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# Optimization of Synthesis Parameters and Biodegradability of A Bioplastic based on Potato Starch Enriched with Coconut Fibers

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**ABSTRACT**

In response to the environmental challenges posed by petrochemical plastics, this study focused on developing bioplastics from sweet potato starch reinforced with coconut fibers. Response Surface Methodology (RSM) was employed to optimize key performance parameters, including solubility, chemical resistance, and water absorption. The starch was used in both native and oxidized forms, while the coconut fibers were treated with an alkaline solution. The main influencing factors identified were the starch mass ($m_s$), fiber mass ($m_f$), and glycerol volume ($V_g$). Optimal formulations were found to be $m_s$ = 3 g, $m_f$ = 0.25 g, and $V_g$ = 1 mL for native starch; and $m_s$ = 2.69 g, $m_f$ = 0.25 g, and $V_g$ = 1 mL for oxidized starch. Biodegradability tests conducted in three different soil types revealed that bioplastics made with oxidized starch, although less biodegradable, demonstrated superior chemical stability. This research offers a promising pathway for the local development of sustainable, eco-friendly packaging materials.

**Keywords:** Oxidized starch, Fibers, Response surface methodology, Bioplastic, Biodegradability.

## INTRODUCTION

Plastic waste, particularly from petrochemical plastics, represents a significant portion of municipal solid waste and is largely non-biodegradable. According to Tripathi *et al.,*[1], the use of petrochemical plastics will lead to an annual production of 850 million tons of waste by 2050. These petrochemical plastics are commonly used in domestic packaging applications and in the industrial sector. They are often directly discharged into the environment, leading in many cases to varying levels of pollution. On a global scale where sustainable development is a priority, petrochemical

plastic waste raises growing environmental and health concerns[2]. To address the problems associated with petrochemical plastic waste, significant attention has been paid in recent years to the development of biodegradable plastic materials from bio-resources[3,4]. These biodegradable plastic materials are generally known as bioplastics[5]. The development of bioplastics aims to sustainably preserve the environment and reduce the health risks associated with the proliferation of petrochemical plastic waste[5]. It is in this context that the synthesis of bio-based plastics contributes to the pursuit of sustainable development. Bio-based plastics are obtained from bio-based polymers such as polysaccharides, proteins, lipids, or from substances derived from microorganisms[6]. Bio-based plastics or bioplastics can also be synthesized from mixed biological substances[7]. In recent years, several studies have been devoted to the development of bioplastics[8] from the perspective of their synthesis, mechanical aspects, toxic aspects[9], biodegradability, etc., through mechanical approaches. These works aim to find bioplastics that are safe for health, biodegradable, and low-cost. One of the difficulties in improving both the mechanical responses and biodegradability of bioplastics lies in the composition of the reagents used in the synthesis[1]. In the present study, Response Surface Methodology (RSM) is used to optimize responses (Solubility, Chemical Resistance, and Water Absorption) of bioplastics synthesized from sweet potato starch, using coconut fibers as reinforcement. The general objective of this study is to optimize responses in the synthesis of bioplastics based on sweet potato starch reinforced with coconut fibers.

## MATERIALS AND METHODS

### Study Bioresources

Sweet potato tubers *(Ipomoea batatas)* were harvested from the field edge in Lokaha[2] (9°45'; -5°37'), a village located 5 km from the town of Sinématiali, in the Northern region of Côte d'Ivoire (Fig. 1). The tubers were then placed in a plant fiber bag and transported to the laboratory. Fresh, mature coconuts *(Cocos nucifera)* were harvested in the city of Abidjan (Côte d'Ivoire), more precisely in the commune of Port-Bouët, to obtain the plant fibers used as reinforcements in the study (Fig. 2). The fresh coconuts were then placed in a plant fiber bag and transported to the laboratory.

