximum	0.02432	239.150
Minimum	0.02432	239.150



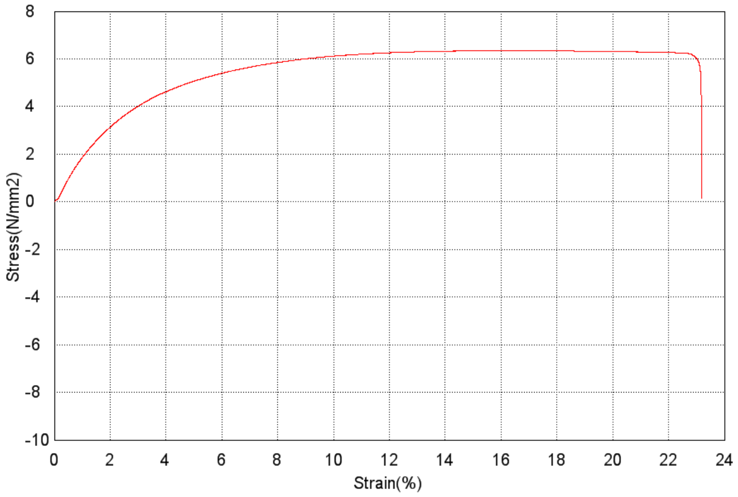
15 wt % starch composition



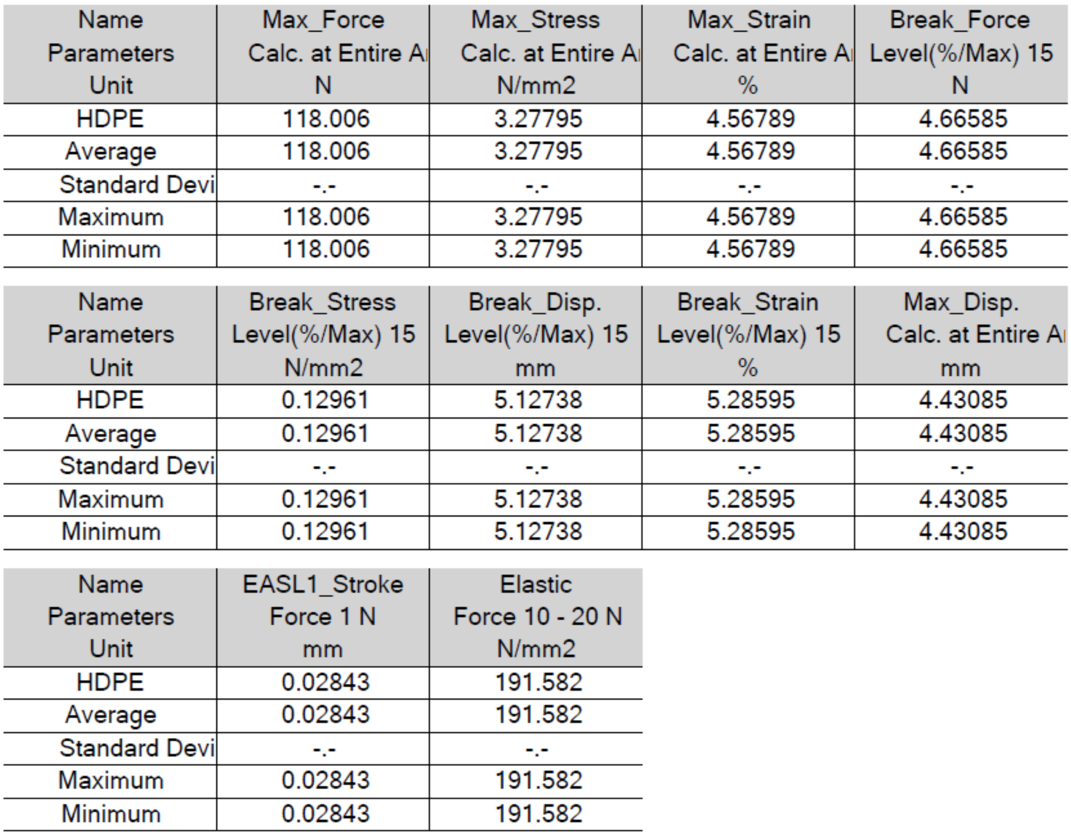
Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	228.297	6.34158	16.0799	6.62645
Average	228.297	6.34158	16.0799	6.62645
Standard Devi	-.-	-.-	-.-	-.-
Maximum	228.297	6.34158	16.0799	6.62645
Minimum	228.297	6.34158	16.0799	6.62645

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.18407	22.4842	23.1796	15.5975
Average	0.18407	22.4842	23.1796	15.5975
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.18407	22.4842	23.1796	15.5975
Minimum	0.18407	22.4842	23.1796	15.5975

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02807	238.432
Average	0.02807	238.432
Standard Devi	-.-	-.-
Maximum	0.02807	238.432
Minimum	0.02807	238.432



