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En vue de l'obtention du diplôme

MASTER

Thème

Valorisation des sous-produits de la pomme de terre par les industries agroalimentaires

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Summary

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Introduction

Food wastes has been considered as a serious economic and environmental problem over the world, therefore the valorization concept becomes more and more necessary to ensure food security and decrease environmental threats. In addition, the valorization of biowastes contributes to the market development, to the job creation and reduces pressure on natural resources **(Anonyme 1).**

Many studies have confirmed the abundance of interesting biomolecules in vegetable wastes which can contribute to develop new nutritional food formulations **(Bello et al., 2013).** Large quantities of by-products are generated from vegetal raw material processing, and used as source for added value compounds **(Di Mauro et al., 2002, Bildstein et al., 2009)** with interesting therapeutic and nutritional roles **(Hashmi et al., 2021)**.

Potato (*Solanum tuberosum* L.) is one of vegetables with interesting by-products. It is a tuber globally considered as a part of staple diet **(de Oliveira et al., 2021)**. More than 300 million tons of potatoes are produced every year around the world. China, is the biggest producer with 99 122 420 tons/year, followed by India with 43 770 000 tons/year. Our country (Algeria) marked 4 782 690 tons/year **(Anonyme 2).**

Potato processing by-products can be classed on two categories: whole or cut potatoes not destined for human consumption, and potato processing wastes deriving from the manufacture of potato ingredients or potato-based food products **(Charmley et al., 2006)**. The reuse of these by-products was invested in the beginning mainly as cattle feed, a source for biofuel and as biotechnological molecules. Then, with increasing demand for natural food additives by consumers, researches were interested to functional ingredients recovered from natural material and the reuse of such by-products seems to be promising alternative. Potato peels, which are the major processing wastes, contain a large nutritionally and pharmacologically interesting compounds **(Akyol et al., 2016, Sampaio et al., 2020, Joly et al., 2021)**.

The objective of this work is to bring together and synthesize scientific studies data carried out about the valorization of potato byproducts in food industries during the period of the last six years.

We are interested particularly in potato peelings as byproduct because of their large availability since the industrial processing generates between 70 and 140 thousand tons of peels worldwide annually **(Chang, 2011)**. Furthermore, potato peels possess an important nutritional value thanks to its various chemical composition that promising good benefits for human health.

The plan followed begins with an introduction including informations about the potato production and its by-products as well as the objective of the work. Then, we will tackle a chapter about potato peels, in particular an analysis of data from scientific studies carried out and the composition of peels. In the next part, we will present the chapter dealing with the valorization of peels by the agro-food industries, to finish with a conclusion.

Chapter I Potato peels

I-1) Data analysis

The worldwide potato production still huge and reaches 75.9 million tons in 2021 **(Anonyme3)**. In general, varieties are classified into a few groups based on common characteristics, like russet potatoes (rough brown skin), red potatoes, white potatoes, yellow potatoes (also called Yukon potatoes) and purple potatoes **(Anonyme 4)**. The figure 1 illustrate an example of potato production in United States of America which ranked on fifth position with 20 607 342 tons/year **(Anonyme 5)**.

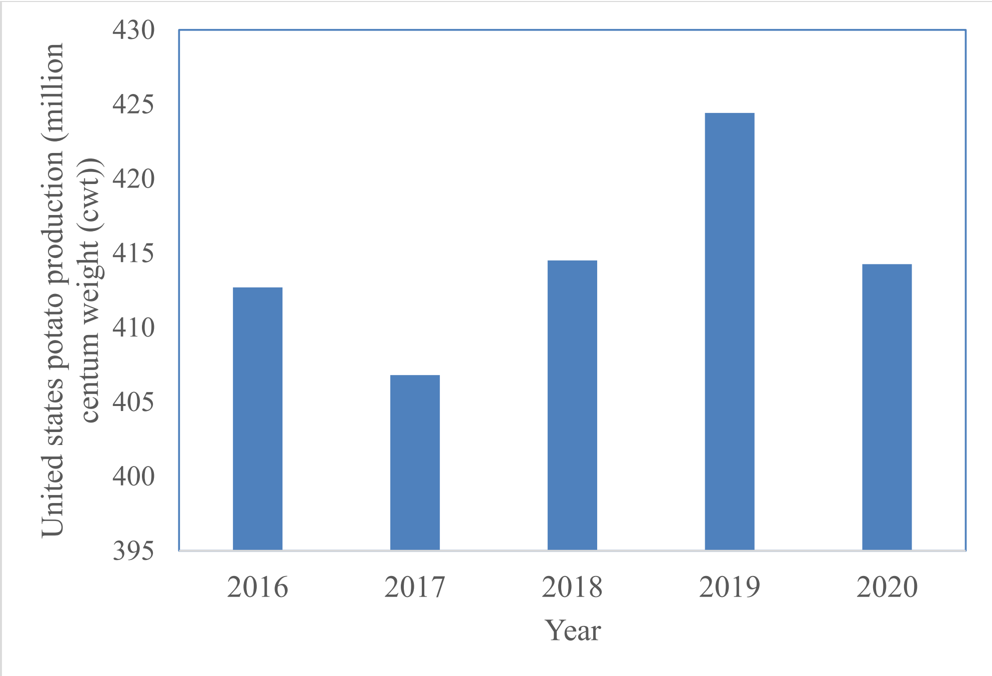

Figure 1: United States potato production from 2016 to 2020 **(Anonyme 6)**.

Hence, the managing of potato wastes still an environmental and economic problem. UNEP (United Nations Environment programme) FOOD WASTE INDEX REPORT (2021), estimates that food waste from households, retail establishments and the totals food service industry reached 931 million tons each year **(Anonyme 7)**. For that, food industries including potato-processing ones are more and more interested and focused on valorization process to find economical and ecofriendly managing solutions what motivated scientific researchers to be oriented to this concept. The figure 2 is an estimation of scientific works done during the last six years, with a global assessment of 66% practical studies. There were many studies in 2016 and 2017 which decreased on 2018. However, in

2019 and 2020 researches interested again to this by-product where many works were published, but in the current year of 2021, until the month of June, the number of studies decreased.

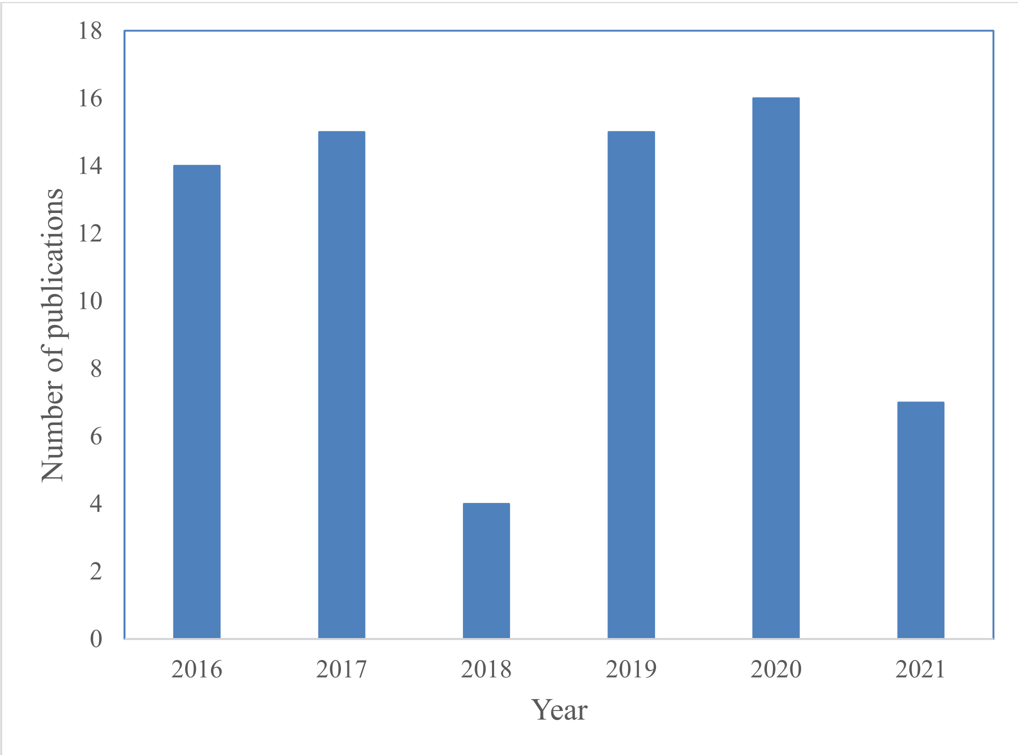

Figure 2: Scientific publications from 2016 to 2021 (science direct, springer and google scholar data with topic search 'potato peels and food industries').

