INSTITUTO POLITÉCNICO DE BRAGANÇA
Escola Superior de Tecnologia e de Gestão

Chemical, physical and bioactive properties of different cultivars of potatoes (*solanum tuberosum L.*) and their peels

Christian Teixeira Rodrigues

Thesis final dissertation presented to the School of Technology and Management of the Polytechnic Institute of Bragança to the fulfillment of the requirements for the Master of Science Degree in

Chemical Engineering

Supervisors:

Prof. Márcio Soares Carocho

Prof. Lillian Bouçada de Barros

Bragança, 2021

ACKNOWLEDGMENTS

The work of a master's degree is not the end but beginning of a new opportunity for life.

For that, I want to share my thanks to the people who help me on this dissertation work.

To my supervisors. Dr. Márcio Carocho, and Dra. Lillian Barros, for the instruction, guidance, support, competence and assistance in the elaboration of this dissertation.

To the Centro de Investigação de Montanha (CIMO) and all its collaborators, especially to Izamara de Oliveira and Mariana Correia, who help me with various laboratory issues.

A special thanks to Dr. Spyridon Petropoulus from the University of Thessaly for providing the potato samples.

To my school, School of Technology and Management of Bragança, one of a kind.

To my family, particularly mom Josefina Augusta Teixeira Rodrigues, dad João Inácio Pereira Rodrigues, and brother Jean-Luc Teixeira Rodrigues, for all the support, kindness, and most importantly, love, they give me every day.

Last but not least, to all my friends, particularly the village friends, who know what it is to suffer to have what we believe in life.

RESUMO

O desenvolvimento de produtos sustentáveis tem sido a principal agenda do século XXI. Um dos principais focos é a reciclagem de produtos das indústrias de processamento de alimentos. Há algumas décadas, os subprodutos da indústria de alimentos foram convertidos em energia e outros produtos de valor agregado. A batata é o quarto alimento mais importante do mundo, porém os seus subprodutos, nomeadamente as suas cascas contêm nutrientes e moléculas de interesse, sendo candidatas a aplicações como conservantes alimentares, corantes ou matéria nutricional para outros alimentos. Neste trabalho, foram estudadas 29 polpas e cascas de variedades de batata. Foram determinados o valor nutricional, teor de açúcares solúveis, ácidos orgânicos, atividade antioxidante pelo método TBARS e atividade antimicrobiana. Além disso, foram também analisados o pH, atividade de água, textura e cor da casca e da polpa da batata. Devido ao grande número de amostras diferentes, houve sobreposições aquando da classificação das amostras. Assim, uma análise discriminante linear foi utilizada para agrupar as batatas de acordo com os valores obtidos para cada análise. Assim, as batatas foram agrupadas em 5 clusters que as aproximam por região geográfica. No geral, as batatas e as cascas parecem apresentar moléculas bioativas que podem ser exploradas, assim como corantes que podem ser usados na indústria alimentar. Além disso, a diversidade das 29 variedades de batata mostra que este vegetal é muito diferente e adaptado a diferentes climas, o que se manifesta nas suas propriedades intrínsecas.

Palavras-chave: Batatas; *Solanum tuberosum*; Perfil Nutricional; Bioatividade, Análise Linear Discriminante

ABSTRACT

The development of environmentally friendly products has been the main agenda of the 21st century. One of the main focuses is the recycling of products from the food processing industries. For some decades now, the by-products of the food industry have been converted into energy and other value-added products. Potatoes are the fourth most important food in the world, however their by-products, namely their peels contain nutrients and molecules of interest, being candidates for applications such as food preservatives, colorants or nutritional matter for other foods. In this work, 29 pulps and skins of potato varieties were studied. Nutritional value, soluble sugar content, organic acids, antioxidant activity by the TBARS method and antimicrobial activity were determined. They were also pH, water activity, texture and color of potato skins and pulps. Due to the large number of different samples, there was a lot of overlapping of ratings. Thus, a linear discriminant analysis was used to group potatoes according to the values obtained for each analysis. Thus, the potatoes were grouped into 5 groups that approximated them by region. Overall, the potatoes and peels seem to show bioactive molecules that could be exploited, as well as colorants that could be used in the food industry. Furthermore, the diversity of the 29 potato varieties shows that this vegetable is very different and adapted to different climates, which shows in their intrinsic properties.

Keywords: Potatoes; *Solanum Tuberosum*; Nutritional Profile; Bioactivity; Linear Discriminant Analysis.

INDEX

FIGURE INDEX

TABLE INDEX

LIST OF ABBREVIATIONS

a* - Red-Green

A_w - Water Activity

AOAC - Association of Official Analytical Collaboration

b* - Yellow-blue

CIE - International Lighting Commission

DAD - Diode Array Detector

EC_{50} - The concentration that reduces by 50% the oxidants existing in the solution

EFSA - European Food Safety Authority

EU - European Union

FAO - Food and Agriculture Association of the United Nations

FD - Fluorescence Detector

FID - Flame Ionization Detector

fw - Fresh Weight

GC - Gas Chromatography

HPLC - High Performance Liquid Chromatography

ISO - International Organization for Standardization

L* - Luminosity

LDA - Linear Discriminant Analysis

MIC - Minimum Inhibition Concentrations

MS - Mass Detector

N - Nitrogen

NGOs - Non-Governmental Organizations

OxHLIA - Oxidative Haemolysis Inhibition Assay

PLP2 - Primary Porcine Liver Cells

RI - Refraction Index

SD - Standard Deviation

TA. XT - Plus texturometer from Stable Micro Systems

TBA - ThioBarbituric Acid

TBARS - ThioBarbituric Acid Reactive Substances

TCA - Trichloroacetic Acid

TPA - Texture Profile Analysis

UFLC - Ultra-Fast Liquid Chromatography Coupled

USDA - United States Department of Agriculture

1. INTRODUCTION

1.1. Food Waste

Globally, nearly one third of food produced for human consumption is lost or wasted, equalling a total of 1.3. billion tonnes of food per year (Gustavsson et al., 2011). As the production of food is resource-intensive, food losses and wastes are indirectly accompanied by a broad range of environmental impacts, such as soil erosion, deforestation, water and air pollution, as well as greenhouse gas emissions that occur in the processes of food production, storage, transportation, and waste management (Mourad, 2016). Scenarios for Europe indicate a considerable potential for reducing emissions through the reduction of food waste (Rutten et al., 2013) along the stages of the food production and consumption chain (Schanes et al., 2016).

Due to these growing environmental but also social and economic concerns, food waste is increasingly acknowledged as an urgent issue among governments, businesses, NGOs, academics, and the general public. In response, there is a mounting evidence base on the quantities of food wasted and the related emissions along the food production-consumption chain (e.g., Beretta et al., 2013; Edjabou et al., 2016).

Fruits and vegetables are consumed raw, minimally processed, as well as processed, due to their nutritional value and health-promoting effects. With the growing population and changing diet habits, the production and processing of horticultural crops, especially fruits and vegetables, have increased very significantly to fulfil the increasing demands. Significant losses and waste in the fresh and processing industries are becoming a serious economic and environmental problem. The United Nations Food and Agriculture Organization (FAO, 2014) has estimated that losses and waste in fruits and vegetables are the highest among all types of foods and may reach up to 60% of the total market.

Processing operations of fruits and vegetables produce significant waste and/or by-products, which constitute about 25% to 30% of the whole commodity (Schieber et al., 2001, Vilariño, 2017). The waste is composed mainly of seeds, skins, rinds, and pomaces, containing good sources of potentially valuable bioactive compounds, such as carotenoids, polyphenols, dietary fibers, vitamins, enzymes, and oils, among others. These phytochemicals can be used in different industries including the food industry, for

the development of functional or enriched foods, the health industry for medicines and pharmaceuticals, and the textile industry, among others.

