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Influence of Plasticizer Type on Physical and Structural Properties of Corn Starch-Based Bioplastic Films: A Comparative Study of Glycerol, Sorbitol, and Their Binary Blend

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تأثير نوع الملدن على الخواص الفيزيائية والبنيوية لأغشية البلاستيك الحيوي المعتمدة على نشا الذرة: دراسة مقارنة للجليسرول والسوربيتول ومزيجهما الثنائي

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Abstract:
Starch-based bioplastics represent promising alternatives to petroleum-derived packaging materials. However, the influence of plasticizer selection on corn starch film properties remains incompletely characterized, particularly for binary plasticizer systems. To evaluate the effects of glycerol, sorbitol, and their equimolar blend on the physical and structural properties of corn starch-based bioplastic films. Films were prepared via solution casting using locally extracted corn starch (5% w/v) with 10% plasticizer and acetic acid as processing aid. Physical properties (thickness, density, moisture content, water absorption, water solubility) and structural characteristics (FTIR spectroscopy) were systematically evaluated. Plasticizer type significantly influenced all measured properties. Sorbitol films exhibited highest density (1.702 g/cm³) and superior water resistance (18.09% absorption), while glycerol films demonstrated maximum flexibility but elevated water sensitivity (57.81% absorption). The glycerol-sorbitol blend showed intermediate characteristics (29.03% absorption). FTIR analysis confirmed successful plasticizer incorporation through modified O−H stretching patterns (3200–3500 cm^{-1}). Sorbitol plasticization yields films with enhanced water resistance suitable for moisture-sensitive packaging, while glycerol provides maximum flexibility for conformable applications. Binary plasticizer blends offer tunable properties for diverse packaging requirements. Locally sourced corn starch represents a viable feedstock for biodegradable packaging materials.

Keywords: Bioplastic; Corn starch; Glycerol; Sorbitol; Plasticizer; Biodegradable packaging.

الملخص :
تمثّل اللدائن الحيوية المعتمدة على النشا بدائل واعدة لمواد التغليف المشتقة من النفط. ومع ذلك، ما يزال تأثير اختيار الملدّن في خصائص أغشية نشا الذرة غير موصوف وصفًا كاملًا، ولا سيما في أنظمة الملدّنات الثنائية. وتهدف هذه الدراسة إلى تقييم تأثيرات كلٍّ من الجلسرين والسوربيتول وخليطهما المتساوي المولات على الخصائص الفيزيائية والبنيوية لأغشية اللدائن الحيوية المعتمدة على نشا الذرة. جرى تحضير الأغشية بطريقة الصبّ من المحلول باستخدام نشا ذرة مُستخلص محليًا بتركيز 5% (وزن/حجم)، مع إضافة 10% من الملدّن، واستُخدم حمض الأسيتيك بوصفه عاملَ مساعدةٍ في المعالجة. وتمّ تقييم الخصائص الفيزيائية (السماكة، والكثافة، ومحتوى الرطوبة، وامتصاص الماء، والذوبانية في الماء) والخصائص البنيوية (مطيافية الأشعة تحت الحمراء بتحويل فورييه (*FTIR*) بصورة منهجية. أظهر نوع الملدّن تأثيرًا معنويًا في جميع الخصائص المقاسة. فقد أبدت أغشية السوربيتول أعلى كثافة 1.702 (غ/سم3) وأفضل مقاومة للماء (18.09% امتصاصا)، في حين أظهرت أغشية الجلسرين أعلى مرونة، لكنها سجّلت حساسية مرتفعة للماء (57.81% امتصاصا). وأظهر خليط الجلسرين–السوربيتول خصائصَ وسطية (29.03% امتصاصا). وأكّد تحليل FTIR نجاح دمج الملدّنات من خلال تغيّر أنماط استطالة رابطة O-H ضمن المجال 3200-3500 سم$^{-1}$. تُفضي ملدن السوربيتول إلى أغشية ذات مقاومة مُحسّنة للماء، ما يجعلها مناسبة لتغليف المنتجات الحسّاسة للرطوبة، بينما يوفّر الجلسرين أعلى مرونة للتطبيقات التي تتطلب قابلية عالية للتشكّل والتوافق مع الأسطح. كما تتيح خلطات الملدّنات الثنائية إمكانية ضبط الخصائص لتلبية متطلبات تغليف متنوعة. ويمثّل نشا الذرة المُستخلص محليًا مادةَ تغذيةٍ أولية مجدية لإنتاج مواد تغليف قابلة للتحلل الحيوي.

الكلمات المفتاحية: البلاستيك الحيوي، نشأ الذرة، الجليسرول، السوربيتول، الملدن، التغليف القابل للتحلل الحيوي.