I-2) Composition of potato peels

I-2-1) General composition

The most important components of potato peels are: starch, non-starch polysaccharides (cellulose, hemicelluloses and pectin), lignin, proteins, lipids and ash **(Camire et al., 1997)**.

Singh et al. (2017) reported that hemicellulose potato peel consists of Mannan, Xylan and Arabinan.

Mateos-Aparicio and Matias (2019) and **Mudondo (2019)** reported that carbohydrates are the highest fraction after water in potato peels**.** Dos Santos et al. (2016) reported that carbohydrates such us starch, cellulose, and hemicellulose and other reducing sugars, are the most compounds in potato peels. They added that these molecules are among the most compounds which are the subject of published studies within the last five years.

The biochemical composition of raw potato peel was illustrated on the table I.

Table I : composition of raw potato peel **(Javed et al., 2019)**.

Compound	**Values Range (**g per 100 g)
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 dietary fibers	2.5
Total phenolics content	1.02–2.92
Total flavonoids	0.51–0.96
Ash	0.9–1.6

A comparative study of nutritional composition data of potato peels of some varieties was demonstrated in the table II **(Sampaio et al., 2020)**. Results showed a slight difference between varieties, even between organic and non organic ones.

Table II: Values of nutritional composition of potato peels as reported in the literature over the last ten years by **Shirley L. Sampaio (2020)**

Proximate	**Potato peel variety and origin**				
	Organic Russet United States	**Non-organic Russet -** United States	**Red potato-** United States	**Gold potato -** United States	**Lady Rosetta -** Ireland
Moisture	3.67	3.78	4.46	5.66	6.98 ±0.05
Carbohydrates	76	71	72	70	72.53 ± 0.08
Protein	11.98	17.19	15.99	14.17	11.17 ± 0.03
Fat	1.12	1.1	0.81	1.17	2.09 ± 0.01
Ash	7.32	7.34	6.69	9.12	7.24 ± 0.02
Reference	**(Elkahoui et al., 2018)**				**(Kumari et al., 2017)**
Proximate	**Potato peel variety and origin**				
	Lady Claire - Ireland	**Spunta -** Tunisia	**Agria**–Spain	**Unknown variety -** Greece	
Moisture	4.08 ± 0.04	7.3 ± 0.3	7.30 ± 0.23	**-**	
Carbohydrates	77.38 ± 0.65	88.0 ± 4.4	86.97 ± 0.43	68.7	
Protein	12.44 ± 0.09	2.099 ±0.105	6.47 ± 0.23	8	
Fat	1.27 ± 0.38	0.733 ±0.037	0	2.6	
Ash	4.83 ± 0.13	0.906 ± 0.006	5.46 ± 0.17	6.34	
Reference	**(Kumari et al., 2017)**	**(Jeddou et al., 2016)**	**(Amado et al., 2014)**	**(Arapoglou et al., 2010)**	

Values expressed in g/100 g dry weight (mean values ± standard deviation).

I-2-2) Polysaccharides

Polysaccharides are bioactive molecules existed in plants and have used as additives in the food formulations **(Sinha et al., 2008).** They constitute a diverse group of carbohydrates with diverse structures and compositions because of their high degrees of polymerization formed by glycosidic bonds between monosaccharides **(Phillips and Williams, 2000)**. These molecules have been used to improve the texture, water retention and stabilization of emulsions and widely known by their prebiotic effect **(Warrand, 2006)** and biological activities such as anti-tumor **(Saima et al., 2000),** immunostimulation (Tzianabos et al., 2003), anti-inflammation **(Scheppach et al., 2004)**, anti-coagulation and anti-oxidation activities **(Zhao et al., 2005)**.

Recently, studies are interested to the functional and antioxidant properties of polysaccharides extracted from potato peels. **Jeddou et al. (2016)**, **Xu et al. (2019)** and **Shehata et al. (2020)** noted functional properties of the extracted polysaccharides with interesting water-holding, fat-binding capacities, good foaming and emulsion properties. The analysis of the antioxidant activity of this polymer showed interesting 1,1-diphenyl-2- picrylhydrazyl ($DPPH^{\bullet}$) radical-scavenging capacity, strong 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) ($ABTS^{\bullet+}$)radical scavenging activity, reducing power and β-carotene bleaching inhibition activities. The same authors highlighted the structure of potato peels polysaccharides constituted mainly of glucose (Jeddou et al., 2018, Xu et al., 2019)**,** and the study of **Scharf et al. (2020)** demonstrated that the composition of biopolymers include pectins and hemicelluloses.

Researchers have proven that potato peels are not just a source of polysaccharides and this by-product can be converted on cellulose through bacterial production **(Abdelraof et al., 2019)**.

Non-digestible oligosaccharides are short chains of monosaccharides linking two to ten molecules **(Roberfroid and Slavin, 2000, Weijers et al., 2008)**. Manno- oligosaccharides consist of a linear chain of mannose sugar with prebiotic properties preventing pathogen colonization in the digestive tract of human and animals **(Srivastava et al., 2017)**. The potato peels according to **Liang et al. (2014)** analysis contain fermentable carbohydrates like starch, galactan, xylan, arabinan and mannan. Manno-oligosaccharides are produced by depolymerization of mannan through various methods; enzymatic hydrolysis, physical and chemical method **(Singh et al., 2017).**

I-2-3) Reducing sugar and protein

A study of the variation of biochemical parameter in different parts of potato by **Sharma et al. (2016)** gave the information that, potato peels contain reducing sugar and starch even in lowest quantities. Another study of **Choi et al. (2016)** in the same year, characterized and determined the proportions of reducing sugar and protein content in peels of different varieties of potato using high performance liquid chromatography (HPLC) analysis. Fructose, glucose and sucrose were characterized, and glucose exhibited the highest amount. Crude protein content can reach 10. 6g per 100g of dry weight with a content of 666 mg per 100g of dry weight of essential amino acids among a content of 2077 mg per 100g of dry weight of sum all amino acids. According to **Prandi et al. (2019)**, crude protein content determined with the Kjeldahl method reached 10% of dry matter basis of potato skins and, the percentage of the nine essential amino acids in the total amino acid pool, determined by HPLC based assays with fluorescence detection, exceed 30%, containing mainly: aspartate, alanine and glutamate acids.

Routray and Orsat (2017) reported that potato by-products contain also dietary fibers and phenolic acids.

I-2-4) Fibers

Dietary fibers are a natural carbohydrates polymers present in the plant cell wall, constituted of soluble dietary fibers such as pectin, β-glucans, gums, mucilage, oligosaccharides and inulin which can be dissolved in water and, insoluble dietary fibers such as cellulose, hemicelluloses, lignin and resistant starch **(Capuano, 2017)**.

Potato peels are rich on dietary fibers **(Gumul et al., 2011, Kumar et al., 2020, Sharoba et al., 2013)**. The study of **Xie et al. (2017)** showed that soluble dietary fibers extracted from potato peels composed of ash, moisture and monosaccharides including galactose, arabinose, mannose, glucose, galactose, and rhamnose, have interesting physicochemical and anti-oxidante properties. The main dietary fiber physicochemical properties are hydration properties, oil-holding capacity, swelling capacity, emulsifying activity and emulsifying stability **(Elleuch et al., 2011, Xie et al., 2016)**.