The Food and Agriculture Association of the United Nations (FAO, 2014), estimates that one-third of the production of food worldwide (estimated as 1.3 billion metric tons), are wasted every year (FAO, 2014), although horticultural waste reaches a higher proportion, of 60% (Gustavsson, 2011). Postharvest losses in the United States are estimated to be 2% to 23% depending on the commodity, with an overall average of 12% (Kader, 2005), while in the United Kingdom is estimated to be 9%, (Garnett, 2006). This waste is an unintended result of the way food production and supply systems function in their institutional and legal framework (Parfitt, 2010). Thus, the use of waste to produce various crucial bioactive components is an important step toward a sustainable development (Sagar, 2018), due to many of the compounds present in the waste, residue or by-products having bioactive properties that can have beneficial health attributes: antibacterial, antitumor, antiviral, antimutagenic, and cardioprotective activities (**Figure 1**) (Dilas et al., 2009, Yahia, 2010).

Food Waste

Waste generated during and after processing fruits and vegetables.

Production of various bioactive compounds and value-added products via extraction and solid-state fermentation.

- Polyphenols
- Dietary Fibbers
- Enzymes and protein

Industrial Application of Bioactive Compounds

- Health care
- Food Sector
- Pharmaceutic/Nutraceuticals
- Chemical Industry

Figure 1. Overview of how food waste can be recovered and transformed as raw materials for specific industries. Adapted from Sagar et al. (2018)

Tuber Residue as Waste

The cultivation and processing of sweet potatoes into a variety of products yields both solid and liquid organic waste. Solid waste includes peelings and trimmings from the sweet potato root and sweet potato leaves and vines. Liquid waste results from various processing methods and creates significant amounts of nutrient rich wastewater. Sweet potato waste materials contain carbohydrates, proteins, phenolic compounds, macro and micronutrients, and pigments that have the potential of being extracted or utilized for various downstream processes and products. This review examines many of the different ways that these waste products can be utilized. (FAO, 2016).

1.2. The Importance of Potatoes in Human Diets

Potato (*Solanum tuberosum L.)* has historically been one of the most important staple foods in the world for many civilizations. Its main importance is due to being an important source of carbohydrates. Extremely versatile, potatoes can be consumed in the most varied forms, namely fried, boiled, roasted, and even extruded, to produce starch and chips (Lutaladio et al., 2009, Narvaez-Cuenca et al., 2018, Stokstad, 2019).

With very good sensory properties, potato has a true arsenal of nutrients for the body. With little amount of fat, in its natural form, potato average about 0.74 calories/g. In addition, it contains vitamins B and C, important minerals such as phosphorus, iron, potassium, and calcium. Potatoes are also an important source of starch, a carbohydrate used as a source of glucose, indispensable for the human metabolism. They are also rich in vitamin K, a nutrient that helps with artery elasticity, therefore, helping prevent prevents cramps, and reduce stroke incidence (USDA, 2015).

Potato consumption is also related to beauty, being effective for skin health, being inclusively used in several products to cure or remove acne marks (Kenny, 2013).

Historical Importance

The history of the potatoes begins in South America, namely the Andes Mountains. They trace back to 8000 BC, and probably originated in Peru, but it is likely that they had been cultivated before that. Their cultivation covered a vast area from present-day Venezuela to Chile (Ugent, 1988).

From its origin, it has spread throughout the world, being today a staple in many countries. It arrived in Europe before the end of the XVI century through two different ports of entry: the first in Spain around 1570, and the second through the British Isles between 1588 and 1593. The first written mention of the potato is a dated delivery receipt of November 28, 1567, between Las Palmas and Antwerp. In France, at the end of the 16th century, the potato was introduced in Franche-Comté, in the Vosges de Lorraine and in Alsace. The potato has gradually become an important staple crop in northern Europe.

Hunger in the early 1770's contributed to its acceptance, as did government policies in several European countries and climate change during the Little Ice Age, when traditional cultures in this region did not produce as much as before. In times and places where and when most other crops failed, potatoes could still be used to provide food during the coldest years (Abel et al., 1986, Ríos et al., 2007, Duneto, 2018).

In 1557 the potato entered Portugal as reported by António Galvão in the Treaty of Discoveries, of 1731, and Bento Pereira, in his "Prosodia in vocabularium trilingue latinum, lusitanicum et castellanicum" of 1647. But, in Portugal, it would only be cultivated more intensely in the middle of the XVIII century, perhaps before 1760, being mainly cultivated in Trás-os-Montes, and passing to Minho and Beiras and in the valley of the Sado river. Only in the middle of the XIX century, with the demographic growth, did the culture and use of potatoes become widespread among peasants (Salaman, 1985).

Current Importance

Potatoes are edible tubers, available worldwide and all year round. They are relatively cheap to grow and quite rich from a nutritional standpoint. Beyond the nutritional importance, potatoes can also present some benefits to human health: a) bone health; The

iron, phosphorous, calcium, magnesium, and zinc in potatoes all help the body to build and maintain bone structure and strength. Iron and zinc play crucial roles in the production and maturation of collagen (McGill et al., 2013, Kurilich et al., 2013, Davignon, 2013); b) heart health; fiber, potassium, vitamin C, and vitamin B6 in potatoes, along with its lack of cholesterol all support heart health. Fiber helps lower the total amount of cholesterol in the blood, thereby decreasing the risk of heart disease (USDH, 2015); c) Inflammation; Choline is an important and versatile compound present in potatoes, helping with muscle movement, mood, learning, and memory.

It also assists in maintaining the structure of cellular membranes, transmitting nerve impulses, the absorption of fat early brain development. One large potato contains 57 mg of choline of the daily need for adult men of 550 mg, and 425 for woman (Institute of Medicine, 2005); d) Cancer; Potatoes contain folate, which plays a role in DNA synthesis and repair, and so it prevents many types of cancer cells from forming due to mutations in the DNA (Storey, 2009); e) Weight management and satiety; Dietary fibers are commonly recognized as important factors in weight management and weight loss.

They act as “bulking agents” in the digestive system, increasing satiety and reducing appetite. Overall, potatoes are packed with a high nutritional load, along with bioactive compounds and antinutrients that help in many aspects of human health. Beyond this, they are a bulking food, helping the consumer feel satiated.

1.3. Different Types of Potatoes

There are over 200 species of potatoes with varying shapes, sizes, textures, colors, organoleptic profiles, bioactivities, and provenances.

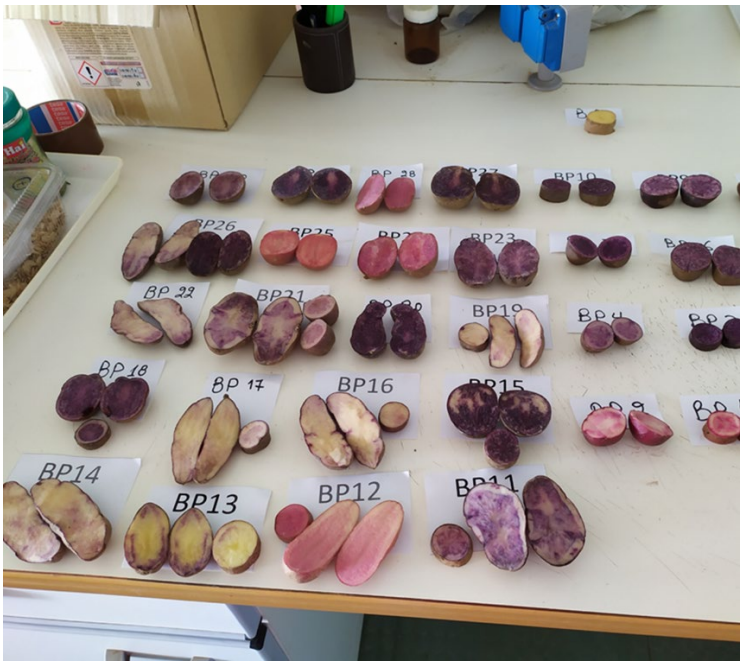

Figure 2. Different varieties of potatoes.

Among these some of the most valuable are:

- Russets

Figure 3. Butte Russet potato. Source: U.S. Department of Agriculture.

Russets are characterized by their rough brown skin and white flesh, varieties such as Butte (Nardozzi, 2009), fall into the dry/mealy end of the texture spectrum. Butte is a potato with white flesh, dry and mealy, and it is suitable for baking, mashing, and French fries (Nardozzi, 2009).

- White Potatoes

Figure 4. Elba potato variety. Source: U.S. Department of Agriculture.

