JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2025, Vol. 6, No. 1, 81 - 87
http://dx.doi.org/10.11594/jaab.06.01.06
E-ISSN: 2723-5106

Research Article

Influence of pH on bioplastic production from sweet potato starch (*Ipomea batatas* L.)

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Article history:

Received 21 September 2024
Revised 22 October 2024
Accepted 16 December 2024
Published 28 December 2024

Keywords:

biodegradable materials
extraction
food waste
nutritious crop
pH influence
sustainable agriculture

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Abstract

Scientists are exploring biodegradable bioplastic polymers as alternatives to traditional plastics to address environmental concerns. Bioplastics are derived from renewable materials such as starch, vegetable oils, and other organic sources. This study specifically focuses on using sweet potatoes to produce a bioplastic. Sweet potatoes are a versatile and nutritious crop that is widely grown around the world. The roots of sweet potatoes contain starch, which makes up a significant part of their composition. Starch is a valuable food source with industrial uses, including as a carrier medium for various substances in the food and pharmaceutical industries. The research was conducted in the Souf region of the Algerian Sahara, where sweet potato starch is obtained through a multi-step process that includes washing, peeling, filtering, and drying. This starch (5g) is mixed with 50 ml of water, hydrochloric acid, and glycerol (5 ml), then heated and dried to create bioplastics. The results show that the starch yield from sweet potatoes varies depending on the pH of the extraction medium, with the highest yield being achieved with a neutral medium (7.6±1.72 g). This study also investigates the potential of recycling industrial food waste, lovely potato peelings, for the production of bioplastics. It highlights the importance of pH in starch extraction and its subsequent use in bioplastics production, highlights environmentally friendly alternatives to traditional plastics, and contributes to the ongoing efforts to reduce plastic waste and pollution.

How to cite:
Ahmed-Salah, R., Alia, Z., Gahtar, A., Belahcene, S., Khechekhouche, E. A., & Amara, D. G. (2025). Influence of pH on bioplastic production from sweet potato starch (*Ipomea batatas* L.). *Journal of Agriculture and Applied Biology, 6*(1): 81 - 87. doi: 10.11594/jaab.06.01.06

1. Introduction

Polymers are the building blocks of plastics. A polymer is a chain of molecules, with each link in the chain usually made of carbon, hydrogen, oxygen, and/or silicon. To create the chains, many monomers are linked through a process called polymerization (Hatti-Kaul et al., 2020). Petroleum and other products are heated and broken down into smaller molecules known as monomers, which serve as the foundational building blocks for polymers (Peplow, 2016). Different of these monomers produce plastic resins with varying properties, such as strength or formability (Chen et al., 2024; Rizan et al., 2020). By 2015, global annual plastics production is estimated to exceed 300 million tons.

Plastics pose a severe threat to our environment as they are non-biodegradable and non-renewable, , leading to significant waste accumulation (Ates & Kuz, 2020; Marta et al., 2022). The first major disadvantage of plastic waste is the crisis it creates in many parts of the world due to shrinking landfill capacity, rising costs, and stringent regulations (Ezgi Bezirhan & Havva Duygu, 2015). Additionally, plastic waste heavily pollutes our oceans, causing extensive harm to the marine ecosystem. The second major disadvantage is that current waste management options for plastic are inadequate. The recycled content of plastics is low, and incinerating plastic release toxic emissions such as carbon dioxide and methane, which contribute to greenhouse gases (GHGs) and exacerbate global climate change (Alia et al., 2019; Arikan & Bilgen, 2019).

Due to environmental, economic, and safety challenges, scientists are partially turning towards biodegradable polymers such as bioplastics to replace petrochemical-based plastics (Prasteen et al., 2018; Reddy et al., 2013). Bioplastics are made from renewable polymeric materials or biomass, including source such as starch, vegetable oils, fruit waste, lignin, cellulose, proteins and lipids from animals (Triawan et al., 2020). Various microorganisms synthesize and degrade these natural biopolymers and accumulate them in microbial cells under stressful conditions. Unlike petroleum-based plastics, bioplastics are environmentally friendly and can be managed conventionally. They can be recycled, landfilled, or burned without leaving harmful plastic waste or contributing to the depletion of our finite resources, such as fossil fuels (Maheshwari et al., 2013).

