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Effect of Cassava Starch on LDPE as Biodegradable Film and its Physical and Mechanical Properties

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ABSTRACT

Background: Biodegradable plastics are made from starch extracted from renewable biomass. Approximately 50% of the biodegradable plastics used commercially are prepared from starch. The research was undertaken to develop biodegradable film from blend of LDPE and Cassava starch at different proportions and to study the Physical and Mechanical properties.

Methods: Biodegradable film was prepared by Blown film extrusion method using LDPE, cassava starch adding glycerol, talc powder and urea (T_0, T_1, T_2, T_3 and T_4) at different proportions. The effects of plasticizer (glycerol) and different proportions of cassava starch on the film properties were determined by the standard methods.

Result: The developed biodegradable film had a tensile strength ranging from 6.68-8.42 MPa. The film thickness from 0.17 to 0.80 mm, transparency from 0.55 to 2.07%, water absorption from 0.007 to 0.067% and moisture permeability from 0.59 to 14.08%.

Key words: Biodegradable film, Cassava starch, LDPE, Physical and mechanical properties.

INTRODUCTION

Plastics derived from petroleum are the most used packaging materials in the food industry. Plastic degradation takes a long time and can cause many environmental problems by being sturdy (Sorrentino *et al.,* 2007; Xu *et al.,* 2005). Low density polyethylene is all the more prevalently utilized for packing as it has a large portion of the qualities of packaging material. It is significantly used to food items, farming items, contract wrapping, electronic products, vehicles, *etc*. LDPE is increasingly inadequate to the assault of microorganisms in decided conditions. One of the feasible choices to quicken the biodegradation by microorganisms is the expansion of characteristic polymers, LDPE similar to starch, to ensure in any event a midway biodegradation.

Bio-plastics are a new generation of plastics which are biodegradable and compostable. They are manufactured generally from renewable raw materials like starch from *e.g.* corn, potato, or plants as a whole is used as a raw material for bio-plastic to get starch, cellulose, lactic acid etc. which are not hazardous in production and degrade back into carbon dioxide. Bio-plastics have 66% less unsafe nursery outflows, including carbon and sulfur oxides, during their generation. Biodegradable films can reduce environmental problems related with food packaging and general packaging. The concept of biodegradability enjoys both adaptable and eco-friendly advantages. Film production by natural and abundant biodegradable polymeric materials as cellulose, gums, starches or proteins, is also convenient due to the lower environmental significant compared with common synthetic plastic materials (Cutter *et al.,* 2006).

Cassava is a significant crop in South America and other countries it is an economical source of starch (FAO, 2004). Cassava starch-based edible films indicate appropriate physical characteristics, since these film are odorless, tasteless, colorless and waterproof to oxygen. Starch is a natural polymer that could be an alternative to produce food packaging materials. It has been carefully studied because it is cheap, biodegradable and edible. Starch is an agricultural biopolymer found in a variety of plants including wheat, corn, rice, beans and potatoes (Kolybaba *et al.,* 2006). Hence the present research aim to study the″ Effect of cassava starch on LDPF as biodegradable film and its physical and mechanical properties″.

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MATERIALS AND METHODS

The experiment was conducted during the session of 2020-2021 (January, 2021- October, 2021) at Central Institute of Plastic Engineering and Technology (CIPET) Ahmadabad and Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India.

Materials

Low Density polyEthylene, cassava starch, glycerol, talc powder and urea were obtained from local market Watwa, Ahmadabad, Gujarat

Methods

The Process of Production of Biodegradable Film Blend of LDPE and Cassava starch is shown in Fig 1.

Blend preparation

Starch was dried to moisture content below 10% for 1.30h in Hot air oven at 60°C. The moisture content of the starch was kept approximately at 10% to enhance processability and no additional grease or other plasticizers and cross linking agent was added to the compound. LDPE blend with Cassava starch was made at the same processing conditions for blending purposes. Compound formulation containing LDPE and Cassava starch was made at 5, 10, 15 and 20% of starch to study the effect of starch content on the properties of the sample. The dried starch and LDPE was mixed at 1500 rpm for 5 min in high speed mixer. LDPE with cassava starch blends was prepared continuously in a Twin screw Extuder. Extrusion was carried out at a screw speed of 160 rpm and the temperature was set at 80°C/90°C/100°C/120°C/125°C and die temperature at 120°C for all blends. The sample was fed manually as much as the extruder would process. The extrudates were palletized using a pelletizer machine for each formulation and dried to remove remaining moisture and stored in an airtight plastic container. Fig 2 shows the Twin Screw Extruder (High Torque ZV 20).