Onaway potatoes are medium to large and are round to oblong in shape. The skin is semi-smooth and a light burlap brown with a few, medium set eyes, (U.S, 2005). Elba has smoother, thinner, and lighter-coloured skin. Considered all-purpose potatoes, they are creamy when baked yet hold their texture when boiled.

- Floury Potatoes

Figure 5. Yukon Gold potato. Source: U.S. Department of Agriculture.

Made familiar by the popular Yukon Gold variety, these potatoes have fine-grained, dense flesh that holds its shape when cooked. They are ideal for potato salad, soups, and stews, but can also be roasted and baked. Carola potatoes also fall into this category (Nardozzi, 2009). Higher in starch and lower in moisture than matte-skinned russets and Idahos, they tend to fall apart when boiled (the starches harden and expand, causing the skin to split and the interior to crumble into meal) (Nardozzi, 2009).

- Coloured Potatoes

Figure 6. All-Blue potato. Source: U.S. Department of Agriculture.

Some of the most known potatoes in these groups are the Vitelotte which originated in France, and Blue Congo also known as 'Blue Swede' or 'Idaho blue'. It is somewhat mealy, making it good for baking. All-Blues keep their colour best when baked, microwaved, or fried. Some people think it has a subtle nutty flavour (Nardozzi, 2009). Cranberry Red, also known as All-Red, has red skin and pink flesh (sometimes swirled with white) with a dense texture that holds its shape, making it ideal for boiling and sauteing. Red Cloud is a red-skinned potato with dry, white flesh that is good for baking (U.S, 2005).

- Russian Banana Potatoes

Figure 7. Russian Banana potato. Source: U.S. Department of Agriculture.

Like the name implies, fingerling potatoes, such as Russian Banana, are shaped like fingers, small and elongated. They have thin, tender skin and are generally eaten roasted (U.S, 2005).

- "New Potatoes"

Figure 8. Red Cloud potato. Source: U.S. Department of Agriculture.

In Portugal they called the New Potatoes or Early Potatoes. Immature potatoes that are harvested in early summer before they are fully mature (before the vines die back). They can be any variety. They have a shorter shelf life than mature potatoes (U.S, 2005). Most potatoes are stored for up to a couple of weeks to set the peel and heal any nicks or cuts, allowing them to last longer. Without this step, new potatoes are moister and seem sweeter, though with a slight, appealingly minerally bitterness in the finish. New potatoes can be stored at room temperature, but because they have not been cured, they will not

last as long regular potatoes, several days instead of several weeks. When refrigerated, they starch will begin to convert to sugar, so if they are chilled for very long, they ’il taste sweet (U.S, 2005).

All these types of potatoes can be used for many different industrial sectors, one of this, is the use of potatoes in fabrication of additives.

1.4. Importance of Food Additives in Modern Diets

Food additives are substances added to a food to preserve it, give it flavour, or improve its taste and/or appearance. Manufacturers use additives in foods to retain nutritional value, maintain freshness and safety, and increase affordability and convenience. Basically, without food additives, the food supply would be limited and costly. Additives such as fibber, vitamins and minerals can improve the nutrient density of a product and help protect against certain health problems (USDA, 2015).

Synthetic food preservatives have been used alone or in combination with natural preservatives both synthetic and natural antioxidants been used in food industry; however, application of synthetic preservatives has potential carcinogenic effects, while the use of natural preservatives alone has a better advantage for human health with low side effects. As a result, attention has been given to vegetable waste that is rich in phenols (Sonia et al., 2016, Mini et al., 2016, Geethalekshmi et al., 2016, Tiwari ,2009). Phenolic compounds are found in plants ubiquitously being of noticeable interest due to their antioxidant and antimicrobial properties (Pezeshk et al., 2015, Ojagh et al 2015., Alishahi, 2015).

Natural Food Additives

Natural food additives have been gaining more interest both from the public and food manufacturers. Generally, the public will choose a food with no additives, when this is not possible, the same consumer will choose a food containing natural additives over synthetic ones. (Carocho et al., 2014). There is no official difference in legislation between natural and synthetic additives, although there is a clear distinction in terms of

their origin, raw material, and production methodology (Baines et al., 2012, Seal, 2012). **Figure 9** shows some natural based food additives, divided into categories.

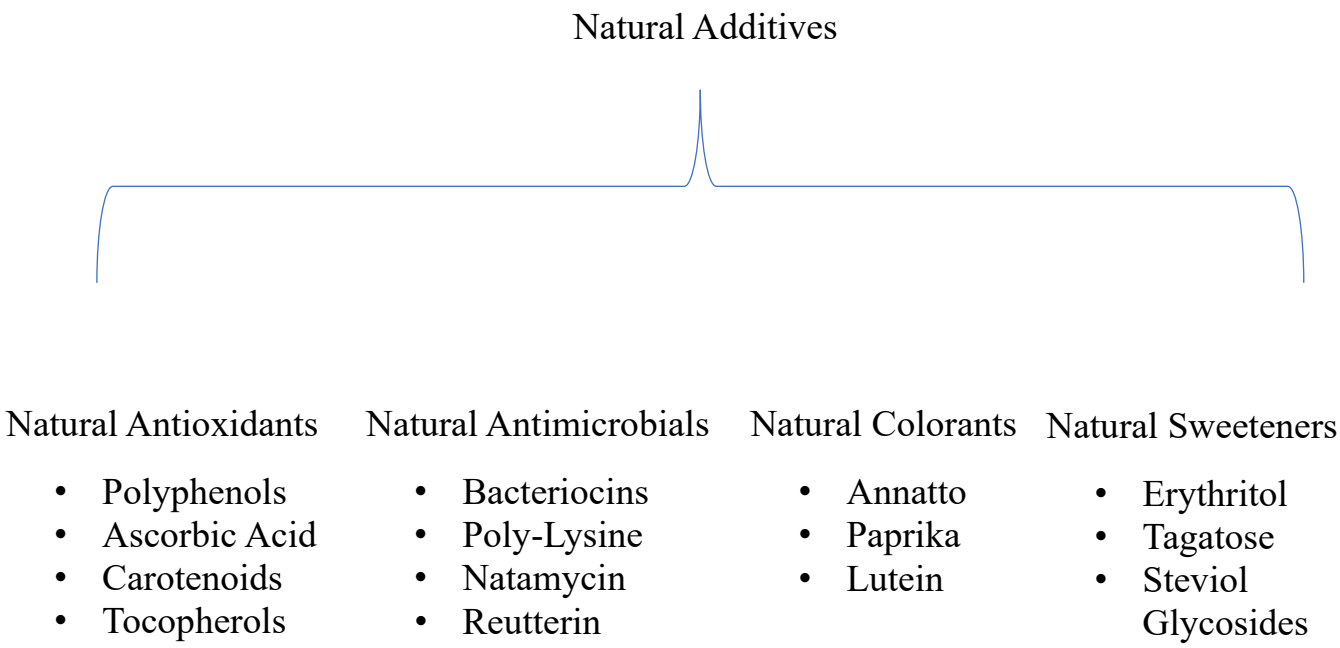

Figure 9. Depiction of the most common natural potential food additives divided in categories. Adapted from Carocho et al., (2014)

1.5. Use of Potato Peels in the Food Industry

In recent years, and thanks to sustainability awareness, potato peels have become a field of interest for many industries due to their putative bioactivities, turning this residue in a raw material of high interest. Furthermore, considering that potatoes are staple foods in many countries, and are mostly consumed without the peels, these skins may constitute a residue with considerable quantity that could have various applications in the food industry (Sampaio, 2020).

Nevertheless, the use of potato skins in the food industry should be regulated due to the risk of high levels of solanine. Solanine is a glycoalkaloid present in skins of potatoes and the potato itself and is a known toxic substance. Its concentration varies with the variety of potato, and thus, varieties with low quantities of this alkaloid should be preferred. A new technique is now being developed to reduce the concentration of this alkaloid in potato skins, namely washing with a pH12 solution. Another way to remove solanine its by dipping the potatoes in vinegar of 30-60 degrees Celsius.

Thus, these techniques should be employed before using potato skins in the industry. Furthermore, extraction of bioactive compounds from peels can be performed to remove solanine from the extract (Romanucci, 2018).

