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RESEARCH ARTICLE

Study of Flexural, Tensile, Impact properties and Morphology of Potato Starch/Polypropylene blends.

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Abstract

The effect of potato starch contents on mechanical and morphological properties of polypropylene starch blends have been investigated in this work. The maleic anhydride grafted PP (PP-g-MA) was used as coupling agent to improve the adhesion between starch and polymer matrix in melt blending as interfacial strength between reinforcement and polymeric matrix has direct effect on the properties of blend. For this purpose the content of starch varied from 15 to 30% and coupling agent (i.e. PP-g-MA) was taken 10%. The blends were compounded on co-rotated twin screw extruder. Then, mechanical properties such as tensile, flexural and impact were evaluated. It was found that the tensile and impact strength remained almost constant, while flexural strength of the blend improved by 45%, and percentage strain decreased with increasing starch content in the blend. The scanning electron micrograph (SEM) supports the finding as its shows uniform distribution of starch particle in the matrix. The chemical structure was analyzed by FTIR. The Melt flow Index (MFI) of blends also supported the uniform distribution of starch within the polymeric matrix.

Introduction

Polypropylene (PP) was the first synthetic stereo-regular polymer to achieve industrial importance. Being lightest and highly crystalline, polypropylene exhibits high stiffness, hardness and tensile strength. Hence, due to high strength to weight ratio, it is widely used in automobile, electrical and household equipment, furniture, and packaging applications[1]. The PP is derived from non-renewable petroleum resources and it is non degradable in nature, which may cause environmental disaster without proper disposal[2]. Hence several government and non-government communities are now more sensitive to the impact of discarded plastic on the environment, including deleterious effects on wildlife and on the aesthetic qualities of cities and forests. The biodegradable polymers opened the way for new consideration of waste management strategies since these materials are designed to degrade under environmental conditions or in municipal and industrial biological waste treatment facilities.

The blend of natural material like starch and synthetic polymers offers a practical approach to this environmental threat. The starch may contribute towards the development of such biodegradable polymers because its properties are quite similar to the petrochemical based polymers[3-5]. Many attempts have used renewable and sustainable materials to prepare biodegradable PP blends to reduce its environment impact[6]. Starch is an important material of choice as approximately 75% of all organic material on earth is present in the form of polysaccharides. The main issue around its use, have been that it is hydrophilic in nature, brittleness in the absence of suitable plasticizers and deterioration of mechanical properties upon exposure to environmental conditions[7-10]. Since, PP and Starch did not react chemically, the maleic anhydride grafted PP (PP-g-MA) used as coupling agent to improve the compatibility between polymer matrix and starch by formation of hydrogen boding [11-14].

Hence, authors selected potato starch, PP and PP-g-MA to prepare biodegradable blend of PP and starch. The content of coupling agent PP-g-MA has been maintained to 10%. In this present work 15 to 30% potato starch treated with glycerol, have been extruded with co-rotated twin screw extruder. The granule so obtained was evaluated for Tensile, Flexural, and Impact strength. The fractured surfaces of the blend were investigated by scanning electron microscope (SEM) providing information for the adhesion of starch/polypropylene.

1. EXPERIMENTAL

2.1 Materials:

Polypropylene (Homopolymer) powder (Melt Flow Index: 35 g/10 min. at 230°C/2.16 Kg load, Grade PP H350FG) was procured from M/s Reliance Industries. The native potato starch (M.W. 162.14) was procured from Loba Chemie, Mumbai. The glycerol was obtained from M/s Fisher Scientific (99.5% pure). The maleic anhydride grafted PP (PP-g-MA) grade Epolene G-3003, was procured from Eastman Chemical Products Co. USA.

2.2 Preparation of PP/Starch Blends:

The potato starch was dried to 1-2% moisture content using a laboratory oven at 70 ^{0}C for six hours and then stored in sealed plastic bags to avoid moisture. The dried starch after proper cooling was mixed with 25% glycerol. The stirring continued till the uniform suspension was obtained. The prepared suspension was left for overnight at ambient conditions of 30°C and 60% RH. After allowing swelling action for 24 hours suspension was rotated in high speed mixer at 3000 rpm for approximately 5 min. so that it gets converted into powder form by heat and shear. The thermoplastic starch powder (TPS) so obtained was mixed with polypropylene powder with the experimental formulation listed in Table No.1.

