BIODEGRADABLE CORNSTARCH-BASED FILMS: PRODUCTION, CHARACTERIZATION, AND APPLICATION IN AGRICULTURAL MULCHING

H. Alejandro Anzorena[1,2], M C. Giaroli[1,2], Olivia V. López[3,4], Dachamir Hotza[5] & Mario D. Ninago[1,2]

[1] *Instituto de Ingeniería y Ciencias Aplicadas a la Industria, San Rafael, Mendoza, Argentina.*
[2] *Universidad Nacional de Cuyo, Facultad de Ciencias Aplicadas a la Industria, San Rafael, Mendoza, Argentina.*
[3] *Planta Piloto de Ingenieria Quimica, Bahia Blanca, Argentina.*
[4] *Departamento de Quimica, Universidad Nacional del Sur, Bahia Blanca, Argentina.*
[5] *Departamento de Engenharia Química e Engenharia de Alimentos, Universidade Federal de Santa Catarina, Florianopolis, Santa Catarina, Brasil.*

**ahanzorena@fcai.uncu.edu.ar*

ABSTRACT

The use of biodegradable films produced from biopolymers such as starch is being widely studied, taking advantage of their low cost and high availability. In the present work, films were obtained from 3% w/v cornstarch suspensions, which were gelatinized using a 1% w/v sodium hydroxide solution. Once gelatinized, 30% w/w glycerol (based on starch) was added, then poured onto 9 cm diameter Petri dishes and dried in an oven at 45°C until constant weight. Films were conditioned at 65 % relative humidity (RH) until their characterization. Simultaneously, spraying capacity of suspensions was tested by employing a manual pulverizing backpack with a plane nozzle. In order to evaluate their performance as soil protective coatings, UV and visible radiation barrier properties were determined spectrophotometry and mechanical properties by puncture tests was also evaluated. Films demonstrated a high barrier capacity, blocking up to 65 % of radiation in the entire UV and visible range. On the other hand, the maximum puncture force was similar to values reported in the literature for starch-based and commercial polyethylene films used as agricultural mulches. Finally, it was demonstrated that proposed formulations can be sprayed and applied *in situ* on land used for vegetable cultivation.

Keywords: Cornstarch suspensions. Alkaline gelatinization. Protective coatings. Biodegradability. Spraying technique.

1 INTRODUCTION

Protective soil coatings for cultivating fruits and vegetables have become a common practice used by farmers to regulate soil temperature, minimize moisture loss, reduce weed growth, increase crop yields, and prevent fruits from coming in contact with soil[1]. Low-density polyethylene (LDPE) is one of the current materials used as plastic cover due to its low cost, easy processing, high durability, and flexibility. However, the use of this non-biodegradable polymer has caused serious environmental pollution problems[2] due to this type of plastic is never completely removed, leaving residues that can remain in the soil for long periods of time, potentially affecting soil properties and even entering the nutritional chain in the form of microplastics[3].

In order to face this global concern, the use of biodegrable polymers obtained from renewable sources is an ecological and sustainable alternative to LDPE since these materials can be incorporated into the soil and be degraded by microorganisms. Among the biopolymers that could be suitable for these applications, starch is the most used for the fabrication of biodegradable films due to its wide availability and low cost, making it a potential substitute for LDPE films. Furthermore, starch is capable of forming films *in situ* and can be processed using methods commonly employed to produce synthetic polymer films[4].

In recent years, besides producing biodegradable materials based on biopolymers, there has been an increasing trend towards developing biodegradable coatings that can be applied by spraying, aiming to replace the traditional method of placing prefabricated films on the soil[5]. This technique allows the film to form directly on the soil, thus eliminating the need to transport and place films or the use of machinery, therefore reducing application costs. Additionally, the pulverization technique is widely used for dosages of pesticides and nutrients on crops; however, its use for production of films based on biopolymers is still under early stages of development, especially for starch. It has been reported the successful pulverization and spraying of some biopolymers for film fabrication such as gum arabic and sodium alginate, which motivates the development of biodegradable coating based on starch, taking advantage of its low cost, abundance, and inherent ability to degrade under natural conditions[6].

The objective of this work was to obtain flexible cornstarch film through alkaline gelatinization, which can be applied by the spraying technique, as well as to characterize the obtained materials by determining their radiometric properties and mechanical resistance.

2 MATERIAL & METHODS

Cornstarch (Egran, Argentina) was employed as polymeric matrix, sodium hydroxide (Biopack, Argentina) was used as alkaline agent for starch gelatinization, and glycerol (Casanova, Argentina) was used as plasticizer.

