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**PRODUCTION AND CHARACTERIZATION OF BIOPLASTIC  
FROM POTATO STARCH OF THE *SPUNTA* VARIETY**

Presented by: Salah Ayache Amani

Boulebsol Hadjar

Bouzelifa Rayane

Zegueur Hiba Rihab

Jury member :

Pr. DJERROU Z.

Dr. BOUDJELLAB Z.

Dr. GHANNAM M.

President

Promoter

Examiner

Univ. 20 Aout 1955

Univ. 20 Aout 1955

Univ. 20 Aout 1955

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# DEDICATION



to my greatest supporters and sources of inspiration

i dedicate this work with all my infinite love and  
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# DEDICATION



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**To my dear grandmother**

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# DEDICATION



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# DEDICATION



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abriviation	meaning
LONDON-NEC	LONDON corporation and unitika
CBMM	Cardia bioplastics malaysia manufacturing
DSA	Agricultural Services Branch
NaOH	Hydroxyde de sodium
pH	hydrogen potential
CH <sub>3</sub> COOH	Acetic Acid
Hcl	hydrogen choloride

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# Production and characterization of bioplastic from potato starch of the « Spunta » variety

## Abstract

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In a context of environmental protection, our aim was to replace petroplastic, which is harmful to the environment, with another polymer of biological origin (plant biomass), which has the same potential for use but is ecologically non-polluting. A plasticization process was applied to starch extracted from peeled tubers and potato peelings of the "Spunta" variety, and the polymer obtained was characterized. The results obtained revealed: an extraction rate of 10.6% and 2% and a plasticization rate of 168% and 86.1% for peeled tubers and peelings respectively. A heterogeneous microscopic appearance was observed in peel-based bioplastics, with a higher calculated opacity. A calculated biodegradation rate for peel-based bioplastics was 1.6 times higher than for tuber-based bioplastics.

---

**key words :** Petroplastic, *Spunta*, Starch, peeled tubers, peelings, Bioplastic, Biodegradation, opacity.

# Production et caractérisation de bioplastique à partir de fécula de pomme de terre de la variété " Spunta "

## Résumé :

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Dans un contexte de protection de l'environnement, notre objectif était de remplacer le pétroplastique présentant une nocivité pour l'environnement par un autre polymère d'origine biologique (biomasse végétale), qui ce dernier possède les memes potentialités d'utilisation mais écologiquement non polluants. Un procédé de plastification a été appliqué sur l'amidon extraite a partir des tubercules épluchés et des épluchures de pomme de terre de la variété « *Spunta* », le polymère obtenu a fait l'objet d'une caractérisation. les résultats obtenues ont révélé :un rendement d'extraction de 10,6 % et 2% et un rendement de plastification de 168% et 86,1% pour les tubercules épluchés et les épluchures respectivement. Un aspect microscopique hétérogène a été observé dans les bioplastiques a base des épluchures avec une opacité calculée plus élevée. Une vitesse de biodégradation calculée pour les bioplastique a base des épluchures était plus élevée de 1,6 fois que celle des bioplastique a base des tubercules.

---

**Mots clés :** Pétroplastique, *Spunta*, amidon, Tubercules épluchés, épluchures, Bioplastique, biodegradation , opacité.

## المخلص

في سياق حماية البيئة، كان هدفنا هو استبدال البلاستيك ببوليمر آخر من أصل بيولوجي (الكتلة الحيوية النباتية)، والذي لديه نفس الإمكانيات للاستخدام ولكنه صديق للبيئة. تم تطبيق عملية تجميل على النشا "سبونتا"، وكان البوليمر الذي تم الحصول المستخرج من الدرناات المقشرة وقشور البطاطس من صنف عليه موضوع توصيف. وأظهرت النتائج التي تم الحصول عليها: زيادة في الاستخراج بنسبة 10.6% و 2% وزيادة في البلاستيك بنسبة 168% و 86.1% للدرناات المقشرة والمقشرة على التوالي. لوحظ ظهور مجهري غير متجانس في البلاستيك الحيوي بناءً على التقشير مع عتامة محسوبة أعلى. كان معدل التحلل البيولوجي المحسوب للبلاستيك الحيوي القائم على التقشير أعلى 1.6 مرة من معدل البلاستيك الحيوي القائم على الدرناات.

**الكلمات المفتاحية** البلاستيك، النشا، الدرناات المقشرة، قشور البطاطس، التحلل البيولوجي، عتامة

# **GENERAL INTRODUCTION**

## INTRODUCTION

Over the past two centuries, the significant growth of the world population and its consumption habits have led to several negative impacts on the environment. The development of a society with more sustainable production/consumption mechanisms should consider scenarios such as deforestation, water pollution, soil silting, and solid (Geyer R, 2017) waste accumulation. Regarding plastic wastes, they represent approximately 12% of the composition of the world's solid waste, and their annual production has been increasing since 1950 and exceeded 6 billion tons of waste generated between 1950–2015 (Geyer R., Jambeck J.R., Law K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* 2017;3:25–29.) .

Most modern plastics are synthesized from fossil petrochemicals such as natural gas or oil. However, such plastics are resistant to biodegradation and, therefore, their widespread use leads to the accumulation of a huge amount of plastic waste. According to a 2016 plastic industry report (Plastics Europe. World Plastics Materials Demand 2016 by Types. Available online: <https://committee.iso.org/files/live/sites/tc61/files/ThePlasticIndustryBerlinAug2016--Copy.pdf> (accessed on 19 May 2021).

In addition, several chemical additives are incorporated to enhance the properties of plastics, which will create negative environmental effects and health hazards. Human health is exposed to these hazardous chemicals during manufacturing and use. The migration of chemicals from plastics into food is also a major challenge. Prolonged intake or exposure to these chemicals can cause direct toxicity to human cells. (R. Thiruchelvi ↑, Aryaman Das, Eesani Sikdar -2021-

Bioplastics as better alternative to petro plastic) Bioplastic is a possible solution to this problem; however, significant research is required for it to replace synthetic or fixed resources based non-biodegradable plastics. The bioplastics produced from renewable resources generally do not possess the required parameters to compete with the readily available synthetic plastics. As such significant research is yet to be done in this field to fully explore the usability of biodegradable bioplastics produced from renewable resources. Several biobased resources including starch, cellulose, chitin, chitosan, protein, etc. have been evaluated for their bioplastic-producing properties .

Among these, starch is a cheap, renewable, biodegradable, as well as easily processible plant-based renewable resource, and is a promising candidate for bioplastic production (Raghav Poudel, Nipu Dutta, Niranjana Karak -2023- A mechanically robust biodegradable bioplastic of

## INTRODUCTION

citric acid modified plasticized yam starch with anthocyanin as a fish spoilage auto-detecting smart film).

In this context, our study focused on the production of plastic from plant biomass, which is the potato in its two components: the tuber and the peel. This work is structured as follows:

- A bibliographical section containing general data on plastics from fossil and renewable biological sources, as well as a precise information on the type of biomass used in this work, which is the potato variety "Spunta".

- An experimental section, divided into 3 main parts: the first involves the extraction of starch from potato tubers and peelings. The second part is devoted to the transformation of the extracted starch into plastic. Finally, in the third section, we will attempt to characterize the bioplastic obtained in order to assess its potential use, in comparison with petro-plastic.

**PART I**

**BIBLIOGRAPHY**

# **CHAPTER I**

## **PLASTIC AND BIOPLASTIC GENERALITIES**

## I-1- Plastic

### I.1.1 Definition :

The term plastic refers to a set of synthetic materials made from hydrocarbons and formed by polymerization, that is, by a series of chemical reactions triggered on organic raw materials (containing carbon), primarily natural gas or crude oil. Their properties will be different depending on the type of polymerization used: they will be hard or soft, opaque or transparent, flexible or rigid.