1. Introduction:

Global plastic production currently exceeds 400 million metric tons annually, with packaging applications accounting for approximately 40% of total consumption. Despite widespread awareness of environmental consequences, plastic waste management infrastructure remains critically inadequate. Current estimates indicate that only 9–14% of plastic packaging undergoes recycling a rate substantially lower than paper (58%) and metals

(70–90%). Of the plastic that enters recycling streams, much is downcycled into lower-value applications rather than achieving closed-loop material recovery. Polyethylene terephthalate (PET) bottles exemplify this challenge: although PET exhibits comparatively favorable recyclability, nearly 50% escapes recycling systems entirely, and only 7% achieves bottle-to-bottle recycling. The predominantly single-use nature of plastic packaging compounds these challenges. Beyond recycled material, approximately 14% of plastic waste undergoes incineration for energy recovery—a process that generates atmospheric pollutants including particulate matter and greenhouse gases. The remaining 72% of plastic packaging is unrecovered: 40% accumulates in sanitary landfills while 32% enters the environment through inadequate collection infrastructure, illegal dumping, or mismanagement, ultimately contaminating terrestrial and aquatic ecosystems[1,2]. The environmental persistence of conventional plastics derives from the same molecular characteristics that confer commercial utility—chemical stability, hydrophobicity, and resistance to biological degradation. With global plastic production projected to continue exponential growth through 2050, the imperative for sustainable alternatives has intensified. Accordingly, contemporary materials research has increasingly focused on biopolymers: materials derived from renewable biological feedstocks that exhibit inherent biodegradability under appropriate environmental conditions[3]. Biopolymers encompass a structurally diverse class of macromolecules synthesized by living organisms. Principal categories include polysaccharides—such as cellulose, starch, chitin, alginate, and carrageenan—and proteins, including collagen, gelatin, and zein. These materials are composed of monomeric units (monosaccharides, amino acids, or nucleotides) linked through hydrolyzable bonds, rendering them susceptible to enzymatic degradation by soil and aquatic microorganisms. Among available biopolymers, starch has emerged as a particularly promising candidate for packaging applications due to its global abundance, low cost, annual renewability, and complete biodegradability[4, 5]. Starch is a semicrystalline polysaccharide comprising two structurally distinct glucose polymers: amylose (a predominantly linear α-1,4-linked glucan) and amylopectin (a highly branched macromolecule with α-1,4 backbone linkages and α-1,6 branch points). The relative proportions of these components—typically 20–30% amylose and 70–80% amylopectin in most botanical sources—fundamentally govern starch physicochemical behavior. Varghese et al. established that the amylose-to-amylopectin ratio serves as the primary determinant of starch functionality, controlling granule morphology, crystalline polymorphism, gelatinization temperature, and retrogradation kinetics. High-amylose starches (>40% amylose) promote robust film formation, elevated gel strength, and resistance to enzymatic hydrolysis, properties advantageous for biodegradable packaging and low-glycemic food applications. Conversely, high-amylopectin (waxy) starches exhibit superior thickening capacity and retrogradation resistance due to elevated peak viscosity, making them preferable for stabilization applications[6]. Despite these favorable attributes, native starch exhibits significant limitations for direct thermoplastic processing. The extensive hydrogen bonding network between starch chains results in elevated glass transition temperatures, high melt viscosity, and pronounced brittleness in cast films. Consequently, native starch cannot function as a standalone thermoplastic material without modification. Chemical, physical, and enzymatic modification strategies have been developed to address these constraints; however, such approaches frequently involve complex reaction conditions, elevated costs, and extended processing times[5,7]. An alternative strategy involves incorporating plasticizers—low-molecular-weight, non-volatile compounds that penetrate the starch matrix and disrupt intermolecular hydrogen bonding. Plasticizers increase free volume within the polymer network, reduce glass transition temperature, enhance chain mobility, and improve film flexibility. Polyols represent the most widely employed plasticizer class for starch-based materials, with glycerol (molecular weight: 92.09 g/mol) and sorbitol (molecular weight: 182.17 g/mol) constituting the predominant choices[7,8]. The effectiveness of specific plasticizers varies substantially depending on starch botanical origin and processing conditions. Glycerol-plasticized potato starch films demonstrate enhanced thermal stability at elevated plasticizer concentrations; however, this benefit is accompanied by increased equilibrium moisture content attributable to glycerol's pronounced hygroscopicity. Comparative investigations of sugar palm starch films revealed that sorbitol-plasticized formulations exhibit superior density and thermal stability—effects attributed to sorbitol's higher molar mass and reduced hygroscopicity—whereas glycerol-based films display elevated water solubility and moisture uptake. Research on cassava starch identified fructose as a superior plasticizer for maintaining structural integrity relative to urea or polyethylene glycol, suggesting that optimal plasticizer selection is highly dependent upon specific starch-plasticizer molecular interactions. Additionally, studies examining phosphorylated Arenga starch demonstrated that chemical modification significantly modulates barrier properties and film thickness, indicating that starch derivatization represents a complementary strategy for property optimization[9, 10 &11]. Recent advances have demonstrated that composite plasticizer systems can overcome limitations associated with single-plasticizer formulations. Wu et al. [12] reported that glycerol/D-fructose combinations, coupled with optimized thermal processing parameters, effectively disrupt starch crystalline domains while establishing superior hydrogen-bonding networks. The resulting thermoplastic starch (TPS) materials exhibited enhanced flexibility and tensile strength compared to conventional single-plasticizer systems. These findings underscore that concurrent optimization of formulation chemistry and processing conditions is prerequisite for achieving commercially viable mechanical properties in starch-based bioplastics. Despite extensive investigation of starch-based films from diverse botanical sources including potato[13], cassava[14], sugar palm[15], and Arenga [16]—limited research has specifically examined

