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EFFECT OF POLYLACTIC ACID (PLA) CONCENTRATIONS ON TENSILE PROPERTIES FOR TRANSDERMAL PATCH

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ABSTRACT: The usage of petrochemical-based polymers is tremendous, and this is partially due to excellent mechanical properties and durability. However, with the continuous usage and development of materials, the after-use of these materials is causing huge problems for the environment. As it is non-degradable and lasts long for hundreds of years, it remains in the environment surrounding us. Conventional patches used in transdermal patches are made from non-degradable polymeric materials, thus, research on biodegradable polymers such as polylactic acid (PLA) is crucial for the usage as a patch. To achieve the requisite flexible properties for transdermal patches, the selection of appropriate materials should be considered. In this study, a fabricated semi-automated patch machine was utilized for the preparation of PLA film. Thus, it is crucial to optimize the PLA concentrations using this device. The tensile properties were examined with various polylactic acid (PLA) concentrations. The goal is to identify the ideal concentration that balances the flexibility and strength of the PLA film. Tensile testing was conducted on PLA films at five different concentrations (7%, 10%, 13%, and 15%) (w/v %). Key factors such as Young's Modulus, ultimate tensile strength (UTS), and strain at break were assessed on these PLA films. According to preliminary findings, the concentration of PLA has a significant impact on the mechanical behavior of PLA films. For transdermal and cosmeceutical patches to have the right flexibility and strength, choosing the best PLA concentration is essential. A sustainable and environmentally responsible alternative to traditional non-degradable polymers can be provided by incorporating these mechanical behavior discoveries into the creation of biodegradable patches. Our research advances environmentally friendly approaches to medicine delivery and material science.

KEYWORDS: *Polylactic Acid (PLA), Flexibility, Ultimate Tensile Strength, Transdermal Patch.*

1. INTRODUCTION

The scope of research on immunology kits, biosensors, and drug delivery devices has greatly expanded over the past three decades. With the development of new pharmacological dosage forms, it is now possible to duplicate the adverse effects of conventional dosage forms by introducing chemicals into the body through the skin [1]. Transdermal drug delivery system (TDDS) or, more commonly, transdermal patches refer to a method of administering medications topically in the form of patches that, when applied to the skin, release the medication at a controlled and predetermined rate throughout the skin to improve therapeutic efficacy and reduce side effects. For an effective transdermal drug delivery system, the drug must be able to easily enter the skin and reach the target site [2].

The main supporting structure (matrix) of a transdermal patch is the polymer. It regulates how the drug diffuses from the patch [3]. The polymer utilized as a matrix must be guaranteed to be secure for skin contact and approved by the US Food and Drug Administration (USFDA) [4,5]. However, the main cause of pollution in the land, air, soil, and water is from non-biodegradable trash [6]. So, degradable polymers have since gained popularity in drug delivery applications. Due to their biocompatibility and degradability qualities [7].

The most widely researched and promising biopolymer is Polylactic acid (PLA), used in transdermal patch development, which has drawn a lot of interest because of its biocompatibility, fully biodegradable, nontoxic, and adaptable mechanical properties.[5]

The purpose of this study is to determine how varying PLA concentrations affect patches' flexibility.

2. MATERIALS AND METHODS

Polylactic acid (Ingeo biopolymer 3251 D) was purchased from Nature Works LLC, Minnetonka, MN, USA with an average molecular weight (Mw) of 148000 g/mol. Chloroform was purchased from HmbG chemicals (analytical grades, Germany) and used as it is.

2.1. Preparation of polylactic acid (PLA) film in various concentrations

PLA beads were oven-dried for 24 hours at 40 °C before using it. Then, PLA beads were dissolved in chloroform to create a solution that had a different concentration, the selected range was (7% to 15% (w/v) as it is shown in Table 1. The solution of PLA and chloroform was left on the stirring plate for four (4) hours. Following the dissolution of the PLA, the solution of the polymer was poured into a clean glass plate, and then cast using the semi-automated patch fabricator and allowed to dry all night. Glass plates are suitable since they have a smooth, clean surface that will make it simpler to peel the patch once the produced film has entirely dried.