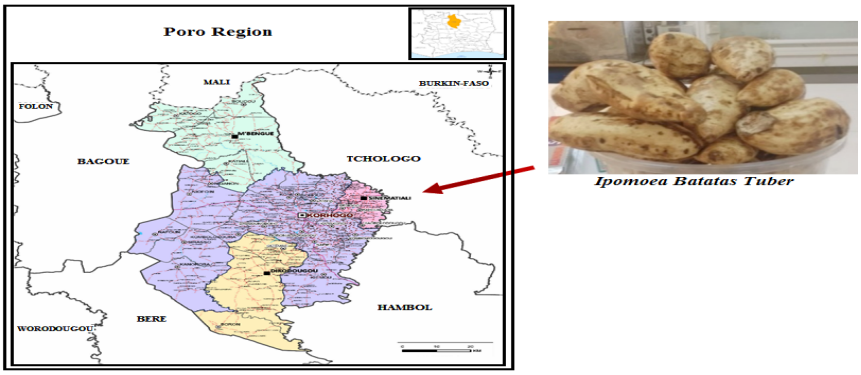


**Fig. 1. Potato collection sites (Map Source : Anstat[10])**

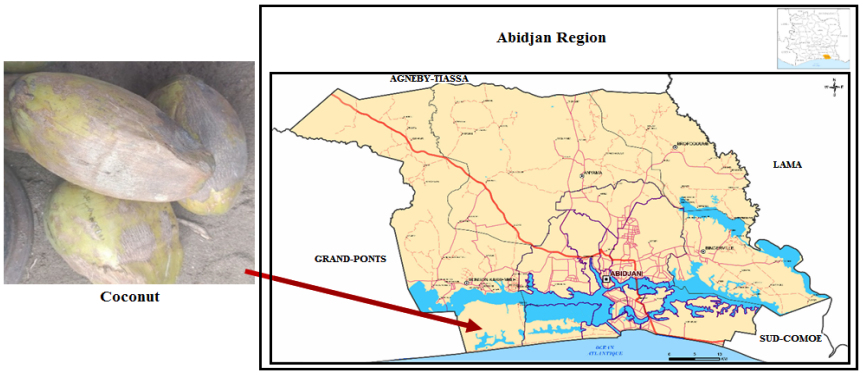


**Fig. 2. Coconut collection sites (Map Source : Anstat[11])**

**Extraction of Native Starch and Fibers**

The transported tubers were abundantly washed with distilled water to remove soil residues and other impurities. The method used for starch extraction was described by[12] with some modifications. A batch of 8 kg of tubers was considered for starch extraction. After peeling, the pieces were carefully washed with distilled water, then placed in a laboratory blender (Luxtrend, professional blender) to be ground with distilled water in a 1:1 ratio. After grinding, the mash was transferred to a crystallizing dish, then filtered using a 100 µm sieve (Saulas, Paris) to collect the starch milk for the next step of extraction. The milk was decanted for 1 h, then the supernatant was carefully removed to obtain a paste representing the crude starch. This crude starch then underwent purification steps to remove residual proteins and lipids. To do this, the paste was successively washed with a 4% NaCl solution and an ethanol solution (0.1M) through a multiple decantation process. The paste was washed with distilled water to obtain purified starch paste. The purified paste was then dried in an oven (Memmert, France) for 24 h at 105°C to obtain the native starch for the study (Fig. 3(a)). In the laboratory, the coconuts were carefully washed, and then the fibrous part *(mesocarp)* was manually separated from the shell by peeling. The mesocarps obtained were completely immersed in a 4% NaOH solution and left to macerate for 24 hours. The obtained fibers were then washed until neutral pH with distilled water and then dried at 105°C in the oven for 24 hours. After drying, the fibers were ground using a laboratory grinder (Luxtrend, professional blender), then sieved using a sieve (Saulas, Paris) with a 250µm mesh diameter (Figures 3(b)).

(a) (b)

**Fig. 3. Native starch and fibers of the study (Source : Study's photo)**

**Native Starch Oxidation**

The oxidation of a portion of the previously obtained native starch was carried out according to the method described by Hamed *et al.,*[13], with some modifications. A quantity of 100 g of native starch was placed in a 1 L Erlenmeyer flask, then 500 mL of a 0.2 M hydrogen peroxide $H_2O_2$ solution were added. The Erlenmeyer flask was covered with aluminum foil and placed on a shaker (Biobock Scientific) for agitation for 24 hours. After agitation, the solution was decanted, the supernatant removed to obtain a paste. The obtained paste was washed several times with distilled water to remove residual hydrogen peroxide, then dried at 105°C for 24 hours. The obtained dry residue represents the oxidized starch from the native starch.

**FTIR Analysis**

The study of the surface functional groups of the starches and fibers was performed by Fourier Transform Infrared spectrophotometry using a spectrophotometer (Agilent Cary 630 FTIR, Santa Clara, California, USA), equipped with an ATR module in the wavenumber range from 4000 $cm^{-1}$ to 500 $cm^{-1}$.

**Classical Synthesis**

He synthesis of the study's bioplastics is based on the method described by Azmin *et al.,* (2020)[14] with some adjustments. A mass $m_s$ (g) (g) of starch is introduced into a 250 mL beaker, then successive additions of mass $m_f$ (g) of fibers, $V_{water}$ (mL) of water, $V_g$ (mL) of glycerol, and $V_{HCl}$(mL) of HCl (0.1M) are made. The mixture is stirred manually using a glass rod, then placed on a hot plate at 120°C while maintaining constant agitation for a given time $t_i$. During agitation, a volume $V_{NaOH}$ of NaOH (0.1M) is added when the viscosity of the mixture becomes significant and slows down the agitation. The mixture

is heated on a hot plate stirrer while stirring with the spoon until it becomes translucent, taking care not to reach boiling. The process is maintained until a viscous and pasty solution is obtained. After adding NaOH, the mixture is poured onto cold glass plates using a glass spatula. The plates are then dried at room temperature for 120 h, and the resulting bioplastics are manually detached.

**Common Physico-ChemicalResponses**

**Water Solubility**

A mass $m_0$ of bioplastic, previously dried at room temperature for 120 h, is introduced into a 250 mL beaker containing 50 mL of distilled water. The beaker is covered with parafilm, then placed on a vibrating shaker at 150 rpm for 24 hours. The bioplastic is then removed by gravity filtration and dried again at room temperature to obtain a new mass m measured using a precision balance. The solubility S of the bioplastic is given by equation (1):

$$S(\%) = \frac{m_0 - m}{m_0} \times 100 \quad (1)$$

Where:

S: Water solubility of the bioplastic( % )
$m_0$: Initial mass of the sample (g)
m: Final mass of the sample (g)

**Chemical Resistance**

The chemical resistance of the bioplastic was evaluated in an acidic medium. A mass $m_0$ of bioplastic, previously dried at room temperature for 120 h, is introduced into a 250 mL beaker containing 40 mL of a 1 M acetic acid ($CH_3COOH$) solution. The beaker is covered with parafilm, then placed on a vibrating shaker at 150 rpm for 24 hours. The bioplastic is then removed by gravity filtration and dried again at room temperature to obtain a new mass mmeasured using a precision balance. The chemical resistance R of the bioplastic is given by the following equation (2):

$$R(\%) = \left(1 - \frac{m_0 - m}{m_0}\right) \times 100 \quad (2)$$

Where:
R: Chemical resistance of bioplastic (%.)
$m_0$: Initial mass of the sample (g)
m: Final mass of the sample (g)

**Moisture Content**

A mass $m_0$ of bioplastic is placed in a crucible of known tare mass. The whole is brought to drying in an oven at 105°C for 24 hours. The mass of the dry sample noted m1 is obtained by subtracting the tare mass of the crucible after cooling. The moisture content H of the sample is given by the following expression:

$$H(\%) = \frac{m_0 - m_1}{m_0} \times 100 \quad (3)$$

Where:
H : Water moisture content (%) (%)
$m_0$ : Mass (g) of crucible+sample (before drying)
$m_1$ : Mass (g) of crucible+sample (after drying)

**Water Absorption Rate**

The mass $m_1$ of bioplastic, previously dried in the oven for 24 h, is introduced into a 250 mL beaker containing 50 mL of distilled water. The beaker is covered with parafilm, then left standing for 24 hours. The bioplastic is then removed by gravity filtration, and the new mass $m_2$ is measured using a precision balance. The water absorption rate (Ab) of the bioplastic is given by the following equation (4):

$$Ab(\%) = \frac{m_2 - m_1}{m_1} \times 100 \quad (4)$$

Where :
Ab : Water absorption rate (%).
$m_1$ : Dry mass of the bioplastic (g)
$m_2$ : Mass of bioplastic (g) after immersion in water.

