J. Myanmar Acad. Arts Sci. 2021 **Vol. XIX. No.1B**

PREPARATION OF BIOPLASTICS FROM POTATO STARCH

Khin Mar Cho[1], Lae Lae Myo[2], Aung Than Htwe[3]

Abstract

This research concerns with preparation of bioplastics from starch (S*olanum tuberosum* L.). The aim of this work is to prepare biodegradable plastics from potato starch and to study the swelling and water uptake properties, physicomehanical properties, antimicrobial activity and biodegradability of the prepared bioplastics. The potato samples were purchased from Maydawee Market in North Okkalapa Township, Yangon Region, Myanmar. Starch was extracted from potato by cold extraction method. The extracted potato starch was characterized by FT IR technique. FT IR spectrum of extracted potato starch was compared with that of commercial starch. Bioplastic films SG-a, SG-b, SG-c, SGV-a, SGV-b and SGV-c were prepared from extracted potato starch using plasticizer as glycerol (4 %, 6 % and 10 %) with and without vinegar. All bioplastic films are clear and flexible. The degree of swelling and water uptake of prepared bioplastic films were determined. The physicomechanical properties (thickness, tensile strength, percent elongation at break and tear strength) of prepared bioplastic films were measured. The morphology of prepared bioplastic films was studied by SEM technique. In addition, the antimicrobial activities of all sample films were tested by agar well diffusion method against six microorganisms. Moreover, the biodegradability of prepared bioplastic films was evaluated by soil burial method. The prepared bioplastic samples were applied for food packaging.

Keywords: potato, bioplastics, physicomechanical properties, starch, plasticizers

Introduction

The major disadvantages of petro-based plastics are non-biodegradable and result in environmental pollution. The petrochemical plastics have been largely used as packaging material due to economical abundance and their desirable properties of good barrier properties towards O_2, aroma compounds, tensile strength and tear strength (Jabeen, *et al*., 2015). Bioplastics of renewable origin are compostable or degradable by the enzymatic action of micro-organisms. There has been an increased interest in the last few years from the food packaging industry towards the development and application of bioplastics for food packaging. The bioplastics nowadays have found applications for both short-shelf life products like fresh fruits and vegetables and long-shelf life products. Two major advantages to bio-based plastic products: they save fossil resources by using biomass and provide the keenly sought-after possibility of carbon neutrality (Özdamara and Ateşb, 2018). Food packaging as a vital part of the subject of food technology is involved with protection and preservation of all types of foods (Jabeen *et al*., 2015). Bioplastic development efforts have focused predominantly upon starch, which is a renewable and widely available raw material. Starch as biodegradable polymer becomes reasonable material for the production of bioplastics because of its low cost (Maulida *et al*., 2016). Edible film made from starch is less elastic and is hydrophilic, and to cope with this, another additional material needs to be added to improve its mechanical characteristic. The addition of glycerol as the plasticizer, is intended to improve its elasticity and to weaken the stiffness of the polymer, and to improve the flexibility of the polymers. Glycerol has the ability to decrease the internal hydrogen bond in the intermolecular bond (Asria, 2016). This paper illustrates the preparation of edible bioplastic film made from potato starch with glycerol as its plasticizer for food packaging purpose.

[1] Dr, Associate Professor, Department of Chemistry, University of Yangon
[2.] MSc Candidate, Department of Chemistry, University of Yangon
[3.] Dr, Assistant Lecturer, Department of Chemistry, University of Yangon

Materials and Methods

Extraction and Characterization of Potato Starch

Firstly, the potato (500 g) was washed with tap water, cleaned and dried. Samples were peeled and then, grated using a grater. The grated potatoes were mixed with distilled water and sieved with metal strainer. It was transferred to a beaker and filtered. The residue was washed with distilled water two times and dried at room temperature for 24 h. The dried insoluble starch was crushed into powder by mortar and pestle. Finally, the potato starch powder was obtained and calculated the yield percent. The extracted starch powder was characterized by FT IR technique.