Plastic has been widely used in various fields all over the world because it is lightweight, durable, and resistant to degradation. (Jens Althoff, directeur, Heinrich-Böll-Stiftung, Atlas du Plastique faits et chiffres sur le monde des polymères synthétiques)

### I-1-2 Production of plastic :

Synthétique plastics are mainly made from petrochemical monomers (**Reyne, 1998**). They are produced from coal or of natural gas, although oil is the most commonly used crude material for the production of plastics (**plastic historical society(phps), 2010**)

The producer of plastics therefore uses as an input naphtha or olefins, which he will transform, by steam cracking, into intermediates, monomers such as ethylene, propylene, butene and other unsaturated hydrocarbons (**plastic historical society(phps), 2010**) (**Reyne, 1998**). These monomers will be transformed into polymers in powder form solid or liquid resin hydrocarbons (**Reyne, 1998**).

Industrialists use polymers as pellets. Polymers produced in powder or resin form must undergo an extrusion process (**Reyne, 1998**). Polymers are rarely used alone, other products are used in the plastics (**plastic historical society(phps), 2010**). Additives are added to improve certain physicochemical properties (**Reyne, 1998**).

### I-1-3 Degradation :

As a rule, widely used plastics do not naturally degrade to a large degree when released into the environment. This is perhaps unsurprising, as one of the primary reasons for the popularity and widespread application of many polymers is their exceptionally high stability and durability ((**Yamada-Onodera, Mukumoto, Katsuyaya, Saiganji, & Tani, 2001**) ((**Zheng, Yanful, & Bassi, 2005**)).

There are four mechanisms by which plastics degrade in the environment: photodegradation, thermooxidative degradation, hydrolytic degradation and biodegradation by microorganisms [Generally speaking, natural degradation of plastic begins with photodegradation, which leads to thermooxidative degradation. Ultraviolet light from the sun provides the activation energy required to initiate the incorporation of oxygen atoms into the polymer ( (Andrady, 2011) ( (Raquez, Bourgeois, Jacobs, Degée, Alexandre, & Dubois, 2011)

This causes the plastic to become brittle and to break into smaller and smaller pieces, until the polymer chains reach sufficiently low molecular weight to be metabolised by microorganisms (Andrady, 2011) ((Zheng, Yanful, & Bassi, 2005) These microbes either convert the carbon in the polymer chains to carbon dioxide or incorporate it into *biomolecules* ((Yamada-Onodera, Mukumoto, Katsuyaya, Saiganji, & Tani, 2001) (Andrady, 2011)

However, this entire process is very slow, and it can take 50 or more years for plastic to fully degrade .This is not aided by the fact that the photodegradative effect is significantly decreased in seawater due to the lower temperature and oxygen availability and that the rate of hydrolysis of most polymers is insignificant in the ocean. (Andrady, 2011).

**I-2 Bioplastic :****I-2-1 Definition and sources :**

Bioplastic simply means the use of living organisms such as plants, animals, and microorganisms for the production of plastic. This type of plastic is different in many ways from fossil fuel-derived plastics (Kumar S, 2019) .

Bioplastics are considered superior polymers compared to synthetic plastics due to their biocompatibility and biodegradability, which make them exceptional for applications in packaging, biomedical and other value-added industrial applications (Pathak, 2014) (prasanth, 2021) .

**I-2-2 Bioplastic History :**

(Rajendran, 2012)

<b>Year</b>	<b>Development</b>
1941	Henry Ford experimented with plastics made from soya beans and produced a plastic car. World war II played an important role in the development of bioplastics.
1992	Metabolix, a bioscience company provided solutions for worlds needs for plastics, chemicals and energy.
2000	Metabolix initiated the research programs for the development of engineered industrial crops for the production of bioplastics.
2005	Toyota began a pilot plant at Hirose plant in Toyota city, Japan to test the ease of producing bioplastics.
2006	LONDON-NEC corporation and Unitika Ltd had developed a bioplastic material reinforced with fibre from the Kenaf plant to reduce the environmental impact of mobile phones
2010	Cardia bioplastics Malaysia manufacturing(CBMM) was developed to manufacture bioplastics products

**I-2-3 Application of plastic :**

- **Packaging industry**

Because of their biodegradable property, the use of bioplastics is popular in packaging sector.

- **Catering products**

It has application in disposable crockery, bowls and spoons.

- **Gardening**

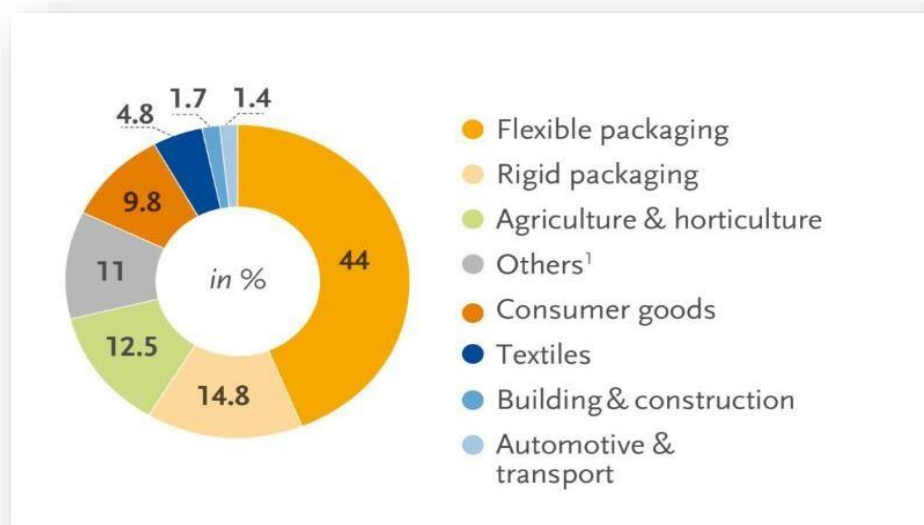
In the agricultural economy and the gardening sector mulch foils and flower pots made of biodegradable bioplastics are used due to their adjustable lifespan and the advantage that they do not leave residues in the soil.

- **Medical products**

Bioplastics made of thermoplastic starch (poly starch) absorbs humidity, which is applied in the production of drug capsules.

- **Automobiles**

It has been reported that Toyota Company is working on eco car made from seaweed biomass which is officially marked as the pioneer of Green automotive movement. (Rajendran, 2012)



**Figure 01 :Bioplastic Applications market(European Bioplastic\_NOVA institute,2021**

#### **I-2-4 Bioplastic classification :**

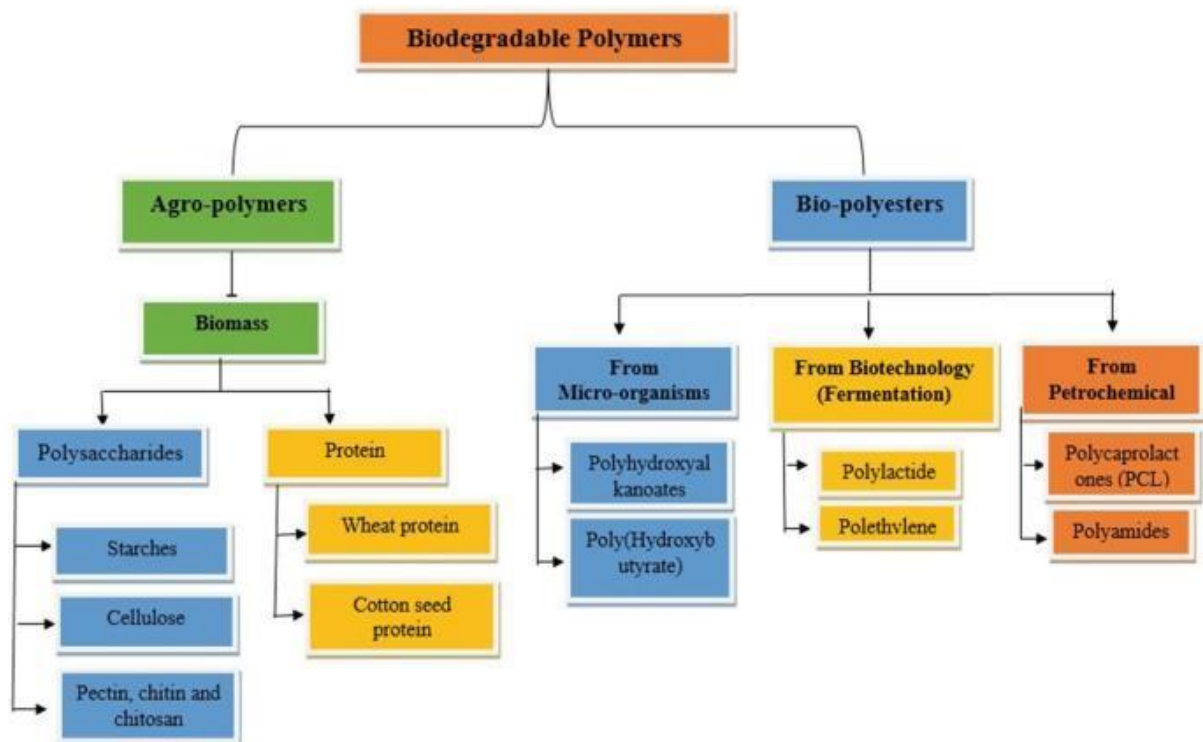
bioplastics are majorly divided into two main categories that are :