**Experimental Design for SynthesisOptimization**

In the first part of the study, Response Surface Methodology was applied to optimize the synthesis of bioplastics. To do this, synthesis parameters such as starch mass, fiber mass, and glycerol volume, which are likely to influence the solubility (S), chemical resistance (R), or water absorption (Ab) of the bioplastic, were selected after screening using the Ishikawa fishbone method[15]. The optimization of the synthesis by Central Composite Design (CCD) involved these three variables or factors. The CCD is divided into three parts: the factorial design, the star points, and the center point of the study domain. The factorial points nfof the two-level factorial design are located at the vertices of the study domain. The axial points n$\alpha$ of the star design are located on the axes and equidistant from the center of the study domain. It is assumed that the axial points are at the same distance $\alpha$ from the

center of the study domain. The center points $n_0$ are planned at the center of the study domain. The value of $\alpha$ is given by the following equation[16].

$$\alpha = \left( \frac{n_f \left( \sqrt{n_f + n_\alpha + n_0} - \sqrt{n_f} \right)^2}{4} \right)^{\frac{1}{4}} \quad (5)$$

The total number of experiments N to be performed for a central composite design is given by the expression:

$$N = n_f + n_\alpha + n_0 \quad (6)$$

The postulated response model (y = (S, R, Ab)) for three factors is given by the following equation:

$$y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_{12} x_1 x_2 + a_{13} x_1 x_3 + a_{23} x_2 x_3 + a_{11} x_1^2 + a_{22} x_2^2 + a_{33} x_3^2 + \varepsilon \quad (7)$$

In this study, preliminary tests led to setting the water volume $V_{water}$ to 20 mL, as well as the volumes of HCl ($V_{HCl}$) and NaOH ($V_{NaOH}$) to 1 mL. The heating duration was also set to 5 min and all tests were performed at room temperature. The design of the central composite plan, regression analysis, graphical data analysis, examination and ANOVA of the results, and the main graphs related to the response surface methodology were performed using the statistical modeling tool Design Expert (version 13.0.5.0). The study domain as well as the experimental matrix are given in Table 1. Thus, for each type of starch (native or oxidized), 20 trials were performed according to the experimental matrix (Table 2).

**Table 1: Study Domain**

| Factor | -α (-1.68) | Lowlevel (-1) | Central level (0) | High level (+1) | +α (+1.68) |
|---|---|---|---|---|---|
| $x_1$ : Starch mass (g) | 0.318 | 1 | 2 | 3 | 3.681 |
| $x_2$ : Fibers mass (g | 0.072 | 0.25 | 0.5 | 0.75 | 0.92 |
| $x_3$ : Glycerol volume (mL) | 0.318 | 1 | 2 | 3 | 3.681 |

**Table 2: Experimental Design and Expected Responses**

| N°Exp | $x_1$ : Starch mass (g) | $x_2$: Fibers mass (g) | $x_3$: Glycerol volume (mL) | S(%) | R(%) | Ab(%) |
|---|---|---|---|---|---|---|
| 1 | 2 | 0.5 | 0.318207 | | | |
| 2 | 2 | 0.5 | 3.68179 | | | |
| 3 | 0.318207 | 0.5 | 2 | | | |
| 4 | 1 | 0.75 | 1 | | | |
| 5 | 2 | 0.920448 | 2 | | | |
| 6 | 3 | 0.25 | 3 | | | |
| 7 | 2 | 0.5 | 2 | | | |
| 8 | 2 | 0.5 | 2 | | | |
| 9 | 2 | 0.5 | 2 | | | |
| 10 | 2 | 0.5 | 2 | | | |
| 11 | 2 | 0.5 | 2 | | | |
| 12 | 3 | 0.75 | 3 | | | |
| 13 | 1 | 0.75 | 3 | | | |
| 14 | 3 | 0.25 | 1 | | | |
| 15 | 1 | 0.25 | 1 | | | |
| 16 | 2 | 0.5 | 2 | | | |
| 17 | 2 | 0.0795518 | 2 | | | |
| 18 | 3 | 0.75 | 1 | | | |
| 19 | 3.68179 | 0.5 | 2 | | | |
| 20 | 1 | 0.25 | 3 | | | |

In the second part, the bioplastics were elaborated with the optimized values of factors allowing them to obtain simultaneously optimal responses with the highest desirability. These so-called optimized bioplastics were characterized by determining their moisture content, solubility, chemical resistance, and water absorption rate.

**Biodegradability of Optimized Bioplastics**

**Preparation of the Burial Matrix**

The biodegradability of the optimized bioplastics was evaluated by burial in three different matrices over a period of 15 days. The three matrices were prepared from soil collected in the botanical garden of the Peleforo GON COULIBALY University.

The collected soil was dried for 72 h at room temperature and sieved to retain a particle size ≤2 mm constituting the so-called normal soil matrix. Two other burial matrices were obtained from the normal soil. The so-called sterile soil matrix was obtained by calcining the normal soil at 600°C, in a muffle furnace for 1 hours. The third matrix, called soil enriched with microorganisms, was obtained by adding 25% of composted cow dung to the normal soil. This dung was collected from a farm located in Lokaha 2 in the department of Sinématiali. The composted dung was dried for 72 h at laboratory temperature and then sieved to obtain a particle size ≤2 mm.