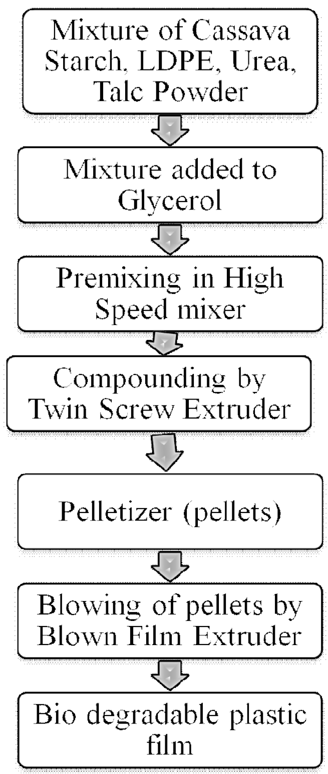

Fig 1: Flow sheet for production of biodegradable film.

Film Formation

The film of blends was produced from the developed pellets the blown film extruder. The polymer was melted inside the barrel of the extruder and then forcing the molten polymer through a narrow slit in a die, perpendicular to form thin walled tube. The temperatures of barrel zone I, II, III, IV and V was set at 180, 185, 190, 200 and 190°C and the melting temperature was 112°C and blowing pressure at 180 Pa. The slit was in a circular form. Air was introduced in the centre of the die to blow up the tube like balloon, air ring blow on to the hot film to cool it (outside and inside the tube). The resulting thin film in the form of a tube, later often referred to as bubble. The tube passed through nip rolls where it was flattened. On winder the tube or film was wounded into roll. Fig 3 shows Blown Film Extruder (Konark plastomech pvt ltd, Velobllow 35).

Properties of Biodegradable Film (Blend of LDPE and cassava starch)

Film thickness

Film thickness was measured with a micrometre (Screw gauge, Make: RSM64) with a least count of 0.001 mm.

Tensile strength

The tensile strength of the films were measured using Texture Profile Analyzer (ASTM D882) with the use of extensibility probe and the highest peak of force is considered as the tensile strength of the film. Each sample

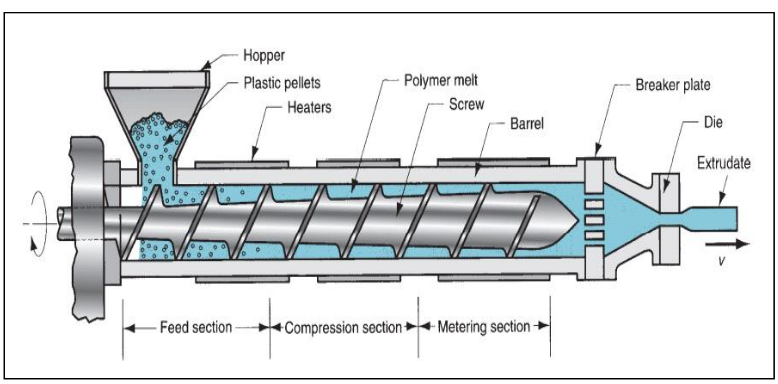

Fig 2: Twin Screw Extruder.

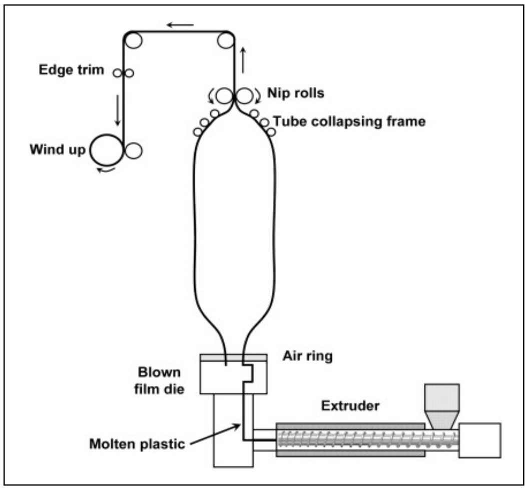

Fig 3: Blown Film Extruder.

film was cut into strips of 12 cm × 1.5 cm size and then the film tensile strength was measured on these strips.

Transparency

The light barrier properties of the films were evaluated by exposing films to light osmosis at a wavelength of 600 nm in an UV-Vis spectrophotometer (Condés *et al.,* 2015). Samples were cut into oval pieces and placed directly in a spectrophotometer test cell for capturing the absorbance spectrum. Experiments were performed using air as the reference value.

Surface pH

To determine the pH, distilled water was taken in a beaker and the electrode of the pH meter was dipped in the distilled water and reading of pH meter was set manually by knob to 7 *i.e.* the values. The film semple were taken in breaker and pH was measured by dipping electrodes of digital ph meter.