\_Agro-polymers

\_Bio-polyesters

\*Agro-based polymers are derived from natural renewable sources that may be polysaccharides, starch, cellulose, lignin, pectin, animal and plant proteins and oils.

\*while the bio-polyesters are obtained from microorganisms, petrochemicals, and biotechnological means (Thuwall M, 2006)



**Figure 02 :**General classification of Biodegradable plastic (Kumar and Thakur 2017; Palanisamy et al. 2019)

### I-2-5 Advantages and disadvantages

#### I-2-5-1 Advantages :

- reduced carbon footprint
- bioplastic are compostable,renouvelable
- Energy efficiency
- Partly based on natural raw material
- Eco-safety ( (Shah, 2021)

#### I-2-5-2 Desadvantages :

- Fragility
- Thermalinstability

- Various recycling issues (Shah, 2021)

### I-2-6 Biodegradation

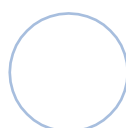
These bioplastics can be degraded very easily in the environment and can be recycled easily. The degradation of polymer is completed in three steps in the environment:

(1) **biodeterioration**, the microorganisms grow in or on the surface of the polymer, which changes the chemical, physical, and mechanical properties of the polymer.

(2) **bio-fragmentation**, the microorganisms act on the large polymer unit and convert it into oligomers and monomers, the smaller units; and

(3) **assimilation**, after the breakdown of polymer into smaller unit monomers, there is a release of a

large amount of carbon, energy, and nutrient sources that are used by the microorganism and convert them into the water, carbon dioxide, and biomass (**Lucas N, 2008**)



# **CHAPTER II**

## **GENERAL INFORMATION OF ABOUT POTATOES**

## II.1 General information about potatoes:

### II.1.1 Definition of potato :

Potatoes rank 4th among all food crops in the world behind maize, wheat and rice (Jean & Claude , 2001). It is the world's first non-cereal crop of South America's origin. It is a perennial plant of the Solanum family of the genus Solanum tuberosum that can reach one meter in height. Potatoes are rich in starch and trace elements such as potassium, phosphorus, iron and magnesium (ITCMI, 2010)



Figure 3: potatoes Solanum tuberosum

### II.1.2 Origin of the potato:

The potato (*Solanum tuberosum* L.) belongs to the Solanaceae family, genus Solanum (Quezel & santa, 1963) , comprises 1000 species of which more than 200 are tuberous (Doré, Varoquaux, Coordinateur, & Hawkes, 2006,1990) It was once thought that the potato was derived from a single wild plant, the species *S. tuberosum*, as early as 1929, botanists had shown that this origin was more complex and that the ancestors of cultivated potato species, different wild plants were (Rousselle, Rousselle, Ellisseche, & Doré, 1992;2006) .. According to Grison (1993), the potato seems to have originated and lived spontaneously in the western shores of Latin America. Its consumption by the Indian population dates back to time immemorial. The introduction in Europe, towards the second halves of the 16th century by navigators or pirates. And it was the entry of the potato into the human diet forever removed the famine that periodically raged.

### II.1.3 Systematic position:

According to (BOUMLIK, 1995). the systematic position of the potato is:

- **Kingdom:** Vegetable
- **Class:** Dicotyledons.
- **Phylum:** Angiosperm.
- **Species:** *Solanum tuberosum*
- **Family:** Solanaceae.
- **Genus:** Solanum.
- **Order:** Polemonial.
- **Subclass:** Gamopetales.

The potato (*Solanum tuberosum* L.) belongs to the nightshade family. The genus solanum includes about 2,000 species, of which more than 200 are tuberous. Whose tubers are the subject of significant international trade. It is a perennial plant that spreads by vegetative

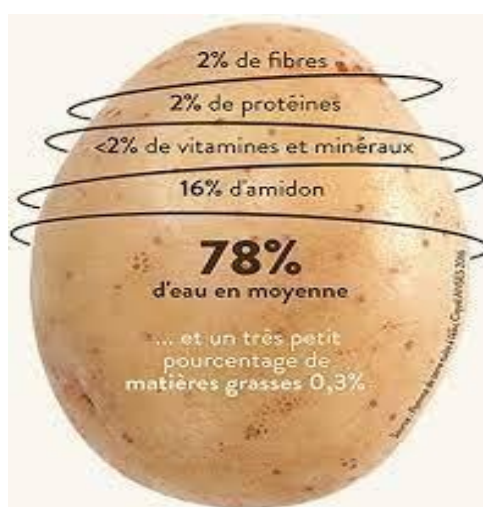
propagation and is cultivated as an annual species (ROUSSELLE et al. 1992 and DUCHARME, 2013)

#### II.1.4 The chemical composition of the tuber:

The tuber consists mainly of water (about 75 - 80% of the weight). The remainder is formed by dry matter, namely starch, amino acids, proteins, sugars (sucrose, glucose, fructose), vitamins (C, B1), mineral salts (K, P, Ca, Mg) and fatty and organic acids (citric, ascorbic) (Bernhards, 1998).

**Table 1:** Chemical composition of 100g of potato tuber (Bernhards, 1998).

Main components	Quantity
Water	75-80g
Protein	2.04 g
Lipids	< 0.1 g
Carbohydrates by difference	16.6 g
Total .fibre	1-1.8 g
Potassium	335 mg
Magnesium	19.7 mg
Copper	0.15 mg



**Figure 4 :** Chemical composition of potato tuber (Ciquil Anses (pomme de terre), 2017)

#### II.1.5 Chemical composition of Solanum tuberosum peelings:

Water is the major constituent of solanum tuberosum peelings with a content of 83.3%. They contain sufficient amounts of starch, cellulose, hemicellulose and lignin (Igor Sepelev, 2015)

**Table 2:** chemical composition of peelings se solanum tuberosum 1g\100g (Igor Sepelev, 2015)

Components (powder)	Minimum and maximum content %
Water	83,3-85,1
Protein	1,2-2,3
Total lipids	0,1-0,4
Total carbohydrates	8,7-12,4
Starch	7,8
Total fiber	2,5
Ashes	0,9-1,6

### II.1.6 Potatoes in Algeria:

In Algeria, the potato was probably introduced for the first time in the sixteenth century by the Andalusian Moors who spread other crops in the region: tomato, pepper, corn, tobacco, then it fell into oblivion having not aroused interest. In the second half of the nineteenth century, the colonists will cultivate it for their use, because the Algerians are reluctant to do so despite the successive famines. It was the last great famine of the 30s and 40s that would overcome this opposition (**Meziane, 1991**). At the Oued Soufi, the first trials of the crop were launched in 1995, 96 and 97 by the technical assistance of DSA in close collaboration with the specialized institutes (**INRA, 2004**).

**Table 3:** Algerian production of solanum tuberosum 2011-2015 (**INRA, 2004**).

Year	2011	2012	2015
Potato production (tonnes)	3800000	4300000	4500000

### II.1.7 Main varieties grown in Algeria:

One hundred and twenty varieties are classified in the Algerian catalogue of cultivated species and varieties.

