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Mémoire de Fin de Cycle
En vue de l'obtention du diplôme

MASTER

Thème

Formulation d'un biscuit à base de la farine de pelure de pomme de terre

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A toute l'équipe du laboratoire 3BS

A tout ce qui me sont chers

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List of abbreviations

AAE : Ascorbic acid equivalent
ABTS : Acide 2.2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonique)

ABTS+• : Radical libre ABTS (Acide2.2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonique)

AFNOR : Association Française de Normalisation.

AOAC : Association of Official agricultural Chemists.

BHA : Butylated hydroxyanisole

BR : Bleaching rate of carotene.

BSA : Bovine serum albumin.
CE : Catechin equivalent.

Df : Degres of freedom.

DPPH : 2,2-Diphenyl-1-picrylhydrazyl.

DPPH. : Radical libre DPPH (2,2-Diphenyl-1-picrylhydrazyl.

DW : Dry weight.

EPP : Potato peels powder extract.
FAO : Food and Agriculture Organization.
Fig : Figure
GAE : Gallic acid equivalents.

GE : Glucose equivalent
HPLC : High performance liquid chromatography

HPLC-LC-MS : liquid chromatography mass spectrometry

HPLC-DAD-ESI-MS : high-performance liquid chromatography with diode array detection and mass spectrometry.

IC50 : Inhibition Concentration (concentration that reduces the effect by 50%).

LPI : Lipid Peroxydation Inhibition.

MRSA : Methicilin-resistant staphylococcus aureus.

ph : Hydrogen potential

P value : probability value.

PP : potato peels.

QE: Quercetin equivalent.

SD : Srandard deviation

TFC : Total flavonoid content.
TPC : Total phenolic content.

List of figures

List of tables

Summary

Results and discussion

List of figures

List of tables

Introduction

Introduction

In Algeria, 15 million tons of fruit and vegetable waste are prescribed **(Aman et *al*., 2019)**, and barely 1% of the organic fraction of this green waste, is exploited in a composting process. Indeed, the report designed by the Ministry of Agriculture and Rural Development **(M.A.D.R),** recorded a production of about 5.5-1156 million tons per year **(APS, 2019).**

On a global scale, the industrial process of potato processing generates a considerable amount of peels (skin), estimated at 70 to 140,000 tons per year **(Hossain et *al*., 2015).**

As a green residue with organic potential, potato peel is the main waste from food processing industries **(Javed et *al*., 2019)**. Its discharge into nature and poses an ecological problem **(Gebrechristos et *al*., 2018)**. Nearly 110 tons or more per day, of which more than 45% is recoverable, this situation has prompted the industrial sector to set up a sustainable green waste recovery system in order to significantly reduce it **(Aman et *al*., 2021).**

This environmentally-friendly solution has been the focus of work on the recovery of agri-food waste and the possibility of reusing it not only for animal feed or organic fertilization, but also as a raw material for the production of functional foods **(Laufenberg et *al*., 2003; Ayala- Zavala et *al*., 2010).**

As agro-residues, potato peels are an excellent source of dietary fiber **(Toma et *al*., 1979)**, biopolymers and natural food additives **(Javed et *al*., 2019)**, phenolic acids **(Habeebullah and Jacobsen, 2010)**, glycoalkaloids and anthocyanins as well as vitamins, minerals **(Maldonado et al., 2014)** and antioxidants **(Freidman et al., 2018)**. The antioxidant property of potato peel extract of some Asian varieties has been reported **(Kurfi Chandramuki, 2021),** and its ability in muscle food and soybean oil has been highlighted **(Kanatt *et al*., 2005; Ziaur-rehman *et al*., 2004).** Indeed, **Albishi et *al*. (2013)** and **Sampaio et *al.* (2020)** have shown a strong correlation between antioxidant activity and the high anthocyanin content of potato peel. Thus, the use of antioxidants is encouraged because of the accumulation of traces of synthetic chemical residues that have a negative impact on consumer health. It is important to stress the need to produce antioxidant-rich extracts from different plant sources **(Alessandro et *al*., 2012)** in order to balance the anti-oxidant/pro-oxidant balance. On the other hand, many biological activities of potato peel have been reported in the literature, such as its protective effect against three pathogenic bacterial strains of Trichomonads **(Friedman *et al*., 2018)**, protozoan

parasite *Trichomonas vaginalis*, a sexually transmitted protozoan parasite that causes trichomoniasis in humans, (**Sotillo et *al*, 1998**), fungus (Candida albicans ATCC 10231), human enteric viruses (**Silva-Beltràn et *al*., 2017**) and insects (**Akyol et *al*., 2016**).

In addition, many other infectious disease outbreaks, such as malaria, Ebola virus disease, the HIV pandemic, and the recent COVID-19 crisis, highlight the need for healthy diets **(Galanakis, 2020)**. As a result, many health organizations have encouraged populations to consume improved foods, such as foods fortified with functional constituents.

So, due to the use of antioxidant phenols in food systems **(Sepelev and Galoburda, 2015)** and the multifunctional nature of potato peel, this study aims to promote the environmentally friendly use of co-product as a raw material in the formulation of a typical cookie. Cookie is a cereal product consumed and enjoyed by the global population **(Dayakar and Bhargavi, 2017)**. The sweet and varied taste, low cost, nutritional value, availability and longer shelf life are the reason **(Sudha *et al*., 2014).**

As a functional food supplement, the cookie offers several possibilities for the management of disorders related to human nutrition. However, some cookies are even used in the nutritional framework against certain chronic diseases (diabetes, obesity, ...ect) by contributing to the compensation of certain nutrients **(Canalis et *al*., 2017; Singh and Kumar, 2017)**. To this end, several foods in the consumer's diet are used as vehicles for fortification strategies.

In this study, our primary aim was to formulate a functional food (biscuit) while promoting a co-product from agri-food processing, for this we have proposed to formulate a biscuit (new product) with potato peel (co-product of potato processing).

In this regard, two parts are devoted:

- A literature review dealing with the functional food (biscuit) and the bio matrix (potato peel) as a substitute for the raw material.
- An experimental work was conducted with the bio matrix in terms of physico-chemical and phytochemical analysis (determination of the phenolic content and the biological activities (antioxidant, antibacterial and antiparasitic) of its powder and/or crude extract and those of the formulated biscuit; finally, the sensory analysis of the latter was performed.

Chapter I

Generalities on biscuit

This chapter is conçu to identify some data on the biscuit that will constitute the center piece of the present study in terms of enrichment. Some bibliographies are illustrated.

I.1. Origin of the term « biscuit »

The term "biscuit"(cookies) derives from the Latin word biscoctus, which means "twice baked ». The origin of the cookie dates back to Roman times to solve the problem of food preservation **(Chavan et *al.*, 2016)**. In baking, the word "cookie" encompasses several product groups. It is called "cookie" in the United Kingdom and France, "cookie" and "cracker." UK and France, "cookie" and "cracker" in the US, and "scone" in New Zealand **(Chavan et *al.*, 2016; Denis, 2011)**. For other authors, cookies are referred to interchangeably as cookies in the UK and Asia **(Cauvain and Young, 2008)**.

I.2. Description of biscuit

Originally, the cookie is a type of cake that requires an initial baking in a hot oven followed by oven drying to reduce its moisture content **(Serrem, 2010; Zhou, 2014)**. The cookie is made from a soft dough, rich in sugar, fats, proteins and low water content **(Delcour and Hoseney, 2010)**.

The cookie is a preparation based on cereals (wheat, rice, barley, oats, rye, corn, millet, sorghum and buckwheat), legumes (pulses), starchy roots (yam, cassava ...), starchy stems and oilseeds in small proportion (**FAO, 2012)**. In addition, it contains flour, sweetener, fat and other minor products such as milk, salt, flavoring and aerating agents as main ingredients **(Devi and Khatkar, 2016; Mamat and Hill, 2014)**. The authorized condiments are able, after baking, to preserve the organoleptic and commercial qualities of a dry cookie for more than a month or a year **(Kiger in Gorga, 2014)**.

Many factors can influence cookie quality, such as the quantity and quality of the ingredients used, the preparation technique, the manufacturing conditions (kneading, resting and molding of the dough) and finally its baking and cooling **(Manouhar et *al.*, 2002)**.

I.3. Biscuit technology

The cookie technology requires 8 steps: mixing, kneading, proofing, rolling, shaping, baking, cooling and packaging **(Fig N°01)**.

The quality and proportions of ingredients as well as the treatment used for example kneading, fermentation and baking **(Sudha et *al.*, 2007; Devi and Khatkar., 2016)**, can influence the quality of the cookie, with other ingredients, flour, sweetener, fat and other minor products such as milk, salt, flavoring and aerating agents **(Devi and Khatkar, 2016; Mamat and Hill, 2014)**. The authorized condiments are susceptible, after baking, to preserve the organoleptic and commercial qualities of a dry cookie for more than a month, even a year **(Kiger in Gorga, 2014).**

The following diagram represents the general manufacturing process of the cookies:

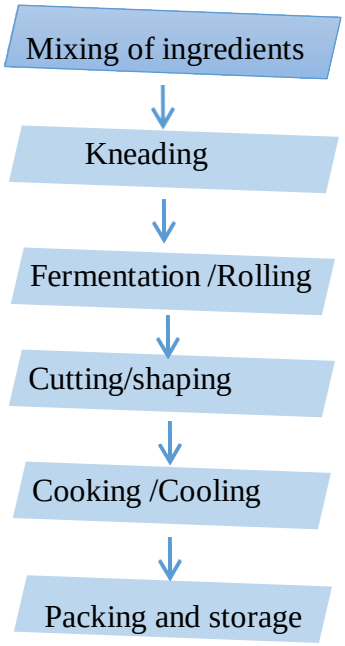

Figure N°01: Diagram of the steps involved in the manufacture of cookies **(Yadav et *al.*, 2012)**.

I.4. Classification of biscuits

Due to varietal diversification in terms of production and the multiplicity of components used in cookie manufacture, the official classification of this food has not yet been determined. However, a classification can be envisaged based on the consistency of the dough before baking **(Mohtedji -Lambalais., 1989; Feuillet., 2000)**.

• Hard or semi-hard doughs giving rise to the dry cookie type;

• Soft dough: industrial pastries such as sponge cakes, madeleines and sponge cakes, madeleines and macaroons. The particularity of these cookies is their high egg and fat content;

• Dough with a high milk or water content and a low fat content **(Mohtedji-Lambalais, 1989; Manoharr et Rao, 2002)**.

A classification can be envisaged according to:

- Name, e.g. biscuits, crackers and cookies, which is basically on the texture and hardness **(Broutain., 2001)**;

• Method of forming of the dough and dough piece, e.g. fermented, developed, laminated, cut (simple or embossed), molded, extruded, deposited, wire cut, coextruded **(Broutain., 2001)**,

• The enrichment of the recipe with fat and sugar **(Fig N°02)**.

(A) **(B)**

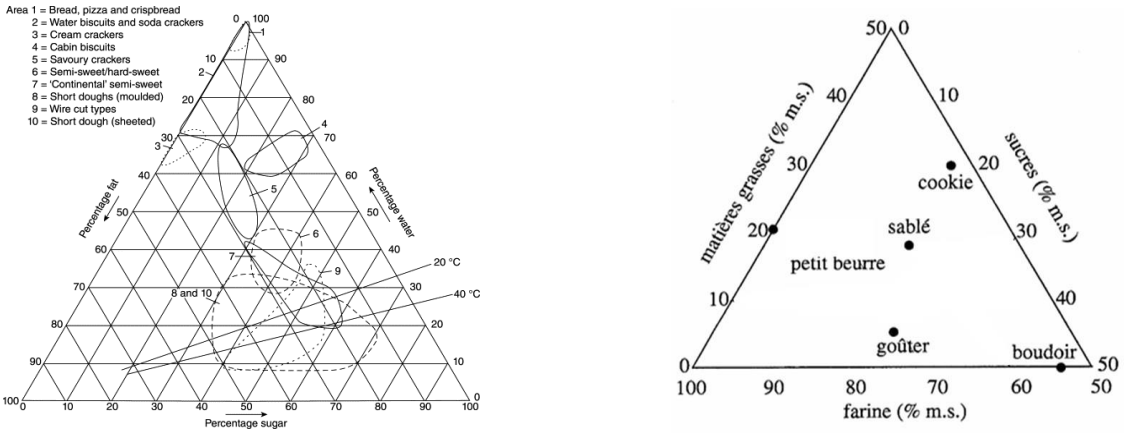

Figure N°02: Rations of fat, sugar and water in biscuit doughs.

(A): D. Manley, 2011; **(B): Fustier, 2006).**

I.5. Composition and energy value

The cookie offers several opportunities for the management of human nutrition disorders. The per capita consumption of cookies is high at 3 kg/year per capita world **(Canalis et *al.* 2017)**.

Its predominant content of cereals (72%), starch (51.5%), proteins and fibers, gives it a nutritional potential **(Ait Ameur, 2006)**. As for its water content varies between 2 and 10% it depends on the recipe. This low moisture content is the reason for the increase of its energy density **(PNNS, 2007)**, which makes it less susceptible to microbial alterations **(Serrem, 2010)** with respect to other bakery preparations whose rate varies from 15 to 30% **(Saadoudi, 2019)**. This diverse composition makes the cookie an ideal product for fortification **(Kadam and Prabhasankar, 2010)**. Indeed, the average proportions of nutrients attributed to adults and children are shown in **(Table I) (Saadoudi, 2019)**.

Table I: Contribution of cookies to nutritional intakes **(Saadoudi, 2019)**.

Nutritional contribution	**Complex carbohydrates**	**Fibers**	**Fats**	**Carbohydrates Simple**	**Energy**
Children	3.9 %	2.5%	4.7 %	4.5 %	3.6 %
Adult	1.7 %	0.9 %	2.1 %	2.9 %	1.8 %

However, some cookies are even used as part of nutritional strategies to combat several chronic diseases: diabetes, obesity, cardiovascular diseases, and cancers **(Canalis et *al*. 2017; Singh and Kumar 2017)**. In addition, they help compensate for certain nutrients in deficiency. This deficiency can be compensated by two ways to improve the nutritional value of the food:

- Administration of micro ingredients with high functional value (isolated and purified);
- Addition of complex macro ingredients (compounded mixture) **(Torri et *al*., 2016)**.

I.6. Enrichment

Fortification is a process in which vitamins, mineral nutrients, and amino acids are added to processed foods to provide consumers with sufficient, but not excessive, amounts of certain nutrients in their diets **(FDR, 2022)**.

I.6.1. Impact of enrichment on health

Worldwide, the three most common forms of micronutrient malnutrition micronutrient deficiencies are iron, vitamin A and iodine. They affect at least a third of the world's population, mainly in developing countries **(WHO, 2001)**.

It is estimated that there are over two billion of people with anemia, just under two billion those whose diet insufficient iodine in their diets, and 254 million pre-school children lacking vitamin A deficiency. A prevalence has been established by the World Health Organization in terms of consequences due to micronutrient deficiency **(Table II)**.

Table II: Prevalence of consequences due to micronutrient deficiency **(WHO, 2001)**.

Région	Anemia[a] (total population)		Iodine intake insufficient[b]		Vitamin C deficienc[c]	
	Number (millions)	% of total	Number (millions)	% of total	Number (Millions)	% of total
Africa	244	46	260	43	53	49
America	141	19	75	10	16	20
South- East Asia	779	57	624	40	127	69
Europe	84	10	436	57	No data	
Eastern Mediterranean	184	45	229	54	16	27
Western Pacific	598	38	365	24	42	27
Total	2030	37	1989	35	254	42

[a]Value based on the proportion of the population with a hemoglobin concentration below the established threshold. [b] Value based on the proportion of the population with a urinary iodine level <100 µg/l. [c]Value based on the proportion of the population with clinical ocular signs and/or having a serum retinol level ≤ 0.70 µmol/L.

Vitamins and minerals contribute to the proper development of the body. Deficiency of these micronutrients is compensated by fortification as one of the interventions to reduce deficiency and improve human health. Evidence from 43 studies, suggest that no adverse effects of fortification are observed **(JK et *al*, 2019)**.

To this end, agencies **(FAO and WHO)** have adopted strategies to improve dietary nutrient intakes: increased production, preservation, and marketing of micronutrient-rich foods, in combination with nutrition education activities; food fortification; supplementation; comprehensive public health measures; and other disease control measures.

A few bibliographies on the incorporation of potato peel in cookie reformulation is presented in (**Table III)**.

Table III: Some works on enriching potato peel-based cookies

The quality of the biscuits was acceptable up to 5% replacement of wheat flour by potato peel fiber. Above 5%, the physical and sensory characteristics of the biscuits were adversely affected.	Dhingra et *al.*, 2012
Remarkable antioxidant effect on biscuits, compared with the effect of BHA. Sensory evaluation reveals that EPP at concentrations of 0.5% and 1% can be used in place of synthetic antioxidants, since no negative effect was observed on the organoleptic properties of the biscuits.	Rowayshed et *al.*, 2015
EPP with a high dietary fiber and protein content improved the nutritional value (higher dietary fiber content) and texture (the cake's hardness was reduced by 30.24%). Sensory analysis showed no statistical difference between the enriched biscuit and the control biscuit.	Ben jeddou et *al.*, 2017
Incorporating 25% EPP into the biscuit gave the best results for physicochemical attributes, while the biscuit enriched with 5% fiber obtained the highest score for sensory evaluation in terms of organoleptic properties	Sagufta et *al.*, 2019

Chapter II

Generalities on potatos

II. Generalities on potato

II.1. Origins and geographical distribution

Native to South America, the potato (*Solanum tuberosum L.*) is a staple food grown in over 100 countries around the world **(Bradshaw and Ramsay, 2009).**

Production expanded worldwide during the 19th century. By the middle of the 20th century, China and India had become the world's leading producers **(Bradshaw and Ramsay, 2009)**.

In Algeria, the potato was introduced in 19th century. It has become one of the main crops for human consumption. Production rose from 2,180,961 tonnes in 2006 to 4,400,000 tonnes in 2014 **(MADR, 2014)**. With an annual consumption of 35kg/capita in 1990, this rose to 102 Kg/capita in 2012 (**FAO, 2014**).