corn starch behavior when formulated with binary plasticizer combinations. Corn starch represents a globally significant feedstock, with annual production exceeding 80 million metric tons, yet systematic evaluation of synergistic plasticizer effects on corn starch film properties remains incomplete. Although glycerol and sorbitol have been studied individually across multiple starch sources, their combined effects at defined ratios—particularly equimolar (1:1 w/w) blends—on the physical, mechanical, and structural characteristics of corn starch films have received insufficient attention. Elucidating such interactions is essential for developing bioplastic formulations that simultaneously achieve the flexibility conferred by glycerol and the dimensional stability afforded by sorbitol. Accordingly, this study systematically investigates the effects of three plasticization systems—glycerol (G), sorbitol (S), and an equimolar glycerol-sorbitol blend (G:S, 1:1 w/w)—on films prepared from corn starch via solution casting. The specific objectives are to: (1) characterize the physical properties (thickness, density, moisture content, water absorption, and water solubility) of films prepared with each plasticizer system; (2) evaluate structural characteristics through Fourier-transform infrared (FTIR) spectroscopy to elucidate starch-plasticizer molecular interactions; and (3) identify the optimal plasticizer formulation for maximizing film functionality with respect to potential food packaging applications.

2. Materials and Methods

2.1 Materials

Local corn was used as the precursor for starch extraction. For film plasticization, Glycerol and Sorbitol were obtained from the Faculty of Science at Sebha University. Acetic acid was employed as a cross-linking/reactive agent, and distilled water was used as the solvent for all solution preparations.

2.2 Starch Extraction

Corn starch was extracted from raw corn kernels using a wet milling method. The corn was initially washed and soaked in water for 30 minutes to soften the kernels. The soaked corn was then blended with 500 mL of distilled water using an electric blender until a slurry was formed. To separate the fibrous material from the starch milk, the mixture was filtered through a cloth sieve. The filtrate (starch suspension) was allowed to settle in a container to facilitate sedimentation. After the starch settled at the bottom, the supernatant water was decanted. The obtaining starch cake was air-dried for 32 hours to ensure complete moisture removal, followed by grinding to produce a fine powder[17].

2.3 Preparation of Bioplastic Films

Biopolymer films were prepared using the solution casting technique. A 5% (w/v) starch solution was prepared by dispersing 5 g of the extracted corn starch in 100 mL of distilled water. The solution was mixed with 10% (v/v) of acetic acid and 10% (v/v) of the designated plasticizer. Three distinct plasticizer formulations were evaluated:

1. Glycerol (G): 100% Glycerol.
2. Sorbitol (S): 100% Sorbitol.
3. Mixture (GS): A 1:1 blend of Glycerol and Sorbitol.

The mixtures were heated to 140°C on a hot plate with continuous magnetic stirring until gelatinization occurred, resulting in a homogeneous and semi-transparent solution. The solution was then poured into petri dishes (10 cm diameter) to ensure uniform film thickness. The cast films were dried in a laboratory oven at 48°C for 24 hours. Finally, the dried films were peeled from the casting surface and stored in a desiccator at room temperature for further characterization[9].

2.4 Characterization Techniques

2.4.1 Film Thickness and Density

The thickness of the prepared films was measured using a digital micrometer (INJECO-Co, China) with a precision of 0.001 mm. Measurements were taken at five random locations for each 2 cm × 2 cm specimen, and the average value was recorded. Film density (ρ) was calculated from the weight (m) and volume (v) of the specimen using Equation (1). The volume was derived from the area and the average thickness of the sample.

$$\boldsymbol{\rho = \frac{m}{v}} \ \textbf{(gm/cm}^3\textbf{)} \qquad (1) \qquad [18]$$