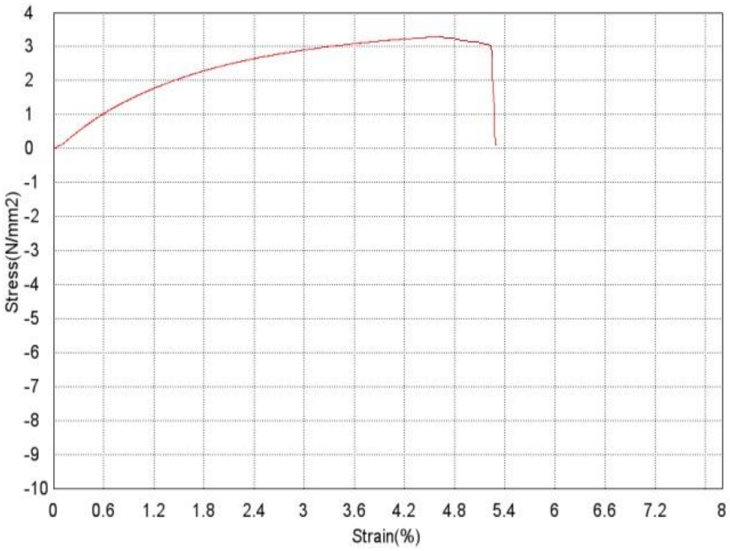
20 wt % starch composition



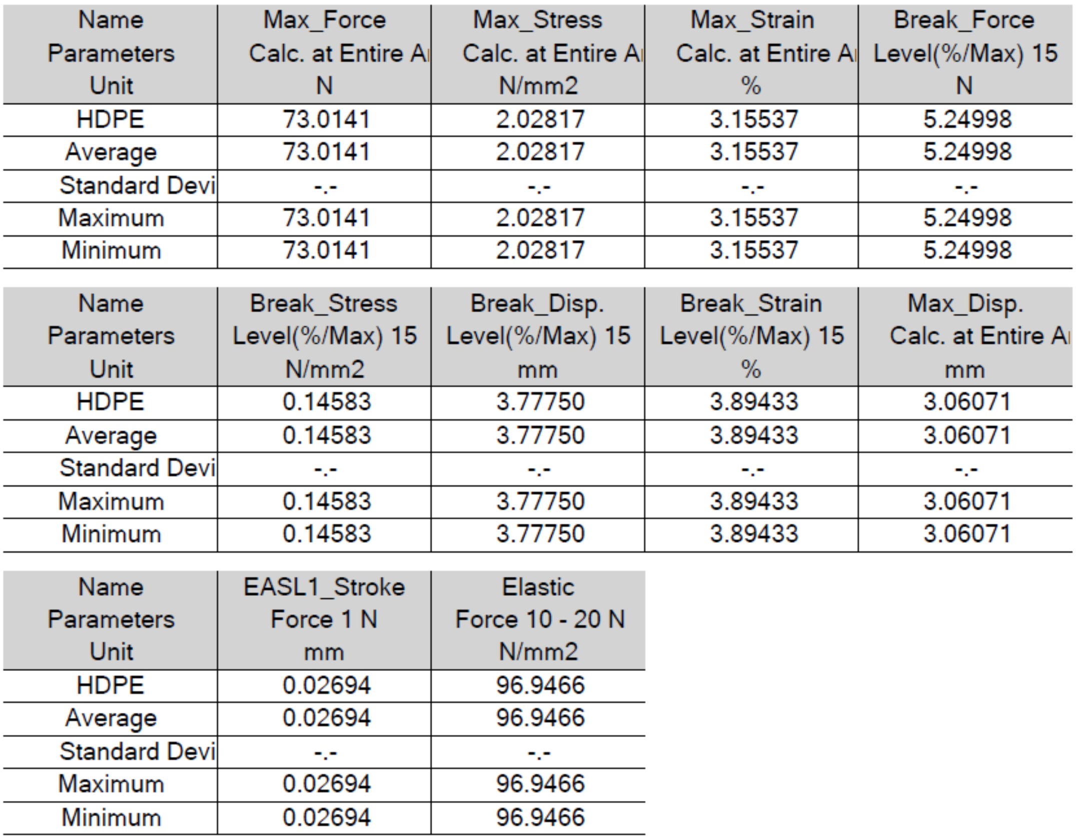
Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	118.006	3.27795	4.56789	4.66585
Average	118.006	3.27795	4.56789	4.66585
Standard Devi	-.-	-.-	-.-	-.-
Maximum	118.006	3.27795	4.56789	4.66585
Minimum	118.006	3.27795	4.56789	4.66585

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.12961	5.12738	5.28595	4.43085
Average	0.12961	5.12738	5.28595	4.43085
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.12961	5.12738	5.28595	4.43085
Minimum	0.12961	5.12738	5.28595	4.43085

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02843	191.582
Average	0.02843	191.582
Standard Devi	-.-	-.-
Maximum	0.02843	191.582
Minimum	0.02843	191.582



25 wt % starch composition



Name Parameters Unit	Max_Force Calc. at Entire A N	Max_Stress Calc. at Entire A N/mm2	Max_Strain Calc. at Entire A %	Break_Force Level(%/Max) 15 N
HDPE	73.0141	2.02817	3.15537	5.24998
Average	73.0141	2.02817	3.15537	5.24998
Standard Devi	-.-	-.-	-.-	-.-
Maximum	73.0141	2.02817	3.15537	5.24998
Minimum	73.0141	2.02817	3.15537	5.24998

Name Parameters Unit	Break_Stress Level(%/Max) 15 N/mm2	Break_Disp. Level(%/Max) 15 mm	Break_Strain Level(%/Max) 15 %	Max_Disp. Calc. at Entire A mm
HDPE	0.14583	3.77750	3.89433	3.06071
Average	0.14583	3.77750	3.89433	3.06071
Standard Devi	-.-	-.-	-.-	-.-
Maximum	0.14583	3.77750	3.89433	3.06071
Minimum	0.14583	3.77750	3.89433	3.06071

Name Parameters Unit	EASL1_Stroke Force 1 N mm	Elastic Force 10 - 20 N N/mm2
HDPE	0.02694	96.9466
Average	0.02694	96.9466
Standard Devi	-.-	-.-
Maximum	0.02694	96.9466
Minimum	0.02694	96.9466