Starch gelatinization was carried out by using a 0.25M NaOH to which starch powder was added up to 3 % w/v. Once starch was gelatinized glycerol 30 % w/w (dry starch basis) was added. Granules structure and gelatinization process were observed by optical microscopy in a digital microscopy (Biotraza, China) using a 40x amplification. In order to obtain the films, 50 g of this gelatinized suspension was poured into a 9 cm petri dish and dried in an over at 45 °C for 24 h to evaporate water. Films were peeled off from molds and stored in a humidifier at 65 % relative humidity until characterization. Parallel to film preparation, pulverization capacity of gelatinized suspensions was tested using a manual backpack (GiberSH12, Argentina) equipped with a plane nozzle.

Previous to optical and mechanical characterization of films, thickness was determined at 10 random locations by using a digital thickness meter (CM-8822, Brazil) and from these data mean and standard deviation were calculated.

To evaluate barrier capacity in UV and visible range, transmittance spectra of films were recorded from 200 to 700 nm. Rectangular pieces of films (10 x 30 mm), were placed into a quartz cuvette and placed into a spectrophotometer (DR600-Hach, USA). From these spectra two indexes were calculated: UV barrier index, which refers to the material capacity to block or reduce the passing of radiation through it in the range between 300 to 380 nm; and *PAR* index, which spans the radiation from 400 to 700 nm, the photosynthetic active radiation involved in the process related to plants photosynthesis. Both indexes were calculated in accordance to the procedure reported by norms ISO 9050:2012(E).

Mechanical performance of cornstarch films was evaluated by puncture test, which were carried out in texturometer *TA-X2i* (Stable Micro Systems, England). Tests were performed using a cylindrical probe of 2 mm diameter, at a constant speed of 1 mm/s, on square pieces of 20 mm side, following the methodology reported by Garcia et al. (2004)[7]. From the strength versus distance curves, the maximum breaking force (N) was recorded.

3 RESULTS & DISCUSSION

Commonly starch gelatinization is achieved by heating of suspensions containing this biopolymer in excess water. However, cold or alkaline gelatinization is an alternative method which results in a simpler and more efficient way to gelatinize starch since it requires shorter times and there is no need to heat the suspensions[8]. As expected, the addition of starch to the sodium hydroxide solution produced an immediate gelatinization of starch, which was evidenced by the reduction of the characteristic cloudiness of the starch suspensions (Figure 1).

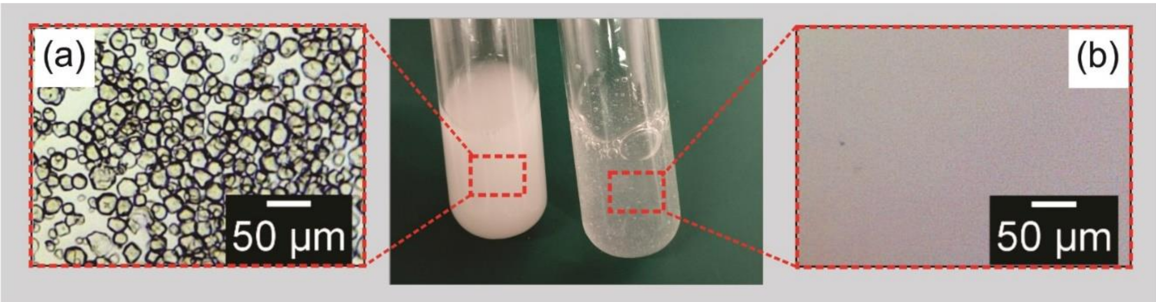

Figure 1 Starch aquous suspensions (a) and alkaline gelatinized starch suspension (b).

Gelatinized suspensions were pulverized and sprayed satisfactorily using a manual sprayer. Despite suspensions had a higher viscosity when compared to water, it was not necessary to carry out a previous dilution to form uniform coatings onto Petri dishes (Figure 2).

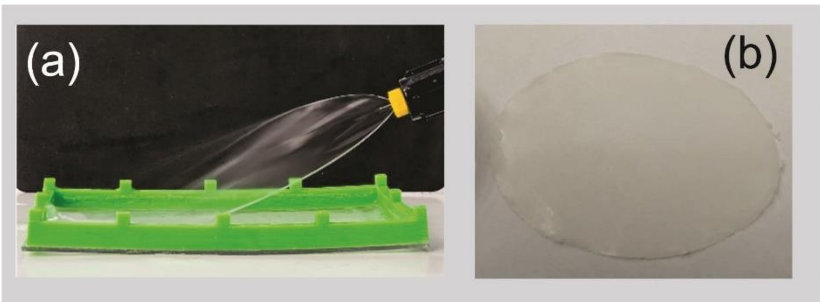

Figure 2 Spraying of corn starch gelatinized suspensions using a manual pulverizing backpack (a) and cornstarch film obtained by casting and dehydration (b).