2.4.2 Moisture Content (WC)

The moisture content was determined gravimetrically. Film samples were weighed (W1) and then dried in an oven at 90°C for 24 hours. After drying, the samples were re-weighed (W2). The percentage of water content was calculated using Equation (2):

$$WC(\%) = \frac{W1 - W2}{W1} \qquad (2) \qquad [19]$$

2.4.3 Water Absorption (WA)

Water absorption was evaluated in accordance with ASTM D-570–98 standards. Samples were dried at 50°C for 24 hours, weighed (M1), and then immersed in distilled water at room temperature. After a specified immersion period, samples were removed, gently wiped to remove surface water, and weighed again (M2). Water absorption was calculated as follows:

$$WA(\%) = \frac{M2 - M1}{M1} \quad (3) \quad [20]$$

2.4.4 Water Solubility (WS)

To determine water solubility, film samples (2 cm × 2 cm) were first dried at 90°C for 24 hours to obtain the initial dry weight (W1). The samples were then immersed in 50 mL of distilled water with constant agitation for 4 hours at room temperature. The remaining undissolved film fragments were filtered and dried again at 90°C to a constant weight (W2). Solubility was calculated using Equation (4):

$$WS(\%) = \frac{W1 - W2}{W1} \quad (4) \quad [21]$$

2.4.5 Structural Analysis (FTIR)

Fourier Transform Infrared (FTIR) spectroscopy was employed to analyze the chemical structure and interactions between the starch and plasticizers. The spectra were recorded over a wavenumber range of 400–4000 cm^{-1} to identify characteristic functional groups.

3. Results and Discussion

3.1 Physical Properties of Corn Starch-Based Bioplastic Films

3.1.1 Film Formulation and Visual Characteristics

Three distinct bioplastic film formulations were successfully prepared from locally extracted corn starch using the solution casting technique. Visual inspection revealed pronounced differences in film texture and consistency attributable to plasticizer type. Films plasticized with glycerol (G) exhibited a soft, flexible, and plastic-like consistency characteristic of highly plasticized materials. In contrast, sorbitol-plasticized films (S) demonstrated a firmer, more rigid texture with enhanced structural integrity. Films containing the glycerol-sorbitol blend (GS, 1:1 w/w) exhibited intermediate textural properties, combining moderate flexibility with improved dimensional stability. All formulations yielded translucent, continuous films suitable for characterization, confirming successful gelatinization and plasticizer incorporation during the thermal processing stage at 140°C. These observations align with the established understanding that glycerol, owing to its lower molecular weight (92.09 g/mol), penetrates the starch matrix more effectively, creating greater intermolecular spacing and enhanced chain mobility. Sorbitol's higher molecular weight (182.17 g/mol) results in reduced penetration efficiency but provides superior structural reinforcement through more extensive hydrogen bonding networks with starch hydroxyl groups[6].

3.1.2 Film Thickness and Density

The physical dimensions and density measurements of the prepared films are presented in Table 1. Film thickness ranged from 0.075 mm to 0.098 mm across the three formulations, with sorbitol-plasticized films exhibiting the lowest thickness (0.075 ± 0.01 mm), followed by glycerol films (0.095 ± 0.01 mm) and the glycerol-sorbitol blend (0.098 ± 0.01 mm).

Table 1: Thickness and Density of Corn Starch-Based Bioplastic Films**.**

Plasticizer System	Thickness (mm)	Density (g/cm³)
Glycerol (G)	0.095 ± 0.01	1.534
Sorbitol (S)	0.075 ± 0.01	1.702
Glycerol-Sorbitol (GS)	0.098 ± 0.01	1.390

Density measurements revealed significant variation among formulations. Sorbitol-plasticized films exhibited the highest density (1.7 g/cm³), followed by glycerol films (1.53 g/cm³), while the blended system showed the lowest density (1.4 g/cm³). The elevated density observed in sorbitol films can be attributed to sorbitol's higher molar mass and the formation of a more compact molecular arrangement within the starch matrix. This finding is consistent with previous investigations by Sanyang et al.[15], who reported that sorbitol-plasticized sugar palm starch films exhibited superior density compared to glycerol-based formulations due to sorbitol's molecular characteristics. The reduced thickness of sorbitol films, despite identical casting volumes, suggests more efficient molecular packing and reduced free volume within the polymer matrix. Conversely, glycerol's smaller molecular size promotes greater chain separation, resulting in expanded film dimensions and reduced overall density. The intermediate density of the GS blend indicates a non-additive interaction between the two plasticizers, potentially suggesting competitive binding to starch hydroxyl groups or phase separation phenomena within the matrix.

3.1.3 Water Content and Water Solubility

Moisture-related properties represent critical parameters for evaluating the suitability of starch-based films for packaging applications. The water content, water solubility, and water absorption values for all film formulations are summarized in Table 2.

Table 2: Moisture-Related Properties of Corn Starch-Based Bioplastic Films.