Both PP in powder form and Starch (TPS powder) were mixed homogeneously in high speed mixer for 2 min. and blends were prepared by melt blending with the help of co-rotating twin screw extruder. The temperature profile of twin screw extruder was 170°C to 190°C and melt temperature was 175°C, screw rpm kept at 275 and melt pressure was maintained around 25MPa during extrusion.

2.3 CHARACTERIZATION:

2.3.1 Fourier Transmission Infrared Spectroscopy:

Fourier Transmission Infrared Spectroscopy (FTIR) spectra of injection molded sample have been recorded by employing M/s Agilent Technologies model carry 630. The samples have been scanned in frequency region 4000 to 600 cm^{-1} with resolution 4 cm^{-1}.

2.3.2 Tensile Properties:

The tensile properties for the blends have been conducted using Instron universal testing machine model 3369 according to ASTM D 638. The specimen was prepared by injection molding and dimensions were according to ASTM standard. The crosshead speed of 50mm/min at 23°C was taken for testing of specimen. The specimen samples were conditioned at 23°C and 50% RH for 24 hours. Five specimens were used to obtain the average value of the tensile properties.

2.3.3 Flexural Properties:

The flexural properties for the blend have been conducted by using Instron universal testing machine model 3369 according to ASTM D 790. The specimen was prepared by injection molding and dimensions were according to ASTM standard. The crosshead speed was 5mm/min was taken for testing of specimen. The samples were conditioned at 23°C and 50% RH for 24 hours. Five samples were used to obtain the average value of the flexural properties.

2.3.4 Impact Strength:

The Izod Impact strength for blends have been conducted by using Ceast Spa impact tester model Resil Impactor according to ASTM D 256. The specimen was pre-conditioned at 23°C and 50% RH for 40 hours. The energy of the hammer was 2.75 J.

2.3.5 Melt Flow Index:

The Melt Flow Index for the blends have been conducted according to ASTM D 1238. The test conducted at 230°C at 2.16 kg load. Five tests were done to obtain the average value of the melt flow.

2.3.6 Morphology Test:

The scanning electron microscopy (SEM) Hitachi model S3700N, was used to evaluate the sample microstructure. The samples have been first dried in an oven to remove the moisture and then sputter coated with a thin layer of gold to avoid electrical charging.

2. RESULTS AND DISCUSSION:

SAMPLE	Polypropylene (Homopolymer Grade H350FG)	Starch (TPS)	PP-g-MA (Epolene G-3003)
PP	100 %	0 %	0 %
PPST-A	75 %	15 %	10 %
PPST-B	70 %	20 %	10 %
PPST-C	65 %	25 %	10 %
PPST-D	60 %	30 %	10 %

3.

4. **Table No.1**: Formulation of PP/Starch Blends

3.1 Fourier Transmission Infrared Spectroscopy(FTIR):

Figure No.1 depicts FTIR spectrum of PP and its blends with different compositions of starch. FTIR spectroscopy was employed to prove the compatibilization among PP-g-MA and starch during the melt blending process on polypropylene matrix. Several strong peaks were observed in 3100-3600 cm^{-1} (O-H stretching from starch), 1749 cm^{-1}(C=O stretching from starch), 1653 cm^{-1} (intramolecular hydrogen bonding), 1255 cm^{-1} (-O-C(O)- and C-OH stretching), 1151 cm^{-1} (C-O-C stretching), 1025 cm^{-1} (C-O stretch vibration), which are characteristic peaks of starch [11,15]. The peak observed near to 1740 cm-1 evidencing strongly that anhydride group is present in PP backbone[11]. The CH_3 bands at 2950 cm^{-1}, 2868 cm^{-1} and 1375 cm^{-1}, the CH_2 bands at 2917cm^{-1}, 2837cm^{-1} and 1457cm^{-1}, and three isotactic peaks at 1167cm^{-1}, 997cm^{-1} and 973cm^{-1} confirmed the presence of the polypropylene component in all the blends[16].