II.2. Botanical description

The potato (*Solanum tuberosum L.*) is a perennial, herbaceous dcotyledonous plant **(Dore et *al.*, 2006)**. It is a flowering plant belonging to the Solanaceae family **(Hawkes, 1990)**, comprising 1,000 species, over 200 of which are tuberous **(Dore *et al.*, 2006 ; Hawkes, 1990)** and genera as varied as *Nicotiana L., Lycopersicon Mill., PetuniaJuss., Datura L., MondragoraL., Capsicum L.* and *Physalis L.* **(Rousselle et *al.*, 1996)**.

The genus *Solanum* (**Quezel and Santa, 1962**), is shared with at least 2000 other species, among them tomato, eggplant, tobacco, chili pepper, and petunia **(Fig Nº03)** (**Ghazi and Ousdidéne, 2017**).

Figure N°03 : Potato tuber **(Ghazi and Ousdidene, 2017).**

II.3. Taxonomie

According to **Khedir and Letoufa (2008)**, the systematic position of the potato is as follows :

Table IV : Taxonomie of potato **(Khedir and Letoufa (2008).**

Kingdom:	**Phanerogams**
Class:	Dicotyledons
Order:	Gamopetal
Family:	Solanaceae
Genus:	Solanum
Species:	*Solanum tuberosum L.*

II.4. Nutritional value

The quality of the potato lies in its characteristics, which are perceived as favorable by the consumer.These include its high starch content (a carbohydrate reserve and source of energy)**(Rousselle et *al*., 1996)** , its richness in vitamin C, which plays an essential role in the formation and maintenance of connective tissue, wound healing and dental health, and vitamin B, whose key role is the transformation of food into energy for the proper functioning of the nervous system and the strengthening of muscles. As for fiber, it helps improve intestinal transit **(Canalis et *al*., 2017)**.

Its composition in terms of caloric content, protein, essential amino acids and minerals, as well as its complementation by a range of bioactive components in small quantities : organic acids (citric and ascorbic acids among others) and phenolic substances (chlorogenic and caffeic acids, pigments, etc.) (**FAO, 2008 ; Li, 2012)** to which we can add its nutritional value humans **(Bradshaw and Ramsay, 2009)**. Average nutritional intakes are illustrated in **(Table VI)** below.

Table V : Composition of raw potato with skin (**Bender, 2014)**.

Coumpund		**Quantity**
Eau		79 g
Valeur calorique		70k cals
Protides		2 g
glucide		19 g
lipides		0.1 g
vitamine	**A**	5 mg
	B1	0.11 mg
	B2	0.04 mg
	B6	0.25 mg
	C	19.5 mg
Les éléments minéraux	**fer**	1.8 mg
	calcium	9 mg
	magnésium	10 mg
	phosphore	26 mg
	potassium	255 mg
	sodium	2.4 mg

Finally, minerals such as potassium (**Skiredj and Haout ,1996)**, which helps regulate blood pressure, copper, which contributes to the formation of bran and bones, niacin, which helps tissues breathe and eliminate toxins, and magnesium, which plays an essential role in growth, as well as acid and iron, which are essential for the formation of epidermis and tissues **(Moênne, 2008).**

Most of the waste generated by the potato processing industries is disposed of in landfills, with the environmental consequences that this entails, or used as animal feed **(Chohan et *al.*, 2020).**

Recently, the use of potato processing residues as an enrichment Iingredient has gained momentum in the food industry.

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Recently, the use of potato processing residues as an enrichment Iingredient has gained momentum in the food industry.

II.5. Potato peels

Potato peelings are a by-product of the potato processing industry. Processing industry, they are a good source of vitamin C, vitamin B, copper, potassium, manganese and dietary fibre **(Bradshaw and Ramsay, 2009)**.

II.5.1. Biochemical composition of potato peel

Peel potato (PP) have an important nutritional value, mainly composed of starch, dietary fibre and protein **(Ben Jeddou et *al.*, 2017).** The metabolites profile in PP peels shows a great variability depending on the genotype **(Inostroza-Blancheteau et *al.*, 2018).** PP are also described as being a rich source of phenolic compounds, which have been related to human health benefits, including antioxidant and antimicrobial properties **(Silva-Beltran et *al.*, 2017).** The content of phenolic compounds in PP is up to ten times higher than in potato flesh **(Albishi et *al.*, 2013 ; Rytel et *al.*, 2014).**

Table VI : Composition of raw potato peel **(Javed et *al.*, 2019).**

Coumpund	Values range (g/100g)
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 polyphenols	1,02 – 2,92
Total flavonoids	0,51 – 0,96
Fiber	2,5
Ash	0,9 -1,6

II.5.2. Phenolic compounds and activities biologiques

Potato peel is endowed with an important phenolic profile such as the favonoides class, phenolic acids and tannins **(Babar and Oberoi, 2014)**. It has been reported that these substances are 10 times more important than 50% of potato tuber polyphenols **(Javed et *al*,**

2019). Acids such as chlorogenic, ferric, gallic, caffeic, protocatechic, couramic, salycilic, vanillic, syringic, p-hydroxy-benzoic and hydroxycynammic are in the majority **(Ravichandran et *al*., 2020).** In the literature, the phenolic profile of potato peel differs according to the method of extraction and quantative analysis, as well as the characterization technique **(Table VIII).**

Table VII : Summury of pratical studies related phenolics and ther recovery realzed out during the last six years.

Potato peel sample	**Extraction method**	**Characterization**		**Reference**
		Method	Results	
Powder of peels dried at 50C°	Maceration solvents : HCl : -methanol (70 :30) - Aceton (70%, v/v) - Ethanol (70%, v/v)	HPLC	Hydroxybenzoic-acid: 130mg/100gdw Hydroxycinnamic-acid 115 mg/100g Flavanols:flavan-3-ols= 43mg/100g.,catechin and anthocyanins: 5mg/100g	**(Hashmi et *al* ., 2021)**
Powder of peels dried at 45 C°	Sonication (Acidified ethanolic)	HPLC	TPC : Chlorogenic:(346.03mg 100g),caffeic(332.58m g100g),gallicacids (233.49 mg/100g). Flavonoids :Quercetin, rutin and ferulic acid .	**(Silva-beltran et *al* .,2017)**
Powder of freeze dried peels	Maceration(methanol80 %) Sonication in ultrasonic bath	HPLC - LC-MS)	Caffeic-acid and , chlorogenic- acid	**(Friedman et *al* .,2017)**
Powder of freeze dried peels	Ultrasoun (Ethanol/water (55/45% -v/v)	HPLC-DAD-ESI-MS	TPC :2.5-7.2mg/gdw Chlorogenic acid:49.3-61% and caffeic acid 2.3-19.9%	**(Riciputi et *al*.,2018)**

II.5.3. Biological activities of potato peels :

Potatoes are significant source of natural antioxidants and exhibit antioxidant activity and anti-bacterial properties as demonstrated in recent time by many authors **(Akyol et *al*., 2016 and Friedman et *al,* 2020) (Table IX)**.

Table VIII : Some bibliographies on the biological activities of PP

Activity	Effect	Reference
Antioxidant	Retarding the oil oxidation. Protection of erythrocytes against oxidative damag.	**Helal et *al*., 2020**
Antibacterial	*E.coli* and *S.aureus*. Inhibition of bacteria(G^{+}) *B.subtilis* ATCC 6633 And *S.aureus* ATCC 29213 (G^{+}) ; *E. coli* ATCC 25 922 (G^{-})and *Salmonella enterica susp enterica serovars thyphumurium* ATCC 14028 *Zymomonas mobilis* (G^{-})	**Khalifa et *al*., 2016** **Helal et *al*., 2020** **Umar Adamu et *al* , 2022**
Antifungal	*C.albicans* ATCC 10231 *Saccharomyces cervisiae*	**Rauha et *al*., 2000** **Umar Adamu et *al* , 2022**
Antiviral	The inhibition of bacteriophages due to the high levels of hydroxycinnamic acids shibit viruses, in the PP extracts. Gallic acid cause moderate inhibition of viral replication. Effective reduction in the virulence of bacteriophages MS2 and Av-05.	**Oh M et *al*., 2013** **Wang et *al*., 2009**
Anti-obesity	Potential anti-obesity effect linked to the high glycoalkaloid content .	**Elkahoui et *al*., 2018**

***S :** *staphylococcus* ; ***C** : *Candida* ; ***G+** : Gram positif **; *G-** : Gram negatif ; ***ATTC :** American Type Culture Collection

II.5.4. Valorization of peel potato

Food processing industries generate phenolic-rich vegetable by-products, and this has been an area of research investigations as a sources of antioxidants and antimicrobial for food preservation **(Pezeshk et *al*., 2015).** The entire tissue of fruits and vegetables is rich in bioactive compounds or phenols but the by-products have higher contents of antioxidant **(Sonia et *al*., 2016)**.

- **Food preservation**

In the food industry, the use of synthetic food preservatives alone or in combination with natural preservatives trigger potential adverse effects. However, the application of the use of natural preservatives alone has a better benefit for human health with few side effects. **(Sonia et *al.*, 2016 ; Tiwari et *al.*, 2009)**. Therefore, the food industry has enforced to seek natural alternatives food preservative **(Pezeshk et *al.*, 2015)**.

- **Antioxidant**

Compared to mature potatoes, young potato skins are an excellent source of bioactive phytochemicals with antioxidant potential **(Arun et *al.*, 2015)**. Potato skin is one of the most important waste products containing sufficient quantities of phenolic compounds, and could therefore be used to replace current synthetic antioxidants and antimicrobials.

Bioactive compounds in potato peel extracts, such as chlorogenic and gallic acids, prevent the oxidation of vegetable oil and could stabilize the soybean oil oxidation reaction by minimizing peroxide, totox and p-anisidine indices **(Amado et *al.*, 2014).**

The ability on minimizing oxidation on vegetable oil, potato peel extracts has equal performance with synthetic antioxidants such as butylhydroxyanisole (BHA) and butylhydroxytoluene (BHT). It is a promising source of natural antioxidant that could be used as eco-friendly product on food industries **(Sampaio et *al.*, 2020).**

- **Antimicrobial**

PP extracts have also shown interesting microbiological potential. In a recent work **(Friedman et *al.*, 2018)** investigated the in vitro antitrichomonad activity of PP powders prepared from commercial Russet, red, purple, and fingerling potato varieties against three pathogenic strains of trichomonads : one *Trichomonas vaginalis* strain (a sexually transmitted protozoan parasite that causes the human disease trichomoniasis) and two distinct strains of the related *Tritrichomonas foetus*, one feline and one bovine.

In a study conducted by **(Silva-Beltran et *al.*, 2017)** PP acidified ethanolic extracts showed antiviral effects against human enteric viruses.

Therefore, potato peel extract is the future and natural against foodborne pathogenic microbial and the broad spectrum nature of the plant help to discover new chemical classes of antibiotic substances that could serve as food preservative in food processing industries **(Gebrechristos et *al.*, 2018 ; Sampaio et *al*, 2020)**. The antimicrobial nature namely bacteriostatic and non-

mutagenic of potato peel extract, could be due to the presence of flavonoids and terpene organic compounds **(Nostro et *al*., 2000)**.

- **Pharmaceutical Ingredient**

Potato skin contains a number of compounds of pharmacological interest, such as glycoalkaloids that could be used as a steroid hormone precursor **(Schieber and Aranda, 2009)**. The the highest amounts of glycoalkaloids are found in potato peel than the flesh part of potato (**Chem, 2009).** In addition, potato powder has wound healing activity as an anti-ulcerogenic agent **(Dudek et *al*., 2013).**

Therefore, use of potato peel as pharmaceutical ingredient is natural, nontoxic, and environmentally friendly. So this could be one of the solutions on prevention of the current threat of drug resistance, emerging disease effective treatment and lower the health damaging side effect of synthetic drugs **(Elkahoui et *al*., 2018)**.

- **Biogas production**

Fruit and vegetable such as potato peel wastes took 55 days for complete digestion to produce biogas in anaerobic condition **(Deressa et *al*, 2015)**. Potato peel waste of an industrial is a mesophilic reactor of biogas production. Chemical pretreatment applied to potato peels, improved biogas yields and CH_4 **(Krus & Lucas, 2014).**

- **Animal feed**

Potato peel is one of the prominent food wastes that could be used as alternative animal feed due to natural sources of energy and fiber with low levels of protein **(Chimonyo, 2017).**

II.5.5. Performance of potato peels in cookies

The first reports on the uses of PP in food applications date back from the 1970's, when **(Toma et *al*., 1979)** described its use as a source of dietary fibre in bread. More recently, **(Curti, Carini, Diantom, and Vittadini, 2016)** applied PP fibre in bread (0.4 g fibre/100 g flour) to study its ability to reduce bread stealing. The authors found that the potato fibre addition in bread increased frozen water content and resulted in a softer bread crumb over 7 days of storage.

Potato peels produced as a by-product of potato processing have potential use as a dietary fiber supplement in baked foods. Sensory analysis of an oatmeal cookie containing 10% or 15% potato peel detected differences in organoleptic properties compared to the control **(Arora and**

Camire , 1994).Dietary fibre extracted from potato peels has been utilized for preparing dietary fibre rich biscuits **(Singh, 2013)**. The quality of biscuit was acceptable up to 5 % replacement of wheat flour with potato peel fibre. The sensory evaluation established by **(Rowayshed et *al.*, 2015**) reveals that potato peel extracts selected at concentrations of 0.5% and 1% can be used in place of synthetic antioxidants. As for that of **(Dhingra et *al*., 2012),** showed that cookie quality was acceptable up to 5% replacement of wheat flour by potato peel fiber.

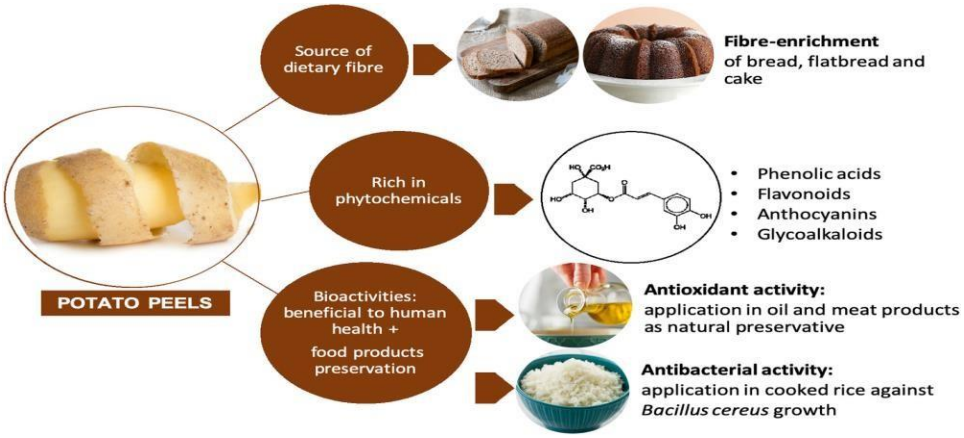

Figure N°04 : Potato peels and their main interesting features for the food industry **(Sampaio et *al*., 2020)**

Chapter III

Material and methods

III. Materials and Methods

III.1. Preparation of potato peel powder

- The *spunta* potato variety (*Solanum tuberosum* L.) was purchased at the Edimco market in the Bejaia city in March 2023. A quantity of 32 kg of tubers (32 kg) were washed with tap water and then with distilled water and peeled manually with a peeling knife to obtain peels of about 1 mm thickness followed by a cutting page in small squares of 5 cm in size.in a microwave the peels were dried in small quantities (80 g) at a power of 200 w for 60 min weighing each 5 min. The dried peelings were ground with an electric grinder to a powder. Using a 250 nm sieve, the powder was sieved and stored in a shaded vial followed by an electronic shredding **(Brahmi et *al*.,2023)**

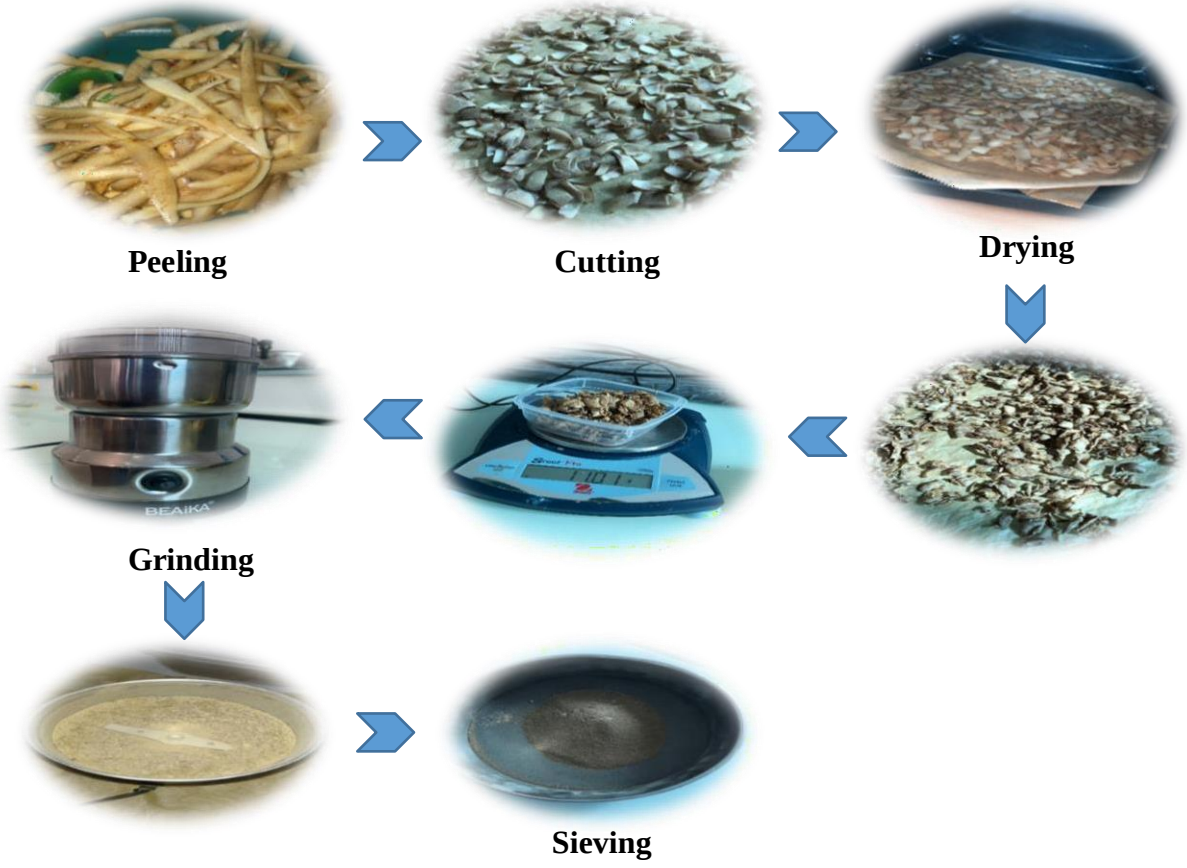

Figure N°05 : Preparation of potato peel powder

III.2. Physico-chemical analysis

III.2.1 Yield determination

Yield was calculated using the formula given by **Falleh et *al.*, (2008) :**

$$R\ (\%) = 100 \times (Mext/Mech)$$

Where :

R : is the yield in %
Mext : is the mass of powder obtained in g.
Mech : is the mass of plant material in g

III.2.2. Moisture content

Measuring the moisture content of a foodstuff has both economic and health benefits. From an economic point of view, the price of the material is defined for a given moisture content. from a sanitary point of view, the moisture content is crucial to the product's preservation.