Plasticizer System	Water Content (%)	Water Solubility (%)	Water Absorption (%)
Glycerol (G)	12.796	65.217	57.808
Sorbitol (S)	12.658	60.289	18.090
Glycerol-Sorbitol (GS)	13.584	61.790	29.032

Water content values were relatively consistent across all formulations, ranging from 12.658% (sorbitol) to 13.584% (GS blend). This narrow range indicates that equilibrium moisture uptake under ambient storage conditions is primarily governed by the hydrophilic nature of the starch matrix itself, with plasticizer type exerting a secondary influence. The marginally elevated water content in the GS blend films may reflect synergistic hygroscopic effects arising from the combined presence of both plasticizers. Water solubility analysis revealed more pronounced differences among formulations. Glycerol-plasticized films exhibited the highest solubility (65.217%), followed by the GS blend (61.790%) and sorbitol films (60.289%). The enhanced solubility of glycerol films is directly attributable to glycerol's intense hydrophilicity and lower molecular weight, which facilitates water penetration into the film matrix and promotes dissolution of the plasticized starch network. These findings corroborate those reported by Edhirej et al. [14] for cassava starch films, where plasticizer hydrophilicity directly correlated with film water solubility. From a practical perspective, elevated water solubility may limit applications requiring prolonged contact with aqueous environments. However, high solubility can be advantageous for applications where rapid biodegradation or water-triggered dissolution is desirable, such as water-soluble packaging for detergent pods or agricultural mulch films.

3.1.4 Water Absorption Characteristics

Water absorption behavior exhibited the most dramatic variation among the measured physical properties, with values ranging from 18.090% (sorbitol) to 57.808% (glycerol)—a greater than three-fold difference. This substantial disparity underscores the profound influence of plasticizer selection on film hygroscopic behavior. Glycerol-plasticized films demonstrated exceptionally high-water absorption capacity (57.808%), absorbing more than half their initial weight when immersed in distilled water. This behavior is mechanistically explained by the abundance of hydroxyl groups in both glycerol and the starch matrix, which establish extensive hydrogen bonding networks capable of sequestering substantial quantities of water molecules. The three hydroxyl groups per glycerol molecule provide multiple sites for water binding, effectively functioning as moisture attractants within the polymer network. In marked contrast, sorbitol-plasticized films exhibited dramatically reduced water absorption (18.090%), representing only 31.3% of the absorption observed in glycerol films. Despite sorbitol possessing six hydroxyl groups per molecule (compared to glycerol's three), its higher molecular weight and the resulting denser molecular packing create a more tortuous diffusion pathway that impedes water penetration. Additionally, the more extensive intermolecular hydrogen bonding in sorbitol-plasticized films leaves fewer hydroxyl groups available for water binding. The GS blend films demonstrated intermediate water absorption behavior (29.032%), approximating the arithmetic mean of the individual plasticizer systems. This proportional response suggests that the blend effectively combines the properties of both plasticizers without significant synergistic or antagonistic interactions affecting water absorption. The intermediate behavior positions the GS formulation as a potentially balanced system for applications requiring moderate moisture sensitivity. These results align with the broader literature on polyol-plasticized starch films. The hydroxyl group density and molecular configuration of plasticizers directly influence water absorption through competitive binding mechanisms—plasticizer hydroxyl groups that form hydrogen bonds with water molecules increase absorption, while those engaged in starch-plasticizer bonding reduce available binding sites for water.

3.1.5 Structural Analysis by FTIR Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy was employed to elucidate the molecular interactions between corn starch and the different plasticizer systems. Spectral analysis confirmed successful plasticizer incorporation and revealed characteristic absorption bands indicative of starch-plasticizer hydrogen bonding.

Native Corn Starch Spectrum:

The FTIR spectrum of unmodified corn starch exhibited characteristic polysaccharide absorption bands. A broad absorption band spanning 3200–3500 cm^{-1} corresponds to O−H stretching vibrations of hydroxyl groups, reflecting the extensive hydrogen bonding network within the native starch structure. Peaks in the 1000–1400 cm^{-1} region are assigned to C−O stretching modes characteristic of the glucopyranose ring and glycosidic linkages.

A weak absorption at 1600–1650 cm^{-1} indicates residual bound water or C=C stretching from trace impurities. The region around 2100–2200 cm^{-1} exhibited minor absorption potentially associated with atmospheric CO_2 or instrumental artifacts.

Glycerol-Plasticized Film Spectrum:

Films plasticized with glycerol displayed characteristic peaks at 621.82 cm^{-1} and 1106.91 cm^{-1}, attributable to C−O stretching and C−C skeletal vibrations of the glycerol molecule. The spectral region from 1400–1700 cm^{-1} exhibited absorption bands assigned to C=C stretching modes, while the broad absorption spanning 2900–3400 cm^{-1} encompasses both C−H and O−H stretching vibrations. The breadth and intensity of the O−H stretching region indicate extensive hydrogen bonding between glycerol hydroxyl groups and starch, confirming effective plasticizer integration into the biopolymer matrix. Notably, the O−H band appears broader in plasticized films compared to native starch, suggesting disruption of the native starch hydrogen bonding network and formation of new starch-glycerol hydrogen bonds.