Food Preservation

Food processing industries generate phenolic-rich vegetable by-products, and this has been an area of research investigations in the search for antioxidants and antimicrobials for food preservation (Pezeshk, 2015). The entire tissue of fruits and vegetables is rich in bioactive compounds or phenolics, but the by-products have higher contents of antioxidant (Sonia, 2016). Due to the suspected long-term negative health effect, the use of synthetic antioxidants and antibacterials on food has become a common concern of consumer safety. Therefore, the food industry has been seeking natural alternatives for food preservatives. Potato peel is one of the most important waste products with a high phenolic quantity, making it a candidate for replacement of the current synthetic food antioxidant and antimicrobials.

Antioxidants

The antioxidant activity of potato peel extracts has strong radical scavenging ability and prevents oxidation reaction in oily foods (Habeebullah, 2010). The dominant phenolic compounds of potato peel extracts are chlorogenic and gallic acids. These are potent sources of natural antioxidants that prevent oxidation of vegetable oil, oil oxidation reaction through minimizing peroxide and p-anisidine indices (Amado et al., 2014, Mohdaly, 2010). Potato peel extracts have equal performance as synthetic antioxidants such as butylhydroxyanisole and butylhydroxytoluene. In comparison with mature potato, young potato peel is an excellent source of bioactive phytochemicals, higher than mature potatoes (Amado, 2014).

Antimicrobials

The antimicrobial activity sought in peels of potatoes is due to the presence of flavonoids and terpenes (Nostro, 2000). Potato peel has bacteriostatic effects nature with no mutagenic behaviour (Amanpour et al., 2015, Sotillo et al., 2015, Hadley et al., 2015, Wolf-Hall, 1998). Some examples include potato peel powder that was used in cooked rice, and showed inhibition of Bacillus cereus, while another study referred the peels as having antibacterial activity against *Escherichia coli* and *Salmonella typhimurium* (Sotillo et al., 1998, Juneja, 2018).

2. OBJECTIVES

The main objective of this work was to study the nutritional, chemical, physical, and bioactive profile of different varieties of potatoes as well as their peels, to understand eventual applicability in the food industry.

For this, specific objectives have been defined:

a) Nutritional profile of the pulp and skins of the potatoes though AOAC procedures;
b) Analysis of organic acids in the pulps and skins through UFLC-DAD;
c) Analysis of soluble sugars present in the pulps and skins through HPLC-RI;
d) Analysis of the pulp pH using a portable pH meter;
e) Analysis of the water activity (a_w) using a dew point equipment;
f) Analysis of the hardness of potato pulps using a texturometer;
g) Analysis of the color of the skin and pulp using a portable colorimeter;
h) Analysis of the antioxidant and antimicrobial potential of the skins;
i) Analysis of the antioxidant potential (TBARS assay).

3. MATERIALS AND METHODS

3.1. Potatoes

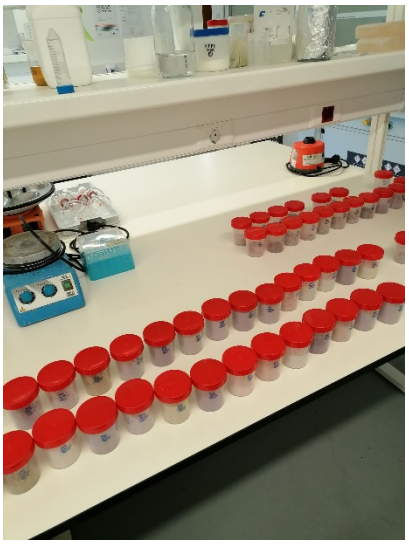

Figure 10. 29 Potatoes and their peels after being reduced to a powder.

The 29 potatoes used in this study were sown and grown in Volos, Greece. As soon as they were harvested, they were shipped to our laboratory where they were subject to different analyses. Immediately after reception, the potatoes were analysed for their peel color, cut in halves with subsequent analysis of their flesh. After analysing their moisture and pH, the flesh was separated from the peels, and both were lyophilized (Labconco Freezone 4.5, MI, USA), milled down to a fine powder, and kept in the dark until further analysis.

3.2. Chemical Analyses

3.2.1. Nutritional Profile

The analyses for the nutritional profile (proteins, fats, moisture and ash) were carried out according to the official methodology of AOAC, 17th edition (AOAC, 2016).

Moisture

The moisture of the potatoes and their peels was determined using a moisture analyser Adam Equipment (model PBM 163, Oxford, USA). The sample, 2 g of each potato and each peel, were placed on a metal plate and inserted in the equipment. The sample was heated to a constant temperature until total evaporation of water. After subtracting the final weight from the initial one, the humidity value is calculated.

Ash

The ash content was determined by the AOAC 923.03 method, which consists of burning organic matter at high temperatures. The lyophilized sample, (0.25 g) was weighed and added to porcelain crucibles, and incinerated in the muffle, calculating the ash after subtracting the weight from the initial weight of crucible (Optic Ivymen System, N-8L, Barcelona, Spain) (**Figure 11**) for 5 h at 550 ºC.

Figure 11. Muffle.

Crude Protein

Proteins are polymers of amino acids. Twenty different types of amino acids occur naturally in proteins. Proteins differ from each other according to the type, number and sequence of amino acids that make up the polypeptide backbone. As a result, they have different molecular structures, nutritional attributes and physiochemical properties. The

protein content was calculated using the AOAC 920.87 method, which consists of the destruction of organic matter with a strong acid and is based on the amount of nitrogen (N) in the sample to quantify the proteins. The analysis was performed using the Macro-Kjeldahl method, and a conversion factor of 6.24 (N x 6.24). Each lyophilized sample (0.5 g) was added to the test tubes and digested with the catalyst, K_2SO_4 / $CuSO_4$, and in 15 mL of sulfuric acid for 70 min at 400 ºC.

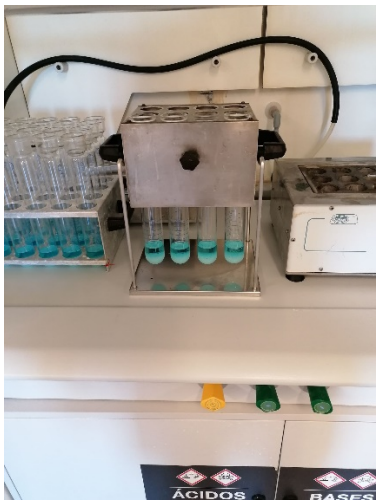

Figure 12. Protein Digester.

After cooling, the tubes were inserted into the Kjeldahl distiller (model Pro-Nitro-A, JP Selecta, Barcelona) where a stable alkaline distillation and a titration occurred, informing the amount of nitrogen.

Figure 13. Kjeldahl Distiller.

Crude Fat

The crude fat content was determined by the AOAC 920.85 method, which is based on the extraction of fat by soxhlet using petroleum ether as the extraction solvent. Each freeze-dried potato sample was weighed, placed in filter paper cartridges and covered with cotton. The cartridges were introduced in the soxhlets (**Figure 14**), together with petroleum ether. The equipment was heated to approximately 80 ºC and after 4 hours, the solution containing the fat was removed, transferred to test tubes, previously weighed, and sent for evaporation. After drying, the test tube was weighed again, and the fat content calculated.

Figure 14. Extractor Soxhlet.

3.2.2. Organic Acids

The determination of organic acids followed the method described by Barros et al. (2013). Each lyophilized sample was weighed (1 g) into a beaker where 25 mL of metaphosphoric acid (4.5%) was added and the beaker cup was covered with aluminium foil. The solution was placed under magnetic stirring at room temperature for 20 min. After 20 min, the samples were filtered, through a paper filter, into a test tube. With the aid of a syringe and a nylon filter, the samples were transferred to 1.5 mL amber vials, to proceed for analysis

by ultra-fast liquid chromatography, coupled to a diode detector (UFLC-DAD) (Shimadzu 20A series, Shimadzu Corporation, Kyoto, Japan).