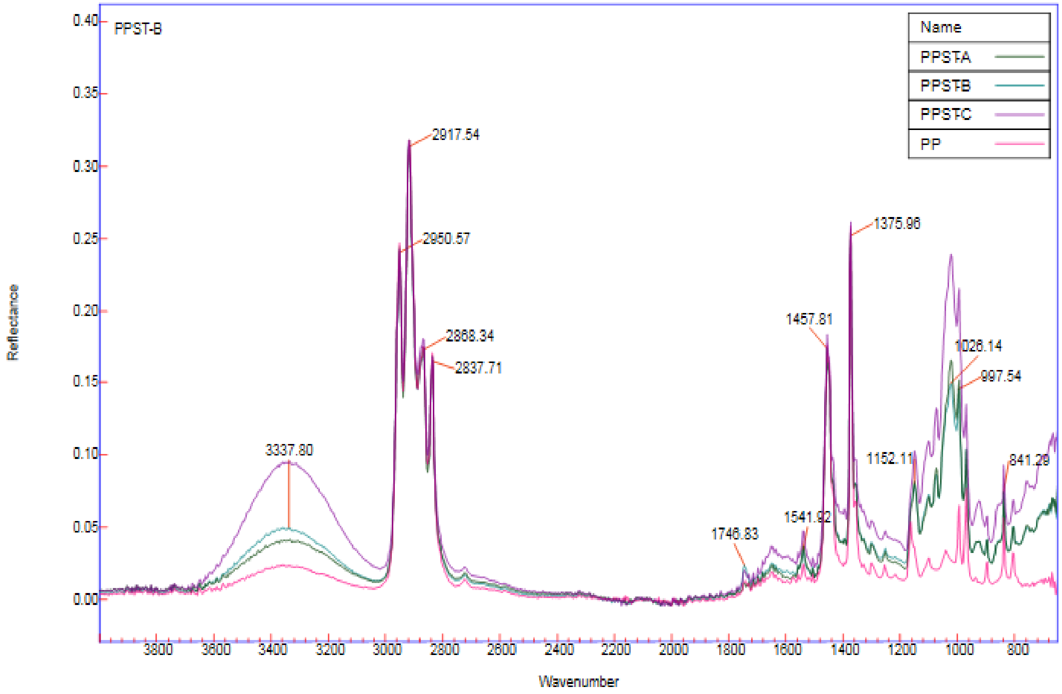


Figure No.1: FTIR Spectrum of Samples PP, PPST-A, PPST-B and PPST-C.

3.2 Mechanical Properties:

As the interfacial bonding is greatly improved because of the presence of PP-g-MA and plasticization of starch, a considerable enhancement in the mechanical properties of the PP matrix is expected, which could be verified by the test results. The addition of starch improved the tensile strength and impact strength remained almost same provides a scope of development. The flexural strength has increased by approximately 45% (Figure no. 2). The %age strain has decreased by 80%. Because % strain is related to the ductility of a material, the presence of PP-g-MA sharply increases the stiffness (flexural strength), thus decreases ductility of the blends.