Jeddou et al. (2017) reported that the water absorption is mainly caused by the number of hydroxyl group existing in the fiber structure and allowing more water interaction through hydrogen bonding **(Rosell et al., 2001)**. Fat absorption capacity is a characteristic of polysaccharides and it is more related to the porosity and the structure of the fiber than to the fiber molecule affinity to oil **(Biswas et al., 2011)**. Routray and Orsat (2017) reported that incorporation of dietary fibers to different food products affected the physio-chemical composition and organoleptic properties of the developed products **(Turksoy and Özkaya, 2011)**. The protective effects on three lactobacillus strains (*Lactobacillus acidophilus* LMG9433T, *Lactobacillus casei* LMG6904T and *Lactobacillus rhamnosus* LMG25859) against heat shock were investigated by **He et al. (2021)** and results showed none influence on the growth of probiotics, while they mostly increased the tolerance to the gastric digestion of *Lactobacillus rhamnosus* LMG25859.

Routray and Orsat (2019) reported that dietary fiber extraction methods have been discussed in different studies and the advantageous properties of dietary fibers are affected by the extraction parameters including solvent, treatment intensities, and drying process **(Fuentes-Alventosa et al., 2009)**. In the study of **Jeddou et al. (2017)** gravimetric enzymatic method was used to extract dietary fibers while **He et al. (2021)** tested alcohol-washing method and results showed the major amount of total dietary fiber (65.2g/100g of the solid weight of potato peels) followed by protein and starch, respectively. The total dietary fibers were constituted of insoluble dietary fibers more than soluble ones. In another study, **Scharf et al. (2020)** used detergent suspension of cold mixed-cation buffer (MCB) (10mMNaOAC, 3mMKCl, 2mM $MgCl_2$ and 1mM $CaCl_2$, pH 6.5) containing Triton X-100 (2 mg/mL) as method of extraction.

I-2-5) Phenolic compounds and anti-oxidant capacities

Phenolics are natural active compounds characterized by properties related to human health benefits including antioxidant and antimicrobial activities **(Agourram et al., 2013, Silva-Beltrán et al., 2017, Chiralt et al., 2020)**. According to **Trigo et al. (2019)**, they are a water-soluble substances (almost 8000 different molecules) synthesized especially by either shikimic acid, pentose phosphate or phenyl propanoid pathways composed of at least one aromatic ring with hydroxyl substituents.

The main classes which can be found in fruit and vegetable by-products are flavonoids, phenolic acids, and tannins **(Babbar and Oberoi, 2014)**. It was reported that their content in potato peels are 10 times more comparing with flesh and reach about 50% of all the polyphenolic potato tuber contents (Javed et al., 2019). They are represented mainly by chlorogenic acid and its isomers (chlorogenic acid isomer II, neochlorgenic acid and cryptochlorogenic acid), ferulic, gallic, caffeic, protocatechuic, syringic, coumaric, gentisic, salicylic, vanillic, *p*-hydroxy benzoic acids and hydroxycinnamic **(Singh and Saldaña, 2011, Farvin et al., 2012, Amado et al., 2014, Etxabide et al., 2017, Onyeneho and Hettiarachchy, 1993, De Sotillo et al., 1994, Choi et al., 2016, Ravichandran et al., 2020, Arapoglou et al., 2010, Javed et al., 2019).**

The analysis by high performance liquid chromatography equipped with photodiode array detection-mass (HPLC-DAD-ESI-MS) showed that chlorogenic acid content represented 49.3–61% of the total phenolic compounds in a study conducted by **Riciputi et al. (2018)**.

The table (IV-a) and (IV-b) represent a summary of practical studies related to phenolics and their recovery realized during the last six years.

Table III-a: A summary of practical studies related to phenolics and their recovery, using maceration method, carried out during the last six years.

Potato peels sample	**Extraction with maceration method**	**Quantitave analysis**		**Characterization**		
		Method	**Results**	**Method**	**Results**	**Reference**
fine powder of peels dried at 60 °C	With solvents: ✓ ethanol 96% ✓ ethanol 80% ✓ water	Folin-Ciocalteu reagent **(Singleton and Rossi, 1965)** and absorbance was measured at the wavelength λ = 725 nm	Total phenolics :40.5 mg of gallic acid /g of dry weight of the extract; this highest value obtained with ethanol 96%. Results with ethanol 80% and water were less then more less respectively			**(Samotyja, 2019)**
Powder of freeze-dried potato peels	method described by **(Valcarcel et al., 2015)** using ethanolic solution (80% v/v)	Folin-Ciocalteu reagent **(Singleton et al., 1999, Kalita and Jayanty, 2014).** Absorbance was measured	Total phenolics : The highest value was 10.79 mg gallic acid equivalents /g dry weight			**(Bădărău et al., 2017)**

		at the wavelength λ = 725 nm				
freeze-dried potato peels	-Cryomaceration -Solvents: ✓ distilled water ✓ Ethanol 10%	Folin–Ciocalteau **(Venturi et al., 2015)**	Total phenolics~ 4 mg gallic acid equivalents /g dry weight was the highest value marked with ethanol 10%			**(Venturi et al., 2019)**
Chopped peels	Maceration with Ethanol 80 %	Folin-Ciocalteau reagent in alkaline medium (with λ=650nm)	Total phenolics : high content of 194 mg/100 g of fresh weight			**(Sharma et al., 2016)**
fine powder of peels dried at 50 °C	Maceration with Solvents: -HCl : methanol (70:30), -methanol(70%,v/v), -acetone (70%, v/v) -ethanol (70%, v/v)	Folin-Ciocalteau reagent **(Li et al., 2006)** with modifications		high performance liquid chromatography (HPLC) **(Peñarrieta et al., 2008)**	Total hydroxybenzoic acid: 130 mg/100g of the powder. total Hydroxycinnamic acid derivatives: ~115 mg /100g. flavanols : flavan-3-	**(Hashmi et al., 2021)**

					ols = 43 mg/100g., catechin and four unidentified fractions Anthocyanins: ~5mg/100g	
lyophilized fresh potato peels	-Maceration with Solvents: Methanol Ethanol -maceration method/heat-assisted extraction	Folin-Ciocalteau method **(Singh et al., 2011, Reyes et al., 2005)**	Total phenolics : highest value with heat processing of methanol extract ~3.83 mg chlorogenic acid equivalents /g of sample powder	high performance liquid chromatography	Highest value with heat processing of methanol extract ~870.54µg of 3-chlorogenic acid /g fresh weight	**(Joly et al., 2021)**
Powder of potato peels	Used ethanol-washing method to obtain these alcohol-insoluble residues(phenolic compounds connected to fibers)	Folin-Ciocalteur eagent method adapted from the 'Q-FC' Assay reported by **(Del Pino-García et al., 2015)**	3 mg gallic acid equivalents per gram of alcohol-insoluble residues.			**(He et al., 2021)**

Table III-b: A summary of practical studies related to phenolics and their recovery using maceration method combined with ultrasonication, carried out during the last six years.