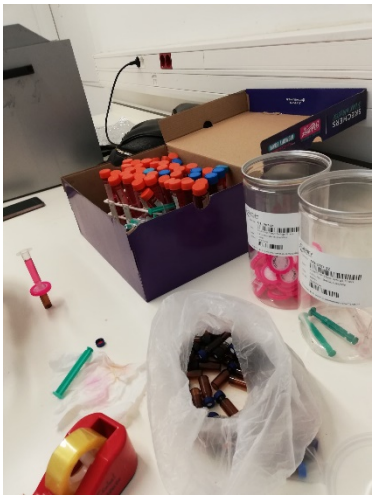

Figure 15. Transfer to amber vials.

The separation of the compounds was carried out through a C18 reverse phase column (250 mm x 4.6 mm, 5 µm, Phenomenex), thermostated at 35 ºC and the detection occurred at the wavelengths of 215 and 245 nm. The elution solvent used was sulfuric acid (3.6 mM). For the identification and quantification of organic acids, retention times and spectra of commercial standards were compared, as well as their respective calibration lines. The results were presented in g / 100 g fresh weight (fw).

Figure 16. UFLC-DAD.

3.2.3. Soluble Sugars

The determination of soluble sugars was performed by high performance liquid chromatography (HPLC) coupled to a refraction index detector (IR) (Knauer, Smartline System 1000, Berlin, Germany) (**Figure 17**), using melezitose as the internal standard, as

described by Carocho et al. (2020). About 1 g of the lyophilized sample was weighed, and 1 mL of melezitose was added (25 mg / ml) and 40 mL of an aqueous solution of 80:20 v/v of ethanol was added. The samples were added to a heated bath at 80ºC for 1 h and 30 min, being stirred every 15 min. After this process, the ethanol was evaporated in rotavapor, and the volume was made up to 5 mL with distilled water in a volumetric flask. Finally, the samples are filtered with 0.22 µm HPLC filter and injected.

Figure 17. HPLC-RI.

For the determination of free sugars, a 100-5 NH_2 Eurospher column (4.6 x 250 mm, 5 µm, Knauer) was used. The mobile phase used was acetonitrile/deionized water (70:30 v/v) at 35 ºC with a flow rate of 1 mL/min (oven 7971 R Grace). The identification and quantification were performed using the retention times of commercial standards. The data were analysed using the Clarity 2.4 software (DataApex, Prague, Czech Republic). Finally, the results were expressed in g/100 fresh weight (fw).

3.3. Physical Analysis

3.3.1. Color Profile

The colors of the potatoes and their peels were analysed in triplicate with the aid of the portable colorimeter CR 400 from Konica Minolta (Tokyo, Japan) described by Carocho et al. (2020). The International Lighting Commission (CIE) standard, with an illuminant D65, with 8 mm aperture and 10º of observation was used. According to the measurement space of the CIE L * a * b *, L * represents the luminosity (L = 0 black, L = 100 white),

a * represents the redness (-a = 0 greenness, + a = redness) and b * represents yellowing (-b = bluish; + b = yellowish).

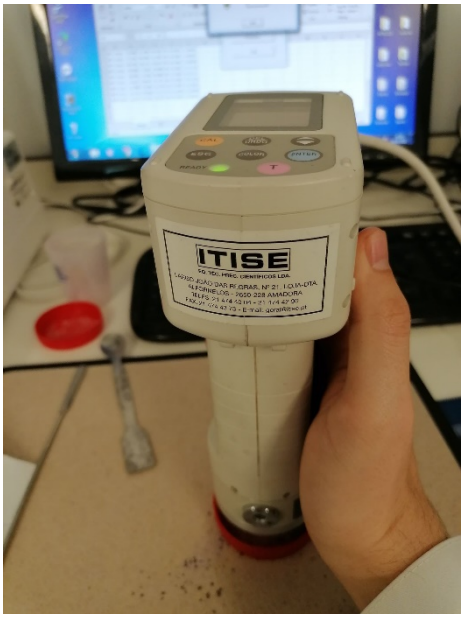

Figure 18. Portable colorimeter CR 400.

3.3.2. Texture Analysis

The potatoes were subject to a texture analysis on a TA. XT Plus texturometer from Stable Micro Systems (Vienna Court, Godalming, United Kingdom), with a load cell of 30 kg. The analysis used was a "texture profile analysis" (TPA), an analysis that mimics human chewing by making two compressions in the same food, managing to extract enough parameters using macros in fundamental parameters. In this way it was possible to analyse the hardness, adhesiveness, resilience, cohesiveness, elasticity, gumminess and chewability. Using a 35 mm metallic cylinder (P / 35) as a probe, a pre-test speed of 5 mm/s, a test speed of 3 mm/s, a post-test speed of 10 mm/s and a voltage of deformation of 25% per potato and their peels, from a force of 10 g as a trigger for the analysis. The results were analysed using the Exponent program.

Figure 19. Texturometer with 30 Kg load cell and P/35 aluminium cylindrical probe.

3.4. Bioactive Analysis

3.4.1. Antioxidant Activity

The antioxidant activity was analyzed through the Thiobarbituric Acid Reactive Substances (TBARS) assay. Briefly, cellular lysates were prepared by adding porcine brain cells to Tris-HCl buffer solution (20 mM, pH=7.4, refrigerate), then centrifuging the suspension at 3500 g for 10 min. The lysate samples were incubated with Thio barbituric acid (TBA), trichloroacetic acid (TCA), and HCl (hydrochloric acid) reagent in water bath at 37.5 °C for 10 min. 10 mg of each extract was added to 1.0 mL of Tris-HCl, from which successive dilutions were carried out, obtaining the concentrations to be tested. 100 uL of ascorbic acid, 100 uL of iron sulfate and 100 uL of the lysate suspension were added to each extract dilution. Two control samples were prepared with Tris-HCl buffer solution and with an ethanolic solvent correspondent to the optimal for HAE and UAE. The dilutions were placed in a water bath for 20 min at 80 °C. Absorbance was measured at 535 nm in a microplate reader (Bio-Tek Instruments, Inc.; Winooski, USA). The antioxidant activity was expressed in EC_{50} (the concentration that reduces by 50% the oxidants existing in the solution).

3.4.2. Antimicrobial Activity

For the antimicrobial activity, 20 mg of each dried sample were prepared and analyzed through the microplate microdilution method, allowing to find the minimum inhibitory and bactericidal/fungicidal concentrations. Different species of food contaminants were used following the procedure described by Soković et al., (2010), namely three Gram-positive bacteria: *Staphylococcus aureus, Bacillus cereus, Listeria monocytogenes* and three Gram-negative bacteria: *Escherichia coli*, *Salmonella typhimurium* and *Enterobacter cloacae.*

3.5. Statistical Analysis

All values are presented as mean ± standard deviation (SD), using a one-way analysis of variance with a Tukey's test for homoscedastic samples and a Tahmane T2 for heteroscedastic samples were used as post-hoc tests. Throughout the work, the significance level is 0.05. Graphs were drawn with Prim 9 from StatGraphics (The Plains, VA, USA). All statistical analysis was performed using a significance of 0.05. A linear discriminant analysis (LDA) was performed to discriminate the different potato samples using Wilk's λ test with an F-value of 3.84 for entering and 2.71 for removal, through the the "leave-one-out" cross validation procedure.

4. RESULTS AND DISCUSSION

4.1. Chemical Analysis

The 29 varieties of potatoes used in the study are shown in **Table 1**, detailing a photo of each variety as well as the name and country of origin. Of the 29 cultivars, 23 were from Europe, 3 from South America, 1 from North America, 1 from Africa and 1 from Oceania.

Table 1. Potatoes used in the study.

Code	Photo	Cultivar Name	Country	Code	Photo	Cultivar Name	Country
BP1		Highland Burgundy Red	England	**BP3**		Blaue St Galler	Switzerland
BP4		Hermans Blaue	Germany	**BP5**		Königspurpur	Germany
BP6		Königsbau (Valfi)	Czech Republic	**BP7**		Blaue Anneliese	Germany
BP8		Black Princess	England	**BP9**		Blue Star	Netherland
BP10		Violet Queen	Italy	**BP11**		Violine de Boree	France
BP12		Red Salad Potato	Germany	**BP13**		Purple Fiesta	Canada
BP14		Linzer Blaue	Austria	**BP15**		Schwarzer Teufel	Germany
BP16		Blaue Tannenzapfen	Germany	**BP17**		Blaue Bamberger Hörnchen	Germany
BP18		Fleuer Bleue	France	**BP19**		Wildkartoffel	Germany
BP20		Blaue Veltlin	Italy	**BP21**		Blaue Hindelbank	Switzerland
BP22		Blaue Ajanhuiri	Bolivia	**BP23**		Blaue Neuseeländer	New Zealand
BP24		Kefermarkter Zuchtstamm	Austria	**BP25**		Lilly Rose	England
BP26		Black Eye	Germany	**BP27**		Purple Rain	Germany

BP28		Pink of Bolivia	Bolivia	**BP29**		Purple from Congo	Congo
BP30		Blue from Peru	Peru				

Yellow countries from Europe, Green from South America, Black from África, Blue from Oceania, and Red from North America.