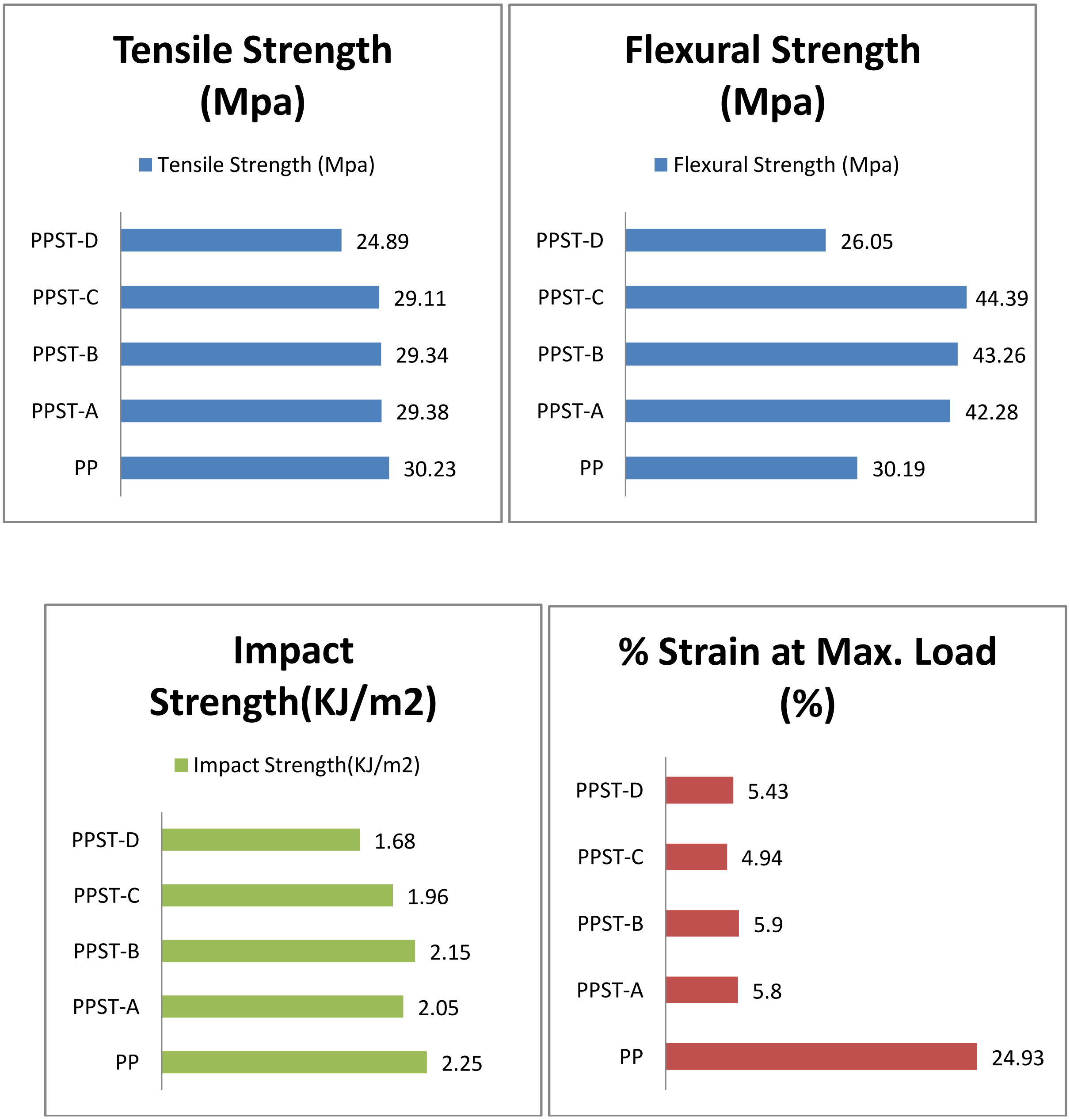


Figure no. 2: The tensile,flexural,impact and %strain of PP/Starch blend.

3.3 Melt Flow Index (MFI):

The melt flow index (MFI) is used as a means of measuring of uniformity of the flow rate of the thermoplastic material. It is the most accepted and widely used practical method to relate the molecular weight and viscosity of the polymer in industry. The MFI value of different compositions of PP and starch indicates the uniform distribution of starch in polypropylene matrix. The PPST-D composition having 30% loading of starch in polypropylene matrix have low value, which exhibits poor dispersion/compatbilization of starch in blend (Figure No. 3), and same has also been reflected by other tests.