Preparation of Bioplastic Films from Potato Starch Powder

The three bioplastic films with 5 mL of vinegar (SGV-a, SGV-b and SGV-c) were prepared by thoroughly mixing 10 g each of potato starch powder with 2 mL, 3 mL and 5 mL of glycerol and 50 mL each of distilled water in separate 250 mL beakers. The starch solution was placed on a hot plate set at 70 ºC and was continued to stir until the mixture became thick and almost transparent. The solution was poured onto a melamine plate and allowed to dry at room temperature for three days. Similarly, another three bioplastic films samples (SG-a, SG-b and SG-c) were prepared without vinegar. The ratios of starch: glycerol: water were (10:2:50, 10:3:50 and 10:5:50 w/v) in each three bioplastic samples (Arıkan and Bilgen, 2019).

Determination of Chemical and Physicomechanical Properties

The chemical properties (degree of swelling and water uptake) and the physicomechanical properties (thickness, tensile strength, percent elongation at break and tear strength) of prepared bioplastic films were determined.

Determination of Morphology, Antimicrobial activity and Biodegradability

The surface morphology of the bioplastic films was investigated by SEM. The study of antimicrobial activity was performed by agar-well diffusion method. The inhibition zone (clean zone) appeared around the agar-well indicating the presence of antimicrobial activity. The extent of antimicrobial activity was measured from the zone of inhibition diameter. To investigate the biodegradability of the prepared bioplastic samples, the prepared samples (equal dimensions) were buried under a soil tray (2' × 2' × 2') at a depth of 1 ft. The the films were taken out from the soil at 24 h interval and degradation were monitored and recorded in physical features by photograph.

Results and Discussion

Extraction of Starch Powder from Potatoes

The potato starch was extracted from potato (S*olanum tuberosum* L.) by cold extraction method and the percent yield of extracted potato starch powder was calculated to be 6.1296 %. The potato and extracted potato starch powder are shown in Figure 1.

(a) (b)

Figure 1 (a) Potatoes (b) The extracted potato starch powder

Characterization of Extracted Potato Starch by FT IR Analysis

Potato starch powder was characterized by FT IR technique to identify the corresponding functional group compared with that of commercial potato starch (Figure 2 and Table 1). The peaks at 3263 cm^{-1} and 2929 cm^{-1} of extracted starch are due to stretching vibration of -OH and -CH groups. The absorption band at 1643 cm^{-1} is related to C-O bending associated with -OH groups of starch. Moreover, the absorption band at 1157 cm^{-1} and 1016 cm^{-1} are attributed to C-O-C asymmetric stretching vibration and C-O stretching vibration of saccharides molecules present in starch, respectively. The characteristic C-O-C ring vibration of starch appeared at 929 and 856 cm^{-1}. It was found that FT IR spectrum of extracted potato starch is matched with that of commercial starch.

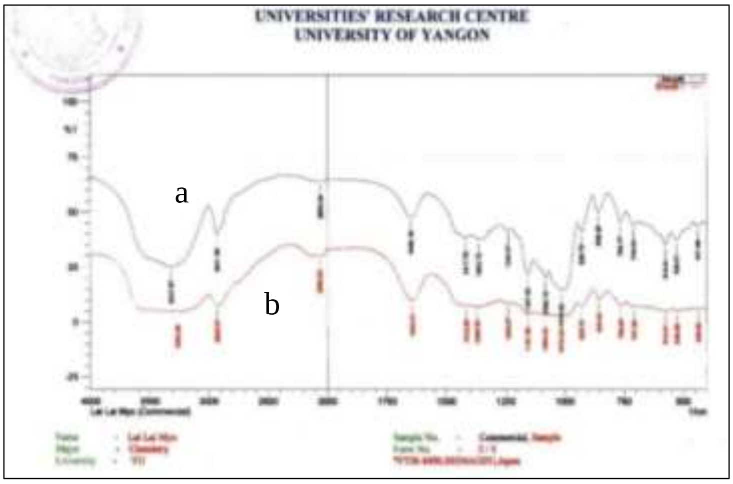


Figure 2 FT IR spectra of the (a) extracted potato starch and (b) commercial potato starch