Water Absorption

The films were cut into a piece of 2.5×2.5 cm in size and weighed in air-dried conditions (W_1). They were then immersed in distilled water (25°C) for 30 min. The w et sample was wiped with filter paper to remove excess water and weighted (W_2). The film was kept in distilled water for 30 min, 60 min, 120 min and 240 min. The amount of absorbed water was calculated using the equation 1.

$$\text{WA (\%)} = \frac{\text{Final weight (g)-Initial weight (g)}}{\text{Intial weight (g)}} \times 100 \qquad \text{Eq...1}$$

Moisture Permeability

For determining moisture permeability, the salt powder was used because it is highly hygroscopic in nature and gains moisture rapidly in normal atmosphere. This moisture gain indicates the moisture permeability through films in 30 days and with this method the moisture permeability was evaluated. For this test 1 g of salt was sealed into each plastic sample films. The film was cut into identical dimensions *i.e.* 4 cm × 4 cm. These packed films were kept in empient atmosphere for 30 days and after 30 days the moisture gain by the salt was calculated (Ranganna 2002) using the equation 2.

Moisture gain % by the salt =

$$\frac{\text{Final wt. of salt-Intitial wt.of salt}}{\text{Intial wt.of salt}} \times 100 \qquad ...2$$

Statistical analysis

Were statistically analyzed by the 'Analysis of variance- One way classification or single factor 'ANOVA' classification.

RESULTS AND DISCUSSION

Physical and Mechanical properties of Biodegradable film

Tensile strength

Tensile strength is the ability of a material to withstand a pulling force. This is an important concept in food packaging. A higher tensile strength is generally needed for food packets used for shipping and it helps to ensure better seal. To be plasticized with some plasticizers *i.e.* Glycerol was used in this study. The tensile strength of films T_1, T_2, T_3 and T_4 are depicted in Table 1. The results showed that the sample T_1 was found to have the maximum strength *i.e.* 7.95 MPa force and the minimum strength for sample T_4 *i.e.* 6.68 MPa force. These differences on the mechanical behavior of the formulated films could be explained by the plasticizers (present in Biodegradable Cassava Starch Film) interacting with film constituents causing changes in the properties of the continuous phases. Similar results were obtained in the studies conducted by Lu *et al.,* (2009), whose work was on starch-based completely biodegradable polymer materials, similarly Ezeoha *et al.,* (2013) whose work was based on cassava starch and PVA. It is observed that the calculated value of F due to treatments is greater than the tabulated value at 5% probability level. Therefore it can be concluded that significant effect of treatments on moisture permeability of samples were observed in Table 1.

Film thickness

Thickness is the physical property which is usually defined as the distance between the top and bottom. Thickness of biodegradable packaging material should be same all over as it affects the other properties of packaging materials. The film thickness was kept constant and the thickness was measured at four different points of each sample. The thickness was then calculated using screw gauge and it was in that the range of 0.1601 mm to 0.8277 mm. Similar results were obtained in the studies conducted by Oromiehie *et al.,* (2012) on rice starch and LDPE composites. It is noticeable that the calculated value of F due to treatments is greater than the tabulated value at 5% probability level. Therefore it can be concluded that significant effect of treatments on thickness of samples were observed in Table 2.

Transparency

Transparent food packaging makes sure the visual authentication of the food content which is an essential factor that affects the consumer's insight of the quality of food. Transparent food packaging not only helps the customer to have a view of the product but it also gives the brands an chance to ensure an good quality and proper condition of the food even after the shipment process of the food packets. The transparency of the film samples were checked using spectrophotometer. Film labeled T_1 was most transparent. Similar results were obtained by Wang *et al.,* (2016). It is noticeable that the calculated value of F due to treatments is greater than the tabulated value at 5% probability level. Therefore it can be concluded that remarkable effect of treatments on transparency of samples were observed in Table 3.

Surface pH

pH should be such that it should not give to microbial growth. Most of the bacterial growth takes place at pH 6.5 to 7. The surface pH of films should be around neutral to avoid any kind of irritation to the mucosal lining of the oral cavity. As an acidic or alkaline pH may cause irritation to the oral mucosa, it was determined to keep the surface pH as close to neutral as possible. Surface pH of the film was ranging from 7.31 to 8.07. Approximate readings were observed by Ferrer *et al.,* (2002) worked on modified atmosphere packaging of minimally processed mango and pineapple fruits. It is observed that the calculated value of F due to treatments is greater than the tabulated value at 5% probability level. Therefore it can be concluded that significant effect of treatments on moisture permeability of samples were observed in Table 4.