The first parameter analysed was the centesimal composition of the potato pulp, which is presented in **Table 2**, expressed in g/100 g of fresh weight (fw), while the energy value is expressed as kcal and kJ.

Table 2. Nutritional composition of the potato pulp in g/100g of fresh weight.

	Moisture	Fat	Proteins	Ashes	Carbohydrates	kcal	kJ
BP1	71.8±0.9^{a}	0.14±0.04^{a}	2.81±0.04^{g}	1.8±0.1^{i}	23.3±0.9^{a}	105±3^{b}	442±16^{b}
BP3	77±3$^{a, b, c}$	0.14±0.03^{a}	1.94±0.16$^{b, c, d, e, f}$	1.14±0.09$^{b, c, d, e, f, g, h}$	19±2^{a}	88±12$^{a, b}$	368±51$^{a, b}$
BP4	79±3$^{a, b, c}$	0.13±0.02^{a}	2.0±0.1$^{b, c, d, e, f}$	1.22±0.05$^{d, e, f, g, h}$	16±3^{a}	77±12$^{a, b}$	323±54$^{a, b}$
BP5	78±2$^{a, b, c}$	0.086±0.02^{a}	2.2±0.2$^{c, d, e, f, g}$	1.1±0.2$^{c, d, e, f, g, h}$	17±2^{a}	80±9$^{a, b}$	338±40$^{a, b}$
BP6	79±2$^{a, b, c}$	0.12±0.01^{a}	2.08±0.097$^{b, c, d, e, f}$	1.11±0.02$^{b, c, d, e, f, g, h}$	17±1^{a}	80±6$^{a, b}$	338±28$^{a, b}$
BP7	79.6±0.9$^{a, b, c}$	0.138±0.008^{a}	1.48±0.07$^{a, b}$	1.26±0.03$^{d, e, f, g, h}$	17.4±0.8^{a}	77±3$^{a, b}$	322±15$^{a, b}$
BP8	81±2$^{b, c}$	0.124±0.004^{a}	2.4±0.1$^{f, g}$	1.37±0.03$^{f, g, h, i}$	14±1^{a}	67±7^{a}	281±32^{a}
BP9	77±2$^{a, b, c}$	0.06±0.01^{a}	1.7±0.1$^{a, b, c, d, e}$	1.18±0.07$^{c, d, e, f, g, h}$	19±1^{a}	84±7$^{a, b}$	353±33$^{a, b}$
BP10	81±2$^{a, b, c}$	0.14±0.019^{a}	1.8±0.1$^{b, c, d, e, f}$	1.19±0.06$^{c, d, e, f, g, h}$	15±2^{a}	70±9$^{a, b}$	296±40$^{a, b}$
BP11	74±7$^{a, b, c}$	0.09±0.03^{a}	2.1±0.3$^{c, d, e, f, g}$	1.2±0.2$^{d, e, f, g, h}$	21±6^{a}	95±28$^{a, b}$	400±118$^{a, b}$
BP12	79±4$^{a, b, c}$	0.12±0.01^{a}	1.1±0.1^{a}	1.31±0.07$^{e, f, g, h}$	17±4^{a}	77±19$^{a, b}$	332±79$^{a, b}$
BP13	77±1$^{a, b, c}$	0.162±0.003^{a}	2.5±0.2$^{f, g}$	1.28±0.02$^{d, e, f, g, h}$	18±1^{a}	85±7$^{a, b}$	357±30$^{a, b}$
BP14	79±2$^{a, b, c}$	0.12±0.02^{a}	2.5±0.2$^{f, g}$	1.2±0.1$^{d, e, f, g, h}$	16±2^{a}	76±10$^{a, b}$	318±44$^{a, b}$
BP15	73±4$^{a, b}$	0.21±0.06^{a}	2.3±0.3$^{e, f, g}$	1.6±0.2$^{h, i}$	22±4^{a}	101±17$^{a, b}$	424±71$^{a, b}$
BP16	81±1$^{a, b, c}$	0.12±0.02^{a}	2.1±0.1$^{c, d, e, f, g}$	0.91±0.03$^{a, b, c, d, e, f}$	15±1^{a}	72±7$^{a, b}$	304±33$^{a, b}$
BP17	77±2$^{a, b, c}$	0.14±0.05^{a}	2.2±0.2$^{c, d, e, f, g}$	1.00±0.05$^{a, b, c, d, e, f, g}$	18±2^{a}	86±10$^{a, b}$	361±45$^{a, b}$
BP18	76±4$^{a, b, c}$	1.0±0.8$^{a, b}$	2.2±0.3$^{c, d, e, f, g}$	0.66±0.03$^{a, b, c}$	20±4^{a}	98±13$^{a, b}$	411±55$^{a, b}$
BP19	76±2$^{a, b, c}$	0.13±0.02^{a}	2.3±0.3$^{d, e, f, g}$	0.80±0.06$^{a, b, c, d, e}$	20±2^{a}	91±11$^{a, b}$	384±46$^{a, b}$
BP20	76±2$^{a, b, c}$	0.16±0.02^{a}	2.24±0.08$^{c, d, e, f, g}$	0.94±0.02$^{a, b, c, d, e, f, g}$	20±2^{a}	92±11$^{a, b}$	387±49$^{a, b}$
BP21	78±1$^{a, b, c}$	0.09±0.002^{a}	2.0±0.2$^{b, c, d, e, f}$	0.96±0.02$^{a, b, c, d, e, f, g}$	18±1^{a}	82±7$^{a, b}$	346±30$^{a, b}$
BP22	81±3$^{b, c}$	0.092±0.007^{a}	2.4±0.3$^{e, f, g}$	1.48±0.69$^{g, h, i}$	14±3^{a}	66±14^{a}	278±62^{a}
BP23	75±3$^{a, b, c}$	0.122±0.004^{a}	2.46±0.09$^{f, g}$	1.16±0.04$^{c, d, e, f, g, h}$	20±3^{a}	93±13$^{a, b}$	389±57$^{a, b}$
BP24	80.4±0.9$^{a, b, c}$	0.08±0.01^{a}	1.64±0.03$^{a, b, c}$	0.93±0.08$^{a, b, c, d, e, f}$	16.8±0.8^{a}	74±3$^{a, b}$	313±15$^{a, b}$
BP25	83±1^{c}	0.049±0.007^{a}	1.1±0.1^{a}	0.49±0.08^{a}	15±1^{a}	65±5^{a}	274±21^{a}

BP26	83±2[c]	0.120±0.002[a]	2.1±0.1[b, c, d, e, f]	0.74±0.08[a, b, c, d]	13±2[a]	65±9[a]	272±38[a]
BP27	80±1[a, b, c]	0.06±0.01[a]	1.9±0.14[b, c, d, e, f]	0.61±0.14[a, b]	17.2±0.9[a]	77±4[a, b]	324±18[a, b]
BP28	79±3[a, b, c]	2±1[b]	1.69±0.07[a, b, c, d]	0.9±0.2[a, b, c, d, e, f, g]	15±4[a]	88±10[a, b]	370±43[a, b]
BP29	78±2[a, b, c]	0.11±0.03[a]	1.8±0.1[b, c, d, e, f]	1.26±0.02[d, e, f, g, h]	18±2[a]	82±9[a, b]	344±39[a, b]
BP30	79±3[a, b, c]	0.137±0.004[a]	2.2±0.2[c, d, e, f, g]	0.95±0.08[a, b, c, d, e, f, g]	16±3[a]	77±15[a, b]	322±64[a, b]