Sorbitol-Plasticized Film Spectrum:

Sorbitol-plasticized films exhibited distinctive peaks at 487.00 cm^{-1} and 621.67 cm^{-1} in the fingerprint region. The 1000–1450 cm^{-1} region displayed pronounced C−O stretching absorptions consistent with the multiple ether-like linkages in the sorbitol-starch complex. Absorption at 1600–1650 cm^{-1} corresponds to C=C vibrations, while the broad O−H stretching band at 3200–3500 cm^{-1} confirms hydrogen bonding interactions. The relatively sharper definition of peaks in the sorbitol spectrum, compared to glycerol films, suggests a more ordered molecular arrangement consistent with the higher density and reduced water absorption observed in physical property measurements.

Glycerol-Sorbitol Blend Film Spectrum:

The GS blend exhibited a composite spectral profile incorporating features of both individual plasticizer systems. Characteristic absorptions appeared in the 550–950 cm^{-1} fingerprint region, with C−O stretching bands at 1000–1450 cm^{-1}. The C=C stretching region (1600–1650 cm^{-1}) and C−H stretching bands (2900–3150 cm^{-1}) were clearly resolved. The O−H stretching region (3200–3500 cm^{-1}) exhibited intermediate breadth between the glycerol and sorbitol formulations, indicating a blended hydrogen bonding environment. The spectral characteristics support the physical property data suggesting that the GS blend combines aspects of both plasticizer systems without dominant antagonistic or synergistic interactions at the molecular level.

Comparative Analysis:

Across all plasticized formulations, the persistence and modification of the O−H stretching band (3200–3500 cm^{-1}) serves as a diagnostic indicator of starch-plasticizer interaction quality. The broader O−H bands observed in glycerol-containing films reflect greater hydrogen bonding heterogeneity and increased moisture susceptibility, correlating with the elevated water absorption and solubility measurements. The relatively sharper O−H absorption in sorbitol films indicates more uniform hydrogen bonding environments, consistent with the superior water resistance of these formulations. The absence of new absorption bands outside the expected regions for starch and polyol plasticizers confirms that film preparation did not induce chemical degradation or unwanted side reactions during thermal processing at 140°C. The acetic acid employed as a processing aid did not generate detectable ester linkages or other covalent modifications, indicating its role was limited to facilitating starch gelatinization rather than chemical cross-linking.

3.2 Comparative Analysis with Published Literature

The results obtained in this study demonstrate substantial agreement with published investigations of starch-based bioplastic films from various botanical sources. The density values reported herein (1.390–1.702 g/cm^3) fall within the range reported by Edhirej et al. for cassava starch films plasticized with various agents, where densities ranged from 1.45 to 1.74 g/cm^3 depending on plasticizer type and concentration. The superior density of sorbitol-plasticized films is consistent with observations by Sanyang et al. for sugar palm starch, who attributed this behavior to sorbitol's higher molar mass and enhanced molecular packing efficiency.

The pronounced difference in water absorption between glycerol (57.808%) and sorbitol (18.090%) plasticized films exceeds the magnitude reported in some previous studies, potentially reflecting differences in starch botanical origin, extraction methodology, or processing conditions. Corn starch, with its characteristic amylose-to-amylopectin ratio (typically 25:75), may exhibit different plasticizer interactions compared to cassava (17:83) or potato (20:80) starches due to variations in granule morphology and molecular architecture.

The water solubility values (60.289–65.217%) are notably higher than those reported for fructose-plasticized cassava starch films (approximately 45–55%), suggesting that both glycerol and sorbitol produce films with greater water sensitivity compared to saccharide plasticizers. This finding has important implications for packaging applications where water resistance is a critical performance criterion.

3.3 Implications for Packaging Applications

The experimental findings suggest distinct application profiles for each plasticizer system:

Glycerol-plasticized films offer maximum flexibility and processability, making them suitable for applications requiring conformable packaging materials. However, their high-water absorption and solubility limit suitability for moisture-sensitive products or humid storage environments. Potential applications include short-term food wrapping for dry goods, agricultural mulch films designed for rapid biodegradation, or water-soluble sachets for controlled-release applications.

Sorbitol-plasticized films demonstrate superior water resistance and dimensional stability, positioning them for applications requiring enhanced barrier properties. The firmer texture may limit conformability but provides better mechanical integrity for rigid or semi-rigid packaging formats. Suitable applications might include trays, containers, or protective packaging for moisture-sensitive products.

The glycerol-sorbitol blend represents a balanced compromise, offering intermediate properties that may satisfy applications requiring moderate flexibility with improved water resistance compared to pure glycerol formulations. This formulation approach provides a tunable system where the plasticizer ratio could be further optimized for specific application requirements.

4. Conclusion

This investigation systematically evaluated the influence of plasticizer type on the physical and structural properties of corn starch-based bioplastic films prepared via solution casting. Three plasticization systems were examined: glycerol (G), sorbitol (S), and an equimolar glycerol-sorbitol blend (GS, 1:1 w/w). The principal findings are summarized as follows:

Successful Bioplastic Fabrication: Corn starch was successfully extracted from locally sourced raw corn using wet milling methodology, and viable bioplastic films were prepared from all three plasticizer formulations, confirming the suitability of the solution casting technique for laboratory-scale bioplastic production.