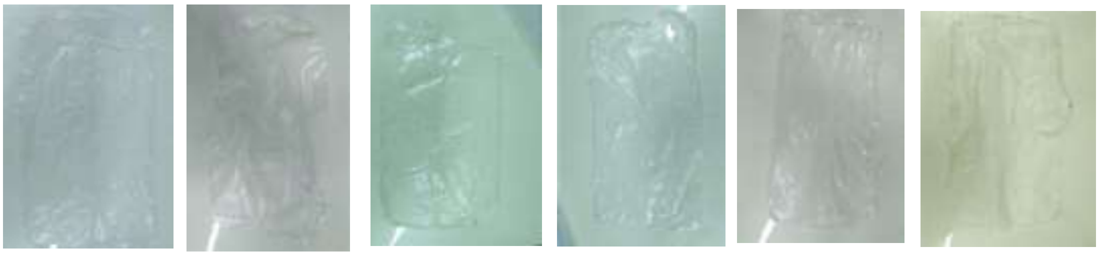
Table 1 FT IR spectral Data of Extracted and Commercial Potato Starch

No	Wavenumber (cm^{-1})			Interpretation
	Extracted Starch	Commercial Starch	Reported Value *	
1	3263	3317	3600-3300	ν_{OH} groups
2	2929	2931	2931	$\nu_{as\ CH}$ groups
3	1643	1649	1637	C-O bending associated with OH group
4	1157	1157	1149	C-O-C asymmetric stretching
5	1016	1016	1200-800	C-O stretching
6	929,856	929,858	920,856,758	C-O-C ring vibration of carbohydrate

(*Abdullah *et al.*, 2018)

Bioplastic Films from Potato Starch Powder

All prepared bioplastic films were clear, transparent and flexible. The prepared bioplastics samples are shown in Figure 3.



SG-a SG-b SG-c SGV-a SGV-b SGV-c

Figure 3 The prepared bioplastic films

Degree of Swelling and Water Uptake

Degree of swelling and water uptake are important properties of membrane. Table 2 shows the percent degree of swelling of bioplastic films with respect to the time-frame presented in minutes. The degree of swelling of all of prepared bioplastic samples decreased with increase in glycerol composition and increased with time. Bioplastic films prepared with vinegar showed higher swelling power than those without vinegar. It was observed that SG-c has lowest swelling power among all samples. The percent water uptake of bioplastic films with respect to the time frame presented in minutes is also shown in Table 2. It was found that, in general, water uptake percent decreased with increase in glycerol concentration in the bioplastic films without and with vinegar. Generally, the bioplastic films prepared with vinegar, SGV-a, SGV-b and SGV-c showed higher water uptake than those without vinegar except SG-a.

Table 2 Variation in Degree of Swelling and Water Uptake of Prepared Bioplastic Films

Samples	5 min		10 min		15 min		20 min		25 min	
	swelling (%)	water uptake (%)	swelling (%)	water uptake (%)	swelling (%)	Water uptake (%)	swelling (%)	Water uptake (%)	swelling (%)	Water uptake (%)
SG-a	22.72	29.40	28.26	39.40	31.03	45.00	32.61	48.40	32.61	48.40
SG-b	23.67	31.00	21.40	27.20	25.05	33.40	17.36	21.00	19.21	23.80
SG-c	10.55	11.80	15.11	17.80	12.58	14.40	11.03	12.40	10.70	12.00
SGV-a	25.70	34.60	27.50	38.00	27.20	37.40	26.70	36.60	27.50	37.20
SGV-b	25.37	34.00	27.22	34.40	29.07	41.00	25.60	34.40	27.11	37.20
SGV-c	33.24	49.80	22.96	29.80	21.75	27.80	19.35	24.00	19.35	24.00

Physicomechanical Properties of Prepared Bioplastic Films

The physicomechanical properties of the prepared bioplastic films were determined at the Myanmar Scientific and Technological Research Department. Tansometer (Monsanto T0212) was used to determine for the tensile strength and elongation at break of the prepared bioplastic films. Although SGV-a and SGV-b films have same thickness, the tensile strength of SGV-a film was higher than that of SGV-b film. It was found that bioplastic film SG-c has lowest in tensile strength among the bioplastic films prepared without vinegar. Similarly, bioplastic film SGV-c has the lowest in tensile strength among the bioplastic films prepared with vinegar. Although having lower elongation at break the bioplastic films SG-a and SVG-a have higher tensile and tear strengths (Table 3).