The sweet potato, scientifically known as Ipomoea batatas, is the seventh most important food crop globally in terms of production. It is cultivated on approximately 9 million hectares of land and yields around 140 million tons, averaging 15 tons per hectare (Jansson & Raman, 2019). This robust and nutritious staple crop thrives in humid tropical and subtropical regions (Kassali, 2011). Sweet potatoes can be consumed in various forms, including raw, cooked, fried, steamed, or further processed into snacks, frozen foods, and canned goods (Belkacemi, 2022).

Roots and tuber crops are abundant starch sources, containing around 70-80% water, 16-24% starch, and less than 4% of proteins, lipids, and other essential vitamins and mineral (Alia et al., 2019; Waterschoot et al., 2015). Starch has several benefits, including maintaining the quality of stored foods by enhancing moisture retention and controlling water mobility in food products. Additionally, it can be used as a delivery vehicle for various substances of interest in the food and pharmaceutical industries, such as antioxidants, dyes, flavors, and pharmaceutically active proteins (Abegunde et al., 2013). The primary aim of this study was to investigate the potential of recycling food industrial waste for bioplastic production. Specifically, the production of bioplastics from potato peel waste was studied, with a focus on environmental and health protection

2. Material and methods

2.1. Study region

The Souf region is situated in the northeastern part of the Algerian Sahara at an altitude of 70 meters. Its latitude ranges from 33° to 34° north, and its longitude is between 6° and 8° east. The region is bordered to the north by the Sahara Atlas Mountains, to the east by the Tunisian border, to the south by the significant eastern erg, and to the west by the Oued Right valley. Notably the northwest of the study area, it is worth mentioning the presence of features Chotts Melghir and Mermouane (Mehdi & Mohamed, 2015).

2.2. Extraction of sweet potato starch

Sweet potato tubers can be used to obtain starch, following the method described by (Saman & Yuliasih, 2019). The first step involved thoroughly, washing and peeling the tubers. Next, the tubers were chopped and placed in a container, followed the addition of distilled water (About two thirds of the amount of sweet potato). The mixture was then stirred and filtered through a sieve (about 5 minutes). After allowing the mixture to stand for a few minutes, the starch settled to the bottom of the container. The water was then removed with a pipette, and the starch is left to dry in the bowl for a few days. Finally, the dried starch powder was collected in a glass container.

2.3. Production of bioplastic

To create bioplastic, a specific set of steps was followed. Firstly, 50 ml of distilled water was placed in a beaker. Then, 5 g of sweet potato starch, 4 ml of hydrochloric acid (HCL), and 4 ml of glycerin were added. This mixture was heated to 100 °C on a hotplate and stirred it continuously by hand for 10-15 minutes. After that, the mixture was allowed to dry for 3-4 days (Jeyasubramanian & Balachander, 2016).

2.4. Statistical analysis

The collected data were analyzed using statistical software including SPSS (IBM 20), Excel-Stat (2014.5.03), and Minitab (17.1.0). The tests used to analyze the data were ANOVA (suitable for normally distributed data), Kruskal Wallis (appropriate for non-normally distributed) and Wilcoxon.

3. Results

3.1. Starch yield results

The starch yield of sweet potatoes was measured across three different media; the results are summarized in Figure 1. The highest amount of starch yield was obtained from a neutral medium, with an average of 7.6 ± 1.72 g from 50 g of sweet potatoes. In contrast, acidic media contained the least starch yielded, with an average of 5.8 ± 1.17 g, while the alkaline medium produced an average of 50 g of sweet potatoes (Fig. 1). Upon ANOVA test comparison, there was no significant difference found (p-value=0.243<0.5) between the lesions resulting from starch media extraction.

3.2. Performance in bioplastic

The bioplastic yield results from 5 grams of sweet potato starch were assessed across three different media with varying acidity levels, as summarized in Figure 2. Among the three media tested, the neutral medium exhibited the highest bioplastic production rate, yielding 21.7 ± 0.40 g. In contrast, the alkaline medium produced 18.7 ± 0.41 g, while the acidic medium yielded 17.3 ± 0.43 g, both of which were significantly lower than the yield observed in the neutral medium (Fig. 2). The ANOVA test shows that there is a highly significant difference (p-value =1.6746E-05< 0.5) between the bioplastic contents of the media examined.