Plasticizer-Dependent Physical Properties: The type of plasticizer profoundly influenced film physical characteristics. Sorbitol-plasticized films exhibited the highest density (1.702 g/cm³) and lowest thickness (0.075 mm), indicating superior molecular packing efficiency. Glycerol films demonstrated intermediate density (1.534 g/cm³), while the GS blend exhibited the lowest density (1.390 g/cm³), suggesting non-additive plasticizer interactions.

Water Sensitivity Variation: Water absorption behavior showed the most dramatic variation among measured properties. Glycerol films absorbed 57.808% of their weight in water, compared to only 18.090% for sorbitol films—representing a 3.2-fold difference. The GS blend exhibited intermediate absorption (29.032%). Water solubility followed a similar trend, with glycerol films showing the highest solubility (65.217%) and sorbitol films the lowest (60.289%).

Structural Confirmation: FTIR spectroscopic analysis confirmed successful plasticizer incorporation into the starch matrix, with characteristic absorption bands indicating hydrogen bonding between plasticizer hydroxyl groups and starch. No evidence of thermal degradation or unwanted chemical reactions was detected, validating the processing protocol.

Optimal Formulation Identification: Based on the collective evidence, sorbitol represents the superior plasticizer for applications demanding water resistance and dimensional stability, while glycerol offers advantages where maximum flexibility is prioritized. The glycerol-sorbitol blend provides a balanced property profile suitable for applications with moderate requirements across multiple performance criteria.

This study contributes to the growing body of knowledge on sustainable packaging materials by demonstrating that locally sourced corn starch can serve as an effective biopolymer matrix for biodegradable film production. The pronounced influence of plasticizer selection on film properties underscores the importance of formulation optimization in developing fit-for-purpose bioplastic materials. These findings support the broader objective of reducing petroleum-based plastic consumption through renewable, biodegradable alternatives derived from abundant agricultural feedstocks.