Table 3 Physicomechnical Properties of Prepared Potato Bioplastic Films

Sample	Thickness (mm)	Tensile Strength (MPa)	Elongation at break (%)	Tear Strength (kN/m)
SG-a	0.91	2.2	17	31.9
SG-b	0.61	2.1	40	15.0
SG-c	0.31	0.7	35	4.70
SGV-a	0.52	3.3	15	34.2
SGV-b	0.52	2.8	45	19.6
SGV-c	0.75	0.9	28	3.90

Morphology of Prepared Bioplastic Films by SEM Analysis

SEM is a type of electron microscope that produces the image of a sample by scanning it with a focused beam of electrons. In this present work, morphological features of the prepared bioplastic (SG-a, SG-b, SG-c) without vinegar and (SGV-a, SGV-b and SGV-c) films with vinegar were examined by SEM. The surface structures of the materials had lost their evenness (Figure 4). The samples exhibited a substantial variation in the structure as reported by Marichelvam *et al*. (2019).

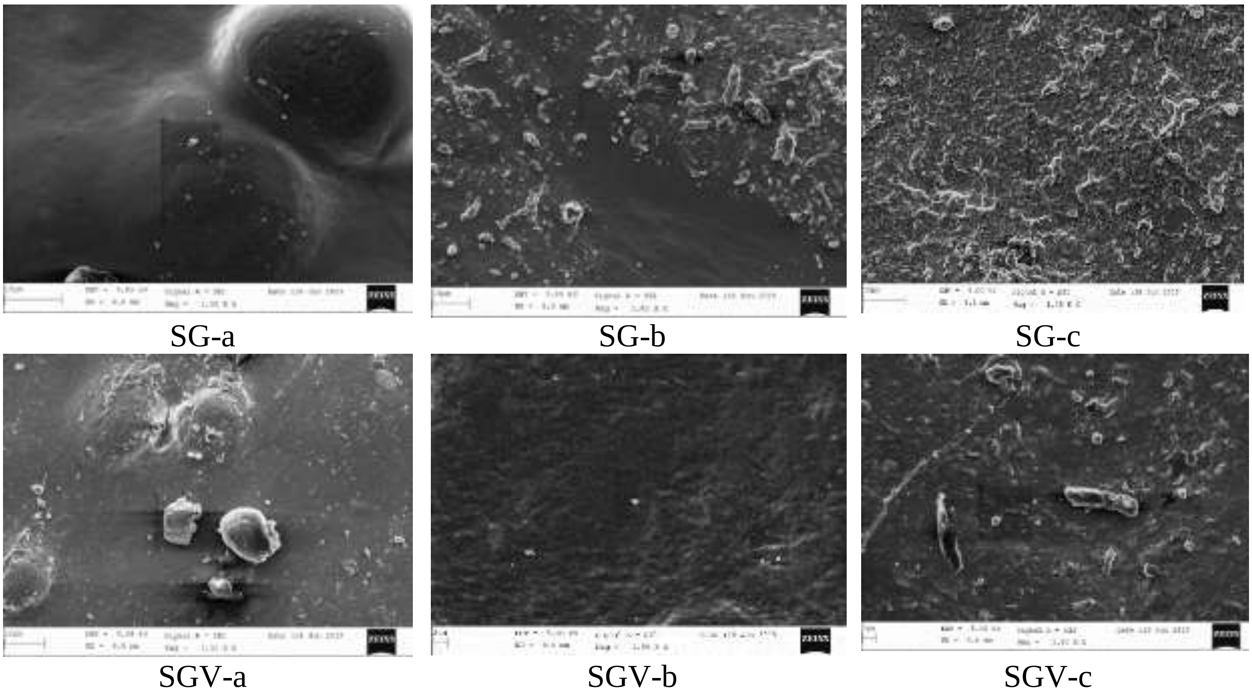


Figure 4 SEM images of prepared bioplastic films

Antimicrobial Activity of Prepared Bioplastic Films

Antimicrobial activities of all bioplastic films were examined against six microorganisms: *Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus pumilus, Candida albicans* and *Escherichia coli* by agar well diffusion method (Figure 5 and Table 5). All samples (SG-a, SG-b, SG-c, SGV-a, SGV-b and SGV-c) showed antimicrobial activities on *B. pumilus*. SG-a and SG-c showed antimicrobial activity on three microorganisms (*S. aureus, B. pumilus* and *E. coli*.) whereas the other samples did not. Only the SGV-a inhibited three microorganisms (*P. aeruginosa, B. pumilus* and *C. albicans*). SGV-b and SGV-c inhibited two bacteria (*B. pumilus* and *E. coli*).

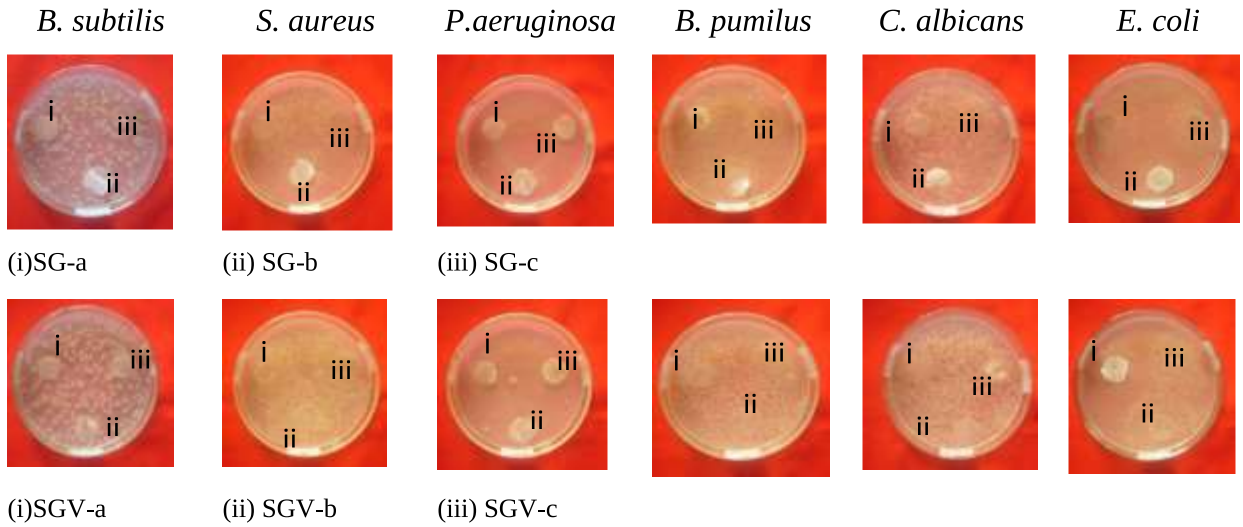


Figure 5 Zone inhibitions of the biodegradable plastic films against six microorganisms

Table 5 Antimicrobial Activities of Bioplastic Films against Six Microorganisms

Sample	*B.subtilis*	*S.aureus*	*P.aeruginosa*	*B.pumilus*	*C.albicans*	*E.coli*
SG-a	–	+	–	+	–	+
SG-b	–	–	–	+	–	–
SG-c	–	+	–	+	–	+
SGV-a	–	–	+	+	+	–
SGV-b	–	–	–	+	–	+
SGV-c	–	–	–	+	–	+

Acceptance criteria (+) inhibited, (-) un-inhibited
Susceptible ≥ 21 mm (+++) Intermediate 17.20 mm (++) Resistant ≤ 16 mm (+)

Biodegradability of Prepared Bioplastic Films

One of the objectives of developed bioplastic film is to make easy throw away materials from degradable plastic to alternative waste disposal problems by means of environmental degradation. Biodegradation is degradation caused by living organisms such as fungi and bacteria (Folino *et al.*, 2020).