The following table expresses the cultivated varieties according to their colors. (**ITCMI, 2010**)

**Table 4:** main varieties of solanum tuberosum grown in Algeria. (**ITCMI, 2010**)

Red varieties	White varieties
Brentina	Spunta
Desiree	Fabula
Kondor	Nicola
	Diamond
	Timate
	Atlas

## II.2 Starch:

### II.2.1 Generalities

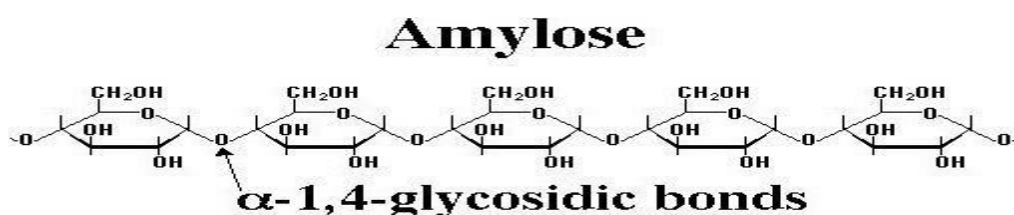
Starch is a polysaccharide of plant origin composed of glucose units (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>). (DAVIDOVIE. A 2006). Resulting from photosynthesis, starch, which constitutes the sugar reserve of plants, is in the form of grains of variable size (1 to 200 μm) and gives a colloidal solution in water (DAVIDOVIE; 2006 and BEN AMARA and THAMER; 2015). It is stored in the reserve organs of plants such as cereals (30-70% of dry matter), potato tubers (60-90%) and legumes (25-50%). (WERT; 2011 and LAURENT; 2013). Starch is also used in many non-food industrial sectors: paper production, pharmaceutical, cosmetic, textile industry, etc. It has also become in recent years an interesting raw material for the production of bio and biodegradable plastics as well as for the production of bioethanol, which is a fuel used in gasoline engines (WERTZ; 2011)

### II.2.2 Composition of starch and their basic structure:

Starch is a homopolymer of D-glucose. It is formed of two polymers of different primary structures: amylose and amylopectin. Amylose is a quasi-linear molecule while amylopectin is branched. It should be noted that starch also contains minor components (lipids, proteins and minerals) whose contents vary with botanical origin and extraction technology. The amylose content also varies with the botanical origin of the starch between 13% and 35%. Starch occurs in granules ranging in size from 1 to 100 μm that have a semi-crystalline structure resulting from the spatial organization of amylopectin and amylose macromolecules (S Jenkins and al., 1995).

#### A. Amylose:

Is a linear polymer, shown in Figure 1, consisting of D-glucopyranose residues linked by bonds α-1,4 (bond with glycosidic oxygen in axial position). It is the α analogue of cellulose, which is a linear polymer of D-glucopyranose residues bonded β-1,4 (glycosidic oxygen bonding at the equatorial position) (Wertz, 2011).



**Figure 5:** Structure of amylose (jean, 2016)

#### B. Amylopectin:

Is a strongly branched polymer consisting of D-glucopyranose residues bonded α. The glycosidic bonds are 1.4 except at the branching points where they are 1.6 (Fig). 5-6% of glycosidic bonds are α1.6 (DAVIDOVIE. Has; 2006 and WERTZ. J; 2011) Molecular weights range from 107 to 108 g/mol.

### Amylopectin

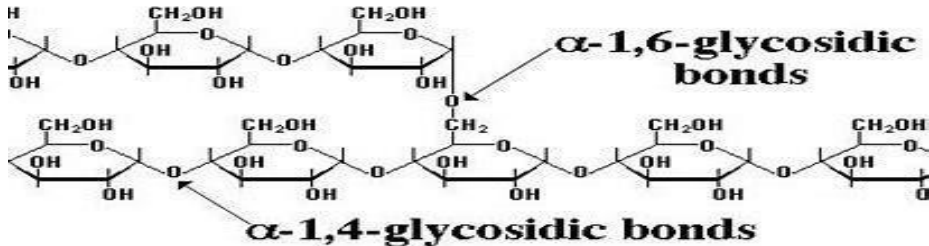


Figure 6: Structure of amylopectin (jean, 2016)

**PART II**

**MATERIALS AND METHODS**

### I. Objective:

. The aim of our work was to produce a bioplastic from peelings and tubers potato starch. The process of transforming this biomass into a bioplastic is divided into two main parts: extraction of the starch and preparation of the bioplastic.

### II. Location and period of experimental study:

Our experimental part of this study took 3 months (March, April and May), it carried out at the biochemistry laboratory at the University of 20 Aout 1955, Skikda in which we did the starch extraction, the elaboration of bioplastic film and perform the characterization test of bioplastic obtained.



**Figure 7:** location of the biochemistry laboratory

### III. Starch extraction:

#### III.1 Materials:

##### III.1.1. the biomass studied:

To carry out our study we chose the potato variety "*Spunta*". This variety is the most produced in Algeria in terms of quantity (CNCC.2010).

- **Spunta variety:**

Genetic origin: Bea X U.S.D.A. 96-56. Breeder: J. Oldenburger (Netherlands). Year of national catalogue: 1988 Category: Consumption. Maturity: Semi-early. Some morphological characteristics and a photo of the spunta variety are shown in table 05 and figure 08, respectively.

Table 05 : Description of the variety Spunta.

characteristics	
Skin suppleness	Average
Tuber shape	Oblong-elongated
Skin color	yellow
Flesh color	Light yellow



Figure8: External appearance of the *Spunta* potato variety.

### III.1.2 Laboratory equipment:

- Two containers
- Blender
- Balance
- Colander
- Oven
- Muslin fabric
- Beaker 1000ml
- Graduated pipette
- Potato peeler
- Cutting board
- Spatula
- Knife

### III.2 Extraction of starch from tubers

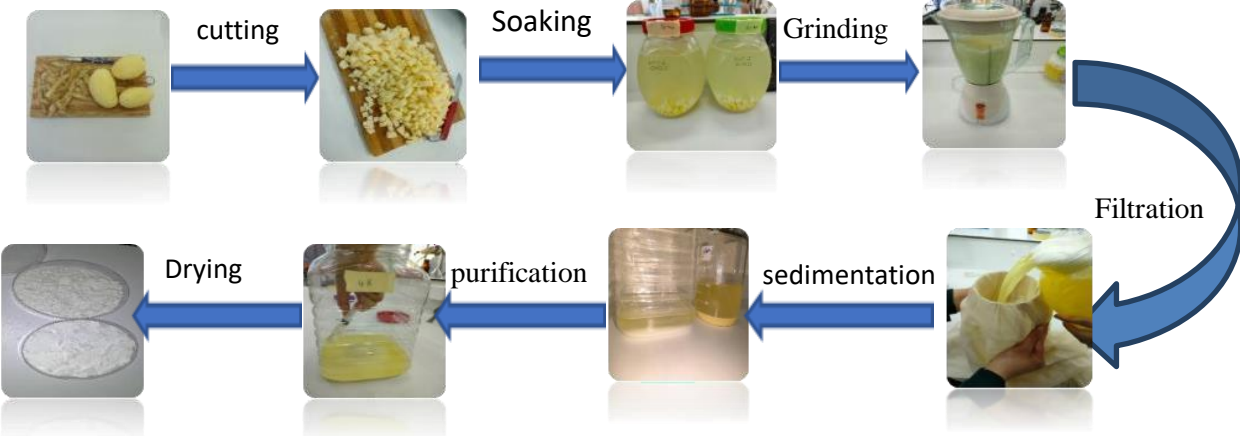
The starch extraction was done according to the protocol described by **Alves et al. (1999) ; Vasanthan 1999; KORICHE 2009.**

- 1-the samples (potato tubers) were washed with tap water
- 2-Peel with a stainless steel knife
- 3-Rinse three times with distilled water
- 4-cut into cubes of 1 cm<sup>3</sup>
- 5\_Tremper in 0.4% NaOH soda solution for 60 Min, with a tuber / soaking solution ratio equal to 1/6, which can ensure good protein dispersion and low starch loss.
- 6-Grind the mixture in a kitchen blender
- 7-Filter on a kitchen strainer
- 8-Rinse the solid fraction retained in the colander thoroughly with distilled water until the rinse water becomes clear
- 9- The filtrate recovered from step 7 and 8 will be filtered through a muslin cloth. All filtrates together constitute starch milk.
- 10- Let starch milk stand for sedimentation for 4 hours at 4°C
- 11- Suck the supernatant and keep only the nerve
- 12- Wash the base with distilled water and then let settle
- 13- Vacuum and throw away the supernatant
- 14- Repeat steps 12 and 13 until the water has a pH of 7
- 15- Add a small amount of ethanol (70 or 95%) to the base obtained from step 13, stir to wash the base
- 16-the base is put for drying at a temperature of 40 ° C in an oven, for 24 hours.
- 17- The dry starch is then ground using a coffee grinder and sieved to obtain a particle size equivalent to that of commercial starch (less than 50µm). The final product after grinding constitutes the native starch.