**Burial in the Matricesand biodegradability**

The study of the biodegradability by burial of the optimized bioplastics was performed with samples of dimension 10 mm × 10 mm for an average thickness of 8 mm. A quantity of 50 g of each type of matrix was placed in a burial vial, then 5 mL of distilled water was added and the whole was homogenized. A bioplastic sample of known mass ($m_i$) to be buried was previously placed on a plastic mesh support. The sample and the support were then placed in a vial in direct contact with the matrix. The vial was closed and then placed away from oxygen for the entire period of biodegradability evaluation (Fig. 4). In total, for each type of matrix, five (5) burial vials were necessary for sequential study, throughout the burial period (15 days).

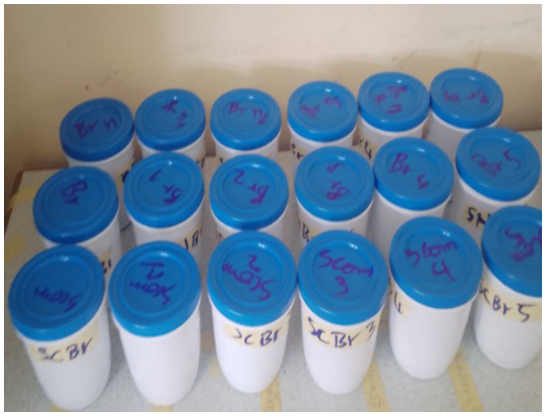

**Fig. 4. Burial vials(Source: Study's photo)**

At every 72-h interval during the biodegradability assessment, the masses of the buried bioplastics were measured.

The biodegradability is calculated according to the following formula :

$$Biodegradability = \frac{m_i - m_f}{m_i} \times 100 \quad (8)$$

## RESULTS

**FTIR Characterization of Bioresources**

The main functional groups of the study's bio-resources (native starch, oxidized starch, and fibers) were examined by infrared spectrophotometry. The results of this examination are presented in Fig. 5. The spectra of native starch (Am_nat) and oxidized starch (Am_ox) show common absorption bands located at 3245.82 $cm^{-1}$, 2913.60 $cm^{-1}$, and 992.75 $cm^{-1}$. However, the spectrum of oxidized starch shows an additional peak at 1711.82 $cm^{-1}$. The fiber spectrum shows absorption bands located at 3729.65 $cm^{-1}$, 2345.04 $cm^{-1}$, and 1003 $cm^{-1}$.

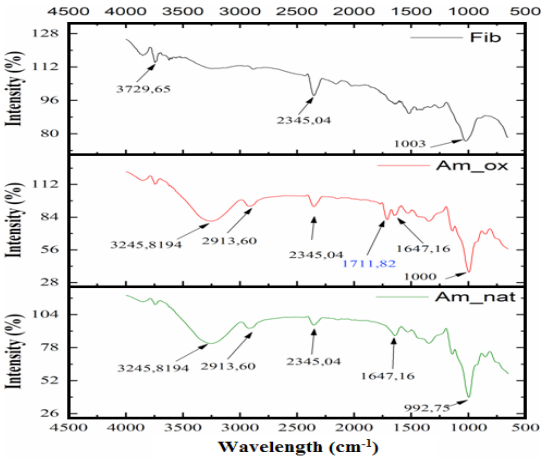


**Fig. 5. FTIR Spectra of Bio-resources**

**Optimization of Synthesis Responses**

The implementation of the central composite design with three (3) factors led to responses on the solubility (S), chemical resistance (R), and water absorption rate (Ab) of the bioplastics. The equations of the different responses obtained for native starch and oxidized starch according to the postulated quadratic model are given below.

**For native starch**

$$S_{nat} = 56{,}08 - 7{,}62x_1 - 1{,}73x_2 + 10{,}82x_3 + 2{,}44x_1x_2 + 0{,}55x_1x_3 + 0{,}53x_2x_3 + 0{,}14x_1^2 - 0{,}65x_2^2 - 4{,}64x_3^2 \quad (9)$$

$$R_{nat} = 41{,}98 + 8{,}08x_1 - 1{,}99x_2 - 10{,}46x_3 - 4{,}24x_1x_2 + 3{,}58x_1x_3 - 2{,}87x_2x_3 + 2{,}79x_1^2 + 1{,}10x_2^2 + 0{,}89x_3^2 \quad (10)$$

$$Ab_{nat} = 47{,}85 - 4{,}94x_1 - 2{,}53x_2 - 4{,}65x_3 + 2{,}80x_1x_2 - 7{,}19x_1x_3 - 8{,}29x_2x_3 + 7{,}61x_1^2 - 4{,}36x_2^2 + 5{,}47x_3^2 \quad (11)$$

**For oxidized starch:**

$$S_{ox} = 60{,}61 - 7{,}49x_1 + 0{,}40x_2 + 11{,}25x_3 - 1{,}36x_1x_2 + 2{,}41x_1x_3 + 2{,}20x_2x_3 - 1{,}20x_1^2 - 2{,}77x_2^2 - 3{,}16x_3^2 \quad (12)$$

$$R_{ox} = 40{,}24 + 7{,}41x_1 + 1{,}02x_2 - 9{,}14x_3 - 2{,}54x_1x_2 - 6{,}08x_1x_3 + 2{,}77x_2x_3 + 0{,}90x_1^2 + 4{,}46x_2^2 + 3{,}41x_3^2 \quad (13)$$

$$Ab_{ox} = 33{,}74 - 6{,}10x_1 - 4{,}06x_2 + 1{,}68x_3 + 3{,}98x_1x_2 - 9{,}18x_1x_3 - 2{,}25x_2x_3 + 7{,}90x_1^2 + 0{,}96x_2^2 + 6{,}21x_3^2 \quad (14)$$

### Statistical Analysis of Responses

The different quadratic models obtained with fibrous bioplastics based on native starch and oxidized starch were subjected to statistical analysis (Table 3).