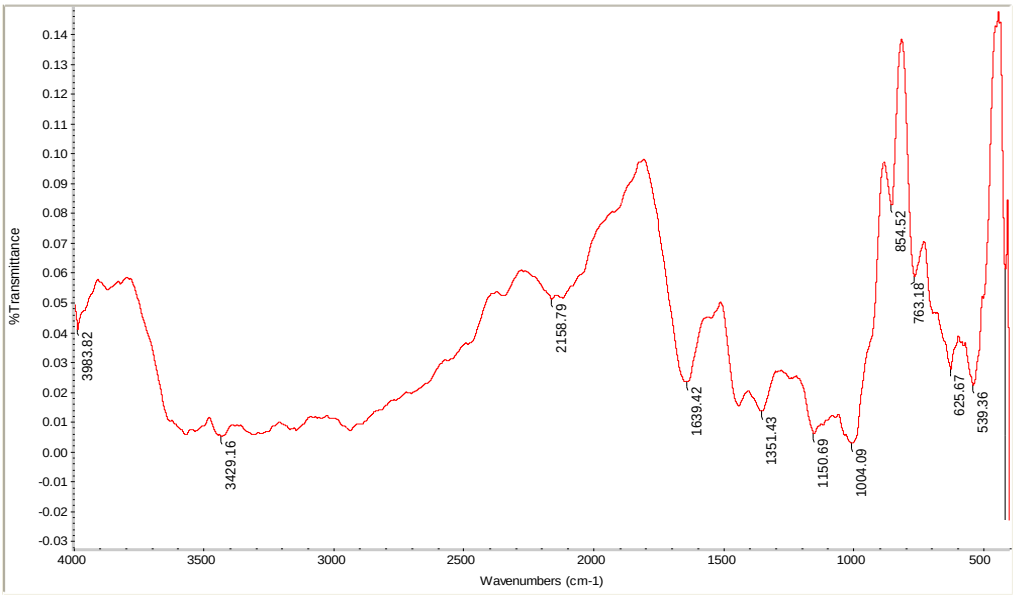

Figure 1: FTIR corn starch

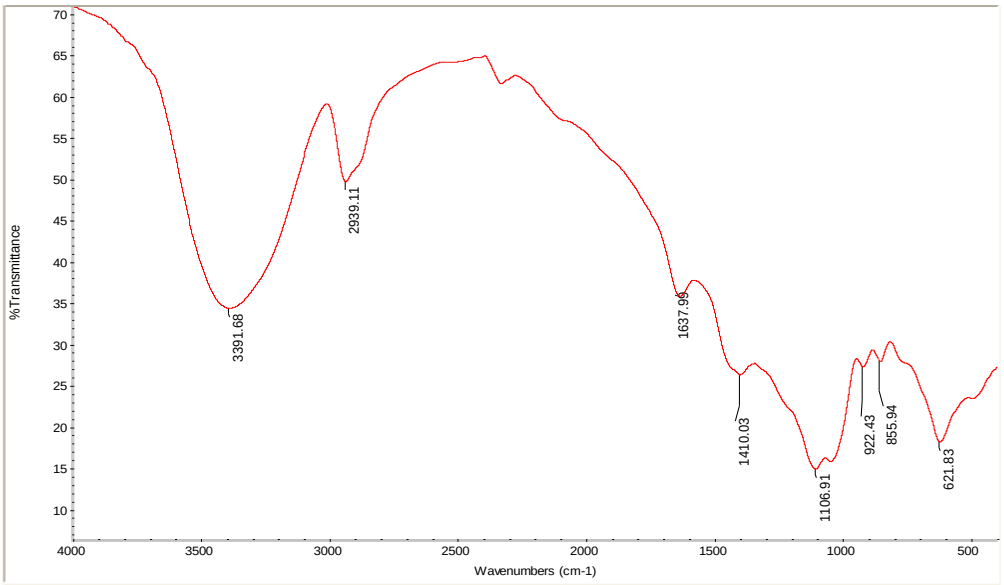

Figure 2: FTIR for Glycerol corn plastic.

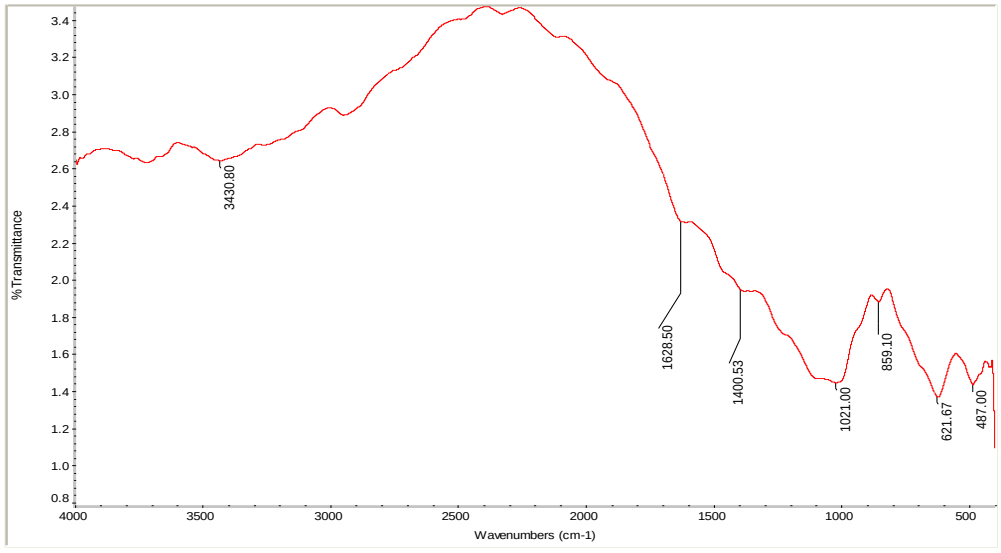

Figure 3: FTIR for sorbitol corn plastic.

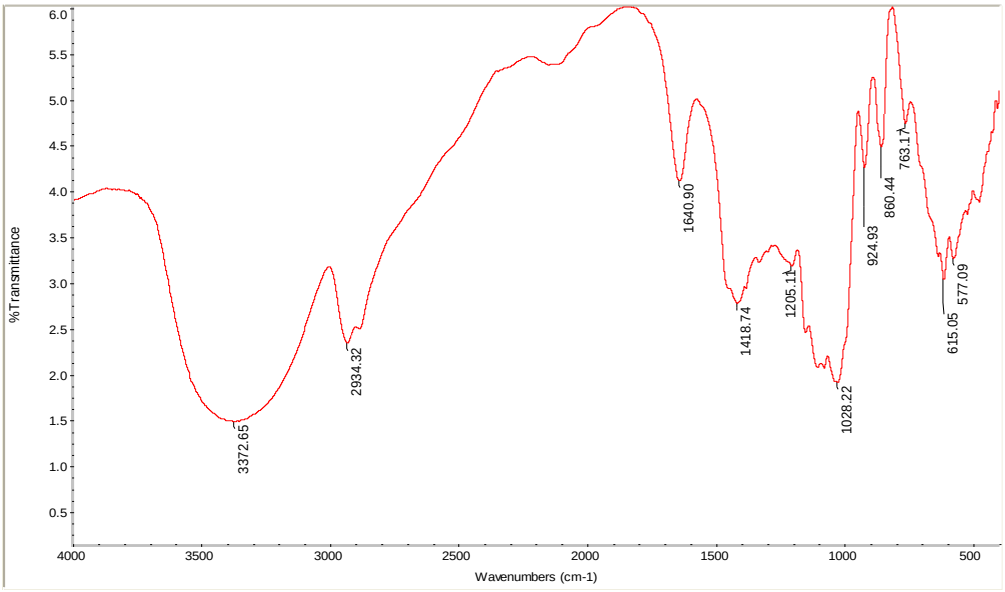

Figure 4: FTIR for (G+S) corn plastic.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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