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

The most abundant nutrient was moisture, wish showed a maximum of 80 g/100g and a minimum of 71, while the second most abundant were the carbohydrates with maximum and minimum at 23 and 14 g/100g of fresh pulp. Obviously, due to the high number of samples, most of the results are quite related in terms of significant differences, thus being quite difficult to draw concrete conclusions. Still, it is evident that BP1 (highland burgundy red) showed the lowest amount of moisture, while the highest amount was sought for BP25 and BP26 (lilly rose and black eye) *in exequo*. Concerning fat, interestingly, only BP 28 (pink of Bolivia) showed statistical difference, showing 2 g/100g of fat, while all other species did not even reach 1g of fat. In fact, the pink of Bolivia's fat content is above many referenced potatoes in literature, namely Liang et al. (2019) who studied 14 different cultivars from China, and none reached 1 g of fat per 100 grams of pulp, making it an interesting candidate for diets with higher fat intake. Highland burgundy red also showed the highest amount of ash, probably due to the least amount of moisture, while all others did not show statistical differences between each other. Concerning carbohydrates, no statistical differences were sought between the 29 potatoes. Finally, in relation to the energy value, BP25 and BP26 (lilly rose and black eye – all European), as expected showed the lowest value, due to the high amount of moisture, while BP1 (highland burgundy red) showed the highest value.

In **Table 3** the individual organic acids are tabled for both the pulps and peels of the 29 cultivars.

Table 3. Individual and total organic acids, detected through UFLC-DAD in both the pulps and peels of the 29 potatoes expressed in mg/100g.

	Pulp				Peel			
	Oxalic acid	**Malic acid**	**Citric acid**	**Total OA**	**Oxalic acid**	**Malic acid**	**Citric acid**	**Total OA**
BP1	0.39±0.01^{a}	3.39±0.05$^{o, p}$	3.03±0.08$^{j, k, l}$	6.8±0.1^{j}	1.72±0.03$^{d, e}$	1.466±0.006$^{d, e}$	1.52±0.01$^{d, e}$	4.72±0.06^{d}
BP3	0.96±0.02^{f}	2.04±0.03^{g}	4.4±0.1^{q}	7.4±0.1$^{l, m}$	3.29±0.09^{l}	1.956±0.007^{h}	3.67±0.09^{o}	8.9±0.2^{r}
BP4	1.004±0.031$^{f, g}$	1.31±0.01^{c}	2.87±0.07^{j}	5.1±0.1$^{d, e}$	2.39±0.01^{i}	1.641±0.005$^{e, f}$	1.570±0.008^{e}	5.605±0.008^{d}
BP5	1.02±0.02$^{g, h}$	0.863±0.007^{b}	2.51±0.04$^{g, h}$	4.40±0.01^{c}	1.513±0.008^{c}	3.16±0.01^{o}	3.18±0.07^{n}	7.86±0.06^{o}
BP6	1.00±0.01$^{f, g}$	2.25±0.02$^{i, j, k}$	2.33±0.01$^{e, f, g}$	5.60±0.05$^{f, g}$	3.66±0.06^{m}	3.10±0.06^{o}	1.392±0.002$^{c, d}$	8.157±0.001^{q}
BP7	0.65±0.01^{d}	2.07±0.01$^{g, h}$	2.63±0.04$^{h, i}$	5.39±0.07$^{e, f}$	2.03±0.02^{g}	2.494±0.008^{k}	1.718±0.006^{f}	6.25±0.03$^{f, g}$
BP8	1.59±0.01^{o}	3.69±0.08^{q}	2.34±0.02$^{e, f, g}$	7.59±0.09$^{m, n}$	2.24±0.01^{h}	2.93±0.04^{n}	3.73±0.05$^{o, p}$	8.9±0.1^{r}
BP9	1.13±0.03$^{j, k}$	1.69±0.01^{e}	1.214±0.008^{a}	4.04±0.05$^{a, b}$	1.796±0.004$^{e, f}$	1.565±0.003$^{d, e}$	2.63±0.01$^{j, k}$	6.00±0.01$^{e, f}$
BP10	1.09±0.05$^{i, j}$	3.6±0.11^{q}	4.26±0.07^{p}	8.9±0.1^{p}	1.67±0.03^{d}	2.083±0.002^{i}	2.54±0.01$^{i, j}$	6.30±0.04$^{g, h}$
BP11	0.403±0.009^{a}	2.11±0.01$^{g, h, i}$	2.889±0.009^{j}	5.40±0.03$^{e, f}$	2.237±0.004^{h}	3.33±0.07^{p}	1.513±0.002$^{d, e}$	7.08±0.07$^{k, l}$
BP12	0.53±0.01^{b}	1.97±0.01$^{f, g}$	3.00±0.08$^{j, k}$	5.5±0.1$^{f, g}$	2.49±0.01^{i}	2.877±0.008$^{m, n}$	1.41±0.01$^{c, d}$	6.78±0.01$^{i, j}$
BP13	1.23±0.01^{l}	3.11±0.07^{n}	1.409±0.009^{b}	5.75±0.09^{g}	0.90±0.01^{a}	3.16±0.07^{o}	2.75±0.02$^{k, l}$	6.8±0.1$^{k, k}$
BP14	0.42±0.01^{a}	2.38±0.08^{k}	2.21±0.01^{e}	5.02±0.06^{d}	3.71±0.08^{m}	3.18±0.05^{o}	3.25±0.08^{n}	10.1±0.2^{u}
BP15	1.49±0.01^{n}	3.52±0.07$^{p, q}$	3.02±0.07$^{j, k}$	8.04±0.15^{o}	2.61±0.06^{j}	1.886±0.007$^{g, h}$	2.05±0.01^{j}	6.55±0.08$^{h, i}$
BP16	1.15±0.01^{k}	2.84±0.04^{m}	3.22±0.08^{m}	7.22±0.14$^{k, l}$	1.55±0.01^{c}	1.417±0.002$^{b, c}$	2.115±0.007^{g}	5.08±0.02^{c}
BP17	0.688±0.001^{d}	1.864±0.007^{f}	2.44±0.01$^{f, g}$	4.99±0.02^{d}	3.08±0.02^{k}	2.64±0.03^{l}	1.71±0.01^{f}	7.44±0.07$^{m, n}$
BP18	1.37±0.01^{m}	3.04±0.06^{n}	2.26±0.01$^{e, f}$	6.68±0.08$^{i, j}$	2.48±0.02^{i}	1.70±0.01^{f}	2.156±0.003^{g}	6.33±0.03$^{g, h}$
BP19	0.53±0.01^{b}	2.71±0.04$^{l, m}$	3.16±0.04$^{k, l, m}$	6.4±0.1^{i}	1.49±0.02^{c}	1.899±0.006$^{g, h}$	2.45±0.01$^{h, i}$	5.85±0.03$^{d, e}$
BP20	0.60±0.01^{c}	2.21±0.03$^{h, i, j}$	2.30±0.01$^{e, f}$	5.12±0.05$^{d, e}$	4.52±0.01^{n}	3.77±0.08^{q}	1.11±0.01^{d}	9.4±0.1^{s}
BP21	1.83±0.01^{p}	4.35±0.05^{s}	1.63±0.02^{c}	7.82±0.01$^{n, o}$	1.49±0.01^{c}	1.3±0.1^{b}	2.89±0.04$^{l, m}$	5.73±0.02$^{d, e}$
BP22	0.80±0.02^{e}	2.34±0.01$^{j, k}$	3.66±0.09^{n}	6.8±0.1^{j}	1.54±0.01^{c}	2.224±0.002^{j}	3.8±0.1^{p}	7.6±0.1$^{n, o}$
BP23	0.65±0.01$^{c, d}$	2.613±0.001^{l}	3.9±0.1^{o}	7.19±0.02$^{k, l}$	1.326±0.001^{b}	1.59±0.01$^{e, f}$	3.02±0.05^{m}	5.93±0.07^{d}
BP24	0.43±0.01^{a}	1.504±0.001^{d}	1.826±0.005^{d}	3.76±0.01^{a}	3.13±0.01^{k}	2.79±0.05^{m}	1.284±0.005^{c}	7.22±0.06$^{l, m}$
BP25	1.34±0.01^{m}	4.08±0.03^{r}	1.560±0.005$^{b, c}$	6.98±0.04$^{j, k}$	2.49±0.01^{i}	1.82±0.01^{g}	4.17±0.04^{q}	8.49±0.07^{q}
BP26	0.422±0.006^{a}	1.566±0.002$^{d, e}$	1.975±0.008^{d}	3.9±0.1^{a}	2.17±0.01^{h}	2.88±0.09$^{m, n}$	3.64±0.03^{o}	8.69±0.15$^{q, r}$
BP27	1.38±0.01^{m}	3.40±0.02$^{o, p}$	4.571±0.096^{q}	9.3±0.1^{q}	1.84±0.01^{f}	1.648±0.007$^{e, f}$	2.36±0.01^{h}	5.85±0.03$^{d, e}$
BP28	1.06±0.02$^{h, i}$	3.33±0.05^{o}	3.206±0.063$^{l, m}$	7.60±0.09$^{m, n}$	n.d.	0.213±0.004^{a}	n.d.	0.266±0.002^{a}
BP29	1.01±0.02$^{f, g}$	2.384±0.007^{k}	2.691±0.040^{i}	6.08±0.01^{h}	n.d.	0.311±0.004^{a}	0.3100±0.003^{a}	0.621±0.008^{b}
BP30	1.459±0.007^{n}	0.440±0.005^{a}	2.398±0.000$^{f, g}$	4.29±0.01$^{b, c}$	n.d.	n.d.	n.d.	n.d.