Films obtained by casting and dehydration of starch suspensions were flexible and easy to handle with a thickness of 225.21 ± 20.99 µm. In this regard, the alkaline medium used to achieve gelatinization proved to be suitable, resulting in intact and flexible films with an opaque appearance. Figure 3 shows the UV-visible spectra of the obtained films. They exhibited a high barrier capacity across the entire analyzed range, preventing the passage of radiation. Regarding the calculated radiometric properties, the PAR index showed a value of 0.29 ± 0.01, indicating that only 29 % of the photosynthetically active radiation (400 to 700 nm) can pass through the film. On the other hand, in the UV range, the value obtained was 85.09 ± 0.27 % that means that approximately 15 % of the radiation (300 to 380 nm) was able to pass through the film.

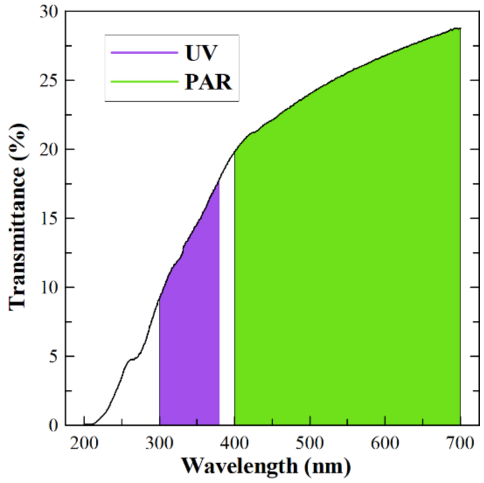

Figure 2 Transmittance spectra for cornstarch films.

The stability and resistance of materials used as protective soil coatings are determined through tests that evaluate their mechanical properties. For agricultural applications, it is essential that these materials maintain their integrity under certain external stresses and/or environmental factors[5]. Cornstarch films analyzed by punctured test showed resistance to penetration compared to synthetic materials like HDPE films used as agricultural mulches. The maximum breaking force was 8.69 ± 1.03 N, while values reported in literature for sweet potato starch films obtained by heat gelatinization were in the range 6 - 16 N and for HDPE films was approximately 8.2 N[9,10].

4 CONCLUSION

Cornstarch films were obtained by molding and dehydrating alkaline gelatinized suspensions and their radiometric and mechanical properties were analyzed to evaluate their performance as protective soil coatings. Additionally, the ability of these suspensions to be sprayed using a commercial backpack sprayer was evaluated. The radiation barrier properties were satisfactory for their application as protective coatings, demonstrating a blocking capacity of approximately 85 % of the total photosynthetically active radiation. On the other hand, the resistance of the films to penetration was similar to that reported for sweet potato starch films obtained by thermal gelatinization, and even to HDPE films used as agricultural mulches. Finally, the suspensions proved to be suitable for application by spraying, using a commercial backpack sprayer.

REFERENCES

1 KADER, M.A., SENGE, M., MOJID, M.A., ITO, K. 2017. Soil and Tillage Research. 168. 155-166.
2 BANDOPADHYAY, S., MARTIN-CLOSAS, L., PELACHO, A.M., DEBRUYN, J.M. 2018. Frontiers in microbiology. 9. 819
3 FEUILLOLEY, P., CESAR, G., BENGUIGUI, L., GROHENS, Y., PILLIN, I., BEWA, H., LEFAUX, S., JAMAL, M. 2005. J. of Pol. and the Environ. 13. 349-355.
4 GAMAGE, A., LIYANAPATHIRANAGE, A., MANAMPERI, A., GUNATHILAKE, C., MANI, S., MERAH, O., MADHUJITH, T. 2022. Sustainability. 14(10). 6085.
5 ADHIRAKI, R., BRISTOW, K.L., CASEY, P.S., FREISCHMIDT, G., HORNBUCKLE, J.W., ADHIKARI, B. 2016. Agri. Water Management. 169. 1-13.
6 MALINCONICO, M., IMMIRZI, B., SANTAGATA, G., SCHETTINI, E., VOX, G., SCARASCIA MUGNOZZA, G. 2008. Progress in polymer Degradation and stability research. 69-114.
7 GARCIA, M.A., PINOTTI, A., MARTINO, M.N., ZARITSKY, N.E. 2004. Carbohydrate polymers. 56(3). 339-345.
8 YANG, Z., SUN, Q., JI, N., DAI, L., XIONG, L., SUN, Q. 2021. Starch-Stärke. 73(7-8). 2000152.
9 BILCK, A.P., GROSSMAN, M.V., YAMASHITA, F. 2010. Polymer testing. 29(4). 471-476.
10 MALI, S., GROSSMAN, M.V.E., GARCIA, M.A., MARTINO, M.N., ZARITZKY, N.E. 2004. Carbohydrate polymers. 52(2). 129-135.

ACKNOWLEDGEMENTS

This study was funded by the Universidad Nacional de Cuyo (UNCuyo, Argentina, Grant SIIP2022: 06/L006-T1), the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, Argentina), the Universidad Nacional del Sur (UNS, Argentina, Grant PGI 24/ZQ18), and the Fondo para la Investigación Científica y Tecnológica (FONCyT, Argentina Grant PICT-2020-SerieA-02022).