Potato peelssample	**Extraction with maceration method combined with ultrasonication**	**Quantitav eanalysis**		**Characterization**		
		Method	**Results**	**Method**	**Results**	**Reference**
Powder of freeze-dried potato peels	-Maceration with Methanol -Ultrasonic method(bath)	total phenolics by modified colorimetric Folin-Ciocalteu method **(Singleton et al., 1999, Chew et al., 2009).** Total flavonoid content was determined by colorimetric method of **(Dewanto et al., 2002)**	The highest value of total phenolics~109µg of gallic acid equivalents /mg of freeze-dried sample(dry weight). The highest value of flavonoids ~6.02µg of quercetin equivalents per milligram of sample.	phenolic compounds by HPLC and LC/MS(Liquid chro matography-mass spectrometry)	3-caffeoylquinic acid (chlorogenic acid), 5-caffeoyl-quinic acid (neochlorogenic acid), 3,4-di-O-caffeoylquinic (iso-chlorogenic) and caffeic acid: highest value of the total=682µg/g dry weight	**(Choi et al., 2016)**
fine powder of peels dried at 45°C	-water extraction assisted with stirring -acidified ethanolic extraction with stirring then sonication treatment	-Total phenolics : methods described by **(Singleton and Rossi, 1965)** with some modifications	The highest value of total phenolics and total flavonoids were noted with acidified ethanolic extract: ~ 14 mg of	Phenolic composition determined by HPLC technique	The highest value of phenolics and flavonoids compounds were noted with acidified ethanolic extract;	**(Silva-Beltrán et al., 2017)**

		-Total flavonoids : method described by **(Chen et al., 2013)** with modifications	gallic acid equivalents/g and ~3mg of quercetin equivalents/g respectively.		three predominant compounds: chlorogenic(~346.03 mg/100 g dry weight) caffeic (~332.58 mg/100 g dry weight) gallic acids(~233.49 mg/100 g dry weight). Flavonoids : Quercetin (the predominant), rutin and ferulic acid.	
Powder of freeze dried peels of nonorganic (conventional) and organic potato varieties	-Maceration with methanol 80% -sonication in ultrasonic bath	-Total phenolic content determined colorimetric Folin-Ciocalteu method **(Chew et al., 2009)** - Total flavonoid determined by colorimetry	-Total phenolic content ranged from 11 to 28.4 µg of gallic acid equivalents /mg of powder weight (organic peels) and 11.3 to 34.4 µg of	characterized by HPLC (high performance liquid chromatography) equipment and Liquid chromatography-mass spectrometry	presence of caffeic acid, chlorogenic acid, and chlorogenic acid isomer	**(Friedman et al., 2017)**

		(Dewanto et al., 2002)	gallic acid equivalents /mg of powder weight (conventional peels) -Total flavonoid: 7.8 to 23 µg of quercetin equivalents /mg of powder weight (conventional peels) and 8.7 to 29.7 µg of quercetin equivalents /mg of powder weight (organic peels).	(LC–MS)		
Powder of freeze dried peels	ethanol/water 55/45 (v/v) with ultrasound bath during 35 min at 35 °C and 1/10 sample/solvent ratio(optimized conditions of			HPLC-DAD-ESI-MS (high performance liquid chromatography-diode array detector equipped with electrospray	chlorogenic acid accounted for a 49.3–61% of the total phenolic compounds, caffeoyl quinic isomers (1-CQA	**(Riciputi et al., 2018)**

	phenolic compounds extraction by response surface methodology (RSM) and Box-Behnken design (BBD)			ionization and mass spectrometry) was used to determine the phenolic compounds in the extracts according to **(López-Cobo et al., 2014)**	and 4-CQA) with 12.2-36.3%, caffeic acid noted 2.3–19.9%, other caffeoyl isomers including dicaffeoyl and dihydrocaffeoyl-spermidine derivatives 0.6-13.4%. Feruloyl derivatives were also detected with 4.2–5.9% of the total phenolic compounds. The total content of phenolic compounds ranged between 2.5 and 7.2 mg/ dry weight.	

About the extraction methods, this data summary shows that the most used method of extraction of phenolic compounds from potato peels was maceration followed by ultrasonication. Many previous studies have investigated the conventional solid–liquid extraction technique such as maceration, soxhlet and heat reflux **(Akyol et al., 2016, Chen et al., 2010)** to extract phenolics.

Sampaio et al. (2020) reported that others techniques such as ultrasound and microwave-assisted treatments enhanced the extraction of phenolic compounds from potato peels.
Martinez-Fernandez et al. (2021a) compared Sequential Hydrothermal Extraction (SeqHTE) with subcritical water extraction (SWE) through their work about techno-economic assessment of potato peels bioactive compounds extraction. SeqHTE is a new method consisting of two-stages of extraction and allowing gradually the fractionation of the biomass for the recovery of several molecules **(Martinez-Fernandez et al., 2021b)**. The first stage at lower temperatures used as pretreatment, to decompose the solid matrix and to promote progressively polar interactions between the subcritical water and molecules. The second stage achieved at higher temperatures to foster less polar interactions by more effects of thermal and mass transfer facilitating the recovery of linked compounds. The results of the study showed that the cost for producing antioxidants with SeqHTE is just slightly higher than with SWE but his yield production allowed the recovery of about 4 kg/hour more of the product.

Routray and Orsat (2017) inform us through their paper that yield extraction depends on the characteristics of the analyte and those of the biomatrix, the used solvent, temperature conditions, and the degree of degradation of the biomatrix containing the analyte during the extraction. Solvent and the extraction method depend on the nature of the analyte. Polar solvents are used to extract polar phenolics while nonpolar ones are used for nonpolar phenolics. Mixture of solvents (polar and nonpolar) is effective for phenolics with moderate polarity or for global extraction of polar and nonpolar ones. Extraction depends also on the degree of connection of different constituents with each others; the case of phenolic compounds connected to fibers ethanol-washing method was used**(He et al., 2021)**.

Another important class of phenolics encompasses anthocyanins were studied by **Mishra et al. (2020).** They are a water soluble pigments belonging to flavonoids **(Fang, 2015)** and provide colors to potatoes peels or flesh **(Fossen and Andersen, 2000)**. Red fleshed varieties contain mostly cyanidin, peonidin and pelargonidin while in purple fleshed varieties petunidin and malvidin can be found in addition **(Giusti et al., 2014)**. It was reported that anthocyanins of potato are affected by high temperatures (100–150°C) **(Nayak et al., 2011)** and the content on total anthocyanins increased with cooking treatments like: raw boiling, steaming, baking or microwaving **(Lachman et al., 2013)**.

They can be recovered by acetone mixed with alcohol (ethanol or methanol) and analyzed by spectrophotometric method or chromatography techniques. Diode array detection (DAD), or mass spectrometry and HPLC techniques are used for the characterization analysis **(Jin et al., 2015)**. Besides, others recent techniques including NMR (nuclear magnetic resonance spectroscopy), HPLC coupled with mass spectroscopy are also employed **(Li et al., 2016).**

Potato anthocyanins are known by their health benefits like high anti-oxidant activity (Ishii et al., 1996), anti-stomach cancer and anti-influenza virus activity **(Hayashi et al., 2006)**.

Antioxidants are compounds with the ability to inhibit or delay oxidation and to reduce the content of transition metal ions and/or free radicals. They can be synthetic or natural **(Trigo et al., 2019)**. Transition metals (iron and copper ions) can initiate oxidation of molecules and produce free radicals **(Allen, 2015)**. Free radicals (atoms, molecules, or ions) possess one or more free electrons which make them highly reactive causing cell damage by attacking lipids, nucleic acids, and proteins **(Babbar and Oberoi, 2014)**.

In previous studies, authors reported that the constituents responsible for the hydrophilic antioxidant activity are primarily phenolic compounds and anthocyanins, whereas carotenoids and tocopherols are the main antioxidant constituents in lipophilic extracts **(Bao et al., 2005)**.