Table 1: Selected Range of PLA Concentration

Sample Code	Volume of Chloroform (ml)	Concentration of PLA (w/v) %	Mass of PLA beads (g)
PLA 7	60	7%	PLA 7
PLA 10	60	10%	PLA 10
PLA 13	60	13%	PLA 13
PLA 15	60	15%	PLA 15

2.2. Universal Tensile Test

Elongation at break, Yield strength, and Young's modulus were determined using a Universal Testing Machine (Shimadzu, AGS-X, Japan). Samples were prepared in the laboratory, cut into 1 cm x 5 cm according to the America Society for Testing and Materials (ASTM D-882 type -V) with a crosshead speed of 5 mm/min. The results were taken as an average of five tests.

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3. RESULTS AND DISCUSSION

2.1. Mechanical properties

properties in terms of mechanical strength. The test shows how a material reacts to the force applied in strain. As observed from Figure 1, PLA10 film is more flexible and less likely to fail during application and usage because it has a higher elongation at break, which means it can withstand greater deformation without breaking.

The tension at which a material switches from elastic to plastic deformation is known as the yield point. The yield point for the PLA10 concentration is at X = 3.344% and Y = 20.31 MPa, indicating a balanced behavior. The PLA10 film has a moderate yield point, which shows that it can withstand tension before deforming plastically. This makes it resilient and less likely to experience substantial deformation under normal conditions.

The 15% PLA concentration (PLA15) demonstrates the largest elongation at break (27.81%), showing good flexibility, but it also displays a higher Ultimate Tensile Strength (UTS) value (28 MPa). The material may be somewhat hard and less flexible under stress at high UTS. The film's excessive stiffness may result in decreased conformability and a higher chance of patch separation. The 7% (w/v%) PLA concentration (PLA7), on the other hand, shows lower elongation at break (7.4%) and UST (7.4 MPa), which indicates decreased flexibility and probable brittleness.

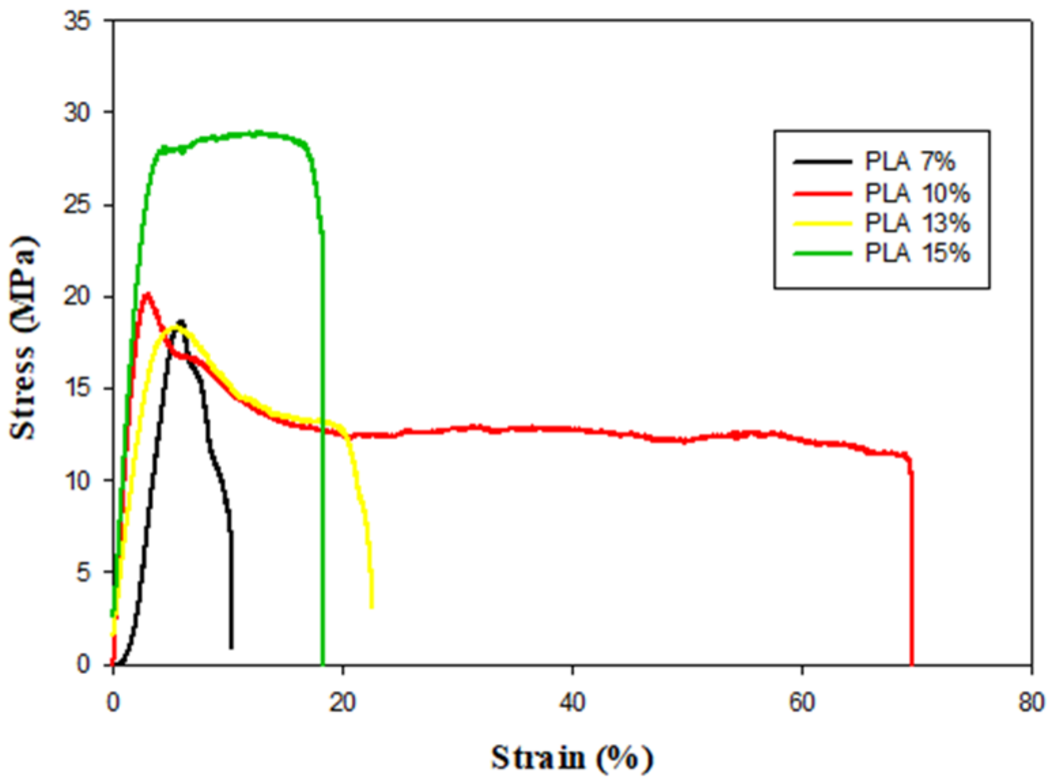

Fig. 1. Effect of PLA concentration on mechanical performance: strain-stress behavior study.