The moisture content was determined by difference in weight after drying approximately 5g of sample at 105°C to a constant weight. According to according to the **AOAC (1990)**. Analyses were performed in triplicate and the results are expressed as follows :

$$\text{Moisture content (\%)} = Mf - Ms / Mf \times 100$$

Mf : Mass (mg) of fresh plant material before drying

Ms : Mass (mg) of plant material after drying.

III.2.3. pH determination

The pH of the sample was measured using the method of **Demirkol and Tarakci, (2018)** consists of immersing the pH meter probe directly into the obtained filtrate. 1 g of powder of the studied potato peel was suspended in 20 mL of distilled water and the mixture was filtered through a filter paper.

III.2.4. Titratable acidity determination

For titratable acidity, the method described by **Rajeev and Kok, (2017)** was adopted. 1 g of powder was dissolved in 20 mL of distilled water. After homogenization, a few drops of phenolphthalein were added. The titration was performed with a sodium hydroxide solution NaOH (0.1N) indicating a color change. The titratable acidity in the sample was calculated as :

$$\text{Acidity (g/100g)} = (V^* N (NaOH)^* EQ (A.T) / m$$

Where :

V : the titer volume of the NaOH (mL)

N : NaOH normality (0.1N)

EQ (A.T) : gram equivalent of tartaric acid (0.75).

m : mass of the test sample in (g)

III.2.5. Estimaion of the ash content

The recommended method of the Association of Official Analytical Chemists **(AOAC, 1990)** was used to determine the percent fresh matter of potato peel. The silica crucible was heated up to 300°C/15min and cooled. A sample of 2.0 g was weighed and taken in the crucible. The charred mineral was then incinerated in a muffle furnace for 6 h at 600 °C. The crucible was then cooled in a desiccator and weighed.

The determination of the ash content is in percent (%) according to the following formula :

$$\text{Ash (\%)} = (m_1 - m_2) / m_i \times 100$$

Where :

m_1: mass (g) of crucible with ash

m_2 : mass (g) of empty crucible

m_i: initial mass (g) of sample.

III.2.6. Fiber content

The fiber content of potato peel was determined according to the method of **Pádua et *al.*,(2004)**. An amount of (0.1 g) of potato peels powder was mixed for 30 min with (10 mL) of (5%) chlohidric acid and then the mixture was filtered and washed with hot water. The residue was mixed with 10 mL of 5% sodium hydroxide at reflux for 30 min, the mixture was filtered and washed with water. The solution was then washed with (1 mL) ethyl alcohol and ethyl ether (1 mL), the residue was dried at 100°C for 2 h and the residual mass was considered as fiber.

III.2.7. Fat content

Ten g of potato peel powder was placed in a dark bottle and homogenized with 50 mL of hexane. After 4 hours in a shaker at a speed of 180 U / min, the mixture was centrifuged at 1000 g for 15 minutes at room temperature (20°C). The supernatant was then filtered on filter paper. After evaporation of hexane**,** The mass obtained is considered to be the lipid content of the dry matter. **(Cheikh Rouhou et *al.*, 2006).**

III.2.8. Protein content

Total protein content of peels powder of potatos was determined by **Bradford's method (1976).** The protein reagent was prepared by mixing 100 mg of Coomassie blue with 50 mL of 95% ethanol. A volume of 100 mL of 85% phosphoric acid was added followed by stirring. The solution was diluted to a volume of 1000 mL.

Protein determination : 3 mL of Bradford reagent was added to a 100 uL volume of potato peel powder extract. The mixture was shaken and incubated at room temperature for 5 minutes.The absorbances were read with a spectrophotometer at a wavelength of 595 nm. The protein content was expressed in mg equivalent BSA per g of dry weigth (mg BSA E /g DW) by reference to a calibration curve **(Annexe 01).**

III.2.9. Total sugars

The total sugar was analyzed through phenol according the method of **Dubois, (1965). 0.5** g of powder is dissolved in 20 mL of 80% ethanol, then stirred for 2 h at room temperature. 500 µL of extract was added to 250µL of phenol 5% and 1.25 ml of sulfuric acid. The mixture was incubated at 30°C for 20 min. The absorbances are read with a spectrophotometer at a wavelength of 490 nm. The results are expressed in mg of glucose equivalent per g dry weight (mg GE/g DW) **(Annexe 02).**

III.2.10. Refractometric index (Brix degrees)

The Brix degree or soluble dry residue determined by refractometry, is the concentration of sucrose in an aqueous solution having the same refractive index as the analyzed product, under certain conditions (eg: temperature). The concentration determined **(AFNOR, 1970)** is expressed as a percentage by mass. It consists in mixing 1 g of sample with 10 mL of distilled water while shaking the mixture energetically. A drop of the mixture is taken and placed on the surface of the refractometer prism. The second prism is slid over the first to obtain a uniform layer of liquid. The interpretation is done by pointing the refractometer towards a light source, where two zones appear: one is clear, the other is dark. The boundary between the two zones indicates the extent of refraction.

III.2.11. Gluten test

This test was carried out at the Eni physical-chemical laboratory of the Soummam mill complex located at Sidi-Aich (Wilaya : Bejaia) according to method **N°06.95.08.**

Determination of wet gluten

Preparing the dough : a quantity of 10 g of the powder was weighed and introduced into a mortar. Using a beaker, 20 mL of the NaCl sodium chloride solution (20g / L) was poured in, shaking the flour with a spatula until a ball of dough was formed, taking care to avoid losses. The dough was rolled between the palms of the hands until it no longer adhered.

Extraction

- Kneading **:** The dough is placed in the palm of the hand and the NaCl solution is poured in drop by drop, but fairly quickly, until an elastic ball is obtained.
- Washing **:** This is carried out over a sieve covered with gas to retain the gluten fragments.

Dewatering using a centrifuge. The dewatered gluten is placed on a pre-weighed metal plate. The mass obtained is that of wet gluten.

Determination of dry gluten

The wet gluten is pressed by a dry gluten press (glutork) and then weighed. The mass obtained is that of dry gluten **(Fig N°06).**

Wringing machine

Dry gluten press

Figure N°06 : The experimental gluten system

III.3. Phytochemical analysis

a) Extraction Process

The sample was pretreated before being introduced into the extraction vessel. The microwav extraction conditions described by **Brahmi et *al.*, (2023)** were applied in this experiment.

The operation consists of extracting secondary metabolites by dissolving in a flat bottomed flask, 2g of potato skin dry matter in a volume of 56 mL of 50 % (v/v) ethanol at a power of 400 W for 123 s. The first supernatant was obtained by centrifugation (5 minutes / 4000 rpm) and filtered using filter paper. The residue was re-extracted with 30 ml of ethanol under the same conditions. The two fractions collected after filtration were combined and adjusted to 86 mL

b) Quantitative phytochemical analyses

- **Total phenolics content**

Potato peels powder extract (PPE) was subjected to the adapted Folin-Ciocalteu method **Brahmi *et al.*, (2015)**. A volume of 100 µL of the extract was dissolved in 6mL of distilled water in reaction with 500µL of diluted 1 N Folin-Ciocalteu (1 :10) and 1.5 mL of 20 % sodium carbonate. The mixture was adjusted to 10 mL with distilled water and incubated at room temperature for 2h. The specific absorbance at 760 nm was immediately measured.

Gallic acid was used as the standard and absorbance was recorded at 765 nm. The total phenol content was determined from the linear regression equation for the gallic acid calibration range : $y = 10,681x + 0,0502$ where the coefficient of determination is $R^2 = 0,99$ **(Annexe 03).** TPC content is expressed in mg gallic acid equivalents per g dry weight (mg GAE/g DW).

- **Total flavonoid content**

Aluminium chloride colorimetric method was used for flavonoids determination **Brahmi *et al.*, (2015).** Briefly, 1 ml of hydroethanolic extract solution was added to 1 ml of 2% methanolic $AlCl_3$_ $6H_2O$ solution. The absorbance was measured with a spectrophotometer (Shimadzu, model: UV 100 Japan) at 415 nm length wave after 10 min of equilibrium. The level of flavonoids is determined from the linear regression equation of the quercetin calibration range, having the equation: $y = 35,907 x + 0,01$ with a coefficient of determination of $R^2 = 0.99$

(Annexe 04). The result is expressed in mg Quercetin equivalent per g of dry weight (mg QE/g DW).

- **Condensed tannin content**

Determination of tannins was performed according to the vanillin/HCl method adapted by **Broadhurst and Jones, (1978).** A volume of 0.5 mL of extract was dissolved in 3 mL of 4% vanillin methaniloc solution and 1.5 mL of concentrated 37% HCl.The mixture was incubated in the dark for 15 min/ 20°C. The absorbance was read using a spectrophotometer (Shimadzu, model : UV 100 Japan) at a wavelength of 500 nm (**Annexe 05).** The results were expressed in mg of catechin equivalent per g of dry weight (mg CE/g DW).

III.4. Assessment of antioxidant status

Spectrophotometric DPPH, ABTS and total antioxidant capacity (phosphomolybdenum -assay) methods were used to determine the total antioxidant activity.

III.4.1. DPPH radical scavenging activity assay

The free radical scavenging capacity was evaluated according to the procedure reported by **Brahmi et *al*, (2015)** using stable DPPH.

The antioxidant radical reaction was carried out for 1 hour, in the dark at room temperature by mixing 250 µL of the extract with a volume of 750 µL of DPPH° ethanol solution. The decrease in absorbance at 517 nm was measured against a pure ethanol blank to estimate the radical scavenging capacity of the extract. The absorbance was measured at 517 nm using a UV spectrophotometer on an ethanol blank. The experiment was repeated three times and the average values were recorded. The radical scavenging activity was calculated and expressed as a percentage of control using the following formula :

$$\textbf{Inhibition \% (I \%)} = (\textbf{Abs}_{\textbf{control}} - \textbf{Abs}_{\textbf{sample}}) / (\textbf{Abs}_{\textbf{control}})$$

Where :

Abs $_{control}$: was the absorbance of the blank (in which the same volume of ethanol was used in place of the extract)

Abs $_{sample}$: was the absorbance in the presence of the extract.

III.4.2. ABTS radical cation decolourisation assay

ABTS, 2,20-azinobis (3-ethylbenzothiazoline-6-sulfonic) diammonium salt is a free radical cation decolorization method. is also a widely used spectrophotometric method for evaluating the antioxidant activity of various products.

The experiment was performed using an improved ABTS decolorization assay **Ramful et *al*, (2010)** This assay is applicable to both lipophilic and hydrophilic compounds. ABTS+ was generated by oxidation of ABTS (7-mM) with potassium persulfate (2,45 mM) for 12 – 16 h before performing in the assay. 1 mL of the ABTS stock solution was further diluted in 50 mL of ethanol and the absorbance calibrated to 0.7 by the cumulative addition of few drops of methanol at 734 nm. 1 mL of the extract was reacted with 2 mLof cationic ABTS solution in a 1 cm long micro cuvette. The decrease in uptake was measured after 6 minutes of incubation in triplicate. IC50 value is obtained by linear regression analysis of the dose-response curve between % inhibition and extract concentrations according to the following equation:

Where:

$$\mathbf{AOX\% = (A_{control} - A_{sample})/A_{control}) \times 100}$$

$\mathbf{A_{control}}$ **:** absorbance of the control (ABTS.+ solution without test sample)

$\mathbf{A_{sample}}$**:** absorbance of test sample at t =6min

The IC_{50} parameter was introduced by **Brand-Williams et *al*, (1995)** and is used by many researchers. It defines the effective substrate concentration that causes the reduction 50% reduction in DPPH activity (**Brand-Williams et *al*., 1995), (Chew et *al*., 2009).** The lower the IC_{50}, the higher the anti-antioxidant activity.

III.4.3. Total antioxidant by phosphomolybdenum assay

The total antioxidant capacity of the PP extract was determined by the phosphomolybdenum assay **Brahmi et *al*, (2023)**. A 1 mL volume of the extract was combined with 1 mL of reagent (0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium). The mixture was incubated in a boiling water bath at 95°C for 90 minutes and cooled to room temperature. Subsequently the absorbance was measured at 695 nm versus blank using a UV spectrophotometer. The results were expressed in mg of ascorbic acid equivalent per g of dry weight (EAA mg/g DW) **(Annexe 07).**

III.4.4. Lipid peroxidation inhibition (LPI) activity

Lipid peroxidation inhibition (LPI) activity was determined using the -carotene bleaching assay, as described by **Chan et *al*, (2009)**. 0.5 mL of extract (4 mg / mL) was added to 2 mL of – carotene / linoleic acid solution. The mixture was incubated at 50 ◦C for 60 min along with two controls, one containing the antioxidant BHA (positive control) and the other one without BHA or extract (negative control). The absorbance was measured at 470 nm. LPI activity expressed as AOA (%) was calculated as follows:

$$\text{Bleaching rate of -carotene (BR)} = \ln[(A_{initial})/A_{sample}] /60$$

$$\text{AOA (\%)} = ((1 - \text{BR sample}) / \text{BRcontrol}) \times 100$$

Where :

Ainitial and **Asample** are absorbance ofthe emulsion before and 1 h after incubation, and **BRsample** and **BRcontrol** are bleaching ratesof the sample and negative control, respectively.

III.5. Evaluation of antibacterial activity

The bacterial activity of potato peel extract against pathogenic germs **(***E. coli, Pseudomonas Aeruginosa, Enterococcus faecalis, klabsiella pneumoniae, staphylococcus aureus, MRSA,Bacillus cereus, Salmonella, Bacillus subtilis, acinetobacter***)** was evaluated by the well diffusion method performed on Mueller Hinton agar medium.

- **Preparation of the extract :**

Preparation of 100 mg /mL concentration of extract in 100 mg/mL of distilled water

Spawning of bacterial species :

Bacterial species were streaked in nutrient agar, then incubated at 37°C to obtain well separated colonies which will be used for inoculum preparation.

- **Preparation of the inoculum :**

Well-separated colonies of the bacterial species were picked with a sterile platinum loop and homogenized in 10 mL of nutrient broth and then brought to incubation for 18 h at 37°C.

- **Standardization of bacterial inoculas :**

  - From a young culture of 18 hours, take a volume that is introduced into tubes containing sterile physiological water to obtain the bacterial inoculum **(Hazzit, 2008)**

  - Adjust the inoculum to an optical density between 0.08 and 0.13 using a spectrophotometer (at a wavelength of 625nm) which corresponds to a concentration of 10*7 to 10*8 CFU /ml.

  - Mix the suspension vigorously before use using a vortex and employ the inoculum with in 15 minutes of preparation **(Oukil ,2013), (CA-SFM,2018).**

- **Procedure :**

The well diffusion method, it is the basic technique used to study the capacity of a substance to exert an anti-microbial effect, it is also called : the agar dilution technique for the determination of active extracts.

- Using a swab, spread 0.1ml of the standardized bacterial suspension on Mueller Hinton agar and allow to dry for 15 minutes at 37°C.

- Wells are formed in the agar using apasteur pipette Then filled with 70 to 100µL of extract, the petri dishes are then put in the refrigerator at 4°C for 3h and finally incubated at 37°C for 24h.

- The antibacterial activity is determined in terms of the diameter of the zone of inhibition produced around the wells after 24 hours of incubation at 37°C measured in millimeters using a caliper **(Garrabé et *al.*, 1998)** and **(Gachkar et *al.*,2007)**

- **Expression of results :**

After 24 hours of incubation, the inhibition zones are measured in mm with a caliper or ruler **(CA- SFM, 2018**). According to **Ponce et *al*, (2013**), the sensitivity of bacteria was classified according to of diameter in inhibition halos, as summarized in this table :

Table IX : Sensitivity degrees of antimicrobial activity.

Diameter in mm	Degree of sensitivity
D < 8	Not sensitive (-)
8 < D < 14	Sensitive (+)
15 < D < 19	Very sensitive (++)
D ≥ 20	Extremely sensitive (+++)

III.6. Cytotoxicity test

Accordind to **pagano et *al*, (1986)** For blood washing, blood and physiological water are mixed in a centrifuge tube and centrifuged, after centrifugation the supernatant is discarded and physiological water is added and centrifuged again, until a clear supernatant is obtained, and the pellet is recovered.