Sampaio et al. (2020) reported that there is a significant positive correlation between the antioxidant activity and the phenolic content of potato peels extracts**. Sampaio et al. (2020)** reported also that bounded phenolics showed an efficient antioxidant capacity like or better than the free ones. Potato peels of colored varieties often showed higher antioxidant capacities because of high anthocyanins content **(Albishi et al., 2013)**. Potato peels antioxidant activity was revealed by scavenging of reactive oxygen species and free radicals *in vitro* conditions. Different analysis are mostly used like: the DPPH (2,2-diphenyl-1-picrylhydrazyl), lipid peroxidation in rat liver homogenates **(Singh and Rajini, 2004)** and iron ion chelation **(Singh and Rajini, 2004, Samotyja, 2019)**, reducing power test and β-carotene bleaching inhibition activity **(Jeddou et al., 2018, Samotyja, 2019)**, ABTS (2,2′ -azino-bis (3ethylbenzothiazoline-6-sulfonic acid)), the ferric reducing antioxidant power **(Choi et al., 2016, Venturi et al., 2019)** and the QUENCHER (QUick, Easy, New, CHEap, and Reproducible) assay was also used to determine the antioxidant activities of linked phenolics **(He et al., 2021)**. In an another work, **Franco et al. (2016)** discovered that the incorporation of potato peels ethanolic extracts to soybean oil reduced lipid oxidation and showed high anti-oxidant activity than butylated hydroxytoluene (BHT), results which were supported by

Samotyja (2019). Finely, potato peel extracts can be used as a natural antioxidant to prevent food products oxidation **(Rommi et al., 2016).**

Antioxidants can be affected by many factors like enzymes, pH, temperature **(He et al., 2021)**. **Javed et al. (2019)** reported that the temperature decreased the antioxidant capacity of potato peels extracts.

I-2-6) Glycoalkaloids

Glycoalkaloids naturally exist in vegetables as secondary metabolites. Potato glycoalkaloids are toxics but those found in leaves protect naturally the plant against pests **(Ginzberg et al., 2009, McCue, 2009).** Potato peel contain 10% of the glycoalkaloids **(Mäder et al., 2009)** and the upper limit tolerated on food processing couldn't exceed 20 mg per 100g **(Cantwell, 1996)**. However, potato peels glycoalkaloid content depends on different factors and conditions like agrotechnical processes, seasonality, and maturation state. More than eighty alkaloids have been identified mainly alpha-solanine, alpha-chaconine, dehydrocommersonine, atomatine, demissine, dihydro-β-chaconine and dihydrosolanine **(Kozukue et al., 2008)**.

Sampaio et al. (2020) reported the glycoalkaloids content of potato peels of some potato varieties as reported in the literature during the last ten years (Table III).

Table IV: Content of glycoalkaloids of potato peels of some potato varieties.

	Potato peel variety and origin							
Glycoalkaloid (µg/g dry weight	**Organic Russet -** United States	**Non-organic Russet -** United States	**Gold potato -** United States	**Red potato -** United States	**Organic Russet -** United States	**Conventional Russet -** United States	**Organic Yukon gold -** United States	**Conventional Yukon gold -** United States
α-Chaconine	593	781	1301	1604	1180 ±110	424 ± 30	2830 ± 370	670 ± 130
α-Solanine	268	347	636	572	374 ± 54	215 ± 43	750 ± 120	253 ± 44
Total glycoalkaloids	861 ± 10	1128 ± 1	1940 ± 170	2180 ± 170	1550 ± 120	639 ± 52	3580 ± 390	920 ± 140
Reference	**(Elkahoui et al., 2018)**				**(Friedman et al., 2017)**			

Values expressed by (mean values ± standard deviation).

It should be noted that recent studies affirmed bioactive properties of these compounds for the human health such as antibacterial, anticancer, anti-inflammatory and antiobesity effects **(Elkahoui et al., 2018, Friedman et al., 2017, Hossain et al., 2015)** and α-chaconine,is the most abundant glycoalkaloid found in potato peels**(Friedman et al., 2017)**.

I-2-7) Mineral composition

Minerals play an important role for our health by participating to several reactions in human body. More recent studies confirmed that potato peels contain high amounts of mineral elements especially potassium, calcium, magnesium iron and zinc and suggested to valorize this by-product in various food preparations **(Dusuki et al., 2020, Vaitkevičienė, 2019)**.

Results of **Hashmi et al. (2021)** study showed that the potato peels contain the following contents (mg/kg): calcium 790±2.87, sodium 513±0.40, potassium 935±0.59, iron 3.35±0.37, and zinc 2.11±0.03.

Chapter II

Valorization of potato peels

II-1) Valorization in food formulations

II-1-1) Enrichment of bread

A review work of **Sampaio et al. (2020)** about the application of potato peels in bread reported that the use of this byproduct in food industry started since the 1970's, when **(Toma et al., 1979)** wrote about its utilization as a source of dietary fibers in bread. The authors noted that potato peels had more advantages comparing to wheat bran, like a dietary fiber contents, the water-holding capacity, the lower quantity of starchy components. The same authors in this review study stated that **Crawford et al. (2019)** tested the effect of potato peel addition in quinoa flatbreads on the reduction of acrylamide content, which is a toxic compound formed in food exposed to high temperature. The use of potato peels powder from the Russet variety at 5% into quinoa flour, noted a significant lowering on the acrylamide content in the baked flatbreads comparing with the control formulation (from 487 to 367µg/kg).

In an another work,**Curti et al. (2016)** have studied the use of potato fibers extracted from peels in betterment of wheat bread physico-chemicals and reducing staling. Bread staling appears during storage of bread and it leads to crumb hardening, crust softening and loss of the fresh flavor of the product **(Gray and Bemiller, 2003)**. Water has an important role in bread staling and the study of water status and dynamics is useful to better understand the bread staling phenomenon. Water migrates from crumb to crust incorporated partially in starch crystals **(Curti et al., 2014, Slade et al., 1991, Vittadini and Vodovotz, 2003, Baik and Chinachoti, 2001)**. However, large added amounts of fibers modify negatively dough and bread properties, production process, and staling-related phenomena (like gluten dehydration, amorphous starch recrystallisation, water molecular redistribution among bread components) **(Fadda et al., 2014, Collar et al., 2007)**. Hence, the potato peels fibers amount was limited to 0.4% on the flour basis (g fibers/100 g flour).

Results showed that potato fibers effected bread properties during tested storage of 7 days. The bread was softer, in particular when the optimum amount of water was used in the bread formulation. Differential Scanning Calorimeter analysis showed a larger presence of frozen water and reduced retrograded amylopectin in bread enriched with potato fibers. Softer crumbs were not the results of retrograded amylopectin it can be related to a stronger water retention of potato fibers and a higher water activity expressed by larger frozen water **(Curti et al., 2016)**.

Molecular mobility characterization carried out using ^{1}H NMR (Nuclear Magnetic Resonance) spectrometer was affected by the presence of potato fibers indicating a decreased rigidity maintained during storage **(Curti et al., 2016)**.

Potato fibers improved the texture of bread probably by retention of water allowing for the upkeep of a softer crumb texture during storage. The effect of higher amounts of potato fibers on bread staling could also be considered, to optimize the level of addition and reunite technological and sensory quality **(Curti et al., 2016)**.

II-1-2) Sweet bakery products

Martins et al. (2017) through their review study about bakery products and food industry by-products, told that the by-product ingredients incorporation had an effect on the extensional properties of wheat cakes dough, especially resistance to deformation or tenacity (P), extensibility (L), elastic resistance and extensibility balance (P/L ratio). The authors reported by comparing results of the work of **Jeddou et al. (2017)** and **Bender et al. (2017)** that tenacity which leads to dough ability to retain gas and can be influenced by the interactions between wheat proteins and polysaccharides increased in cakes enriched with potato peels and decreased with grape pomace addition. The opposite was found for extensibility which is increased with grape pomace addition and decreased with potato peels addition. However, the P/L ratio increased in the final products enriched with potato peels or grape pomace and showed a hard dough in their presence.