**Table 3: Statistical Analysis of Quadratic Models**

| | | $S_{nat}$ | $S_{ox}$ | $R_{nat}$ | $R_{ox}$ | $Ab_{nat}$ | $Ab_{ox}$ |
|---|---|---|---|---|---|---|---|
| | Model p-value | 0,0035 | 0,0002 | 0,0156 | 0,0035 | 0,049 | 0,038 |
| Model cœfficients | a1 | 0,0022 | 0,0002 | 0,0059 | 0,0024 | 0,1413 | 0,087 |
| | a2 | 0,3759 | 0,7631 | 0,4119 | 0,5917 | 0,4332 | 0,2355 |
| | a3 | 0,0002 | < 0.0001 | 0,0011 | 0,0006 | 0,1633 | 0,6123 |
| | a12 | 0,3408 | 0,4417 | 0,1922 | 0,3151 | 0,5034 | 0,3665 |
| | a13 | 0,8263 | 0,1857 | 0,2648 | 0,0299 | 0,1053 | 0,0539 |
| | a23 | 0,8316 | 0,2238 | 0,3655 | 0,2764 | 0,0672 | 0,6049 |
| | a11 | 0,9394 | 0,3639 | 0,2444 | 0,6254 | 0,03 | 0,0302 |
| | a22 | 0,7256 | 0,0535 | 0,6373 | 0,0319 | 0,1782 | 0,7654 |
| | a33 | 0,0287 | 0,0313 | 0,7006 | 0,0862 | 0,0992 | 0,0757 |
| Validation parameters | LOF | 0,4988 | 0,5171 | 0,0057 | 0,1152 | 0,3663 | 0,019 |
| | R2 ajusted | 0,7244 | 0,8573 | 0,6133 | 0,5211 | 0,4673 | 0,4835 |
| | R2 prédicted | 0,31 | 0,6664 | -0,5005 | 0,3288 | 0,4109 | 0,4464 |

The examination of the p-values of the models allowed for the evaluation of the representativeness of equations 9 to 14. It appears that regardless of the starch used, the responses S, R, and Ab present a p-value <0.05, meaning that each regression model is representative and partly explains the variations in the responses. However, the examination of the lack of fit (LOF) and the comparison between adjusted $R^2$ and predicted $R^2$ leads to examining the significance of the coefficients. For the optimization process, a second analysis was performed by decomposing each quadratic model into 3 components: linear, two-factor interaction (2FI), and square component. This led to retaining only linear regressions for the responses $S_{nat}$, $S_{ox}$, and $R_{nat}$ with values of adjusted $R^2$ and predicted $R^2$ very close. The responses $Ab_{nat}$, $R_{ox}$, and $Ab_{ox}$ are better described by the quadratic model, meaning the presence of curvatures in the response surface.

### Optimization

The regression models obtained from the statistical analysis allowed for the search, for each type of starch, of the combination of experimental factors that optimize the different responses by maximizing the combined desirability. To do this, the constraints chosen for the different responses consisted of minimizing solubility and absorption rate, while maximizing chemical resistance. Importance was given to chemical resistance compared to solubility and absorption rate, in the response parameterization process. The optimization results are presented in Fig. 6 for native starch and Fig. 7 for oxidized starch.

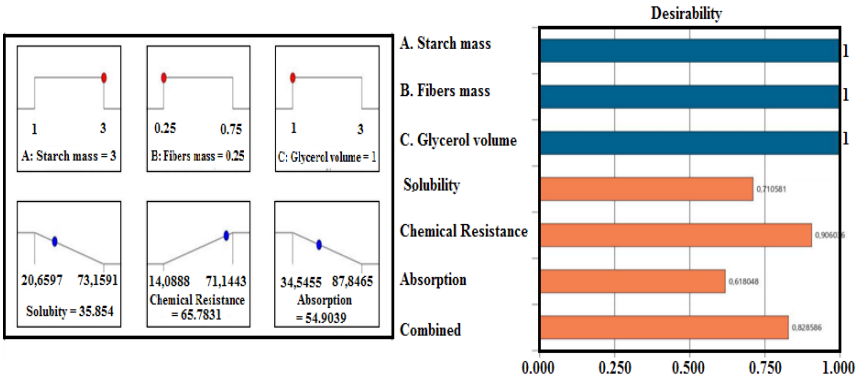


**Fig. 6. Optimal values of factors, response prediction and desirability for the bioplastic based on native starch**

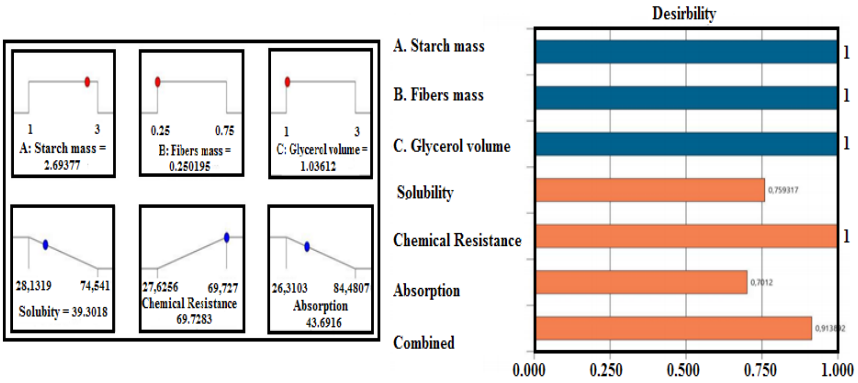


**Fig. 7. Optimal values of factors, response prediction and desirability for the bioplastic based on oxidized starch**

For native starch, the optimal formulation achieved a desirability score of 0.828 with the following factor values: starch mass of 3 g, fiber mass of 0.25 g, and glycerol volume of 1 mL. In comparison, the oxidized starch formulation yielded a higher desirability of 0.913, corresponding to a starch mass of 2.7 g, fiber mass of 0.25 g, and glycerol volume of 1 mL.