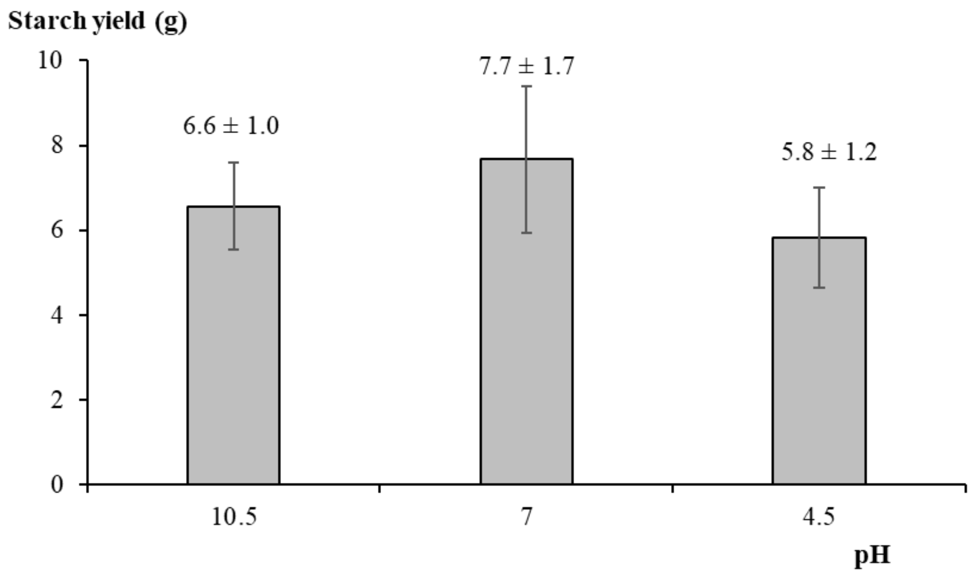

Figure 1: Influence pH on the starch yield

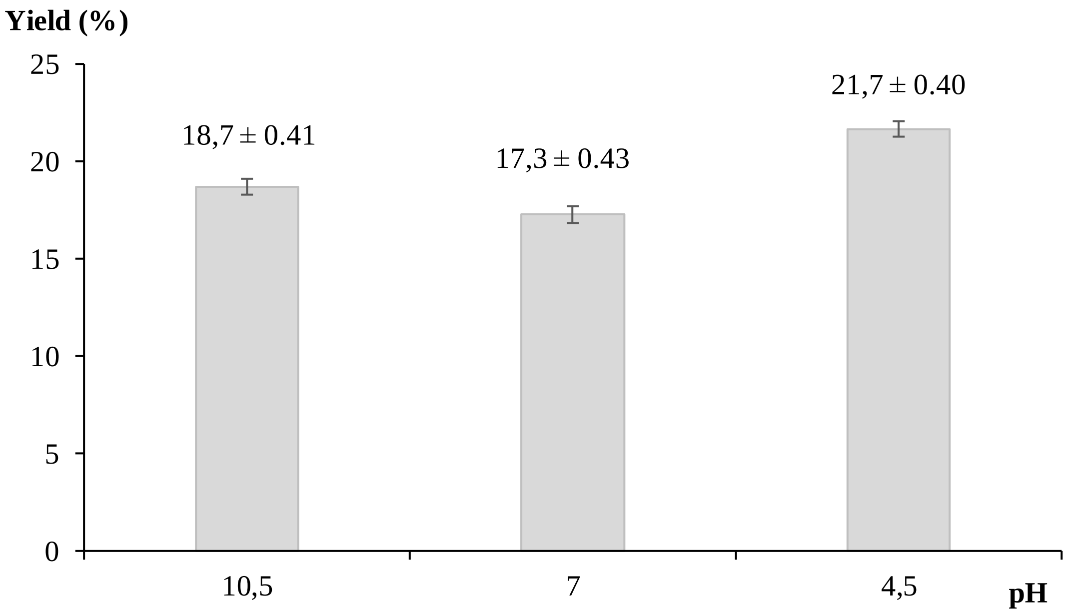

Figure 2. Influence pH on the bioplastic yield

The Tukey test revealed significant differences in bioplastic yield among the three media (Fig. 2). Medium A which is acidic, demonstrated the highest proportion of bioplastic. There is a significant difference between the alkaline and neutral media with p-values of 0.00697 and 0.000015, respectively (Table 1). Medium B is alkaline, exhibiting an intermediate production rate compared to the other extraction media. Notably, there is a significant difference between the neutral and acidic media with p-values of 0.000143 and 0.00697, respectively (Table 1). Medium C is neutral chowing, slightly lower starch content compared to the other media. Furthermore, there is a significant difference between the alkaline and acidic media with p-values of 0.000143 and 0.000015, respectively (Table 1).

Table 1. Matrix of comparisons of the averages (Turkey test) of the bioplastic yield to the three mediums

	Neutral	Alkaline
Alkaline	0.000143	
Acidic	0.000015	0.00697

4. Discussion

Chemically speaking, starch is a polysaccharide H. It consists of chains of monosaccharide (sugar) molecules (glucose) connected by α1–4 and/or α 1–6 linkages (Bojarczuk et al., 2022; DeMartino & Cockburn, 2020). Sweet potatoes are a nutrient-rich food crop with heavy starch content in the first or larger shoots, making them a potential source of ethanol (Zhang et al., 2016).

The results from the three media (neutral, alkaline and acidic) of sweet potato starch grown in Souf showed significant differences between unbiased, alkaline and alkaline, acidic media. Notably, there is a substantial difference between the neutral and acidic media; sweet potatoes require a soil pH of 5.5 to 6.5 (neutral soils), but yields are acceptable in more alkaline soils (up to pH 7.5) or acidic soils (up to pH 4.5) are acceptable (Adabe et al., 2019; Morim de Lima, 2023). A study of 19 sweet potato varieties by (Vithu et al., 2020) found that the starch yield varied between 12.9% and 22.8% during the dry season and between 10.3% and 21.3% during the wet season. In addition, another study on some sweet potato varieties, reported a starch content of 17% (Ho & Noomhorm, 2011).