Jeddou et al. (2017) studied the impact of the addition of potato peel powders on the quality of the wheat dough and cakes. Used powders obtained from two types of potato peel flours contained fibers and proteins, showed a good water binding capacity and a fat absorption capacity. Potato peel flours were incorporated in wheat flour at 0%, 2%, 5% and 10%. The results showed that peel powders improved the alveographe parameters of dough and the texture of the prepared cakes especially the 5% incorporation. Dough resistance to deformation or tenacity increased with the addition of peel powders while the extensibility values were reduced, thus the P/L ratio (elastic resistance and extensibility balance of flour dough) increased with the increasing level of the two potato peel flours.

A significant difference in color analysis was noted between the control dough and the dough containing potato peels. The baking test showed that potato peel flour changed the cake aspect especially the 10% level of powder; the hardness of cakes was decreased compared to the control cake and the crumb color became darker with high values of red component and yellow component. Sensory analysis based on consumers evaluation showed that using potato peels powders in cake formulation preserved the functional characteristics (the weight, volume and the symmetry) and sensory characteristics (appearance, color, odor, taste, tenderness and overall appreciation).

An Egyptian study carried out by **Elhassaneen et al. (2016)** tested the valorization of prickly pear and potato peels on the production of crackers. Prickly pear and potatoes peel powders were obtained by deshydratation and contained 7% moisture content were incorporated at 5% levels to replace wheat flour. Results demonstrated that these by-products enriched the crackers by dietary fibers, carotenoids and total phenolics and didn't affect the sensory characteristics.

Another Egyptian study interested in the valorization of some by-products for the production of cakes and crackers. They tested the impact of the enrichment of these backed products with orange, banana and potato peels powders at 0%, 10%, 15% and 20% of wheat flour and especially the impact on specific volume and the sensory evaluation. Results marked for both of cakes and crackers an increase on the specific volume of samples comparing with the control by increasing the powder content of the by-products. The sensory analysis of crust color, texture, taste, odor and overall acceptability of the final products registered a less acceptability of cakes with potato peels powder comparing to the control. However, the crackers prepared with 15% of potato peels were evaluated as better in crispiness, taste and overall acceptability comparing to the control **(Zoair et al., 2019)**.

II-1-3) Pasta

The incorporation of potato peels in pasta was studied by **Fradinho et al. (2020)** who were interested in the effect of this addition on the quality of gluten-free products. This study emphasizes an important aim giving more choices for people who can't tolerate gluten. Nevertheless, vegetable pasta made with vegetal powder instead of wheat flour can induce disadvantages during cooking because proteins in raw matrix other than wheat can't form a structure similar to the gluten network **(Pagani, 1986)**. The worker team interested to the enrichment of the potato peels bioactive fraction into gluten free pasta. The bioactive fraction was extracted by subcritical water extraction (autohydrolysis) then total phenolic content and antioxidant activity were analyzed. The produced pasta showed an increase in total phenolic content and antioxidant activity with a good technological quality (cooking quality and acceptable color).

II-1-4) Beef patties

In recent study on beef patties fortification achieved by **Pérez-Báez et al. (2020)**, the addition of roselle extract (0%–1%), potato peel flour (0%–2%), and beef fat (0%–15%) was performed and the impact on the physicochemical properties (instrumental color, pH, cooking properties, and texture analysis), antioxidant capacity (DPPH, ABTS, and ORAC (Oxygen Radical Absorbance Capacity)), and total phenols in beef patties using response surface methodology was determined. The addition of potato peel flour increased pH, color parameters, cooking yield, moisture retention and texture quality but decreased the antioxidant power and total phenolic compounds in contrary to the addition of roselle extract. The optimal formulation for beef patties with low-fats, antioxidant capacity and without loss of physicochemical quality was composed of 1.27% of potato peel flour, 0.61% of roselle extract and 3.04% of beef fat.

II-1-5) Instant soup flour

Potato peels were used by **Mudondo (2019)** to make an instant flour intended for soup preparation. The potato peels were subjected to heating at 61°C for 10, 20 and 30 minutes and steaming for 5, 10 and 15 minutes than functional and physicochemical properties of the potato peel flour were determined. The potato peel flour with highest water absorption capacity among the heated and steamed potato peels was used in the formulation of instant soup alongside with corn starch, onions, salt, full cream milk and flavorant. The oil absorption capacity, the water absorption capacity and the water absorption index parameters noted high values for the potato-based soup flour from peels heated at 61°C. However, swelling power and water solubility index showed high values for soup flour samples with steamed peels. The pasting properties analysis showed a highest viscosity for the flours from the potato peels steamed for 5 minutes and ones from the potato peels heated at 61°C for 10 minutes with equal times of cooking of 7 minutes. Finally, the soup formulation which recorded more acceptability within a sensory evaluation was soup prepared with 75% of potato peels steamed flour from point of view of appearance, color, thickness, mouthfeel and overall acceptability.

II-2) Food packaging

Packaging is important to preserve the quality of food during storage and handling. The food market is more and more demanding for safer products with longer shelf-life leading therefore to create new packaging processes like active packaging materials **(Yildirim et al., 2017)**.

II-2-1) Packaging of fish fillets

Starch is used in food packaging bioplastics fabrication thanks to its thermoplastic property but its application is limited because of its hydrophilic character and brittleness. Starch-based films were improved by addition of synthetic polymers **(Rodriguez-Gonzalez et al., 2003)**. Starch is a biopolymer amply present in potatoes with up to 67% content **(Sharmila et al., 2020)**.

Lopes et al. (2021) tested the creation of active starch-based films using phenolic compounds from potato peels. Potato washing slurries composed of water, starch, and small potato slices were the source of used starch. Phenolic compounds of potato peels were extracted and different concentrations (0.1%, 0.5%, and 1% w/w related to starch dry weight) were incorporated into starch-based film preparations. Several parameters were studied to characterize the produced film. It is about optical properties, solubility in aqueous solution, thickness, mechanical properties, water vapor permeability and antioxidant activity. Then, smoked fish fillet packaging was tested by refrigerating at 4°C for 8 days and sensory analysis were carried out after 1, 5, and 8 days. Results showed a yellowish coloration of the films with preservation of transparency property, a water tolerance, elasticity, extensibility and antioxidant activity. Phenolic extract affected the starch-based films mechanical performance, weakened their elasticity and resistance to traction strength but it increased their stretch ability. Smoked seabream fillet packaged with the produced films were highly appreciated by experimented evaluators regarding especially the smell, flavor and color comparing to the fillets packed with commercial plastic.

Kaur and Singh (2016) reported that potato starch films insure the function of oxygen barrier and decelerate the rancidity of vegetable oil and probably all foods containing high content of polyunsaturated fatty acids.

II-2-2) Bread packaging

Borah et al. (2017) successfully experimented the production of a potato and sweet lime by-products based film with interesting properties; limit the weight loss, reduce the hardness and avoid the microbial development on the surface of bread. The films were prepared with different proportions of potato peels and sweet lime pomace powders treated by ultrasound technique for 45 and 60 minutes. All the films were analyzed for their barrier, mechanical and physical properties. It was noted that increasing ultrasound treatment times showed better result in film properties and even less content of potato peels powder marked better film properties. The selected film showed better characteristics compared with all other films; water vapor permeability, moisture absorption, water solubility, breakage strength, elongation capacity and thermal distability at 200°C. The incorporation of clove essential oil (1.5%) in the selected film formulation showed a decrease of surface microbial count for bread wrapped and stored for 5 days.

II-2-3) Plastic film

Ramesh and Radhakrishnan (2019) studied the enrichment of polyvinyl alcohol film with fennel seed oil and cellulose nano particles from potato peels. The properties of the produced film were compared with chitosan nano particle incorporated polyvinyl alcohol film, and polyvinyl alcohol based film with a combination of chitosan nano particle and potato nano particle. Mechanical and physical properties affirmed that potato nano particle - polyvinyl alcohol combination was the best one due to his antioxidant property, more interesting mechanical properties, biodegradability and oxygen gas barrier property. The addition of fennel seed oil to the film showed more antibacterial property hence its recommendation as a good food packaging.