## Biodegradability of Optimized Bioplastics Characteristics

The optimized bioplastics were obtained from the previous optimization. Based on the optimal values, four (4) types of bioplastics were synthesized from native starch and oxidized starch. For a given starch, the fibrous bioplastic (BF) was synthesized along with a control counterpart (BC) without fibers Figure 8.

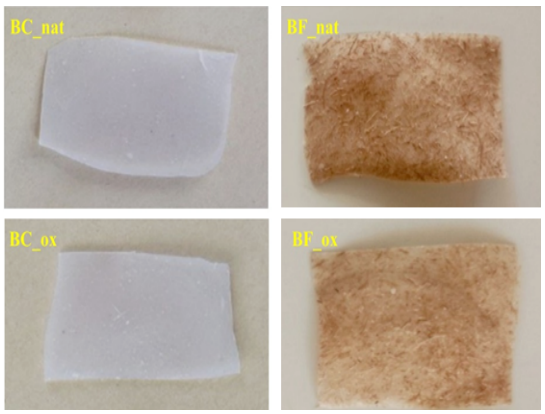


**Fig. 8. Optimized bioplastics**

Characteristics such as chemical resistance (R), solubility (S) in water, water absorption (Ab) of the optimized bioplastics were determined to validate the optimization process. The moisture content of the bioplastics was also determined. The results obtained are recorded in Table 4.

**Table 4: Some compared characteristics of optimized bioplastics**

| | Solubility S (%) | | Chemicalresistance R (%) | | Absorption Ab (%) | | Moisture content |
|---|---|---|---|---|---|---|---|
| | Exp | Pred | Exp | Pred | Exp | Pred | H (%) |
| BF_ox | 38,80 | 39,30 | 68,89 | 69,73 | 45,08 | 43,69 | 7,02 |
| BC_ox | 37,78 | | 66,93 | | 48,80 | | 8,03 |
| BF_nat | 33,73 | 35,85 | 65,22 | 65,78 | 52,33 | 54,90 | 8,03 |
| BC_nat | 33,67 | | 62,59 | | 56,28 | | 8,03 |

Analysis of Table 4 shows that bioplastics have a low moisture content (< 10%). It is observed that oxidation reduces the moisture content of bioplastics only if fibers are introduced. However, this introduction of fibers has no significant effect on the bioplastic based on native starch. Furthermore, the comparison between experimental (Exp) values and predicted (Pred) values for characteristics such as chemical resistance (R), solubility (S) in water, water absorption (Ab) allows us to observe that the results obtained agree with the predictions from the optimization.

## Biodegradability of Optimized Bioplastics

The results from the evaluation of biodegradability in the different soil matrices are presented in Figure 9.