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The ability of a material to stretch and deform before breaking is determined by a mechanical feature called the elongation at break [9]. The elongation at break of polylactic acid (PLA) films made at different concentrations (7%, 10%, 13%, and 15%) (w/v %) for the creation of flexible transdermal patches was examined in this study. Stress-strain curves generated from tensile testing of the PLA films were used to calculate the elongation at break values [5,9].

Figure 2 represents the elongation at break data for each PLA concentration. Based on the data it can be deducted from this figure that elongation at break increases up to 10% (w/v%) PLA concentration and decreases at 7% (w/v). Chain alignment, entanglement, and amorphous morphology are likely best balanced around 10% PLA concentration, allowing for improved chain mobility and deformability. The astounding elongation shown for the 10% (w/v%) concentration is the outcome of this.

Due to the lower concentration of PLA chains, the 7% (w/v%) PLA concentration's restricted elongation at break may be caused by insufficient chain alignment and tangling. With an intermediate elongation value and a 15% (w/v%) PLA content, there may be a balance between some flexibility and growing stiffness, maybe because of increased crystallinity [10].

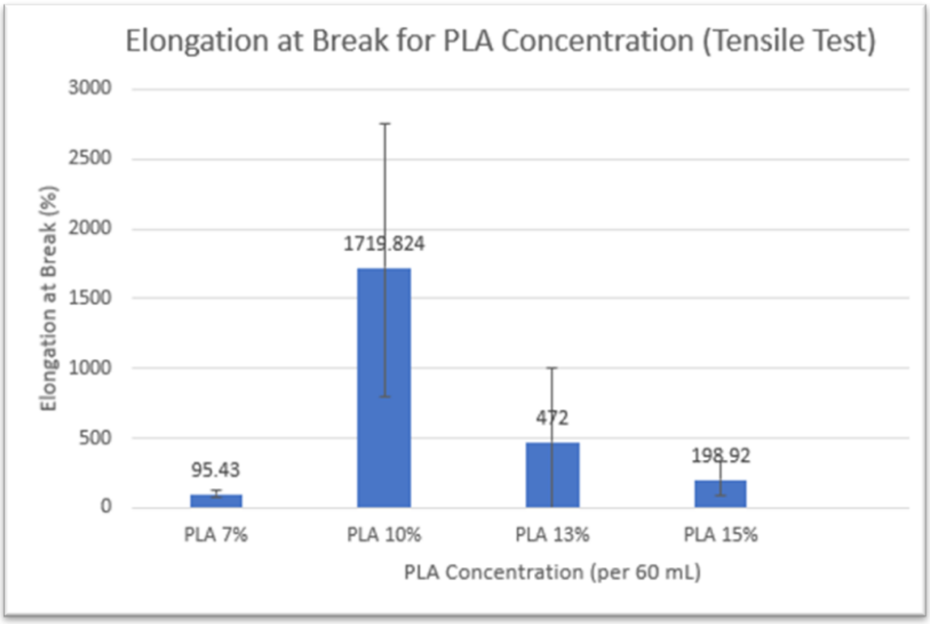

Fig. 2. Elongation at break of films prepared at different PLA concentrations.

4. CONCLUSION

The maximum elongation at break (1719.8%) was seen at the 10% (w/v%) PLA concentration, demonstrating remarkable stretchability and flexibility. The 10% (w/v%) PLA concentration was the most flexible of the investigated concentrations due to decreased Young's modulus and yield stress. Lower elongation at break was observed at the 7% (w/v%) and 15% (w/v %) concentrations, indicating reduced stretchability because of inadequate chain alignment and increased crystallinity, respectively. Overall, flexible PLA films with a 10% (w/v %) PLA concentration showed the best tensile properties to be used as a patch.

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