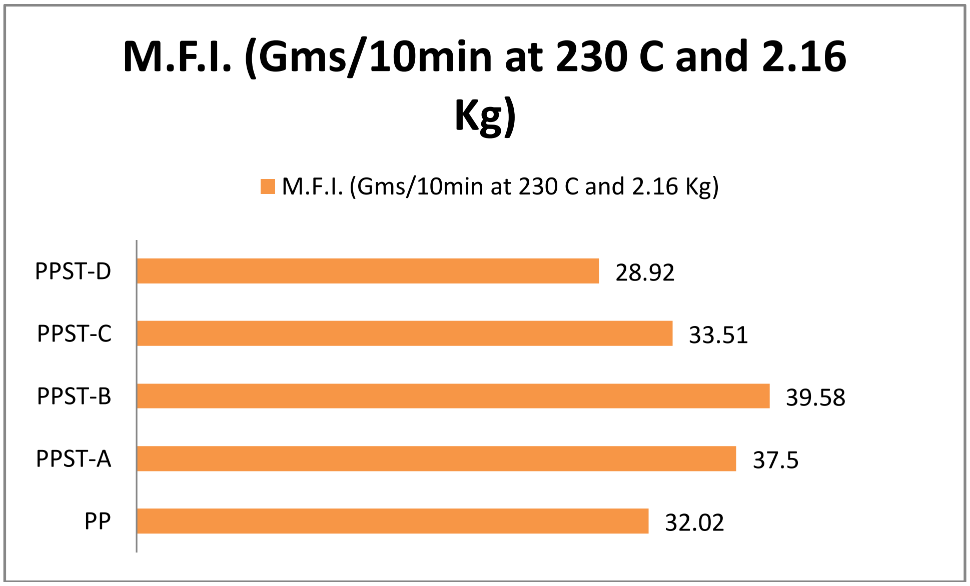
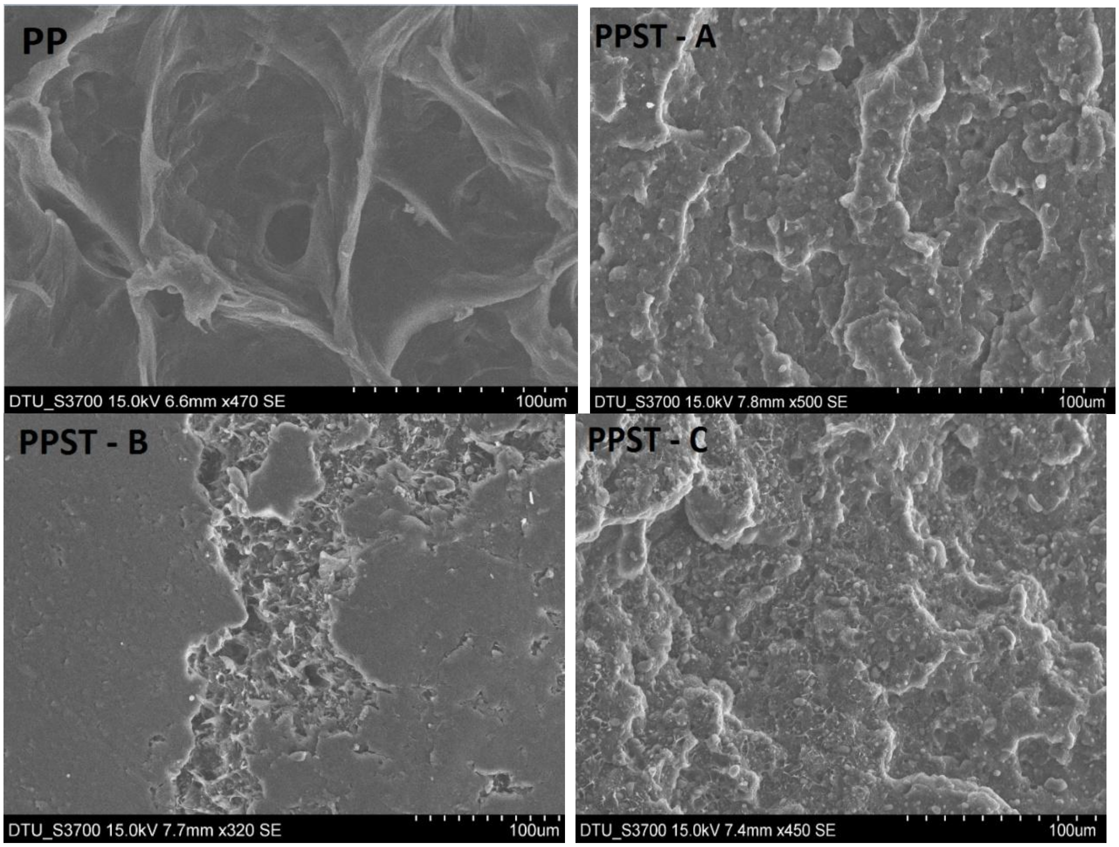


Figure No 3: Melt Flow Index of PP/Starch blends.

3.4 Morphology Analysis:

The SEM micrographs of PP/Starch blend of various compositions are presented in Figure No 4. These micrographs revealed that thermoplasticized starch granules are being continuously and uniformly mixed throughout the PP matrix and form a homogeneous phase. The SEM micrograph ensured that presence of polar group enhances adhesion between two phases (hydroxyl group of starch and polar group of PP). Therefore, the PP-g-MA played a vital role in reducing the interfacial energy and promoting the interfacial adhesion between the potato starch and PP matrix.