In this work, biodegradation of all sample films was tested by soil burial method. Environmental effects mentioned in this work are moisture and soil which may be favourable conditions for the microbial growth. Soil burial is a traditional way to test samples for degradation because of its actual condition of waste disposal. Uniformly sized samples were buried in the soil from waste disposal. The physical appearance of films before and after in the soil buried are shown in Figure 6. The figure clearly showed significant deforming of films at each investigation period. The biodegradation of all sample films was found to be degraded after 5 days. Samples SG-a, SVG- and SGV-b were highly degraded within 5 days according to physical appearances.

Samples	**Before test**	**After test**				
	0 day	**1 day**	**2 days**	**3 days**	**4 days**	**5days**
SG-a						
SG-b						
SG-c						
SGV-a						
SGV-b						
SGV-c						

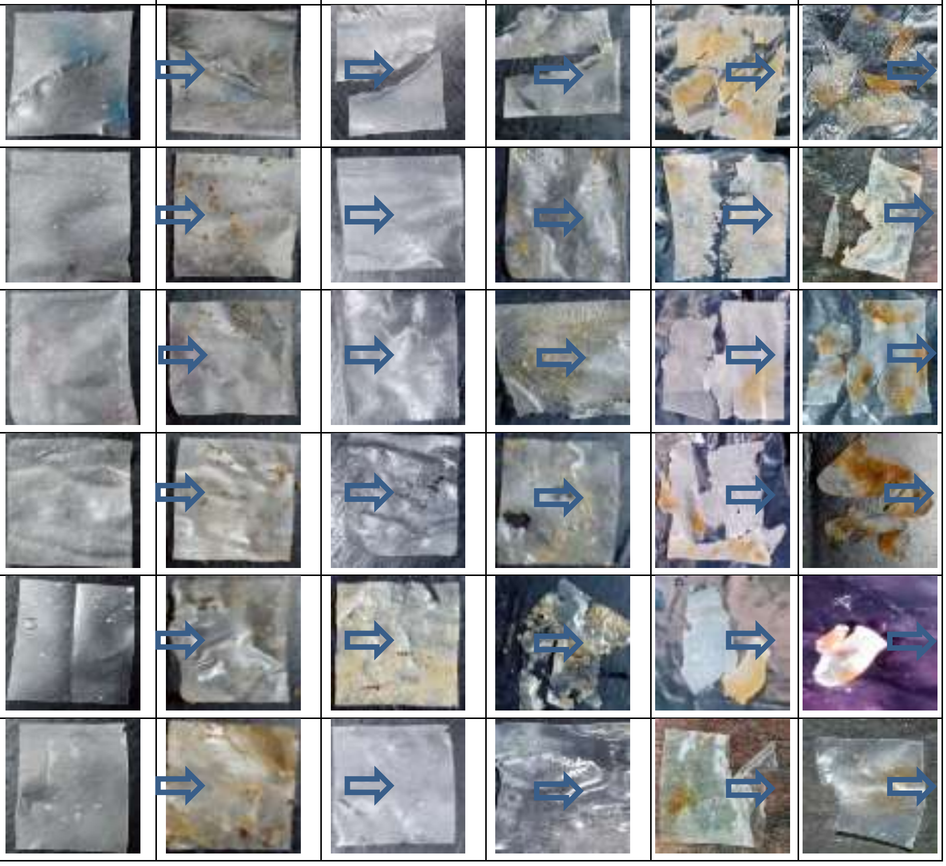


Figure 6 Physical appearance of bioplastic films by soil burial test

Application of Bioplastic Films

In this research, the prepared bioplastics do not contain any chemicals, toxins and thus are safe. So, it can be applied for food packaging. According to water uptake and mechanical properties, both of the bioplastic films SG-a and SGV-a have good water retainability, high tensile and tear strengths and it can be applied for packaging of tea leaves and coffee mix. The bioplastic bags were made by packing tea leaves and coffee mix in the bioplastic film SGV-a and closed the edges by heating. Boiling water was added into a glass which contained tea leaves bioplastic bag and allowed to infuse for 3 minutes. Yellowish brown coloured tea was obtained.The applications of prepared bioplastics are shown in Figure 7.