Water absorption

The water absorption of composite films is directly proportional to starch amount incorporated into polymer matrix. The water absorption would increase by increasing the starch content in LDPE. The starch is responsible for water absorption due to hydrophilic nature of starch and ionic character of hydroxyl groups of starch. Composites with more water absorption have lower mechanical properties. The water absorption of Cassava starch and LDPE blend at different proportions ranged from 0.007-0.071 in different treatments. Similar result was observed by Obasi *et al.,* (2014) for cassava starch compatibilizer on biodegradable and tensile properties of polypropylene. Futher calculated value of F due to treatments is smaller than the tabulated value at 5% probability level. Therefore it can be conducted that significant effect of treatments on water absorption of sample were observed in Table 5.

Moisture Permeability

Moisture absorption properties are crucial that protects the food. Food package with low moisture absorption is preferred. Moisture permeability of film ranged from 0.59% to 14.1%. Similar results were obtained by Bertuzzi *et al.,* (2007a) on starch based films. also the calculated value of F due to treatments is greater than the tabulated value at 5% probability level. Therefore it can be concluded that significant effect of treatments on moisture permeability of samples were observed in Table 6.

Table 1: Tensile strength of biodegradable film.

Tensile strength (MPa)				
Treatments	R_1	R_2	R_3	Mean (MPa)
T_0	8.44	8.43	8.40	8.423
T_1	7.95	7.89	7.87	7.903
T_2	7.35	7.40	7.41	7.387
T_3	6.88	6.78	6.97	6.877
T_4	6.79	6.68	6.70	6.723
S. Ed. (±)	Result of F test		Critical difference at 5%	
0.00067	Treatments found significant at 5% level of significance		0.00143	

Table 2: Film thickness of biodegradable film.

Film thickness (mm)				
Treatments	R_1	R_2	R_3	Mean (mm)
T_0	0.1891	0.1601	0.1621	0.1704
T_1	0.3967	0.3947	0.3895	0.3936
T_2	0.6659	0.6830	0.6716	0.6735
T_3	0.7204	0.6764	0.6884	0.6950
T_4	0.8277	0.7866	0.8072	0.8071
S. Ed. (±)	Result of F test		Critical difference at 5%	
0.03	Treatments found significant at 5% level of significance		0.065	

Table 3: Transparency of biodegradable film.

Transparency (%)				
Treatments	R_1	R_2	R_3	Mean (%)
T_0	0.5525	0.5526	0.5525	0.552533
T_1	0.5750	0.5746	0.5745	0.5747
T_2	1.0216	1.0228	1.0228	1.0224
T_3	1.7097	1.7017	1.6937	1.7017
T_4	2.0750	2.0750	2.0687	2.0729
S. Ed. (±)	Result of F test		Critical difference at 5%	
2E-06	Treatments found significant at 5% level of significance		5E-06	

Table 4: Surface pH of biodegradable film.

Surface pH				
Treatments	R_1	R_2	R_3	Mean
T_0	8.05	8.07	8.04	8.05
T_1	7.63	7.72	7.62	7.65
T_2	7.58	7.60	7.53	7.57
T_3	7.43	7.51	7.38	7.44
T_4	7.33	7.37	7.31	7.33
S. Ed. (±)	Result of F test		Critical difference at 5%	
8.733	Treatments found significant at 5% level of significance		0.0001	

Table 5: Water Absorption of biodegradable film.

	Water Absorption (%)			
Treatments	R_1	R_2	R_3	Mean (%)
T_0	0.007	0.007	0.007	0.007
T_1	0.027	0.031	0.034	0.030
T_2	0.042	0.046	0.049	0.045
T_3	0.054	0.057	0.060	0.057
T_4	0.064	0.068	0.071	0.067
S. Ed. (±)	Result of F test		Critical Difference at 5%	
0.0002	Treatments found significant at 5% level of significance		0.0005	

Table 6: Moisture Permeability of piodegradable film.

	Moisture permeability (%)			
Treatments	R_1	R_2	R_3	Mean (%)
T_0	0.60	0.59	0.59	0.59
T_1	3.78	3.85	3.81	3.81
T_2	6.74	6.79	6.81	6.78
T_3	7.14	7.20	7.19	7.17
T_4	14.05	14.10	14.09	14.08
S. Ed. (±)	Result of F test		Critical difference at 5%	
6.9	Treatments found significant at 5% level of significance		14.7	

CONCLUSION

The results showed that the biodegradable film prepared from the cassava starch have better physical and mechanical properties blend of to be used and LDPE has sufficient packaging material. The average thickness of the biodegradable film was 0.82 mm. The average moisture permeability was 14.08%. The water absorption was 0.071%. The maximum tensile strength of the biodegradable film was 7.95 MPa. From the above test results, it can be concluded that biodegradable film can be used as packing materials and can be used as a substitute to LDPE and other bags. LDPE incorporated with cassava starch film can be used for food packaging application. It can be concluded that cassava starch can be a superior starch with LDPE and can be used as a packaging materials. It can be regarded as a help for our society in controlling pollution.

Conflict of Interest: None.

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