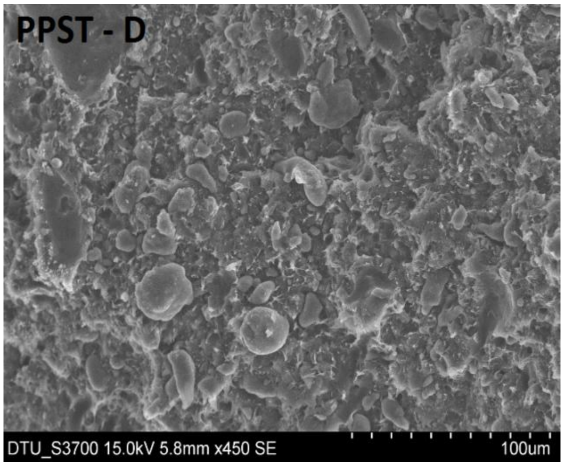


Figure No.4: SEM images of the fracture surfaces of PP/Starch blends at magnification with a scale of 100 um.

Conclusion:

PP/Starch blending using PP-g-MA as the coupling agent has significantly improved mechanical properties and improved the adhesions between starch and polypropylene matrix. The adhesion of 25% starch in PP, increased the flexural strength by 45%, while tensile strength and impact strength remain same is a significant discovery. The FTIR,SEM and Melt flow Index of the blends also indicated improvement in interfacial adhesion between starch and polymer. This discovery may prove a milestone towards developing bio-based polymeric materials in future.

Reference:

1. Karger-Kocsis, J.; Polypropylene as AZ reference; Chapman & Hall; London 1999.
2. Harding,K.G.; Dennis J.S.; Von Blotnitz, H.; Harrison, S.T.I., Environmental analysis of plastic production processes: Comparing petroleum-based polypropylene and polyethylene with biologically-based poly-B-hydroxybutric acid using life cycle analysis. J. Biotechnol. 2007,13,57
3. Huang J.C., Shetty A.S., and Wang S.W.; Biodegradable Plastics: A review Adv. Polym. Tech., 1990,10, 23-30
4. Dbi Y. and Fukuda K.; Biodegradable Plastics and Polymers. Elsevier Science B.V., 1994, 601-608.
5. Potts J.E.; Environmentally Degradable Plastics. In: Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Supp. Vol, John-Wiley, New York, 1981, 638-668
6. Mohanty, A.K.; Misra, M.; Drzal,L.T.; Sustainable bicomposites from renewable resources: Opportunities and challenges in the green material world. J. Polym Environ. 2002,10,19
7. Gupta,A.P.; and Verma, D.K.; Carboxymethyl guar gum- silver nanocomposite: green synthesis, characterization and an optical sensor for ammonia detection, Advance in natural sciences: nanoscience and nanotechnology, IOP,Publishing,Vietnam Academy of science and technology, 2014,5,035018 (8pp).
8. Griffin G.J.L.; Starch polymer blends, Polym. Degrad. Stab. 1994,45,241
9. Sathya Kalambur and Syed S.H. Rizvi “Overview of starch based plastic blends” Journal of Plastics Flims and Sheeting 2006, 22, 1, 39-58.
10. Ramis X; Cadenato, A.; Safla, J.M.; Morancho, J.M.; Valles, A.;CONTAT,l.; Ribes,A. Thermal deradationn of polypropylene/Starch-baseed materials with enhanced biodegradability. Polym. Degad. Stab. 2004,86,483
11. Gupta A.P.; Vijay K., Sharma M., Formulation and Characterization of Biodegradable Packaging Film Derived from Potato Starch & LDPE Grafted with Maleic Anhydride-LDPE composition. J. Polym. Environ, 2010,18,484-491
12. Willet J.L.; Mechanical Properties of LDPE/granular starch composite. J. Appl. Polym. Sci., 1994,54,1485-1495
13. Kim M.; Evaluation of Degradability of Hydroxyl propylated potato starch/polyethylene blend films. Carbo. Polym.,2003,54,173-181.
14. Lim S.T., and Jane J.L.,; Effect of Starch Granule size on Physical Properties of Starch filled polyethylene film. Biotech. 1992,8,51-57.
15. Wang, S.J.,Yu, J.G., Yu, J.L.,; Preparation and Characterization of compatible thermoplastic starch/polyethylene blend. Polym. Degrad. Stab. 2005,87,395
16. Devasahayam, S., Sahajwalla, V., and Sng M.,; Investigation into Failure in Mining Wire Ropes- Effect of Crystallinity. J of Org. Polym. Materials. 2013,3,34-40