\* all water used in the extraction process is cold

\*all these steps are shown, in order, in figure 9.

Figure 9 : protocol for extracting starch from potato tubers



### III.3 Starch extraction from peelings:

Starch is extracted from potato peelings, following steps are taken (KORICHE, Y & al, 2009; Vasanthan, T & al, 1999)

#### 1. Preparation of peelings

100 g of the peelings are washed to remove dirt, they are then cut as a square.

#### 2. Soaking

The prepared peelings were soaked in acetic acid ( $\text{CH}_3\text{COOH}$ ) solution (0.2M) with a ratio: peelings - soaking solution equal to 1/6, stirred at a speed of 250 rpm using a mixer type "WiseStir HS- 30D", at a temperature equal to  $35^\circ\text{C}$  for 60 min.

#### 3. Grinding

After the soaking operation, the potato peelings are crushed.

#### 4. Filtration and Centrifugation

All the crushed peelings were filtered through a muslin cloth and squeezed by hand to have a juice (starch milk). The filtrate is then centrifuged for 10 min at a speed of 5000 rpm. The starch is recovered by scraping afterwards dried in an oven at  $40^\circ\text{C}$  for 1 hour

#### 5. Purification

A purification of the recovered starch was carried out. The starch mass has been put suspended in 300 ml of water, filtered through a funnel, washed with 150 ml ethanol, air-dried, then weighed and stored in an airtight container.

all these steps are shown, in order, in figure 10

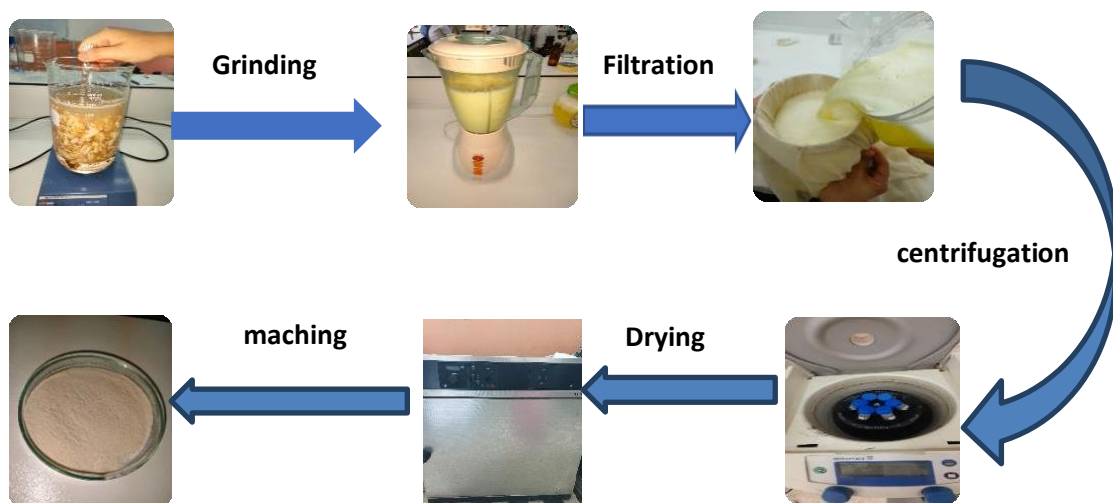


Figure 10 : protocol for extracting starch from potat peelings

### IV. Starch plasticization

The starch- plasticization steps for peelings and peeled tubers are the same, using the laboratory equipment listed below

#### IV. 1 Materials

- 100ml beaker
- Magnetic hot plate/stirrer
- Glass baguette Thermometer
- Graduated pipette
- petri dishes Hairdryer
- Spatula Oven



Figure 11: plasticizing materials and reagents.

#### IV.2. Reagent

The reagents used in the plasticizing step and their roles are presented in the following table.

Table 6: the various reagents used for plasticizing potato starch

Reagents	Role
Starch	Glucose polymer that makes up our material
Glycerol	Plasticizer, It simply increases the free volume between two polymer chains to reduce interactions and thus promote the movement of one in relation to the other, reduces heating, it makes the plastic film transparent, which is very practical at the application level. A film made is completely biodegradable and non-toxic.

Hydrochloric acid	Promote the destructuring of the starch grain by a phenomenon of managed hydrolysis. The separation of amylopectin / amylopectin and the passage of amylopectin in solution is then promoted.
Sodium hydroxide	Reduce the viscosity of the solution

### IV.3. Method:

The steps of starch plasticization are the same for peeled tubers and peels as follows (Djetouiet, Z, & al, 2012; Vikas Mishra et al, 2015)

1. In a beaker of 250ml is mixed 5 g of starch with 40ml of distilled water.
2. 6 ml of (HCL) a (0.1 mol/l) and 5ml of plasticizer (glycerol) (solution Aqueous at 50% by volume)
3. The whole and placed in a water bath and mixed with a baguette Of glass agitation.
4. the temperature was measured using a thermometer, when the temperature Reaches 90 ° c is added 2ml d (NaOH) (0.1mol /l)
5. continued stirring for 8 minutes and added 2 ml of (NaOH) for Neutralize the mixture
6. The resulting mixture is poured in to a well-spread glass plate, then Place in an oven at 40°C for one hour
7. finish drying with hair dryer (it must be placed about ten cm from the Film), then peel off the film gently to turn it over to dry it completely.

### V. Starch extraction yield:

The yield of starch extraction from peeled tubers and peelings was expressed as a percentage and calculated according to the following formula (Kundu et al.2011)

$$Y = (M_1 / M_0) \cdot 100$$

**Y:** extraction yield in %.

**M<sub>1</sub>:** mass in grams of the final extract.

**M<sub>0</sub>:** mass in grams of the initial plant material.

### VI . Bioplastic yield:

The yield of the bioplastic produced was expressed as a percentage and calculated using the starch extraction yield formula.

$$Y = (M_1 / M_0) \cdot 100$$

**Y (%):** bioplastic yield.

**M<sub>0(g)</sub>:** mass of starch used

$M_{1(g)}$ : mass of bioplastic.

## VII. Characterization of bioplastic obtained:

The bioplastic obtained was characterised to assess its final quality. This characterisation was based on a number of tests relating to the visual appearance, mechanical properties and water composition of the biopolymer.

### ➤ Macro et microscopic aspects of bioplastic films

The bioplastic films obtained was observed under binocular and microscope (magnification x10) to appreciate some visual characters .

### ➤ Biodegradability test

The biodegradability of the samples (bioplastic) was assessed by measuring the mass loss of composites as a function of time in a compost environment. Samples of size 30 mm \* 30 mm were weighed and buried in compost boxes. The samples were buried at a depth of 12 to 15 cm. A biodegradability test was also performed on samples without the addition of compost (control sample). After 2 days, the buried samples were removed, washed with distilled water then dried in an oven at 50 ° C for 8 hours and balanced on a desiccant (CaSO<sub>4</sub>) for 4 hours. The samples were then weighed before returning them to the compost at 2-day intervals over a period of 25 days (**wu, July 2011**)

- The mass loss assessment was calculated using the following formula:
- 

$$\text{Mass loss \%} = \left[ \frac{(m_f - m_i)}{m_i} \right] \cdot 100$$

With:

$m_f$ : The final mass of the sample tested;  $m_i$ : The initial mass of the sample tested. This ratio is, in general, negative due to the weight lost.