The stability of native starch changes unfavorably with pH value and temperature. For example, native starch granules are water-insoluble at room temperature and are very resistant to hydrolysis by amylases. Leading to limited functionality (Egharevba, 2019). The structure of starch chains in aqueous media is influenced by the pH of the medium. Acids sand alkalis such as those at pH 5 and 10, can also damage the starch chains. Amylase is more susceptible to chain degradation compered to amylopectin, particularly in Alkaline conditions (e.g. pH 9), which promotes chain dissociation in solution, particularly for amylase (Lee et al., 2009).

Starch gelatinize sand loses it is crystalline structure. After cooling it forms an opaque gel that is initially flexible and then become a solid gel (bioplastic). This final stage of bioplastic production aligns with other results from starch polymerization research (Agarwal et al., 2023). In this study, the bioplastic yields across for the three media showed highly significant difference. We found that the three media that found that the chemical composition of starch is not identical across the media. All of the studies we consulted primarily targeted biochemical and non-industrial processes to calculate yields and physical and chemical properties of bioplastics (Alia et al., 2019; Gamage et al., 2022).

5- Conclusion

This study further examines the viability of repurposing industrial food waste, specifically sweet potato peelings, to produce bioplastics. The significance of pH in the process of starch extraction and its subsequent application in the development of bioplastics is emphasized. This underscores the exploration of ecologically sustainable alternatives to conventional plastics and contributes to on-going effort to mitigate plastic waste and pollution.

Author's declaration

On behalf of all the authors of the aforementioned manuscript, I am writing to confirm that we have no conflicts of interest related to the research, authorship, and publication of this article.

None of the authors have any financial, personal, or institutional interests that could be perceived as influencing the outcomes or interpretations presented in the manuscript. The findings and conclusions in our study are based solely on objective scientific data and analysis. We assure you that this work was conducted without any bias or external influence that could compromise its integrity.

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