- 1 ml of the recovered pellet is diluted in 9 ml of physiological water.
- In eppendorf tubes 500 µL of potato extract is added to 500 µL of the pellet.
- Control (-) : 500 µL of the pellet is mixed with 500 µL of physiological water.
- Control (+) : 500 µL of the pellet is mixed with 500µL of distilled water.
- The eppendorf tubes are incubated for 10 min then centrifuged at 5000 rpm / 5 min.
- The supernatant is recovered and the absorbance is read with a spectrophotometer at a wavelength of 540nm against a blank (500µl of potato peel flour extract + 500µl of physiological water)

- **Expression of results :**

% hemolysis = (abs of extract / abs of distilled water) * 100

Table X : Degree of toxicity

Percentage	degree of toxicity
0% - 9%	no toxic
10% - 49%	slightly toxic
50% - 89%	Toxic
90%-100%	highly toxic

III.7. Evaluation of the Anticoccidial Activity

Eimeria Oocysts Isolation and Purification Oocysts sample of *Eimeria spp*. Was isolated from fresh faeces of broilers suffering from coccidiosis in Bejaia area (Algeria). The oocysts were sporulated by incubation in 2.5% $K_2Cr_2O_7$ solution in the presence of suitable humidity (> 70%) a and temperature (29 C°) (**Carvalho et *al*., 2011)**. Sporulation in our study was carried out under laboratory conditions (where all the experiments were carried out). Sporulated oocysts were washed and counted using Malassez chamber. Mean number of oocysts per millilitre of sample was calculated.

The identification of *Eimeria* species in chickens was made on the basis of some standard parasitological techniques **(Carvalho et *al*., 2011)**. The oocysts were identified according to shape, presence or absence of micropyle, time of sporulation, intestinal location and appearance and coarse characteristics of intestinal lesions.

The purification of the oocysts was carried out from one-litre phosphate-buffered saline (PBS, containing 8 g/L NaCl, 0.2 g/l KCl, 1.13 g/L Na_2HPO_4, $2H_2O$ and 0.2 g/l KH_2PO_4) with some modifications (**Rhayour et *al*., 2003)**. Neutral substrates containing antibiotics (penicillin V 100 IU) were added to prevent any bacterial evolution and Fluconazole (17 mg/mL) was added as antifungal agent.

- **Effects of the peel potato extract (PPE) on the Decrease of Oocysts Number**

The activity of peel potato extract (PPE) and sunythetics compounds (Algicox) was determined in triplicate by incubation at ambient temperature for 24 h **(Remmal et *al*., 2011)**. The suspension solution was incubated at diferent periods of time 24 h. One millilitre suspension contains : 100 µL of washed suspension of *Eimeria* oocysts at **13.4×10^5** oocystes / mloocysts / mL ; 700 µL of PBS; 200 µL of the optimum peel potato extract (PPE). After incubation, the samples were centrifuged at 320 g for 5 min and the absorbance of the supernatant was measured at 273 nm by spectrophotometer (Shimadzu, model : UV 100 Japan). Then, the percentage of destruction of sporulated oocysts was estimated. The number of oocysts was counted three times in a cell volume of 1 µL amounts to 13.4×10^5.

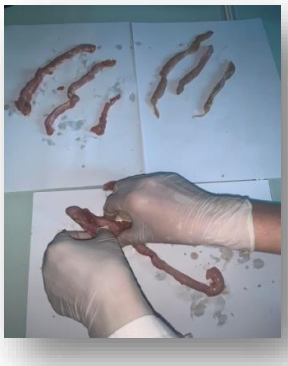


Figure N°07 : Photos taken during the Anticoccidial Activity

III.8. Cookie making

III.8.1. Cookie Preparation

The cookies were prepared according to approved method **10-54.01 (AACC, 2000)** with slight modifications. The formulation of a standard cookie using 100% wheat flour and 5 cookies enriched with different percentages of potato flour (10% and 20%) is shown in **(Table XII)**, for preparation ; granulated sugar, granulated brown sugar, skim milk powder, salt and all-purpose shortening were mixed using a mixer **(Kitchen Aid, USA)** to obtain a uniform creamy mixture, followed by the addition of water. After the addition of the flours and powders, the mixture was kneaded into a uniform dough. The dough was then rolled out to a thickness of 7mm and shaped with a circular cookie cutter. Baking was performed at 205°C for 11 minutes in an oven **(Simsek Laborteknik, Ankara, Turkey).**

Table XI : Ingredients for the control cookie (100% wheat flour)

Ingredients	Weight (g)
all-purpose shortening	32
granulated sucrose	26.8
granulated brown sugar	8
skim milk powder	0.8
Salt	0.5
Water	17.5
Sodium bicarbonate	1
Wheat flour	40

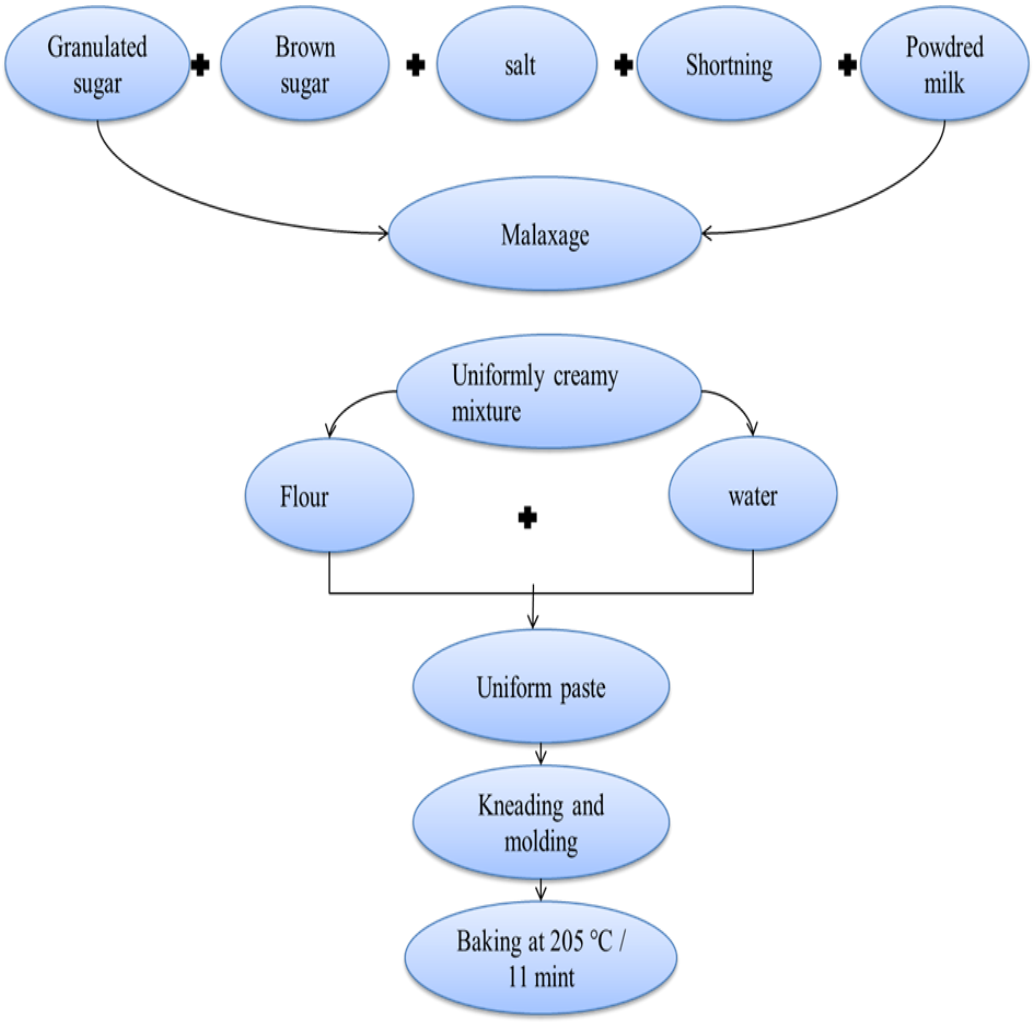

Figure N°08 : cookie production diagram

III.8.2. Mixture design

The aim of this study is to optimize a cookie recipe, so we have chosen a mixture design which will enable us firstly to evaluate the influence of factors on the chosen responses, and secondly to determine the optimum values for these factors **(GOUPY and CREIGHTON, 2002).**

The selected factors are :

X_1 : wheat flour **; X_2 :** potato peel powder **; X_3 :** cornstarch.

The answers are :

Y_1 : Color **; Y_2 :** Hardness **; Y_3 :** Friability **; Y_4 :** Odor **; Y_5 :** Mouthfeel **; Y_6 :** Sweetness **; Y_7 :** Consistency.

The mixing scheme leads to a polynomial equation written as :

$$Y = \beta_0 \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k-1} \sum_{i<a}^{k} \beta_{ia} X_i X_a + \sum_{i=1}^{k} \beta_{ii} X_i^2$$

With :

- **X_i :** Independent variable.
- **b_0** : interception **b_i , b_{ii} , b_{ia}** : coefficient of regression ,linear , quadratic er interaction terms
- **k** : number of variables.

Table XII : Experimental combinations with variable response for cookies.

Run	X1-Wheat Flour	X2-potato peel flour	X_3-cornstarch	Y1	Y2	Y3
1	0,8	0,2	0	32	8	0
2	1	0	0	40	0	0
3	0,8	0	0.2	32	0	8
4	0.8	0.1	0.1	32	4	4
5	0,9	0.1	0	36	4	0
6	0,9	0	0.1	36	0	4

III.9. Sensory evaluation of cookies

For the sensory evaluation, 10 panellists were selected from the University of Bejaia. Sensory analyses were carried out on 06 cookie samples (5 enriched and one control). The samples were presented to the panel in random order. Color, hardness, brittleness, odor, mouthfeel, sweetness, consistency and overall appreciation of the cookies were evaluated according to the percentage of powder incorporated.

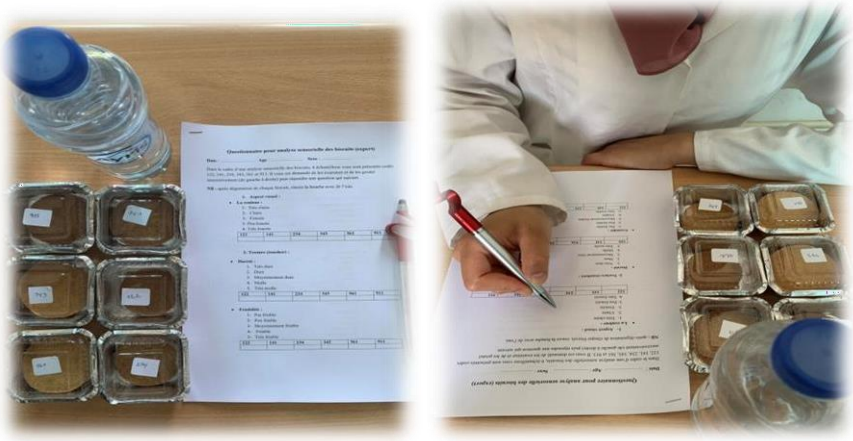

Figure N°09 : Photos taken during sensory analysis

III.10. Statistical study

Descriptive statistics parameters (means and standard deviations) were calculated using Microsoft Excel 2016.

JMP pro was used for statistical analysis using (ANOVA) ; and the tukey test. Results were expressed as mean ± SD to determine significant differences between means for all tests at a P value <0.05. All values are expressed as the mean of three trials (n= 3).

The letters a, b, c and d indicate significant differences between the different types of cookies prepared during the same week of storage ($p < 0.05$). With a >b >c>d.

Letters A, B, C and D indicate significant differences for the same type of cookie. During storage ($p < 0.05$). With a > b > c >d.

Chapter IV

Results and discussion

IV. Results and discussion

Due to their decomposition in the environment, food by-products such as potato peels contain essential organic matter (**Rawaa et *al*., 2023**).

This study presents the potential use of potato peelings as a food fortification ingredient, thus helping to promote environmentally-friendly food industries and minimize accumulated traces of synthetic products.

IV.1. Physicochemical analysis

Results of the physicomical parameters are given in table XIII. The yield of potatoe peel powder is about 10.21%, while its moisture content is 12.36%. The lower the water content, the lower the solubility of nutrients and the higher the nutritional and energy content of the product (Adegunloye and Oparinde., 2017). The water content of our sample is significantly higher than that reported in the literature (4.09%, 3.67%. 4 .08 % and 6.99%, respectively) (Rowayshed et al., 2015; Kumari et al., 2017; Elkahoul et al., 2018; Kndumari et al., 2017; Helal et al., 2020). In the other hand, **Ben jeddou et *al*., (2016)** reported a moisture content of 7.3% for the Spunta variety of Tunisian origin, this difference could be attributed to the influence of certain factors on physico-chemical properties, such as intra-specific variability or the drying procedure **(Helal et *al*., 2020)**.

Table XIII: The physicochemical properties and chemical composition of Potato peel powder

Content	**Potato peel powder**
Yield (%)	10.21
Moisture (%)	12.36 ±0.16
pH	5.54 ±0.05
Titratable acidity (%)	0,0001 ±0.00
Ash(%)	1.09 ± 0.10
Fiber (%)	47.3 ± 0.50
Total sugars (mg/g)	0.78 ±0.02
Gluten (g)	0±0
Protein (mg/g)	13.96 ± 0.35
Fat (%)	0.04 ± 0.00
Brix %	2.33±0.05

Concerning the pH of the studied sample, it is about 5.54. This value coincides with the norms recommended by Algerian standards and (5.5 - 8.5). Pradoxically, **Choumane et *al*., (2021)** and **Farvin et *al*., (2012**) have found a pH value of 8.12 and 6.05, respectively and **Vanabelle et *al*., (2000**) have reported 3.34 in potato peel purée. 5.03 ± 0.02 and 6.93 ± 0.01 have been obtained before and during the agroresidue fermentation process **(Adegunloye and Oparinde, 2017)**

Determining acidity plays an essential role in ensuring that convenience products meet specific requirements (appearance, texture, taste, nutritional information, etc.). In this study, titratable acidity (0.0001%) is almost absent compared to that noted by earlier recherchers. Indeed, **Vololonirina et *al*., (2021**) reported 2.01±0.001; 5.51±0.1; 2.04±0.008% with three potato varieties (white with red skin, white with white skin and orange flesh with orange skin), respectively and **Adegunloye and Oparinde, (2017**) found values between 0.80 ± 0.02 % and 3.80 ± 0.04 % before and during fermentation.

Ash content represents the total mineral content of foodstuffs, they play an important role from a physico-chemical and nutritional point of view **(Adegunloye and Oparinde, 2017).** Although minerals represent a small proportion of dry matter, often less than 7%, and the percentage of ash content was 1.09%, this result in agreement with that reported by **Elkahaoui et *al*., (2017**) who found traces (1.1%) in the potato peel. In contrast, a low content (0.73%) was recorded by **Ben jeddou et *al*., (2016)**. In comparison with the respective ash contents (9.03%; 6%. 7.92%) of potato peel noted by **Liang and McDonald, (2014); Rowayshed et *al*., (2015) and Helal et *al*., (2020**), that of our biomatrix is poor in this constituent.

Potato peel fiber can be considered as a potential ingredient for the formulation of lightweight food products. This co-product has a significant nutritional value, mainly composed of starch, dietary fiber and protein **(Ben jeddou et *al*., 2017)**. This class of compounds can have a positive impact on human health, such as cholesterol-lowering effect and improved diabetes control (soluble dietary fiber), as well as regulation of intestinal health (insoluble dietary fiber) **(Ben jeddou et *al*., 2017)**.

A recent report noted a fiber content of 51% **(Kumari et *al*., 2017)**, when studying potato peels of the Lady Claire variety, this amount is similar to that found in the present study (47.3%); but still lower (0.90%) then that reported by **Ben Jeddou et *al*., (2016)**, also lower contents have been reported (19, 59%; 22.39% and 7.92%, respectively) in the Spunta variety

(Elkahoui et *al*., 2018; Helal et *al*., 2020). The discrepancy between the proportions may be linked to the metabolic profile of the studied varities, which shows great variability depending on the genotype **(Inostroza-Blancheteau et *al*., 2018)**.

These molecules have been used to improuve the texture, water retention, and stabilization of emulsions widely know by their prebiotic effect **(warrand, 2006)**, and biological activities: anti-inflammatory, anti-coagulant and anti-oxidant activities **(Scheppach et *al*., 2004; Zhao et *al*., 2005).** The result of our study recorded a low 0.78 mg/g DW sugar content. In contrast, **(Choi et *al*., 2016)** brought a higher percentage: glucose 566-723 mg/100 g DW; fructose 433-683 mg/100 g DW; and sucrose 290-427 mg/100 g DW. Similarly, other works **(Elkahoui et *al*., 2018; Helal et *al*., 2020)** have reported higher values (65.47 and 70 g/100g DW).

A review of the literature highlighted that protein is the second most abundant macronutrient in potato skin, although its content varies considerably from one study to another, ranging from 2 to 17 g/100 g DW **(Sampaio et *al*., 2020)**. In our study, the protein content extracted from potato skin is 13.96 mg/g DW, which is higher than that reported by **Dhingra et *al*., (2012)** with a value of 14.04%. In contrast, **Choi et *al*. (2016)** reported a total protein content between 9.52-10.58 g/100 g DW. Our biomatrix was found to be richer in protein compared to those (17.19% and 18%) found by **Elkahoul et *al*. (2018)** and **Liang and McDonald, (2014)**, respectively on the same matrix. In the same way, **Ben jeddou et *al*. (2016) and Sato et *al*. (2017)** showed lower contents (0.2% and 2%, respectively).

Even among different varieties, the fat content of PP is very low. **Amado and *al*. (2014)** have highlightd the absence of these compounds; and others researchers have found 2.6 g/ 100 g DW and 2.80 g/100g DW, respectively **(Arapoglou et *al*., 2010; Helal et *al*., 2020)**; which are higher than found in our study (0.04mg/10g DW). In the other hand, a high lipid content (8.43%) extracted from potato skin is obtained by **(Rowayshed et *al*., 2015)**.

The refractometric index of potato peel determines its soluble sugar content. According to a study carried out on the Solanaceae family, between 1999 and 2002 between the beginning of June and the end of September, the Brix level was ranged from 4.5 to 5.2 (**Stâubli, 2003)**, these later exceed that of our sample, which is 2.33 ±0.05 %.