### ➤ Humidity test :

Moisture in general encompasses all substances that evaporate By heating by causing a loss of mass of the sample. The humidity level of Films, which are confused with the moisture content of these, was determined by drying small. Pieces of prepared films previously weighed in an oven at 110 °C for 6 h (**Belibi et al. 2014**).

### ➤ Solubility test :

Before the test, the samples were cut and dried at 105 ± 2 °C to determine their initial weights. Water solubility of bioplastic films was determined by immersing 10 × 10 × 3 mm samples in 30 cm<sup>3</sup> distilled water. After 24 h immersion the samples were taken from the beaker. Then, the samples were dried at 105 ± 2 °C for 5 h to determine their final weight. The percentage of water solubility was calculated using the following equation:

$$R_s = \frac{(M_f - M_i)}{M_d} \cdot 100$$

$R_s$ : solubility rate

$M_i$ : initial mass

$M_f$ : final mass

➤ **Opacity:**

The opacity of the films was determined by measuring the optical density of the films cut into rectangular pieces with a size of 1×4 cm at a wavelength of 500 nm. Subsequently the opacity was calculated according to the following equation described by (Gontard N., 2017)

**Opacity = absorbance at 500 nm / thickness of bioplastic film**

The thickness of the bioplastic film was measured under an optical microscope at x10 magnification, using a micrometer eyepiece shown in figure xxx.

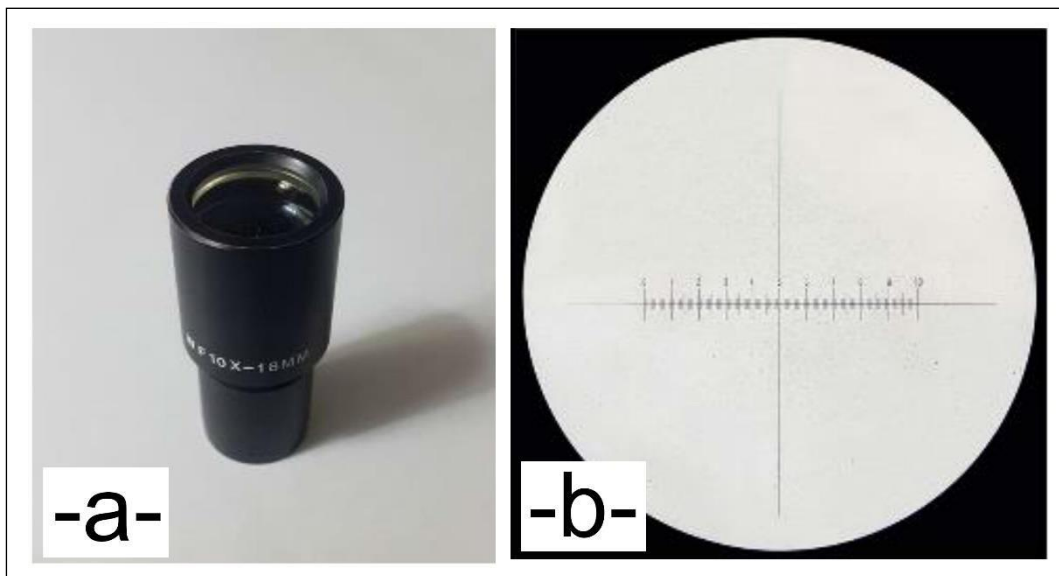


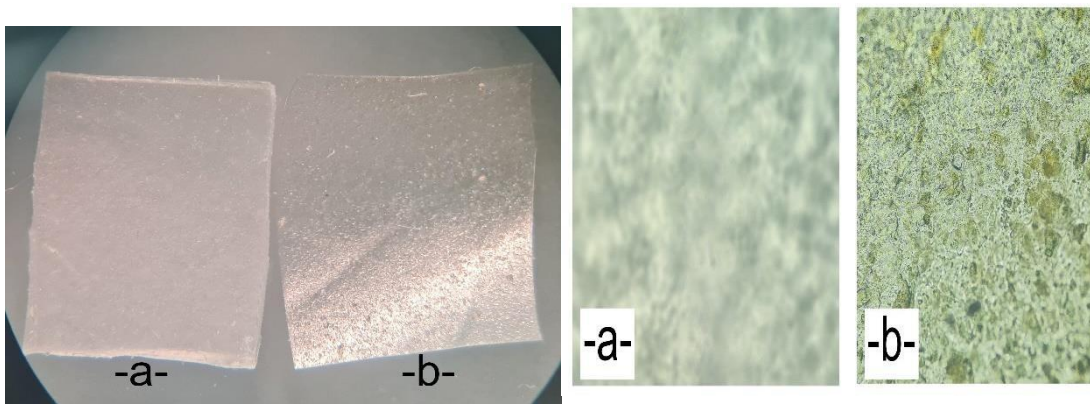
Figure 12: (a) Microscopic eyepiece WF 10X/18mm ; (b) microscopic field showing graduations for measuring dimensions.

# **PART III**

## **RESULTS AND DISCUSSION**

## I. visual Observation

According to the observations shown in figure 13 drawn up under a binocular and microscope. we noted a difference in the surface plane. which was perfectly smooth with a homogeneous texture observed under the microscope (figure 13) for tuber-based bioplastics. whereas the opposite was observed for peel-based bioplastics: rough surface. heterogeneous texture (figure 13 ( b)).



**Figures 13:** Macroscopic aspect under binocular: a) Tuber-based Bioplastic; b) Peeling-based Bioplastic

**Figure 14:** Microscopic aspect under microscope (magnification x10): a) Tuber-based Bioplastic; b) Peeling-based Bioplastic

## II . Mechanical Properties

Depending on the temperature and the drying time. two types of bioplastic are obtained:

- Flexible bioplastic for a temperature of 90°C for one hour
- Rigid bioplastic for a temperature of 130°C for one hour.
- Bioplastic obtained is transparent

Applying a temperature of 130°C during heat treatment led to more advanced drying of the bioplastic compared with treatment at 90°C. This higher temperature led to a significant removal of the water initially present in the biopolymer. resulting in a rigid. non-flexible appearance of the final material obtained. This suggests that temperature plays a crucial role in bioplastic properties during manufacture.

### III . Starch extraction yield

the results of starch extraction obtained from 500g of tubers and 400g of peelings respectively are shown in the following figure :

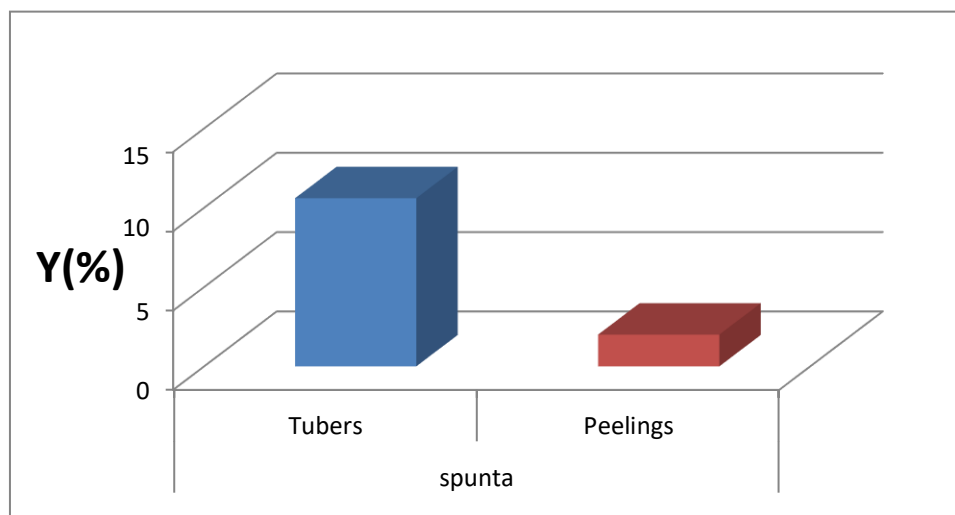
**Table7** : calculation of extracted starch yield

Family	Method	M0(g)	M1(g)	Y(%)
SPUNTA	Tubers	500	53	10.6
	Peelings	400	8	2

$Y(\%)$ =extracted starch yield.