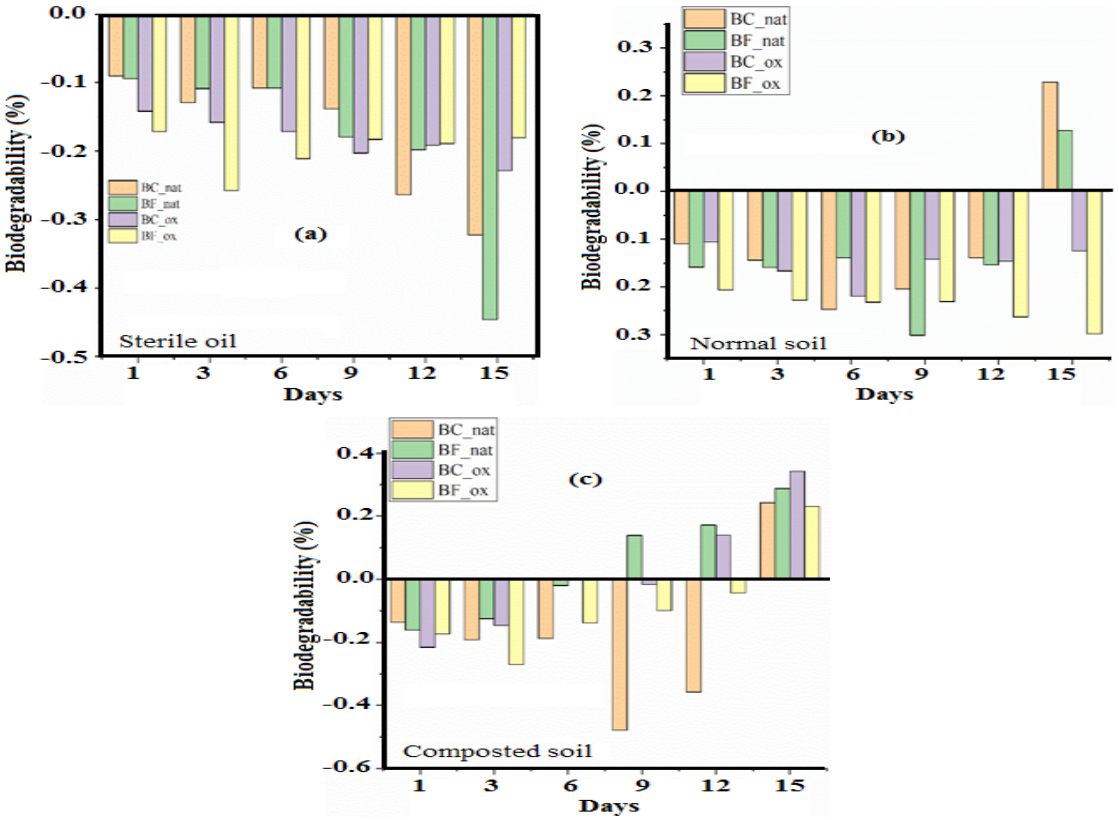


**Fig. 9. Biodegradability of optimized bioplastics in the different soil matrices**

Analysis of Fig. 9 (a, b, and c) reveals two phases in the degradation process. In the first phase, negative biodegradability is noted for some bioplastics, and in the second phase, positive biodegradability. Regardless of the bioplastic buried in sterile soil, the biodegradability is negative over the entire observation period. A negatively increasing trend in biodegradability is noted, with a maximum for the fibrous bioplastic from native starch (BF_nat). In normal soil, the negative biodegradability trend is observed for all bioplastics up to the twelfth day, with a peak on the sixth day for BC_nat and for BC_ox. The negative peak for BF_nat is observed on the ninth day, while BF_ox continues a negative increase until the fifteenth day. On the fifteenth day, positive biodegradability is noted for BC_nat and BF_nat. In composted soil, the biodegradability becomes positive for all bioplastics in the study on the fifteenth observation day, with a maximum degradation for BC_ox.

## DISCUSSION

In this study, bioplastics based on sweet potato starch reinforced with coconut fibers were developed following an optimization of three operational parameters, using Response Surface Methodology. The FTIR analyses performed on the obtained starches and fibers allow for a better understanding of the structural modifications induced by the applied treatments. The comparison of the spectra of native starch (Am_nat) and oxidized starch (Am_ox) highlights notable similarities, particularly the absorption bands observed at 3245.82 $cm^{-1}$, 2913.60 $cm^{-1}$, 1647.16 $cm^{-1}$, and 992.75 $cm^{-1}$. These bands are characteristic of O-H stretching vibrations, CH2, as well as C-H bonds in the glycosidic structure of starch[17]. However, the appearance of the additional peak at 1711.82 $cm^{-1}$ in the spectrum of oxidized starch constitutes a key indicator of the chemical modification performed. This band is typical of carbonyl (C=O) stretching vibrations, generally associated with carboxylic acids[18]. This result indicates that the native starch treated with hydrogen peroxide underwent a significant functional modification leading to an intensification of the presence of C=O groups. Regarding the fibers, the bands observed at 3729.65 $cm^{-1}$, 2345.04 $cm^{-1}$, and

1003 $cm^{-1}$ allow for the assessment of the effects of the alkaline treatment. The presence of the band at 3729.65 $cm^{-1}$ indicates an O-H stretching vibration of cellulose, thus confirming the removal of non-cellulosic compounds by the NaOH treatment. The absorption at 2345.04 $cm^{-1}$ corresponds to the carboxylic O-H vibration resulting from the chemical modification of cellulose. The peak at 1003 $cm^{-1}$ represents the C-C group valence vibration. The optimization through the execution of a central composite design involved three factors: starch mass, fiber mass, and glycerol volume. This optimization proved particularly effective and led to examining the influence of the three factors on the chemical resistance, solubility, and water absorption rate of the reinforced bioplastics derived from the two types of starch. The ANOVA analysis allowed for obtaining, for each type of starch, three adjusted linear and quadratic models that best describe the solubility (S), chemical resistance (R), and absorption rate (Ab) responses. These adjusted models all show a non-significant lack of fit ($p > 0.05$), and adjusted $R^2$ coefficients very close to the predicted $R^2$. Similar results were obtained by Silviana and Rahayu[19] in their study on the optimization of the tensile strength of sago starch-based bioplastic reinforced by bamboo cellulose. These authors revealed a quadratic response between the cellulose fiber content and the mechanical strength of starch-based bioplastics. The R, S, and Ab responses are optimal for operational parameter values $m_s$ = 3 g, $m_f$ = 0.25 g, and $V_g$ = 1 mL with native starch and $m_s$ = 2.69 g, $m_f$ = 0.25 g, and $V_g$ = 1 mL for oxidized starch. These optimal responses were obtained with overall desirabilitiy of 0.828 and 0.913 respectively, thus confirming the theoretical effectiveness of the experimental design used. Validation through the synthesis of optimized bioplastics (with controls without fibers) confirmed the theoretical results with experimental characteristics of chemical resistance, solubility, and absorption close to theoretical values. Furthermore, the optimized bioplastics (fibrous and non-fibrous) present low moisture content. The reduction in moisture of the oxidized bioplastics (BF_ox and BC_ox) could be explained by the oxidized nature of their base starch. Indeed, oxidation makes the starch less hydrophilic, and this can be reflected in the resulting bioplastics. The drop in moisture observed after the introduction of fibers could be explained by an absorbent character related to the presence of fibers towards water molecules. These results agree with the study by Azmin *et al.,*[14], who worked on composite bioplastics of cellulose and sugarcane bagasse fibers. These authors observed a drop in moisture when the fiber ratio increased from 0 to 100%. The oxidation of starch and the incorporation of fibers in small quantities reinforced the hydrophobic character of the resulting bioplastics, improved chemical resistance, and reduced solubility, as also observed by Józó *et al.,*(2022) 20 and Pooja *et al.,*[21]. The study of the biodegradability of optimized bioplastics revealed the determining role of microorganisms in the degradation process of bioplastics. In the absence of microorganisms (sterile soil), the degradation process is almost invisible and results in a swelling process due to ambient moisture (biodegradability <0%). The reversal of biodegradability in normal soil can be explained not only by natural factors[22] but also inevitably by the action of microorganisms. This action of microorganisms is more sustained in composted soil. Regardless of the soil type, the fibrous bioplastic based on oxidized starch proved to be less degradable. This relatively resistant character could be linked to the chemical modification of starch leading to a reduction in the water absorption rate, likely to slow down the absorption by microorganisms.