Gluten is composed mainly of two groups of reserve proteins: gliadins (wheat prolamins) and glutenins (wheat glutenins) **(Bushuk, 1986; Perten 1989)**. The dough's

elasticity is due to gliadins and its toughness to glutenins. In fact, gluten proteins (prolamins), thanks to their spiral and elastic structures, give bakery products softness and excellent baking properties. The result shown in **(Table XIII)** indicates the absence of gluten in the analysed sample. According to the literature, potato peel is gluten. In terme of the physicochemical analysis we have noticed a difference in most of the parameters between our sample and those studied by other researchers, this result can be explained by their taxonomic differentiation and the geographical or experimental conditions **(Vololonirina et al., 2021).**

IV2. Phytochemlical analysis

In order to determine whether there is a link between the ethnomedical applications of (*Solanum tuberosum* L.) and its antioxidant activities, different tests were performed to evaluate the free radical scavenging capacity and activity of the ethanolic extract of potato peel. We evaluated the total phenolic content (TPC), total flavonoid content (TFC), condensed tannins, DPPH free radical scavenging, reducing power, ABTS, ß-Caroténe and total antioxidant based on phosphomolybdate method activities of the extract from potato peels (EPP). The results are presented in the table below.

Table XIV: Phenolic compounds and biological activities

Phenolic compounds and biological activities		**Results**
TPC (mg GAE/g DW)		0.78 ± 0.02
TFC (mg QE/g DW)		0.31 ± 0.00
Condensed tannin (mg CE/g DW)		0.48 ± 0.08
Dpph° %		55.79 ± 1.60
Phosphomolybdate activity (mg AAE/g DW)		1.87 ± 0.06
ABTS IC50 (mg/ml)		6.77 ± 0.8
LPI (%)		42.23 ± 0.04
Anticoccidial Activity(%)		11.46 ± 0.23
Cytotoxicity (%)	**Concentration 5%**	1.19 ± 0.09
	Concentration 10%	1.69 ± 0.07

TPC : total polyphenols content ; TFC : total flavonoid content ; LPI : lipidic peroxydation inibition.

Potatoes are a good source of phenolic compounds, but their presence in its peels is not well documented **(Sagufta et *al.*, 2019)**. In the present study, we used gallic acid as the standard and the results are expressed in milligram equivalents of gallic acid per gram (mg GAE/g DW)

of dried extract. We have systematically recorded the quantitative estimation of phytoconstituents in ethanolic extract of potato peels with a low content (0.78 mg GAE/g DW). Indeed, previous studies have shown that most phenolics are found in the skin, but small quantity are found in its flesh **(Albishi et *al*., 2013)**.

A very low concentration is dteceted in the studied matrix compared to those reported in the literature about other varieties. Indeed, 4.64 -13.85 mg GAE/g of dried PP have been reported by **Albishi et *al.* (2013)**, whereas, hight content (20-83 mg GAE /g DW) has been found using subcritical water extraction **(Alvarez et *al*., 2014; Arun et *al*., 2015)** and almost content (3.310 and 14.031mg GAE/g) has been reported in the acidified ethanol and water extracts **(Silva-Beltrán et *al*., 2017)**. Additionnaly, **Hsieh et *al*. (2016)** quantified a very high phenolic acid content (86.3 mg GAE/100 g DW) in aqueous extracts of PP, contrary **Friedmân et *al*. (2017)** have noted a very low content (11.3 µg/mg) compared to that obtained in our study. Content of our sample is potentially lower that abtained in the same extraction conditions (86.54 mg GAE/100g DW). (**Brahmi et *al*., 2023**).

Concerning the total flavonoid content (TFC), **Silva-Beltrán et *al*., (2017)** suggest that despite the low concentration of flavonoids such as rutin and quercetin, PP can be considered a good source of flavonoids based on its composition. Our results confirm the presence of flavonoids in the extract, based on quercetin as the standard. Indeed, TFC are expressed as milligram equivalents of quercetin per gram (mg QE/g DW). The content found (0.31 mgEQ/g DW). This is higher than those reported by **Friedman et *al*. (2017)**, which about 0.007 and 0.023 mg/g DW, with methanolic extracts from six cultivars and that reported by **Helal et *al*. (2020)** with an amount of 0.13 mg Rutin /g of DW). High level of total flavonoids (3.310± 0.331 mg EQ/g DW) has been reported in ethanol extract **(Silva-Beltrán et *al*., 2017)**, while the aqueous extract has exhibited a lowerconetent (1.016 ± 0.116 mg EQ/g DW). Highest content is recorded by **Freidman et *al*. (2017)** which is in the range of 780 to 2300 mg EQ/100g DW. In the other hand, 6.02 mg EQ /g DW) are found by Choi **and his coworkers. (2016)**. The lowest levels of total flavonoids (0.007 and 0.023 mg/g DW) are reported by **Friedman et *al*. (2017)**, who worked on 80% methanolic extracts of six cultivars.

The discrepancy between the TPC and TFC contents obtained in this experiment and those reported in the literature can be attributed to the diversity of potato genotypes, growing conditions and the extraction process **(Joly et *al*., 2020)**. However, factors such as cultivar,

harvesting, storage conditions and processing **(Karaman et *al*., 2013)** can be responsible for this variation.

IV.3. Antioxidant activities

Numerous studies have reported the antioxidant capacity of potatoes **(Friedmàn et *al*., 2017; Helal et *al*., 2020).** In addition, the use of EPP (peeled potato extract) as a source of primary antioxidants or free radical terminators **Singh and Sakariah, (2011**) and **Joy et *al*, (2021)** has been evaluated.

The antioxidant activity of potato peel was assessed by DPPH, ABTS, ß-Caroténe and molybdate assays **(Tab XV)**. We used three methods to determine antioxidant activity because different mechanisms are involved in the antioxidant processes of polyphenolic compounds **(Llorent-Martínez et *al*., 2016)**. In addition, previous studies have shown the limitations of using a single method to determine this activity **(Su et *al*., 2020)**.

The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging test is simple, rapid, reliable and reproducible method for assessing the free radical scavenging activities of pure compounds and plant extracts, making the DPPH method ideal for modelling the reaction between antioxidants and lipids in the food system (**Koleva et *al*., 2002**; **Marxen et *al*., 2007**). The method is based on the reduction of purple DPPH to yellow diphenylpicrylhydrazine and the measurement of the remaining DPPH **(Cardoso et *al*., 2013)**.

The inhibition percentage of 55.97±1.6% was noted in our study, this result is in line with that reported in previous works. In fact, it has been reported that the antioxidant effect of the ethanol extract from potato skin, obtained after a long induction period, was effective **(Franco et al., 2016; Helal et *al*., 2020)**. In the same way, the oxidation of soybean oil is delayed by the use of potato extract, which has increased its induction period and shelf life **(Samarin et *al*., 2001)**. The longest induction period is attributed to synthetic antioxidants due to the purity of their components, unlike natural antioxidants which are composed of complex mixtures and a low concentration of active principle. The use of natural extracts is healthy for human **(Samarian et *al*., 2012; Amado et *al*., 2014)**. The inhibition rate of our biomatrix is much higher than that (9%) obtained after an extraction pretreatment using pulsed electric fields to potato peels. (**Lima et *al*., 2021)**

The antioxidant activity of potato extract was determined also by the ABTS method, which was chosen because it can be applied to assess the antioxidant capacity of hydrophilic and hydrophobic bioactives in plant extracts **(Dai and Mumper, 2010)**. Our extract was able to

inhibite 50% of the free radicals at a concentration of 6.77 ± 0.8 mg/ml, a very high positive correlation was recorded between TPC and ABTS ($r = 0.99$) according to the regression equation (Y=4.86x +20.12). Our biomatrix expresses less antioxidant power than that displayed by **Ben jeddou and his coworkers (2016)**, this group of researchers **have reported an inhibition of** 50% with only 2 mg/mL. In a study carried out on *HeiJingang* and *Favorita* varieties **(Makori and Sun, 2021)**, the showed higher ABTS radical scavenging capacities (55.02 and 48.25 mg AAE/100 g DW, respectively) with a significant difference ($P < 0.05$) between them.

The difference observed for the two tests could be justified by the lipohilic nature of the constituents, which express a higher antiradical activity than hydrophilic compounds (**Joy et *al.*, 2020**).

The phosphomolybdenum test based on the reduction of Phosphate-Mo (VI) to phosphate-Mo (V) was used to assess the total antioxidant capacity (TAC) of potato peel extracts. Referring to a regression curve of the standard (ascorbic acid), the ability of the ethanolic extract of PP to reduce molybdate ions was about1.87±0.06 mg AAE/g DW **(Tab XIV)**. This biological property is certainly linked to the therapeutic virtues attributed to a range of bioactive molecules synthesized by potato skins. These natural phenolic molecules are highly sought-after as sources of antioxidants and antimicrobials for food preservation **(Pezeshk et *al.*, 2015)**.

Khalil, (2000) has reported that 90% ethanol extracts from potato peels exhibited antioxidant activity in model systems (ß-carotene/linoleic acid emulsions). In order to confirm this activity, we have attempted to test the efficacity of our sample by using the β-carotene bleaching method based on linoleic acid oxidation. Hydroperoxides of linoleic acid react with the β-carotene molecule, resulting in the rapid disappearance of the characteristic orange color **(Binsan et *al.*, 2008)**. The presence of an antioxidant can hinder the effect of β-carotene by acting on linoleate free radicals and other free radicals formed in the system **(Balti et *al.*, 2011).**

In agreement with our results, several authors have reported that the bleach inhibition activity of β-carotene **(Ben jeddou et *al.*, 2018)**, potato skin extracts in rat liver homogenates **(Singh and Rajini, 2004)** and iron ion chelation indicates the antioxidant potential of this bioresidue. An inhibition rate of 45.34± 3.65% and 90±1.5% at a concentration of 50 mg/mL was noticed. BHA has a moderate antioxidant activity, with a reduction rate of 44.23±0.04l% and potato peel extract (PPE) showed an inhibition rate of 42.22% which presents a significant difference ($p \leq 0.05$) with the standard (BHA). This result is less significant than that by **Ben Jeddou et *al.* (2018)**.

IV .4. Cytotoxicity of potato peels

The results of the cytotoxicity effect of potato peel powder are shown in **Table XV**. for the two tested concentrations (5% and 10%) the haemolysis rate was 1.19 and 1.69%, respectively, these rates are lower than (9%), which means that potato peel powder is not toxic, which means that we can incorporate it into our product.

IV.5. Anticoccidial activity

A study by **Freidmàn et *al,* (2018)** evaluated the antiprotozoal activity of potato skin on three pathogenic species of trichomonads. These authors showed that compounds such as caffeic, chlorogenic acids and quercetin in PP were mildly active against the parasites.

As part of a literature review on food processing containing bioactive compounds active against cancer cells **(Friedman et *al.*, 2015)** and pathogenic microorganisms **(Juneja et *al.*, 2018)** and to reduce weight gain in mice fed a high-fat diet **(Elkahoui et *al.*, 2018)**, we tested potato peels, a by-product of the potato processing industry, against protozoan parasites (coccidia) belonging to the genus *Eimria,* isolated from naturally infected broilers. In fact, evaluation of the PP extract showed a percentage oocyst ihibition of (11.46%). This destructive effect is manifested by the alteration of the wall and fragmentation of sporulated oocysts (infecting form), resulting in the release of intracellular contents such as aromatic amino acids and nucleotides, which are expressed by UV-absorbing substances at a wavelength of 273 nm after 24h treatment **(Remmal et *al.*, 2011).** This anticoccidial activity could be attributed to an individual or combined effect of bioactive compounds **(Kalmobé et *al.*, 2017).** Potato peel constituents such as chlorogenic, acid and favonoids **(Choi et *al.*, 2016; Hachemi et *al.*, 2021)**, phenolic compounds and carotenoids, which may be responsible for antioxidant and anti-inflammatory properties, may be linked to anticoccidial activity **(Fard et *al.*, 2015; Abdel-Latif et *al.*, 2017)**.

Our result is in line with **Friedman et *al,* (2018)**, who showed that raw potato peel extracts have different antiprotozoal inhibitory effects depending on genotype and strain, but, as observed in the inhibition of complex organisms **(Smith et *al.*, 1985)** , the peel of the Russet variety, despite the lowest content of bioactive elements , showed the highest inhibitory effect, suggesting the presence of additional compounds capable of influencing the bioactivity of these compounds and modulating their final effect.

IV.6. Antimicrobial activity

The results of the antibacterial activity of the potato peel extract samples are shown in the table below.

Table XV: Results of antimicrobial activity analysis

Bacterial strains	Gram	Average zone of inhibition sizes (mm)	Standard devations
Staphylococcus aureus	+	25,75	0,1767
Enterococcus feacalis	+	24,85	0,2121
Bacillus subtilis	+	24,8	0,2828
Bacillus cereus	+	20,65	0,4949
Acinetobacter	-	21,3	0,2828
E.colie	-	18,35	0,2121
Salmonella typhie	-	17,75	0,3535
Klebseilla pneumonaea(ATCC)	-	17,5	0,7071

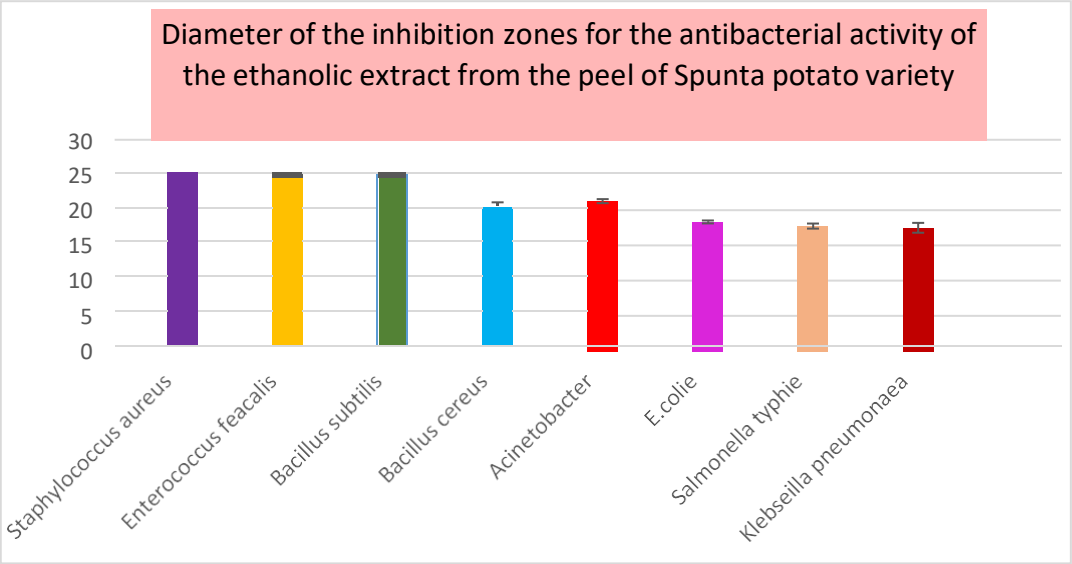

Figure N°10: Diameter of the inhibition zones for the antibacterial activity of the ethanolic extract from peels of *spunta* potato variety

Potato peels, often considered mere kitchen waste, have recently gained attention in scientific research due to their potential antibacterial properties.

Data in (**Tab XV)** illustrated that potato peels extract was more effective in inhibiting Gram-positive than Gram-negative. According to the table reported by Ponce **et *al*, (2003)**, our results show an extreme sensitivity of Gram-positive bacteria to our extract. On the other hand, Gram-

negative bacteria exhibit variable sensitivity, ranging from highly sensitive to extremely sensitive.

According to the graph **(Fig N°10)** we observe that the zone of inhibition for Gram-positive bacteria is higher, ranging from 20,65 ±0,49 mm to 25,75 ±0,27 mm for the bacterial strains *Bacillus cereus* and *Staphylococcus aureus* respectively. In contast, the halo sizes range from 17,50 ± 0,70 mm to 21,30 ± 0,28 mm for the bacterial strains *Klebseilla pneumoneae* and *Acinetobacter*, both of which are Gram-negative bacteria.

This antibacterial activity potential may be attributed to the presence of polyphenols, flavonoids, tanins and alkaloids in the phytochemical composition of potato peels, as well as their antioxidant activity.

These results are agree well with those found by **M.M. Helal et *al*, (2020)** and **Amnpour et *al*, (2015)**, who reported that Potato peels extract has antibacterial activity and its activity on Gram-positive bacteria was more pronounced than Gram-negative bacteria.

(Khalfa et *al*., 2016) that potato peels methanol extract has antibacteral activity against *Echerichia coli* and *Staphylococcus aureus*. **Naz et *al*, (2017)** reported that phenolic compounds extracted from potato peels and pulp has significant effect on *Bacillus subtilis* growth**. N. Sinha and D. Dua, (2016)** show that the antibacterial activity of methanolic extract of potato peels was determined by agar well diffusion method and it showed significant effect on growth inhibition of Gram-positive (*B amyloiquefaciens* and *Staphylococcus aureus)* and Gram-negative *(Echerichia coli* and *Pseudomonas aerugenosa).*

Potato peels naturally contain a variety of alkaloids, predominantly Solanine and Chaconine, which are chemical compounds potentially toxic to many organisms, including bacteria. The amphiphilic natur of alkaloids gives them the property of disrupting the lipids in the bacterial membrane, which are esential for its integrity and function. This disruption can lead to the destruction of the membrane and cellular lysis, resulting in bacterial cell death or inhibition of bacterial growth.

Overall, the antimicrobial mechanisms of polyphenols, flavonoids and tanins involve disrution of bacterial membranes, interference with enzymatic activity, modulation of gene expression, and induction of oxidative stress, collectively contributing to the inhibition of bacterial growth.

IV.7. Mixture design results

The results of the design adopted during our experiment are shown in the following table.

Table XVI: Responses from the mixture design matrix.