$M0(g)$ = mass in grams of potato used.

$M1(g)$  = mass in grams of starch extracted.



**Figure 15** : Yield of extracted starch

The results show a significant difference in yield between tubers and peelings. Tubers showed a starch extraction yield five times higher than that of peels. This difference can be explained by the higher proportions of starch present in the tubers compared with the peelings. Tubers contained a high concentration of starch(16%)(**Bernhards. 1998**). . which facilitated extraction at higher yields. In contrast. peelings contained a lower

proportion of starch(7.8) (**Igor Sepelev.2015**) necessitating a more complex extraction protocol using acid hydrolysis.This resulted in lower extraction yields for the peels.

**IV . Yield of bioplastic:**

5g of dry matter (in powder form) obtained from the extraction of starch from tubers and peelings. were used to produce the bioplastic the results obtained are shown in the following table .

**Table8** : the yield of Bioplastic Films

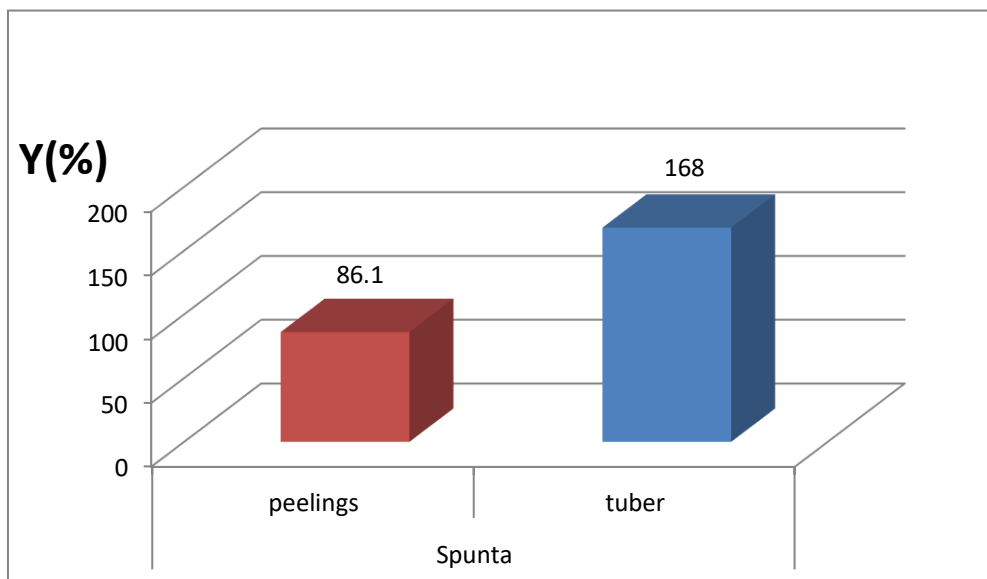
Family	Type of biomass used	M0(g)	M1(g)	Y(%)
SPUNTA	peeling	5	4.305	86.1
	tuber	5	8.4	168

Y(%)=bioplastic yield

M0(g)= mass of starch used

M1(g)= mass of bioplastic

**Figure 16** :Yield of bioplastic films



according to starch plasticization yield. it was found that starch from tubers was almost twice as high as that from peelings. This can be explained by the chemical difference

between the starch extracted from the two sources. Some of the dry matter extracted from peelings, assumed to be starch, turned out to be chemically different (impurities). These impurities reduced the plasticization yield, as they do not interact with the reagents added to form the bioplastic (glycerol.hydrochloric acid.sodium hydroxide).

V . Characterization of bioplastic obtained

1. Biodegradability Test

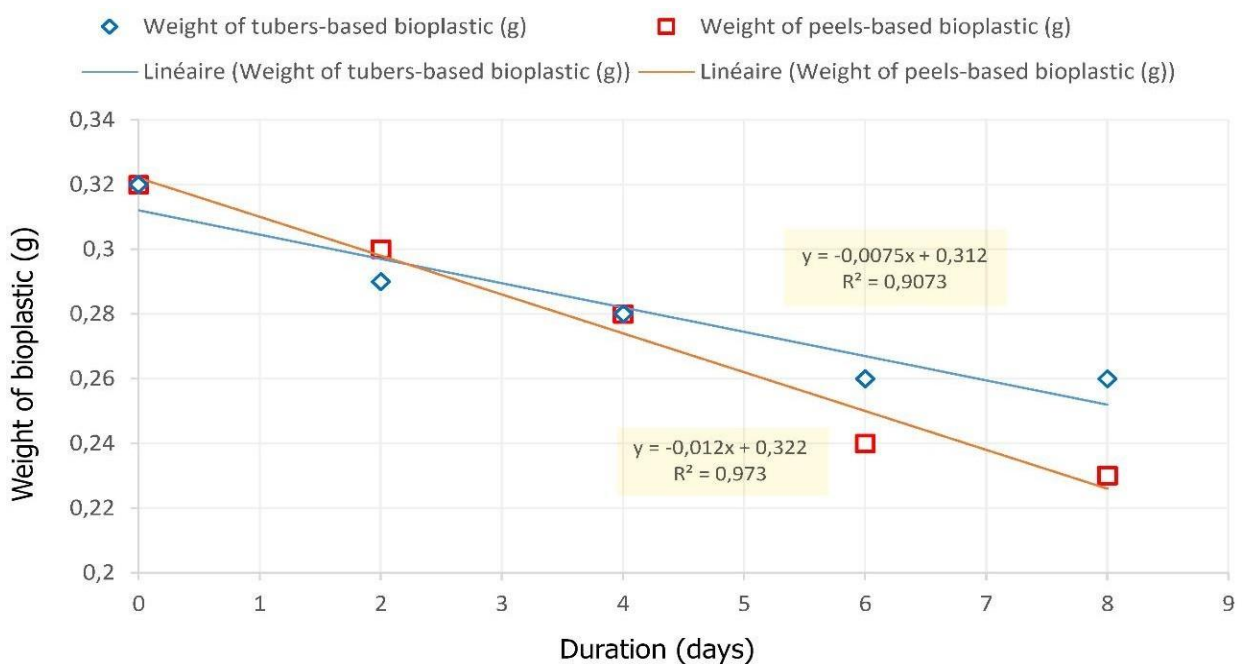


Figure 17 : linear regression of biodegradability test applied on bioplastic films

According to the results obtained, shown in figure ( ), the degradation rate of peel-based bioplastics was faster than that found for tuber-based bioplastics. This degradation rate is calculated by the regression line, which is equal to 0 . 012g/d for peelings whereas it was equal to 0.075 for tubers. This means that a quantity of bioplastic of 0.32g is totally degraded after 26 days and 19 hours in the case of peelings whereas this total degradation is produced after 41 days and 8 hours for tubers.

## 2 . Humidity Test

the following figure shows the moisture content of bioplastic films(tuber-based Bioplastic and peeling-base Bioplastic).

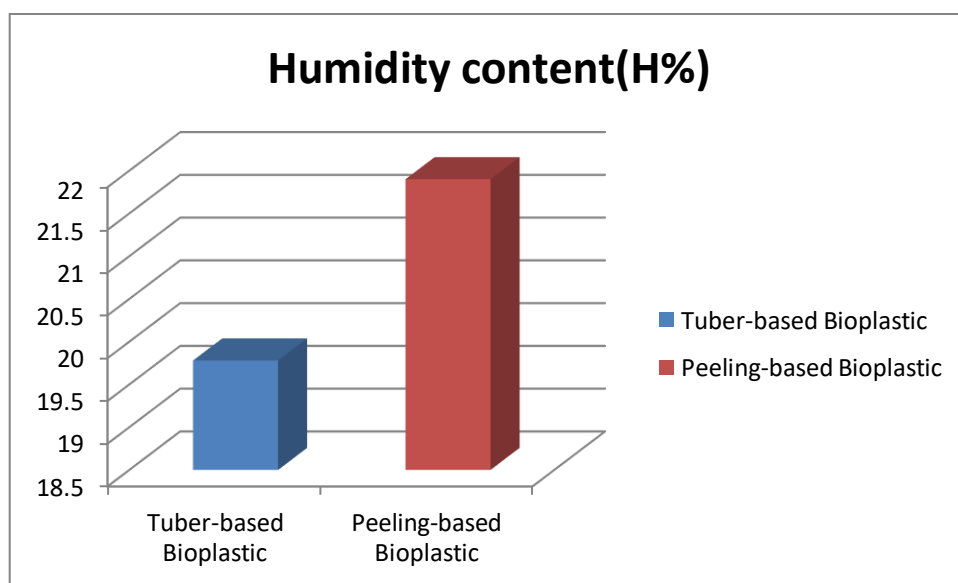
**Table 9** : moisture content of bioplastic films.