## CONCLUSION

This research aimed to optimize the synthesis of durable and biodegradable bioplastics using locally sourced biomass. Following the extraction of fibers and starch, part of which was oxidized, the optimization process focused on enhancing three key properties: solubility, chemical resistance, and water absorption. This was successfully achieved using Response Surface Methodology (RSM). Theoretical predictions were validated experimentally with satisfactory results. The optimized bioplastics exhibited high chemical resistance, low solubility, and relatively low water absorption. Biodegradability tests supported the theoretical findings, particularly regarding the chemical resilience of fiber-reinforced bioplastics based on oxidized starch. These bioplastics showed resistance to degradation in both normal and sterile soils. However, when the normal soil was enriched with 20% compost, noticeable degradation began by the fifteenth day of the study.

Overall, this work demonstrates the feasibility of producing biodegradable bioplastics reinforced with minimal amounts of coconut fiber. It

highlights a promising pathway for the valorization of local biomass in the development of environmentally friendly plastic alternatives.

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**Conflict of interest**

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**Ekou Lynda:** Conceptualization, Methodology

**Ekou Tchirioua:** Supervision, Validation

**Data availability statement**

The data are available and can be provided on request.

**Ethical approval statement**

All authors involved in this study fully consent to its publication. Furthermore, this research did not involve the use of animals at any stage of the experimental process.

**Informed consent statement.**

All people whose names appear as authors in the article are aware of the text of the article and its submission to this publication.

**REFERENCES**

1. Tripathi, N.; Misra, M.; Mohanty, A. K., *ACS Engineering Au.,* **2021**, *1*(1), 7–38,Doi: 10.1021/ACSENGINEERINGAU.1C00011.
2. Deeney, M.; Green, R.; Yan, X.; Dooley, C.; Yates, J.; Rolker, H. B., *J Clean Prod.,* **2023**, *397*, 136567, Doi: 10.1016/j.jclepro. 2023.136567.
3. Zhao Zhao, X.; Wang, Y.; Chen, X.; Yu, X.; Li, W.; Zhang, S., *Matter.,* **2023**, *6*(1), 97–127, Doi: 10.1016/j.matt.2022.11.006.
4. Liao, J. J.; Latif, N. H. A.; Trache, D.; Brosse, N.; Hussin, M. H., *Int J Biol Macromol.,* **2020**, *162*, 985–1024, Doi: 10.1016/j.ijbiomac. 2020.06.168.
5. Ross, G.; Ross, S.; Tighe, B. J. Tighe Brian J. Bioplastics: New Routes, New Products., *Brydson's Plastics Materials: Eighth Edition. Elsevier Inc.*, **2017**, 631–52.
6. Brodin, M.; Vallejos, M.; Opedal, M. T.; Area, M. C. A Review. *J Clean Prod.,* **2017**, *162*, 646–64, Doi: 10.1016/j.jclepro.2017.05.209.
7. Qazanfarzadeh, Z.; Kumaravel, V., *Trends Food Sci. Technol.,* **2023**, *138*, 27–43,Doi: 10.1016/j.tifs.2023.06.002.
8. Delgado, M.; Felix, M.; Bengoechea, C., *Ind Crops Prod.,* **2018**, *125*(March), 401–7,Doi: 10.1016/j.indcrop.2018.09.013.
9. Amin, M. R.; Chowdhury, M. A.; Kowser, M. A., *Heliyon.*, **2019**, *5*(8), e02009, Doi:10.1016/j. heliyon.2019.e02009.
10. Anstat. Agence Nationale de la Statistique/ Carte de la région du Poro. Géoportail. Available at https://geoportail.anstat.ci/details-cartes/26.Accessed November 16, **2025**.
11. Anstat. Agence Nationale de la Statistique/ Carte du District Autonome d'Abidjan. Geoportail.Available at https://geoportail. anstat.ci/details-cartes/32.Accessed November 2, **2025**.
12. Zoungranan Y.; Dobi-Brice K.K.; Saran S.; Lynda E.; Tchirioua E., *World J. of Environ. Biosc.*, **2024**, *13*, 39–46.DOI:10.51847/DAIFX vcyrK

13. Hamed, O. T. S.; Zoungranan, Y.; Lynda, E.; Tchirioua, E., *Indian J. Sci. Technol.,* **2025**, *18*(6), 452–63,Doi:10.17485/IJST/v18i6.3736.
14. Azmin, S. N. H. M.; Hayat, N. A. binti M.; Nor, M. S. M., *Journal of Bioresources and Bioproducts.,* **2020**, *5*(4), 248–55,Doi: 10.1016/j.jobab.2020.10.003.
15. Goupy, J.; Creighton, L. Introduction aux plans (3e édition). Dunod. Paris, France: Imprimerie CHIRAT., **2006**.
16. Pham H. editor. Springer Handbook of Engineering Statistics. London: Springer London; **2023**.doi:10.1007/978-1-4471-7503-2.
17. Hassan, I.; Wani, I. A.; Hussain, P. R.; Dar, A. H., *J Packag Technol Res.,* **2021**, *5*(3), 175–84, Doi: 10.1007/s41783-021-00121-4.
18. Zhu, L.; Luo, H.; Shi, Z.-W.; Lin, C.; Chen, J., *Food Chem X.*, **2023**, *17*, 100602,Doi: 10.1016/j.fochx.2023.100602.
19. Silviana, S.; Rahayu, P., *J Phys.Conf.Ser.,* **2019**, *1295*(1), 012073,Doi:10.1088/1742-6596/1295/1/012073.
20. Józó, M.; Várdai, R.; Bartos, A.; Móczó, J.; Pukánszky, B., *Molecules.,* **2022**, *27*(19), 6423, Doi:10.3390/molecules27196423.
21. Pooja, N.; Shashank, S.; Singh, B. N.; Mazumder, N., *RSC Adv.,* **2024**, *14*(33), 239, 43–51,Doi:10.1039/D4RA04263H.
22. Zoungranan, Y.; Lynda, E.; Dobi-Brice, K. K.; Tchirioua, E.; Bakary, C.; Yannick, D. D., *J Environ Chem Eng.*, **2020**, *8*(5), 104396,Doi: 10.1016/j.jece.2020.104396.