(a) (b) (c)

Figure 7 Application of bioplastic film SVG-a in food packaging (a) tea leaves in prepared bioplastic bag (b) coffee mix in prepared bioplastic bag and (c) tea leaves bag in hot water

Conclusion

Potato starch is a feasible component in the preparation of bioplastic films and glycerol is a plasticizer that is compatible with starch. Percent yields of extracted potato starch was found to be 6.1296 % based on wet sample. All prepared bioplastic film samples are clear and flexible. Functional groups shown in FT IR spectrum of the extracted potato starch were matched with those of commercial starch. SEM images showed all samples had rough surface and lost their evenness. The antimicrobial activities of all bioplastic films were investigated by agar well diffusion method using six microorganisms. All bioplastic films showed the antimicrobial activity on *Bacillus pumilus*. It was found that higher levels of glycerol decreased both tensile strength and tear strength. Variable elongation at break for plastic films with and without vinegar may be due to unequal thickness. In soil burial method, biodegradation of all sample films was degraded after 5 days. From the study of water uptake, antimicrobial activity and mechanical properties, both of the bioplastic films SG-a and SGV-a have good water retainability, can resist on *Bacillus pumilus*, high tensile and tear strengths so that they can be applied for food packaging. It is clear that bio-based packaging materials offer a versatile potential in case of packaging industry, however, there is need of certain storage tests to be performed on packaging machinery in order to certify the use of these packaging films on a commercial scale. A critical evaluation is required to access the functionality of bio-based packaging materials before they are launched into the market as sole substitutes for conventional packaging materials.

Acknowledgement

The authors would like to mention their sincere thanks to Dr Ni Ni Than, Professor of Head of Department of Chemistry from University of Yangon for providing research facilities and Myanmar Academy of Arts and Science Association for submission of this research paper.

References

Abdullah, A. H. D., Chalimah, S., Primadona, I. and Hanatyo, M. H. G. (2018). "Physical and Chemical Properties of Corn, Cassava, and Potato Starchs". *IOP Conference Series Earth and Environmental Science,* vol.160 (1), pp. 1755-1315

Arıkan, E. B. and Bilgen, H. D. (2019). "Production of Bioplastic from Potato Peel Waste and Investigation of Its Biodegradability". *International Advanced Researches and Engineering Journal,* vol. 3(2), pp. 093-097

Asria, M. (2016). "Preparation and Characterization of Edible Film from The Belitung Taro Starch (*Xanthosoma sagitifolium*) and Chitosan". *Journal of Chemical and Pharmaceutical Research,* vol. 8(6), pp. 57-62

Folino, A., Karageorgiou, A., Calabrò, P. S. and Komilis. D. (2020). "Biodegradation of Wasted Bioplastics in Natural and Industrial Environments: A Review". *Sustainability,* vol. 12 (15), pp. 1-37

Jabeen, N., Majid, I. and Nayik, G.A. (2015). "Bioplastics and Food Packaging: A Review", *Cogent Food & Agriculture*, vol. 1, pp. 1-7

Marichelvam M. K., Jawaid, M. and Asin, M. (2019). "Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials". *Fibers*, vol. (7), 32, pp. 1-14

Maulida, Siagian,M. and Tarigan, P. (2016). "Production of Starch-based Bioplastic from Cassava Peel Reinforced with Microcrystalline Cellulose Avicel PH101 Using Sorbitol as Plasticizer". *Journal of Physics Conference Series,* vol. 710 (1), pp. 1-7

Özdamara, E. G. and Ateşb, M. (2018). "A Research on Starch Based Bioplastic". *J Sustain. Construct. Mater. Technol.,* vol. 3(3), pp. 249-260