	<b>Initial Mass(MI)</b>	<b>Final Mass(Mf)</b>	<b>Humidity content(H%)</b>
<b>Tuber-based Bioplastic</b>	2.838	2.27	19.78
<b>Peeling-based BIOPLASTIC</b>	2.838	2.21	21.9

**M<sub>i</sub>(g)**= mass of bioplastic films before testing

**M<sub>f</sub>(g)**= mass of bioplastic films after testing

**H(%)**=Humidity content



**Figure 18:** Humidity content of different films

The results revealed a negligible difference in the moisture content of the bioplastic. This suggests that the different experimental conditions had no significant impact on the moisture content of the final material. A constant moisture content may be beneficial for ensuring consistent stability and properties of the bioplastic.

### 3 . Solubility Test

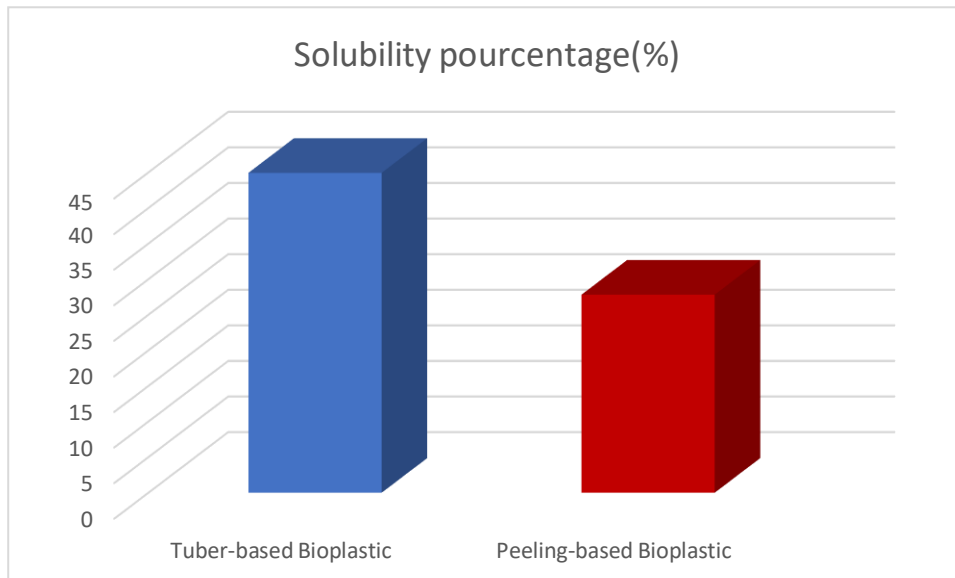
**Table10 :** Solubility content of bioplastic films.

	<b>Mi(g)</b>	<b>Mf(g)</b>	<b>Solubility pourcentage(%)</b>
<b>Tuber-based Bioplastic</b>	2.397	1.32	44.93
<b>Peeling-BASED BIOPLASTIC</b>	2.397	1.73	27.82

Mi(g) : solubility of films before test.

Mf(g) : solubility of films after test.

S(%) :pourcentage of solubility.

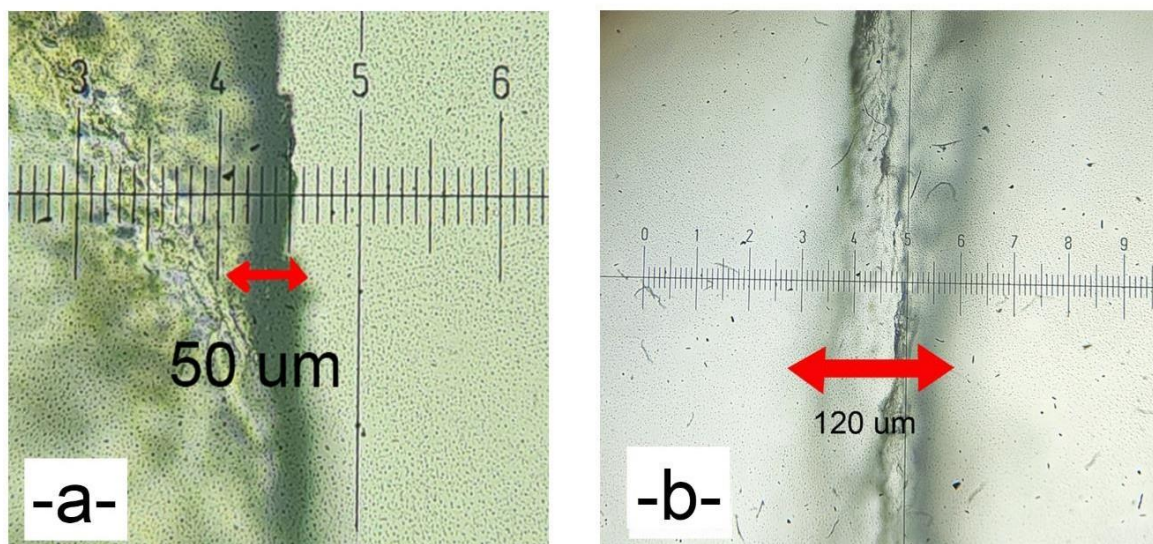


**Figure 19:**Solubility of different films.

Based on the results obtained, the solubility of the tuber-based bioplastic film proved to be doubly more soluble in water than that obtained from the peelings

#### 4. Film opacity

The opacity of the films was determined by the ratio between the absorbance of films which is measured by a spectrometer of 500 nm and their thickness measured under an optical microscope at x10 magnification. using a micrometer eyepiece shown in figure (19)



**Figure 20:** Thickness of : a- peeling-based film ; b- tuber-based film.

**Table 11:** Results of plastic film opacity calculation.

Type of films	Thickness(um)	Absorbance	Opacity
Tuber-based films	130	0.388	$2.9 \cdot 10^{-3}$
Pelling-based films	50	0.328	$6.5 \cdot 10^{-3}$

according to the table showing the results obtained from the calculation of the film opacity . taking into consideration their respective thicknesses. we constant that the opacity of peeling-based film is almost 2 times greater( $6.5 \times 10^{-3}$ ) than noticed for tuber-based film ( $2.9 \times 10^{-3}$ ). This suggests that the presence of impurities in peeling-films considerably increase their opacity. Microscopic observations of the films confirmed the presence of a large number of particles (c.f figure 13). generally of green hue. responsible for the absorption of light beams corresponding to the green spectrum of light applied during the opacity test (500 nm).

# **GENERAL CONCLUSION**

## **General conclusion**

Based on the results obtained, we deduced that using potato peels as a source of starch to produce bioplastic required a more complex extraction protocol than that applied to tubers, involving an additional acid hydrolysis and centrifugation stage, which will have a major impact on the large-scale production of bioplastic (logistics employed, production and marketing costs). The extra cost of producing bioplastic from peelings is amplified by the mediocre extraction and plasticization yield. As for the quality of the bioplastic film obtained, it has been shown to be superior with a fine polymer when the starch is extracted from the tubers. The initial target was achieved by producing a polymer that degrades 300 times faster than conventional plastic, however it is important to optimize the extraction and plasticization protocol by varying certain parameters (e.g., plasticizing temperature, soaking time ...) and reactives this would increase the yield and quality of the bioplastic .

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