II-2-4) Bioactive film

An application of the subcritical water technology to produce a packaging film has been done by **Zhao and Saldaña (2019)**. They successfully demonstrated the efficiency of this technique to produce a bioactive film with potato by-products (peels and cull) and gallic acid. Results showed interesting properties of the film; better elongation, enhanced antioxidant activity, less stretching resistance and, low water activity inhibiting the microbial development.

II-2-5) Packaging for fresh pork

Xie et al. (2020) tested the production of biodegradable film based on potato peels and bacterial cellulose. The scanning electron microscopy showed compatibility between the bacterial cellulose and the potato peels matrix especially with low quantities of bacterial cellulose because of a good dispersion of the bacterial cellulose particles making the film denser. Bacterial cellulose incorporation did not affect the crystallinity and the thermal stability of the films which was confirmed by the X-ray diffraction and thermogravimetric analysis. The tensile resistance of the film was up graded but water vapor permeability, oxygen permeability and moisture content have been decreased.

II-3) Valorization as an antioxidant additive for fresh-cut apple

Venturi et al. (2019) tested the use of potato peels as natural food additive which can be a substitute for synthetic preservatives by using water or ethanol aqueous solution (10%) to recover high contents of total phenol compounds.

The peels have been recovered using a ceramic knife then immediately stored in an inert atmosphere (N_2) in a stainless-steel vat controlling automatically the temperature. The peels have been kept in direct contact with solid CO_2 (ratio peels/CO_2, s = 1/1 w/w) for more than 24 h to maximize the recovering of the bioactive fraction. The cryogen causes the freeze of the intracellular water then the lesion of cellular membranes allowing the release of the cellular compounds **(Zinnai et al., 2015)**. Two solvents (distilled water and 10% ethanol solution) were used to optimize the extraction method. The extraction time reached 24 hours in the dark and inert atmosphere (N_2) under the conditions of : T = 27 °C and stirring rate = 650 rpm (Revolutions per minute). All the extracts were filtered under vacuum and maintained in inert atmosphere (N_2) at T = **-** 20 °C until analysis. Results showed a very interesting concentration in total phenol compounds in the both potato extracts but the ethanol one marked the highest value.

For the used apples, they were selected for uniform size and without defects then washed, peeled and cored using a ceramic knife and then cut into cubes which were dipped in different preserving solutions (apples/solution, 1:4 w/w) for 2 min manually stirring. The preserving solutions with precise concentration and pH for each ones were prepared using standard chemical compounds (citric acid, butylated hydroxytoluene, ascorbic acid) often adopted in minimally processed apple and new natural compounds obtained from potato peels. The potato extracts were used alone or in mixture with citric acid known as an anti-browning agent (Son et al., 2001).

Fresh-cut products are submitted to enzymatic browning catalyzed by polyphenoloxidase in the presence of oxygen **(Martinez and Whitaker, 1995)**. This enzyme released during cutting reacts on phenols causing browning of cut-apple surface **(Amiot et al., 1995)**. After two hours of storage, the browning has been evidently showed in control but with adding preservative agents the tissue browning was significantly decreased. The potato extracts, both water and ethanol solutions, showed an anti-browning effect similar to the standard preserving solutions thanks to their phenolic contents **(Amiot et al., 1992)** especially chlorogenic acid and caffeic acid **(Choi et al., 2016)**. Both potato extracts used in mixture with organic acids showed also a positive effect confirming the efficiency of organic acids in keeping low pH values.

All apple cubes samples manifested a good texture but those treated with the standard preserving solutions showed the lowest values of firmness because of the lesion of cell wall and the weakly of cell adhesion influencing tissue strength **(Rux et al., 2017)**. The firmness remained unchanged for apples treated with potato extract mixed with citric acid avoiding the softening of flesh tissues. The maintaining of firmness is important in minimally processed apples and it is a canon for consumer acceptability **(Toivonen and Brummell, 2008, Rux et al., 2017).**

II-4) Valorization in food pigments production

The synthetic pigments are very used in food industries but there is the worry that they can be carcinogenic and cause birth defects **(Babitha et al., 2006)**. Compared with synthetic pigments, natural ones which are bio-based are biodegradables, less or not toxic and with eco-friendliness **(Yusuf, 2017)**.

Microbes use wastes for growth by fermentation process and produce new compounds. Recently, many agro-industrial wastes have been used for pigment production especially as substrate that can contribute to the reduction of the production expenses **(Venil et al., 2020)**. According to several studies, Monascus generais the producer of the great part of biopigments **(Dufossé, 2006, Méndez et al., 2011, Panesar et al., 2015).**

The utilization of potato peels for the production of biopigments using solid state and submerged fermentation by the mold *Monascus purpureus* MTCC 369 was tested by **Sehrawat et al. (2017)**. Potato peels were used as a carbon source for the mold growth and results showed a better production yield with solid state fermentation than the submerged one. Monascus pigments generally encompassed red (490-530 nm), orange (460-480 nm) and yellow pigments (330-450 nm) **(Yang et al., 2015)**.

II-5) Enzyme production

It was reported in the review of **Teigiserova et al. (2019)** that enzymes are among bio-based products with high value **(Haddadi et al., 2018)**. They can be produced by microorganisms especially *Saccharomyces cerevisiae*, *Aspergillus* and *Bacillus* sp **(Haddadi et al., 2018)** which degrade polymers found in plants on sugars to fabricate enzymes**(Ravindran and Jaiswal, 2016)**. Various extracellular hydrolytic enzymes including polygalacturonases, proteases and amylases are produced by *Bacillus subtilis* using potato peels **(Arapoglou et al., 2009, Javed et al., 2019).**

Bharathiraja et al. (2017) reported the use of potato peel for the production of cellulolytic enzymes from *Aspergillus niger*. **Ergun and Urek (2017)** tested potato peels as a substrate for the production of ligninolytic enzymes like laccase, manganese peroxidase, lignin peroxidase and aryl alcohol oxidase by *Pleurotus ostreatus* under solid state fermentation conditions. It was noted that potato peels, in addition to their utilization as substrate, served as a matrix for the attachment of *Pleurotus ostreatus*. This might be due to a high hydrophobicity and surface charge of potatoes as supported by **Osma et al. (2007)** who reported that the most important property influencing adhesive behavior of filamentous fungi to the support is the hydrophobicity and the surface charge of the substrates.

II-6) Valorization in glucose production

Kumar et al. (2016) used potato peels as a source of starch to produce glucose. Potato starch was hydrolyzed to glucose under microwave irradiation using the silicotungstic acid (HSiW) catalyst. Results noted the glucose, levulinic acid and formic acid as products of the conversion of the starch, and the obtained glucose yield was 59% (weight percentage) under microwave irradiation time of 15 minutes with 1100W. This study demonstrated that the use of solid acid catalyst with microwave irradiation is a fast and ecofriendly process for glucose production from starch based waste materials.

II-7) Valorization in volatile fatty acids production

Volatile fatty acids and their derivatives are amply invested in food, pharmaceutical, leather, textile and plastics industries **(Dishisha et al., 2013, ElMekawy et al., 2013)**. A co-culture of *Klebsiella mobilis* and *Escherichia coli* was investigated to produce short and medium chain volatile fatty acids; this study was conducted by **den Boer et al. (2016)** using kitchen biowaste and potato peels as substrates. The experiments were performed with a bioreactor of 250 L at pilot-scale installation, under microaerobic conditions. Volatile fatty acids and ethanol were determined by gas chromatography equipped with a flame ionization detector. This work highlighted the advantage of culture in symbiosis of those two strains for the formation and chain elongation of volatile fatty acids. The products were acetic acid, propionic, butyric and valeric acids.