	EXPERIMENTAL VALUES									
	X_1- Wheat flour	**X_2- PP**	**X_3- cornstarch**	**Y_1- Color**	**Y_2- hardness**	**Y_3- Friability**	**Y_4- Odor**	**Y_5- mouthfeel**	**Y_6- sweetness**	**Y_7- Consistency**
1	0.80	0.20	0.00	4.45	1.82	2.36	2.82	4.27	3.27	3.64
2	1.00	0.00	0,00	2.36	2.64	3.33	2.08	3.73	3.73	3.18
3	0.80	0.00	0.20	3.25	2.10	3.00	2.25	4.27	3.82	3.55
4	0.80	0.10	0.10	2.64	2.17	3.18	2.50	4.09	4.00	2.91
5	0.90	0.10	0.00	3.18	1.92	2.91	2.50	4.00	3.82	3.55
6	0.90	0.00	0.10	2.90	2.27	2.91	2.36	3.91	3.73	3.45
	PREDICTED VALUES									
	X_1-wheat flour	**X_2- PP**	**X_3- cornstarch**	**Y_1- expected values**	**Y_2- expected values**	**Y_3- expected values**	**Y_4- expected values**	**Y_5- expected values**	**Y_6- expected values**	**Y_7- expected values**
1	0.80	0.20	0.00	4.45	1.82	1.82	2.82	4.27	3.27	3.64
2	1.00	0.00	0.00	2.36	2.64	2.64	2.08	3.73	3.73	3.18
3	0.80	0.00	0.20	3.25	2.10	2.10	2.25	4.27	3.82	3.55
4	0.80	0.10	0.10	2.64	2.17	2.17	2.50	4.09	4.00	2.91
5	0.90	0.10	0.00	3.18	1.92	1.92	2.50	4.00	3.82	3.55
6	0.90	0.00	0.10	2.90	2.27	2.27	2.36	3.91	3.73	3.45

Processing of the color results indicated a variation of the appriciaction from 2.36 to 4.45, with the quantity of powder incorporated having an influence on this property, the highest value being observed when a large quantity was used 20 %.

However, for hardness, results ranged from 1.82 to 2.64, with the opposite effect was observed, with the highest value observed in the cookie without the potato powder.

For friability, results ranged from 2.36 to 3.18, with the highest value observed when 10 % was incorporated.

For odor, results ranged from 2.08 to 2.82. The quantity of powder incorporated had an influence on this property, with the highest value observed when a high quantity was used 20%.

For mouthfeel, results ranged from 3.73 to 4.27, with the highest value observed in cookie 01 where 20% of powder was incorporated and in cookie 3 without powder.

For sweetness, results ranged from 3.27 to 4, with the highest value observed in cookie 04 where a quantity of 10% was added.

For consistency, results ranged from 2.91 to 3.64, with the highest value observed in cookie 01, so the amount of 20% powder incorporated influenced this property.

Table XVII shows the individual and interactive effect of three independent variables

$\mathbf{X_1}$ quantity of wheat flour; $\mathbf{X_2}$ quantity of potato peel powder; $\mathbf{X_3}$ quantity of cornstarch on cookie properties.

Table XVII: The individual and interactive effect of three independent variables

	Y_1-Color			Y_2-Hardness		
Source	**Estimatio**	**Df**	**Sum of squares**	**Estimation**	**Df**	**Sum of squares**
Model		5	2.64		5	0.41913333
X_1- wheat flour	2.36	1	5.569600	2.64	1	6.9696000
X_2-PP	4.45	1	19.802500	1.82	1	3.3124000
X_3- cornstarch.	3.25	1	10.562500	2.1	1	4.4100000
X_1*X_2	-0.9	1	0.033750	-1.24	1	0.0640667
X_1*X_3	0.38	1	0.006017	-0.4	1	0.0066667
X_2*X_3	-4.84	1	0.976067	0.84	1	0.0294000
	Y_3-Friability			**Y_4-Odor**		
Source	**Estimatio**	**Df**	**Sum of squares**	**Estimation**	**Df**	**Sum of squares**
Model		5	0.55108333		5	0.32088333
X_1- wheat flour	3.33	1	11.088900	2.08	1	4.3264000
X_2-PP	2.36	1	5.569600	2.82	1	7.9524000
X_3- cornstarch	3	1	9.000000	2.25	1	5.0625000
X_1*X_2	0.26	1	0.002817	0.2	1	0.0016667
X_1*X_3	-1.02	1	0.043350	0.78	1	0.0253500
X_2*X_3	2	1	0.166667	-0.14	1	0.0008167
	Y_5-Mouthfeel			**Y_6-Sweetness**		
Source	**Estimatio**	**Df**	**Sum of squares**	**Estimation**	**Df**	**Sum of squares**
Model		5	0.22275000		5	0.30068333
X_1- wheat flour	3.73	1	13.912900	3.73	1	13.912900
X_2-PP	4.27	1	18.232900	3.27	1	10.692900
X_3- cornstarch	4.27	1	18.232900	3.82	1	14.592400
X_1*X_2	1.61e-15	1	1.0798e-31	1.28	1	0.068267
X_1*X_3	-0.36	1	0.005400	-0.18	1	0.001350
X_2*X_3	-0.72	1	0.021600	1.82	1	0.138017
	Y_7-Consistency					
Source	**Estimatio**	**Df**	**Sum of square**			
Model		5	0.39120000			
X_1- wheat flour	3.18	1	10.112400			
X_2-PP	3.64	1	13.249600			
X_3- cornstarch	3.55	1	12.602500			
X_1*X_2	0.56	1	0.013067			
X_1*X_3	0.34	1	0.004817			
X_2*X_3	-2.74	1	0.312817			

- The mixture design led to the following equations:

$\mathbf{Y_1} = 2{,}36X_1+4{,}45X_2+3{,}23X_3- 0{,}9X_1X_2+ 0{,}38X_1X_3+4{,}84X_2X_3$

$\mathbf{Y_2} = 2{,}64X_1+1{,}82X_2+2{,}1X_3-1{,}24X_1X_2- 0{,}4X_1X_3+0{,}84X_2X_3$

$\mathbf{Y_3} = 3{,}33X_1+2{,}36X_2+3X_3+ 0{,}26X_1X_2-1{,}02X_1X_3+2X_2X_3$

$\mathbf{Y_4} = 2{,}08X_1+2{,}82X_2+2{,}25X_3- 0{,}2X_1X_2+ 0{,}78X_1X_3-4{,}84X_2X_3$

$\mathbf{Y_5} = 3{,}73X_1+4{,}27X_2+4{,}27X_3-1{,}61e\text{-}15X_1X_2- 0{,}36X_1X_3-0{,}72X_2X_3$

$\mathbf{Y_6} = 3{,}73X_1+3{,}27X_2+3{,}82X_3+1{,}28X_1X_2- 0{,}18X_1X_3+1{,}82X_2X_3$

$\mathbf{Y_7} = 3{,}18X_1+3{,}64X_2+3{,}55X_3- 0{,}56X_1X_2+ 0{,}34X_1X_3-2{,}74X_2X_3$

IV.8. Phytochemical analysis and antioxidative activities of cookies

From the results shown in Figure N°11, it can be seen that the total polyphenol contents of the six cookies differ according to the incorporated percentage of potato peel powder; However, it is noticeable that the contents for cookies 01 and 05 are the highest 0.38±0.06 mg GAE/g DW and 0.32±0.00 mg GAE/g DW; respectively, followed by cookie 04 with a content of 0.30± 0.01 mg AGE/g DW, cookies 03, 02 and 06 presented almost similar values 0.28± 0.00 ; 0.29 ±0.2 and 0.29± 0.1 mg GAE/g DW, respectively

Table XVIII: phytochemical parameters and antioxidant activities of cookies.

	Cookie 04	**Cookie 03**	**Cookie 05**	**Cookie 02 (control)**	**Cookie 06**	**Cookie 01**
TPC (mg GAE/g DW)	0.30±0.01	0.28±0.00	0.32±0.00	0.29±0.02	0.29±0.01	0.38±0.00
Flavonoids (mg Q.E/g DW)	0.07±0.01	0.16±0.05	0.23±0.01	0.22±0.02	0.08±0.01	0.37±0.00
Condensed tannin (mg CE/g DW)	/	/	/	/	/	0.32±0.02
Dpph° %	40.10±3.94	18.43±0.34	33.45±3.63	18.86±1.64	20.94±0.60	42.33 ±0.53
Phosphomolybdate (mg AAE/g DW)	1.35±0.04	2.09 ±0.07	1.66 ± 1.6	1.68±0.15	1.77±0.2	2.12 ±0.22
ABTS IC50 (mg/ml)	/	/	/	17.06 ±0.2	/	16.31 ±0.4
LPI (%)	42.09±0.04	42.19±0.03	42.22±0.01	42.27±0.04	42.16±0.05	42.29±0.07

Statistical analysis revealed a significant difference (P<0.05) in TPC content between cookie 01 and cookies 04, 02, 06 and 03, However no significant difference was recorded between cookie 06 and 03. This amount of phenolic compounds is similar (0.33 ± 0.64 mg GAE/g DW) than that reported in a recent study on the same matrix (**Tlay R. H. et *al.*, 2023)**.

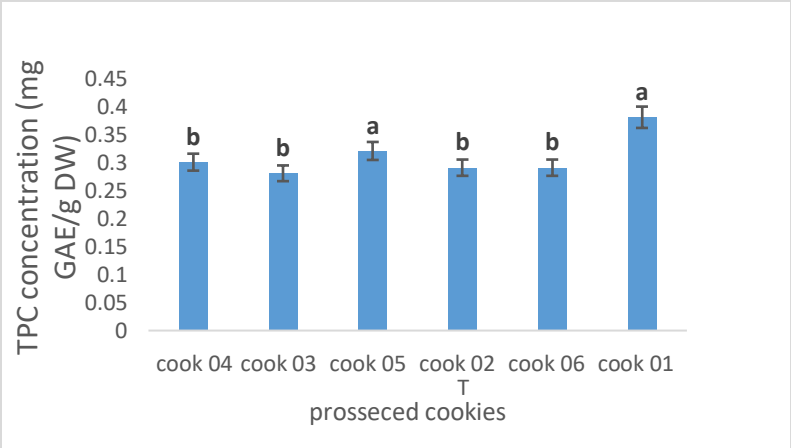

Figure N°11: TPC content of processed cookies

Flavonoid content was determined from the quercitin calibration curve, expressed as mg QE /g DW. The main reason for assaying this class of polyphenols is that flavonoids are the most important polyphenol class. The results obtained are shown in **Figure N°12**.

According to the results shown in the table, the flavonoid content of cookie 01 is higher (0.37±0.00 mg QE/g DW) than that of the other cookies. While almost similar contents are recorded for cookies 02 and 05 with (0.22±0.02 and 0.23±0.01 mg QE/g DW, respectively), However cookies 06 and 04 have almost negligible contents (0.08 ±0.01 and 0.07±0.01 mg QE/g DW, respectively). Statistical analysis reveals a significant difference (P<0.05) in flavonoid content between all cookies, except for cookies 05 and 02.

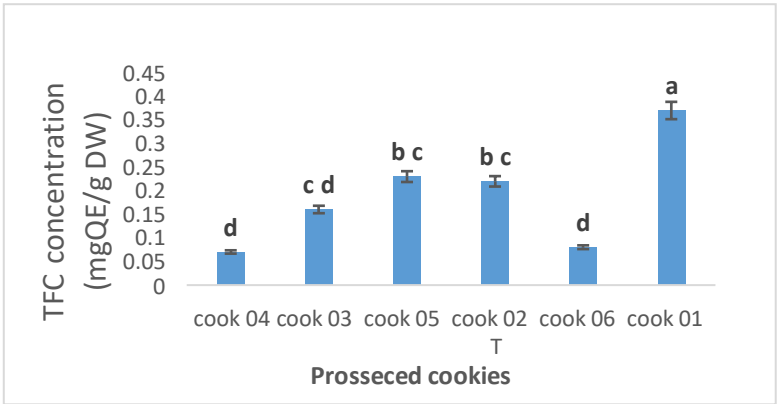

Figure N°12: flavonoid content of processed cookies

The results of the tannin assay are expressed as mg catechine equivalent per g dry weigth, and are shown in **Table XVIII**. These results clearly show that cookie 01 contains a low quantity of condensed tannins (0.32 ± 0.02 mg CE/g DW), whereas the other cookies are completely devoid of these bioactive substances.

The IC50 ABTS values for the cookie types, which indicate the concentration that scavenges 50% of free radicals, are shown in the **Table XVIII**. Concerning the ABTS test, extracts from cookie 02 and 01 showed almost similar antioxidant activity in both tests, with an IC50 values of 17.02 ± 0.2 and 16.31±0.4 mg/ml, respectively. Statistical analysis showed no significant difference between cookies 02 and 01.

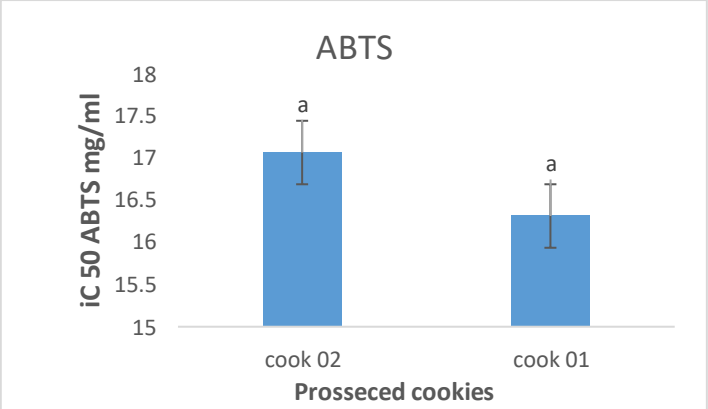

Figure N°13: The IC50 ABTS of processed cookies

According to our results presented in the **Figure N°14**, we identified levels ranging from 18.86±1.64% corresponding to cookie 03, to the highest percentage 42.33±0.53% corresponding to cookie 01, no significant difference is recorded between cookies 04, 01 and 02, but there is a difference between the latter and cookies 06, 02 and 05.

On the other hand, **Tlay et *al*. (2023)** reported a slightly higher inhibition percentage (54.71) compared to that exhibited by our sample (42.33± 0.53).

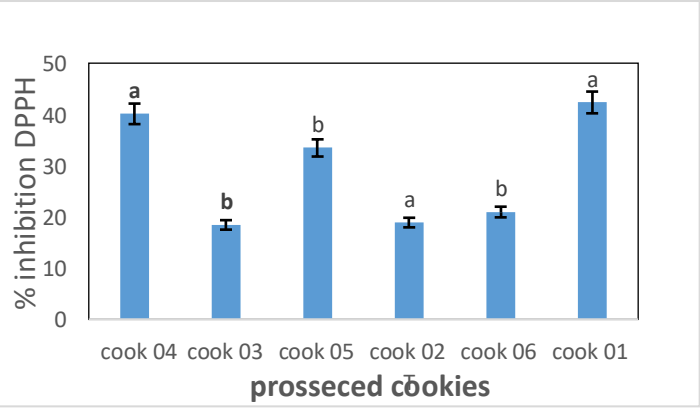

Figure N°14: DPPH rate for processed cookies

The molybdate antioxidant activity of the six cookies was determined on the basis of the ascorbic acid calibration curve; the results obtained are shown in the **Figure N°15.** The greatest effect for the molybdate test was exhibited by cookies 01 and 03, with similar values (2.12 ±0.22 and 2.09 ±0.07 mgAA/g DW). While cookie 04 showed the lowest value with (1.35±0.04 mgAA/g DW). Statistically, no significant difference was detected between cookie 01 and 03, but it exist between cookies 01 and 03 and the other cookies (04, 05, 02 and 06). There is no significant difference between cookies 06, 02 and 05, but these three cookies are significantly different from cookie 06.

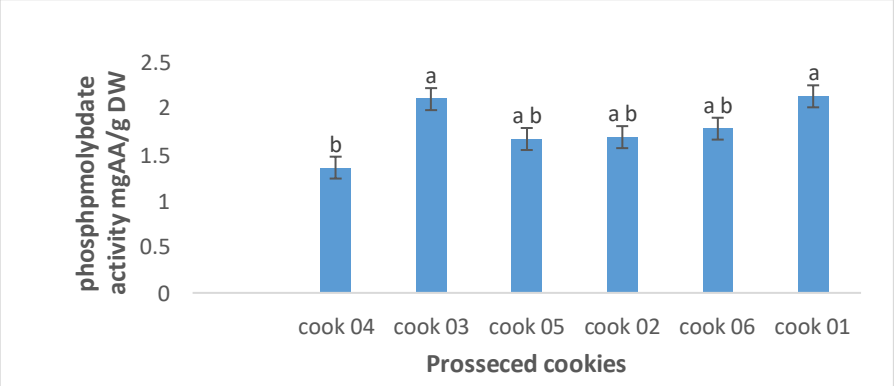

Figure N°15: Phosphomolybdate activity in processed cookies

On the basis of the results illustrated in **Figure N°16**, the percentage of LPI activity is almost similar for all the cookies with values limited between (42.09±0.04% and 42.29±0.07%) as long as the statistical study reveals that no significant difference exists between the cookies (04, 05, 02 and 01) on the other hand a slight difference is detected between these last cookies and the cookies 03 and 06.

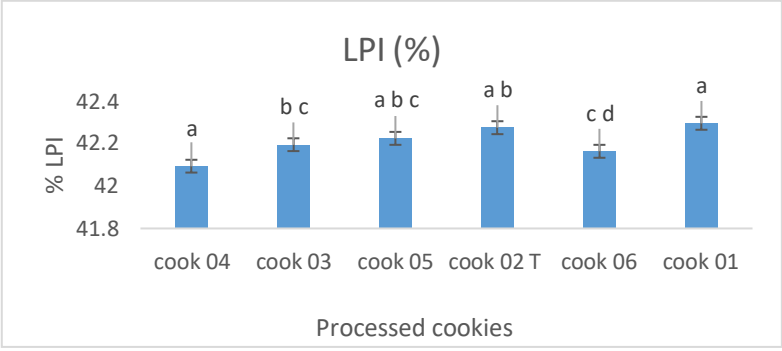

Figure N°16: LPI rate of processed cookies

IV.9. Sensory analysis

For the sensory analysis, before carrying out the various tests on XLSTAT, an experimental design was created. Once the data from the expert juries has been reported to the software, the experimental design generation procedure is launched.

IV.9.1. Product characterization

Product characterization enables us to identify which descriptors discriminate best between products, and which characteristics are important for sensory analysis (**Husson and Pages, 2009**).

A. Discriminating power by descriptor

This test is illustrated in **(Fig N°17),** and displays the descriptors ordered from the one with the highest discriminating power on the product to the one with the lowest.

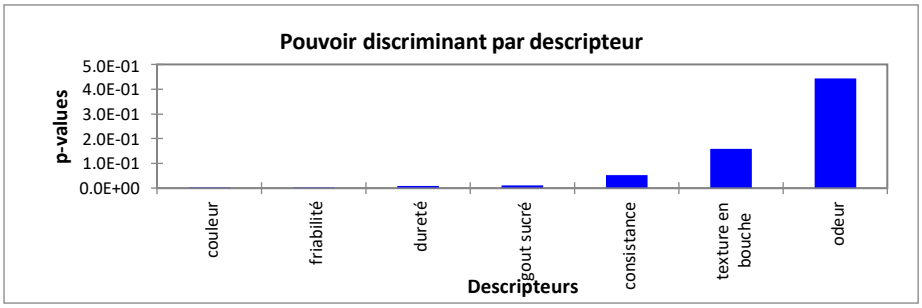

Figure N°17: Discriminating power by descriptor

The graph above shows that color and brittleness are the most discriminating descriptors, i.e. these characteristics differ between the six cookies. On the other hand, the least discriminating descriptor is odor, meaning that there is no difference in odor for the six cookies according to the judges.

B. Model coefficients

In **Figure N°18**, for each descriptor and for each product, the coefficients of the selected model are displayed: The following figure shows at a glance what defines the products (cookies 121, 141, 234, 343, 561 and 911).

Characteristics with significantly positive coefficients are shown in blue, those with significantly negative coefficients in red and those with insignificant coefficients in white.

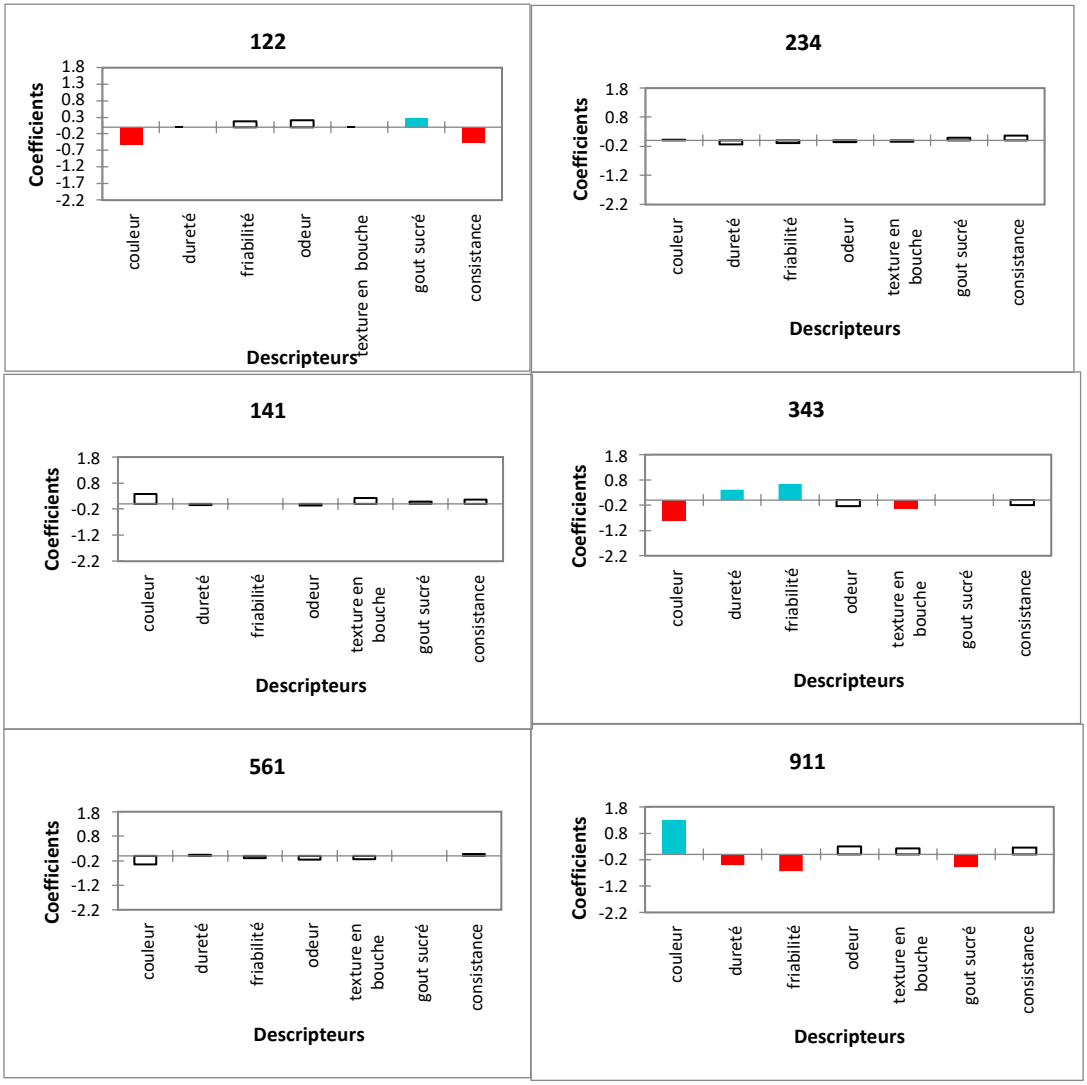

Figure N°18: Coefficients of elaborated cookie models.

- **Biscuit 122 (04):** In blue, the characteristic whose coefficient is significantly positive is displayed, i.e. according to the judges, this sample is characterized by a very sweet taste. In white, product characteristics with scores close to the average are displayed: hardness, crumbliness, odor, mouthfeel - they have an average intensity according to the scores awarded by the expert judges. Characteristics with below-average scores are shown in red. Cookie 122 is therefore characterized by a color that is neither light nor dark, with little consistency.
- **Biscuit 141 (03):** In white, are displayed the characteristics (mouthfeel, color, sweetness, crumbliness, hardness and odor.) of the product that have scores close to the average, in this cookie all characteristics have an average intensity according to the scores assigned by the expert judges.

- **Biscuit 234 (05):** In white, product characteristics with scores close to the average are displayed. In this cookie, all characteristics have an average intensity according to the scores awarded by the expert judges.
- **Biscuit 343 (02):** In blue, is displayed the characteristic whose coefficient is significantly positive, so according to the judges this sample is characterized by high friability and very hard, and the characteristics: odor, sweetness, and consistency have an average intensity. Characteristics with below-average intensity are color and mouthfeel.
- **Biscuit 561 (06):** In white, product characteristics with scores close to the average are displayed. In this cookie, all characteristics have an average intensity according to the scores awarded by the expert judges.
- **Biscuit 911 (01):** In blue, the characteristic whose coefficient is significantly positive is displayed, so according to the judges this sample is characterized by a very dark color. Characteristics with below-average intensity are hardness, friability and sweetness. Both odor and consistency have an average intensity, according to the scores awarded by the expert judges.

C. Adjusted averages by product

This test highlights the averages when the different products and characteristics are cross-tabulated. Blue indicates averages that are significantly larger than the overall average, and red indicates averages that are significantly smaller than the overall average. White indicates averages that are not significantly larger or smaller than the overall average.

Table XIX: Adjusted averages by product.

	couleur	texture en bouche	consistance	odeur	gout sucré	friabilité	dureté
911	4,455	4,273	3,636	2,818	3,273	2,364	1,818
141	3,545	4,273	3,545	2,455	3,818	3,000	2,182
234	3,182	4,000	3,545	2,455	3,818	2,909	2,091
561	2,818	3,909	3,455	2,364	3,727	2,909	2,273
122	2,636	4,091	2,909	2,727	4,000	3,182	2,364
343	2,364	3,727	3,182	2,273	3,727	3,636	2,636

- **Biscuit 911 (01):** The color descriptor has a significantly positive effect on the product. Unlike sweetness, crumbliness and hardness, which have a significantly negative effect on the product. This sample is characterized by a very dark color.
- **Biscuit 141 (03):** characteristics are close to the average scores given by the judges.
- **Biscuit 234 (05):** the characteristics are close to the average scores given by the judges.
- **Biscuit 561 (06):** the characteristics are close to the average scores given by the judges.
- **Biscuit 122 (04):** sweetness has a significantly positive effect on the product. On the other hand, color and consistency have a significantly negative effect. This sample is characterized by a very sweet taste.
- **Biscuit 343 (02):** the color and mouthfeel descriptor has a significantly negative effect on the product. Friability and hardness, on the other hand, have a significantly positive effect. This sample is very crumbly and very hard.

IV.9.2. Preferred external mapping (PREFMAP)

This method links the preferences expressed by consumers to the organoleptic characteristics of the products determined by the expert panel. This approach is essential, as it is the basis on which marketing teams can adapt products to consumer tastes.

Preference MAPPING enables objects to be displayed on the same graphical representation (in two or three dimensions), together with indications showing the consumer's level of product preference.

To create this preference map, we first need to perform a PCA and a CAH.

A. Principal component analysis (PCA)

PCA can be considered as a projection method that allows observations to be projected from the p-dimensional space of p variables to a k-dimensional space. ($k<p$) such that a maximum of information is retained (information is measured here through the total variance of the scatterplot) on the first dimensions.

Observations can be represented on a 2 or 3-dimensional graph, greatly facilitating interpretation. **(Jolliffe, 2002).**

(Fig N°19) shows the correlations between variables and factors using PCA.

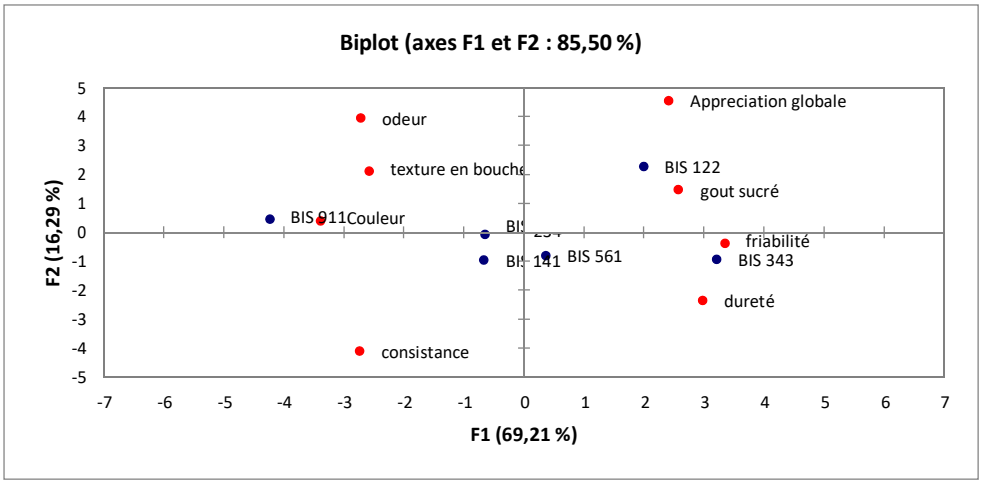

Figure N°19: Correlation between variables and factors.

From this figure we can clearly see that samples 122, 141, 234, 343, 561 and 911 have different characteristics.

- **Biscuit 122** is characterized by its very sweet taste.
- **Biscuit 141** is characterized by high consistency.
- **343 et 561** are characterized by their high friability and hardness.
- **911** is characterized by its dark color, intense aroma and mouthfeel.

b. Hierarchical ascending classification (HAC)

The CAH data analysis application generates several tables and graphs. The class profile graph (based on preference data) enables visual comparison of the averages of the various classes created **(Fig N°20).**

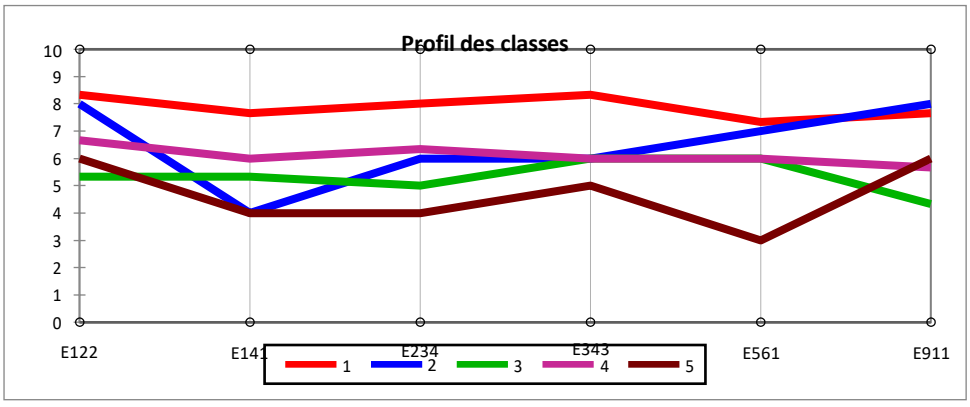

Figure N°20: Profile of classes created.

According to **Figure N°20**: three consumer classes were created from the preference scores:

Class 1: prefers cookie 122, followed by cookie 343 then cookie 234, followed by cookie 141 then cookie 911 and finally cookie 561.

Class 2: prefers cookies 122 and 911 with the same degree, followed by cookie 561 then cookies 343 and 234 with the same degree and finally cookie 141 is the least preferred.

Class 3: prefers cookie 561 and 343 with the same degree, followed by cookie 122 and 141 with the same degree, then cookie 234 and finally cookie 911.

Class 4: prefers cookie 122 then cookie 234 followed by cookie 141, then cookie 343 and 561 with the same degree and finally cookie 911.

Class 5: prefers cookie 122 then cookie 911 followed by cookie 343, then cookies 234 and 141 with the same degree and finally cookie 561.

IV.9.3. Preference mapping PREFMAP

This test was carried out to find out the consumer's preferences for our products and why they chose them.

The two contour lines and preference maps are superimposed and **(Fig N°21)** is obtained.

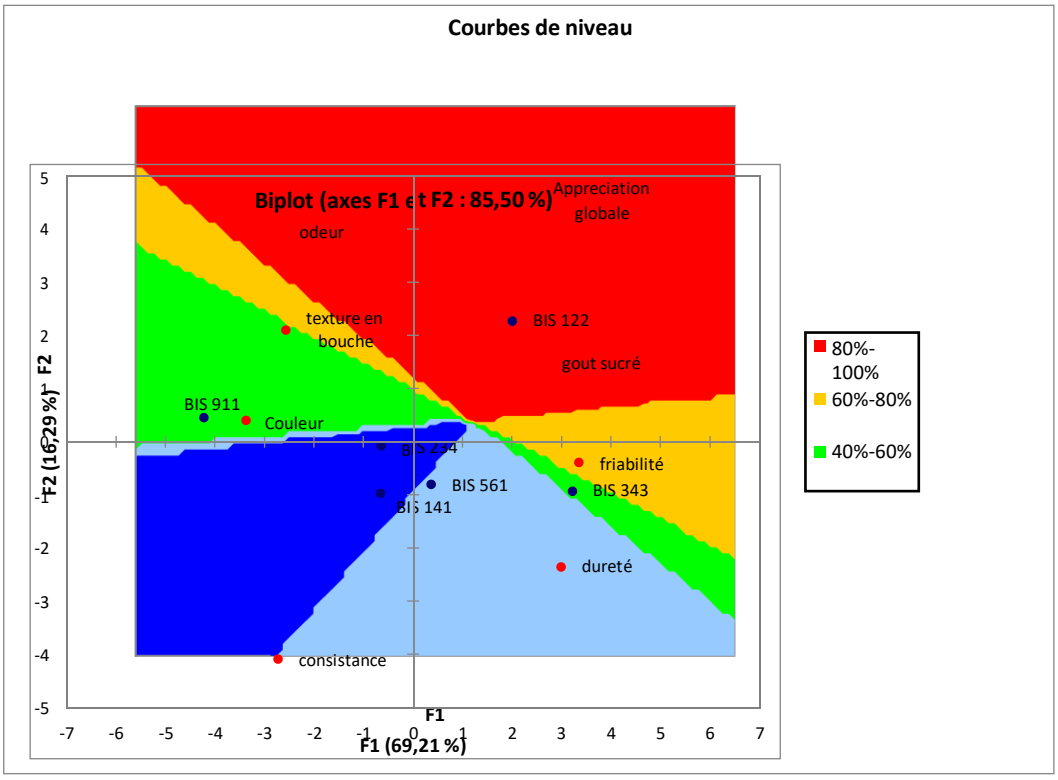

Figure N° 21: PREFMAP preference card

According to the previous figure, cookie 122 is the most appreciated (preferred by 80% of tasters), followed by cookie 343 preferred by 60% of tasters. Next, cookie 911 is moderately appreciated by 40% of tasters, followed by cookies 561 and 141 with the same percentage of appreciation by tasters (20%), and finally cookie 234, which is not appreciated (0%).

Conclusion and prospects

The aim of this work is to contribute to the valorization of potato peel by exploiting it for the enrichment of a high value-added food product (cookie). To this end, physicochemical and phytochemical analyses and the evaluation of biological activities (antioxidant, antibacterial and anticoccidial) were carried out. Based on the results obtained, a number of key points were highlighted.

The physico-chemical parameters highlighted the high fiber and protein content of potato peel powder *(Solanum tuberosum L.),* and the total absence of gluten, which is an advantage in the development of products for people suffering from gluten intolerance.
While phytochemical analysis has shown our bio-matrix to contain moderate levels of TPC, TFC and condensed tannins.

In addition, for enriched cookies, these analyses showed fairly high levels of phenolic compounds, while others were negligible, depending on the percentage of potato peel powder incorporated.

The same applies to biological activities, on the one hand, the antioxidant activity of potato peel powder assessed by the DPPH test is very high, and on the other, the results showed a fairly high percentage also for the most enriched cookie.

Evaluation of antibacterial and anticoccidial activity showed that potato peels have promising potential as antibacterial and anticoccidial agents,

Finally, a sensory analysis by expert juries (10 people) was carried out to study tasters' acceptability and appreciation of the enriched cookies.
From all the results listed, we can deduce that the addition of potato peel flour to the cookies positively modified its phytochemical and sensory properties, proving that potato peel flour could become a good alternative to wheat flour.