A higher volatile fatty acids yield was reached with potato peels comparing to other substrate biosources according to the study of **Zhang et al. (2020)** who inoculated the reacted active sludge collected from a mesophilic liquid anaerobic-fermenter (Zibo, Shandong province, China) fed with cattle manure under anaerobic fermentation. The quantitative and qualitative analysis of produced volatile fatty acids were accomplished using gas chromatography related to flame ionization detector and a Nukol free fatty acid phase fused silica capillary column (DB-FFAP, 30m× 0.53mm× 1.0 µm, Agilent). Results noted a production of considerable amounts of propionic, acetic and butyric acids besides of less quantity of valeric and hexanoic acids. The impact of pH was evaluated in another study by the same research team **(Lu et al., 2020)**. Results showed that the higher production yield was noted at pH=7 comparing with other levels (pH 5, pH 11, and uncontrolled).

Conclusion

Food by-products valorization methods have attracted many interests nowadays like a tool of sustainable management. These substances represent an underexplored resource for the recuperation of natural constituents. The importance of food by-products is related with their content in dietary fibers and various bioactive molecules that can be exploited especially in the food and nutraceutical industries. Polyphenols are one of the principal substances extracted and purified.

Among the generated by-products potato peels whose valorization showed interesting advantages which can be useful for eco-friendly industrials. These by-products are characterized by a rich and various nutritional composition (carbohydrates, fibers, proteins, minerals, phenolic compounds and glycoalkaloids). The most applications of potato peels are relied to their polyphenols recovered using several green methods with economic and environmental advantages. However, industrial production with specific analysis (cost-efficiency) is still a challenge since it is essential to optimize capital investment, energy consumption, the nature of the solvent, yield and integration into current processing lines. Practically, none of methods described in the literature encompasses all them.

Additionally, it is important to underline that the peeling method has been found affecting the composition of potato peels. Peels can be collected using potato hand peeler or knife, or by steaming method and, depending on the peeling method the nutritional quality of peels differs. Besides, it was suggested in the literature that researches should be oriented towards increasing the safety of potato peels based products by finding methods to reduce glycoalkaloids content in the by-product matrix.

The valorization of potato peels in food industries showed interesting results and many advantages. The most use of these by-products was to replace partially wheat flour in different products like bread, sweet bakery products and pasta. Thanks to the peels fibers content which is more interesting than wheat, water retention was stronger, hence the texture of bread was improved and risk of stale during storage was reduced. Besides, potato peels incorporation increased tenacity which leads to dough ability to retain gas due to the interaction between wheat proteins and potato peels polysaccharides. Others advantageous physical effects were the impact on extensibility of dough, volume and the symmetry of final products. However, it is important to underline that the amount of potato peels incorporated should be limited because large added content of fibers modify negatively dough and bread properties.

Sensory characteristics of the formulated products especially crust color, texture, taste, odor and overall acceptability showed a percentage of acceptability depending on the type of final product for example cakes enriched with potato peels powder were less accepted comparing with enriched crackers. Furthermore, in gluten-free pasta, the incorporation of potato peels bioactive fraction increased the nutritional value and antioxidant activity of the final product, and brought good technological quality (cooking quality and acceptable color).

Regarding packaging, the incorporation of potato peels gave yellowish coloration of films with preservation of transparency property, a water tolerance, elasticity, extensibility, antioxidant activity, biodegradability and oxygen gas barrier property. Other interesting properties were found in bread packaging; limit the weight loss, reduce the hardness and avoid the microbial development on the surface of bread.

Various other applications of potato peels have been explored so they were invested on the production of food coloring products especially Monascus pigments including red, orange and yellow pigments. Another type of valorization invested on the production of enzymes like cellulolytic and ligninolytic enzymes. Potato peels were also used to produce glucose thanks to their starch content, and they were effectively employed in fatty acids bio-production as substrate.

In overall, it should be noted that the potato peels are an important source of compounds which can be used for the preparation of other food products apart from those mentioned above. On the other hand, the need for *in vitro* and *in vivo* studies to help better mastering of pharmacological and nutritional properties of potato peels bioactive compounds was expressed to develop more interesting nutraceutical products and their application in other fields such as pharmaceuticals and cosmetics.

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Abstract
Potato (*Solanum tuberosum* L.) is a tuber globally considered as a part of staple diet with a big worldwide production, hence the huge generation of its by-products. The current study focuses on the valorization of peels as a principal potato byproduct. The main objective was to identify scientific studies data about the valorization of potato peels in food industries during the period of the last six years (2016-2021). It was revealed that this byproduct constitute a prominent source of naturally nutritional and bioactive compounds such as polysaccharides, fibers, diverse mineral salts, glycoalkaloids and phenolic compounds. These constituents have contributed to the biological activities and beneficial effects of potato peels hence the need for their valorization in different fields. Several forms of valorization were noted, the important form was their employment as natural alternative antioxidants to elaborate novel functional foods citing the preparation of bread, cakes, pasta or for the preparation of active packaging. This by-product has also others valorizations in particular to produce biopigments, enzymes, glucose and volatile fatty acids. In overall, the utilization of potato peels in food industries seems to promote interesting contributions to sustainable development by providing economical and eco-friendly investments.
Keywords: *Solanum tuberosum* L.; peels; chemical composition; biological effects; valorization; food industries.

Résumé
La pomme de terre (*Solanum tuberosum* L.) est un tubercule globalement considéré comme faisant partie de l'alimentation de base avec une grande production mondiale d'où l'énorme génération de ses sous-produits. La présente étude porte sur la valorisation des pelures comme principal sous-produit de la pomme de terre. L'objectif principal est de recenser les données d'études scientifiques sur la valorisation des pelures de pommes de terre dans les industries alimentaires au cours de la période des six dernières années (2016-2021). Il a été révélé que ce sous-produit constitue une source importante de composés naturellement nutritionnels et bioactifs tels que les polysaccharides, les fibres, divers sels minéraux, les glycoalcaloïdes et les composés phénoliques. Ces constituants ont contribué aux activités biologiques et aux effets bénéfiques des pelures de pommes de terre d'où la nécessité de leur valorisation dans différents domaines. Plusieurs formes de valorisation ont été notées, la forme la plus importante est leur emploi en tant qu'antioxydants alternatifs naturels pour élaborer de nouveaux aliments fonctionnels citant la préparation du pain, de gâteaux, de pâtes ou pour la préparation d'emballages actifs. Ce sous-produit a aussi d'autres valorisations notamment pour produire des biopigments, des enzymes, du glucose et des acides gras volatils. Dans l'ensemble, l'utilisation des pelures de pommes de terre dans les industries alimentaires semble favoriser des contributions intéressantes au développement durable en fournissant des investissements économiques et respectueux de l'environnement.
Mots clés : *Solanum tuberosum* L.; épluchures; composition chimique; effets biologiques; valorisation; industries alimentaires.

ملخص
البطاطس (*Solanum tuberosum* L.) هي درنة تعتبر على مستوى العالم جزءًا من النظام الغذائي الأساسي مع إنتاج عالمي كبير، ومن ثم الكمية الهائلة من منتجاتها الثانوية. اخترنا القشوركمنتج ثانوي للبطاطس ركزنا عليه في دراستنا. كان الهدف من عملنا هو جمع البيانات من الدراسات العلمية حول تقييم تقشير البطاطس في الصناعات الغذائية خلال فترة السنوات الست الماضية (2016-2021). تمت ملاحظة العديد من أشكال التثمين، والشكل المهم هو لمركباتها النشطة بيولوجيًا وأنشطتها خاصة كمضادات الأكسدة البديلة الطبيعية أو العبوات النشطة بيولوجيًا. كما تمت دراسة ترقيات أخرى لإنتاج الأصباغ الحيوية والإنزيمات والجلوكوز والأحماض الدهنية المتطايرة. أخيرًا، يبدو أن استخدام قشور البطاطس في الصناعات الغذائية يعزز مساهمات مثيرة للاهتمام في التنمية المستدامة من خلال توفير استثمارات اقتصادية وصديقة للبيئة.