As a follow-up to this work, it would be interesting to :

- Incorporate potato peel powder into another food product for gluten-intolerant people, such as pasta.

- Further research to evaluate the efficacy and applicability under in vivo conditions of potato peel extract as antibacterial and anticoccidial agents.
- Vary and optimize extraction methods.
- Reproduce the formulations from this study on a pilot scale in an agri-food industry.

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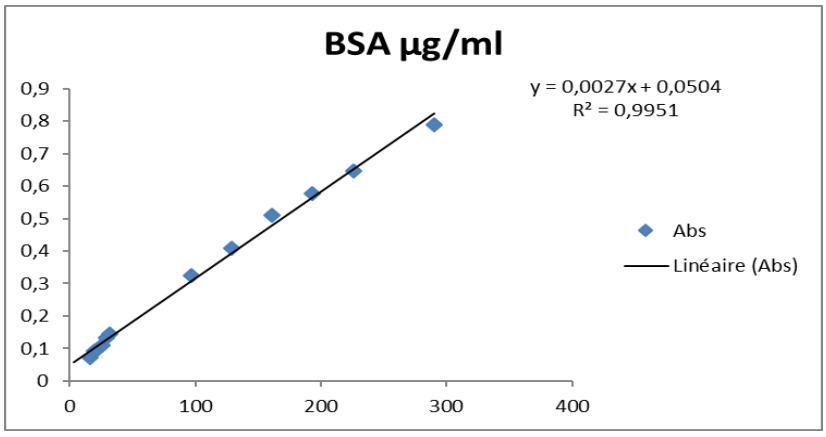
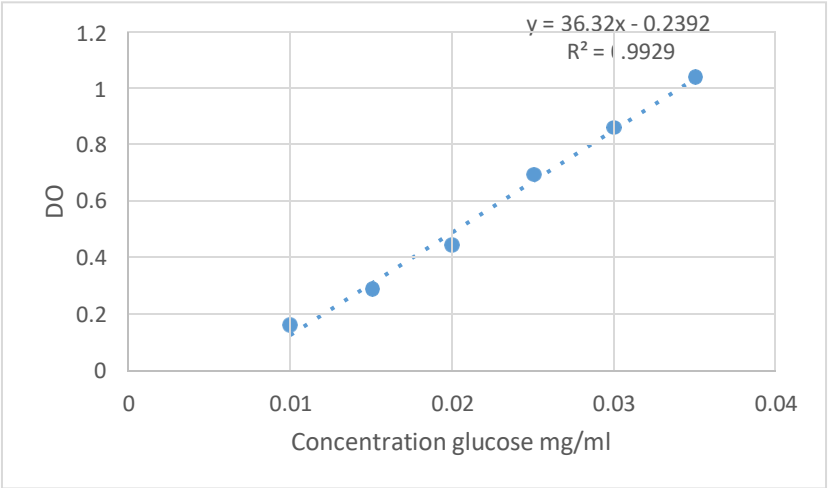
Annexes

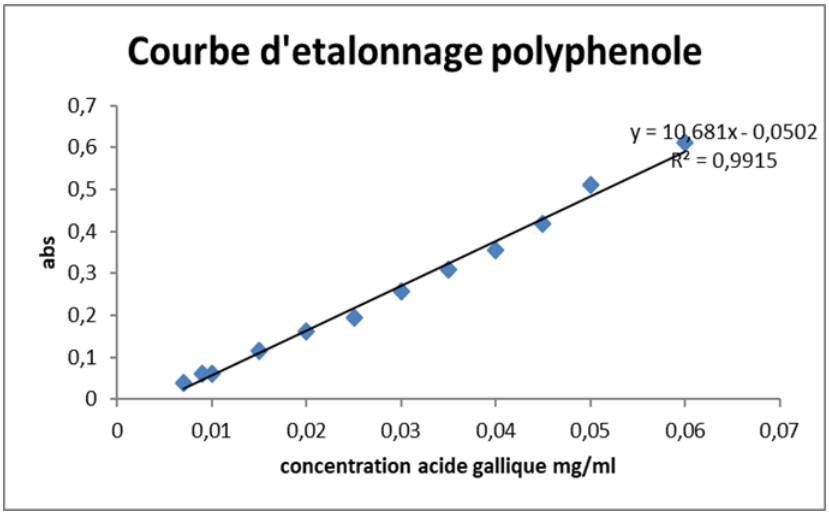
Annexe N°01 : Calibration curve for protein determination



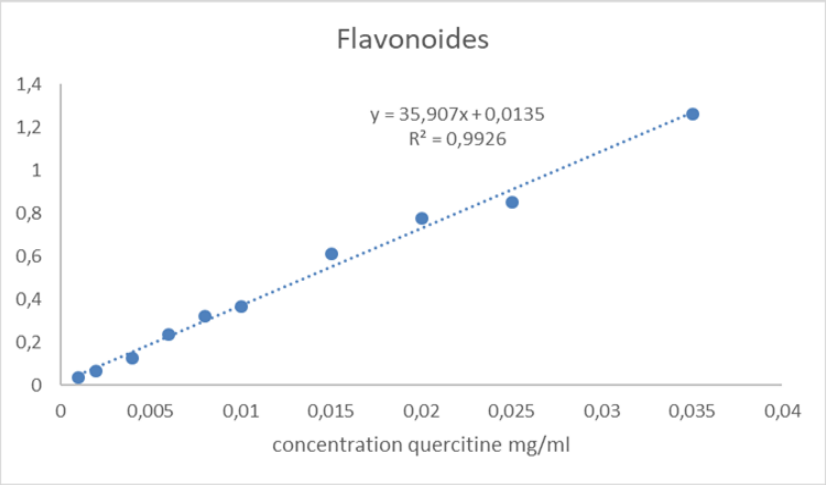
Annexe N°02 : Calibration curve for the determination of total sugars



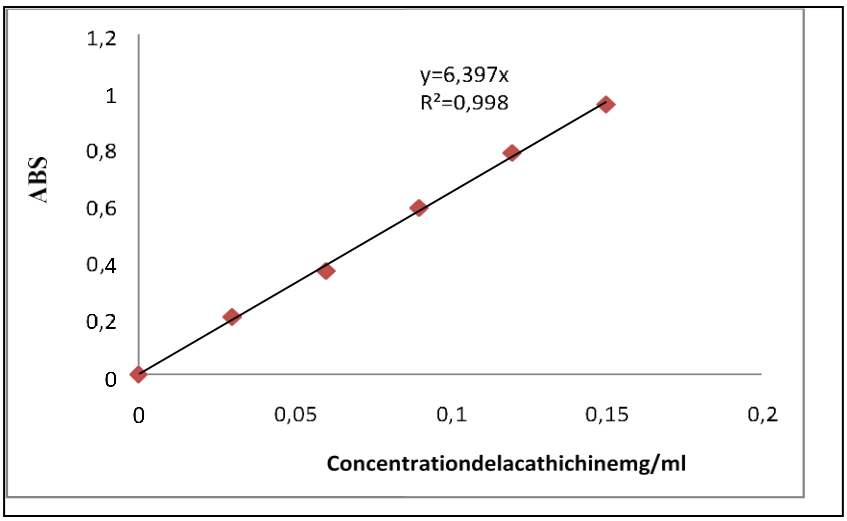
Annexe N°03 : Calibration curve for the determination of total polyphenols.



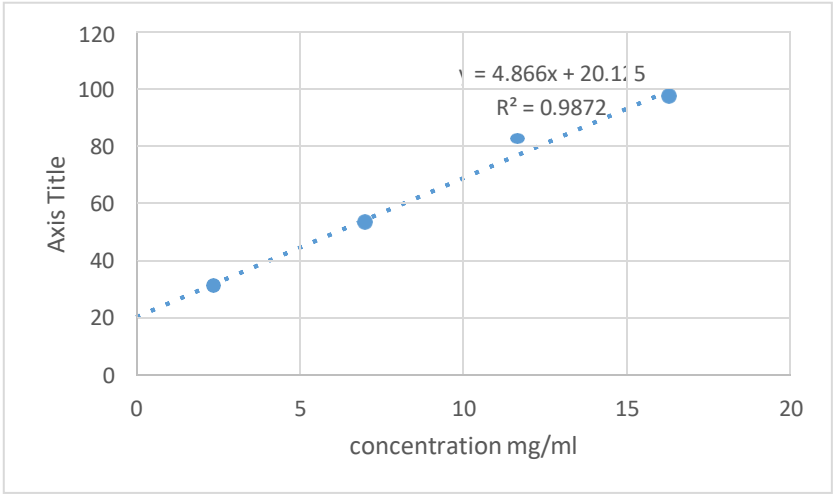
Annexe N°04 Calibration curve for flavonoids determination



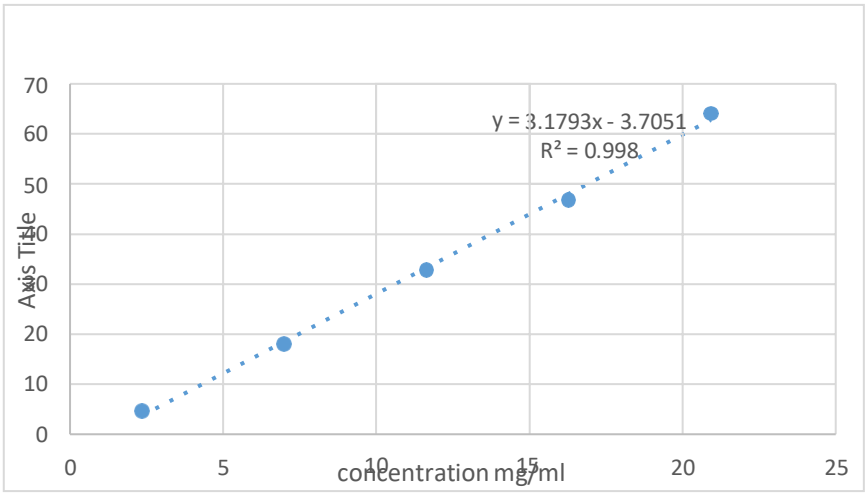
Annexe N°05 : Calibration curve for the determination of condensed tannins



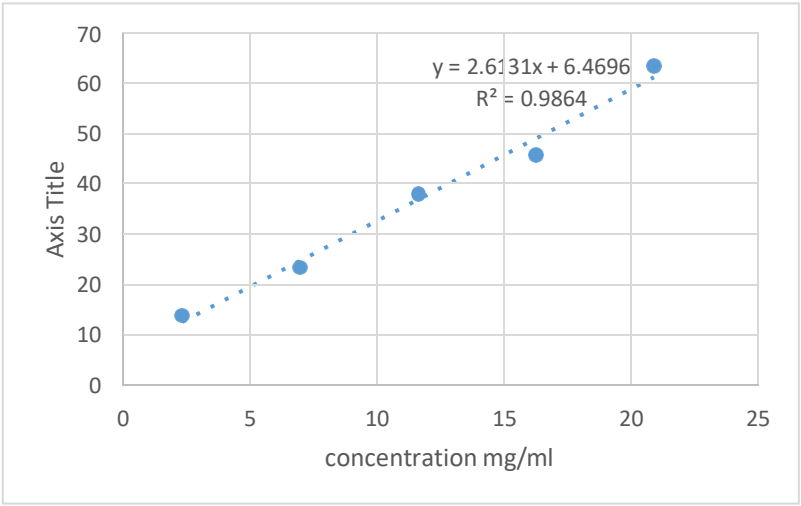
Annexe N°06 : IC50 calibration curve for ABTS in potato peel flour



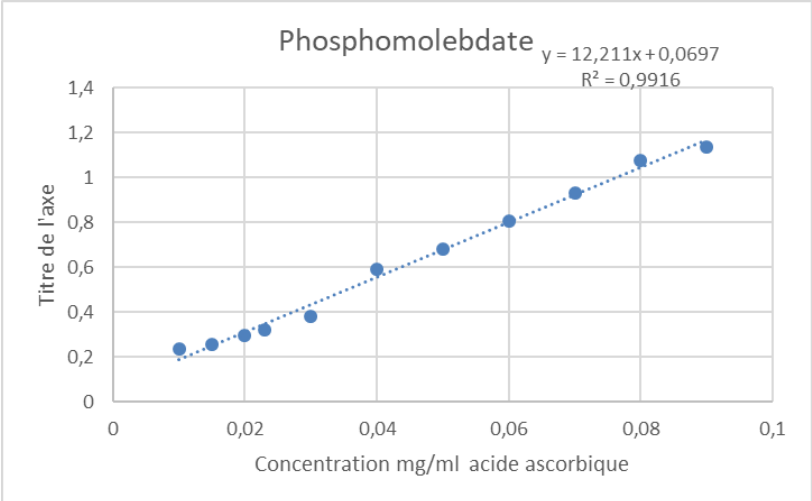
Annexe N°07 : ABTS IC 50 calibration curve for control cookie 02



Annexe N°08 : C50 ABTS calibration curve for cookie 01



Annexe N°08 : calibration curve for phosphomolybdate



Annexe N°09 : sensory analysis questionnaire for processed cookies.

Questionnaire pour analyse sensorielle des biscuits (expert)

Date : …… **Age** : ……. **Sexe** : ……

Dans le cadre d'une analyse sensorielle des biscuits, 6 échantillons vous sont présentés codés 122, 141, 234, 343, 561 et 911. Il vous est demandé de les examiner et de les gouter successivement (de gauche à droite) puis répondre aux question qui suivent

NB : après dégustation de chaque biscuit, rincez la bouche avec de l'eau.

1- Aspect visuel :

- **La couleur :**
  1- Très claire
  2- Claire
  3- Foncée
  4- Peu foncée
  4- Très foncée

122	**141**	**234**	**343**	**561**	**911**

2- Texture (toucher) :

- **Dureté :**
  1. Très dure
  2. Dure
  3. Moyennement dure
  4. Molle
  5. Très molle

122	**141**	**234**	**343**	**561**	**911**

- **Friabilité :**
  1- Pas friable
  2- Peu friable
  3- Moyennement friable
  4- Friable
  5- Très friable

122	**141**	**234**	**343**	**561**	**911**

3-Odeur :

- **Intensité de l'odeur :**
  1- Absente
  2- Faible
  3- Moyenne
  4- Forte
  5 - Très forte

122	**141**	**234**	**343**	**561**	**911**

4- Texture en bouche

1- Très pâteuse
2- Pâteuse
3- Peu croquante
4- Croquante
5- Très croquante

122	**141**	**234**	**343**	**561**	**911**

5- Le gout sucré :

1- Absent
2- Faible
3- Moyen
4- Fort
5- Très fort

122	**141**	**234**	**343**	**561**	**911**

6- La Consistance :

1- Très légère
2- Légère
3- Peu légère
4- Consistante
5- Très consistance

122	**141**	**234**	**343**	**561**	**911**

7-appreciation globale :

Attribuer à chaque biscuit une note de préférence entre 1 à 9, sachant que le numéro 1 correspond au biscuit le moins préféré et le numéro 9 à celui le plus préféré.

122	**141**	**234**	**343**	**561**	**911**

Abstract

The study focused on the phytochemical composition of PPP (Solanum tuberosum L.) and enriched cookies, as well as physicochemical analysis and evaluation of the biological activities of our bio-matrix. PPP is rich in fiber (47.3 ± 0.5%), protein (13.96 ± 0.35 mg/g) and gluten-free. Phytochemical analysis showed moderate levels of TPC (0.78 ± 0.02mg EAG /g DW), TFC (0.31 ± 0.007mg E.Q/g DW) and condensed tannins (0.48 ± 0.08 mg EC/g DW) for the powder, and for the enriched cookies, the highest levels were recorded for cookie 06 with (0. 38±0.006 mg GAE /g DW) of TPC, (0.37±0.009 mg QE/g DW) of TFC and (0.32±0.02 mg EC/g DW), the antioxidant activity of PPP and cookie 06 assessed by the DPPH test is very high with a percentage of (55.79 ±1.6%) (42.33 ±0.53 %) respectively. Antibacterial and anticoccidial activities showed the potential of PPP as antibacterial and anticoccidial agents (11.46%). The incorporation of potato peel powder in the cookies showed enrichment in terms of phenolic compounds. Sensory analysis of the cookies showed that cookie 01 (80% wheat flour, 10% PPP and 10% maizena) was appreciated by the tasting panel.

Keywords : Potato peels extract, chemical composition, phenolic compounds, antioxidant activity, antibacterial activity, anticoccidial activity,gluten, cookie.

Résumé

L'étude a été menée sur la composition, phytochimique de PPE (*Solanum tuberosum L.*) et les biscuits enrichis ainsi que les analyses physicochimique et l'évaluation des activités biologiques de notre bio matrice. La PPP détienne une forte teneur en fibre (47.3 ± 0.5%), en protéines (13.96 ± 0.35 mg/g) et dépourvue de gluten. L'analyse phytochimique a démontré une teneur modérée en TPC (0.78 ± 0.02mg AGE /g MS), en TFC (0.31 ± 0.007mg Q.E/g MS) et en tannins condensés (0.48 ± 0.08 mg CE/g MS) pour la poudre, et pour les biscuits enrichies les meilleures teneurs sont enregistrées pour le biscuit 06 avec (0.38±0.006 mg EAG/g MS) de TPC, (0.37±0.009 mg EQ/g MS) des TFC et (0.32±0.02 mg EC/g MS) , l'activité antioxydante de PPP et le biscuit 06 évaluée par le test au DPPH est très importante avec un pourcentage de (55.79 ±1.6%) (42.33 ±0.53 %) respectivement . Les activités antibactérienne et anticoccidienne ont monté le potentiel de PPE en tant qu'agents antibactérienne et anticoccidien (11.46%), L'incorporation de la poudre de pelure de pomme de terre dans les biscuits a montré un enrichissement en terme de composés phénoliques. L'analyse sensorielle des biscuits a montré que le biscuit 01 (80% de farine de blé, 10% de PPP et 10% de maizena) a été appréciée par le jury de dégustation.

Mots clé : Extrait de pelure de pomme de terre, composition chimique, composés phénoliques, activité antioxydant, activités antibactérienne, activité anticoccidienne, gluten, biscuit.