n.d. not detected. Different letters in each row mean statistically different values, using a *p*-value of 0.05.

Both the pulps and peels were analysed for organic acids due to the antioxidant properties that some of them possess and could constitute nutrients to enrich or functionalize other foods. Three individual organic acids were detected, namely oxalic, malic and citric acid, being the two latter the most abundant. Once again, due to the high number of samples, most classifications were linked, which does not offer much clarity for expressing statistical differences. Concerning the pulp, the lowest amount of oxalic acid was found in BP1, BP11 and BP24 (highland burgundy red, violine de boree and kefermarkter zuchtstamm – all European), while the highest was sought

for BP4, BP5, BP6, and BP29 (hermans blaue, königspurpur, Königsbau and purple from Congo). Malic acid was found in all pulp samples and showed the highest values for BP8, BP10 and BP15 (black princess, violet queen and Schwarzer Teufel – all European), while the least amount was sought for BP30 (blue from Peru), which is an American cultivar. Citric acid, and important organic acid with uses in the food industry as a stabiliser was found in higher amounts in the pulp of BP23 (Blaue Neuseeländer) from New Zealand, while the least was found in BP9 (blue star – European). Finally, still regarding the pulp, the overall total organic acid content was found in higher values in sample BP15 (Schwarzer Teufel) a European cultivar, while the least were found in BP24 and BP26 (kefermarkter zuchtstamm and black eye – both from Europe). The peel of the potatoes did not show all the organic acids, namely for cultivars BP28 through to BP30. Still for oxalic acid, differences were found from the amount of organic acids in the pulp and the peel. The least amount was found in BP13(purple fiesta) from Canada and not as expected, in BP1 and BP11 which showed the least amount on the pulp. The cultivar with the highest amount was BP20 (blaue veltlin) from Italy, and not, as expected in BP18 (Fleuer Bleue). For malic, citric and total organic acids, the samples with the least amounts were BP28 to BP30, while the highest amounts were, for malic acid BP20, the sample with the highest amount also in the pulp, for citric BP25, also the one with the highest amount in the pulp, and finally, BP20 for total organic acids, also the one with the highest in the pulp.

Table 4 shows the individual and total soluble sugars found in the pulp and peel of the potatoes.

Table 4. Soluble sugars of the pulp and peel of the 29 cultivars, expressed in g/100g of fresh weight.

	Pulp			Peel		
	Fructose	**Glucose**	**Total OA**	**Fructose**	**Glucose**	**Total OA**
BP1	6.593 ± 0.004^{s}	0.501 ± 0.001^{b}	7.094 ± 0.003^{n}	0.44 ± 0.01^{a}	$0.717\pm0.002^{g, h, i}$	$1.16\pm0.01^{a, b}$
BP3	3.84 ± 0.05^{l}	1.32 ± 0.07^{k}	$5.16\pm0.1^{k, l}$	1.398 ± 0.002^{a}	1.242 ± 0.005^{o}	$2.6414\pm0.0005^{a, b, c, d, e, f, g, h}$
BP4	$3.18\pm0.01^{j, k}$	$0.90\pm0.01^{e, f, g}$	4.08 ± 0.03^{h}	1.364 ± 0.004^{a}	$0.81\pm0.01^{j, k, l, m}$	$2.17\pm0.01^{a, b, c, d, e, f, g}$
BP5	$1.83\pm0.05^{c, d, e, f}$	0.145 ± 0.005^{a}	1.98 ± 0.05^{b}	1.7 ± 0.1^{a}	$0.75\pm0.08^{h, i, j}$	$2.4\pm0.2^{a, b, c, d, e, f, g}$
BP6	$4.30\pm0.01^{n, o}$	1.204 ± 0.002^{j}	5.52 ± 0.02^{l}	2.10 ± 0.08^{a}	1.09 ± 0.01^{n}	$3.16\pm0.09^{c, d, e, f, g, h, i}$
BP7	3.11 ± 0.06^{j}	$0.935\pm0.009^{f, g, h}$	4.06 ± 0.07^{h}	2.77 ± 0.09^{a}	$0.87\pm0.01^{l, m}$	$3.65\pm0.08^{e, f, g, h, i}$
BP8	$2.00\pm0.02^{e, f, g}$	$0.98\pm0.04^{g, h, i}$	$2.98\pm0.06^{e, f}$	1.16 ± 0.02^{a}	0.892 ± 0.003^{m}	$2.05\pm0.02^{a, b, c, d, e, f, g}$
BP9	3.08 ± 0.04^{j}	1.36 ± 0.02^{k}	4.44 ± 0.07^{i}	1.30 ± 0.03^{a}	$0.859\pm0.005^{k, l, m}$	$2.17\pm0.03^{a, b, c, d, e, f, g}$
BP10	2.6 ± 0.1^{i}	0.68 ± 0.04^{c}	3.26 ± 0.16^{f}	0.96 ± 0.05^{a}	$0.681\pm0.004^{f, g, h}$	$1.63\pm0.05^{a, b, c, d}$
BP11	$4.17\pm0.01^{m, n}$	$1.02\pm0.01^{h, i}$	$5.194\pm0.004^{k, l}$	3 ± 2^{a}	0.89 ± 0.02^{m}	$4\pm3^{h, i}$

BP12	6.1±0.2^{r}	0.80±0.03$^{d, e}$	6.9±0.2^{n}	2.57±0.04^{a}	0.880±0.004$^{l, m}$	3.44±0.04$^{d, e, f, g, h, i}$
BP13	2.44±0.02$^{h, i}$	0.49±0.03^{b}	2.94±0.05$^{e, f}$	0.73±0.07^{a}	0.51±0.04$^{c, d}$	1.2±0.1$^{a, b, c}$
BP14	1.801±0.001$^{c, d, e}$	1.37±0.01$^{k, l}$	3.17±0.01^{f}	0.541±0.003^{a}	0.82±0.04$^{j, k, l, m}$	1.38±0.04$^{a, b, c}$
BP15	0.95±0.06^{b}	0.87±0.02$^{d, e, f}$	1.83±0.08^{b}	0.57±0.03^{a}	0.467±0.004$^{b, c}$	1.04±0.02$^{a, b}$
BP16	0.58±0.01^{a}	0.823±0.002$^{d, e}$	1.41±0.01^{a}	0.271±0.004^{a}	0.46±0.05$^{b, c}$	0.73±0.05^{a}
BP17	0.89±0.002^{b}	0.525±0.001^{b}	1.418±0.001^{a}	0.74±0.02^{a}	0.65±0.03$^{e, f, g}$	1.38±0.05$^{a, b, c}$
BP18	2.10±0.02$^{f, g}$	0.91±0.02$^{e, f, g}$	3.01±0.04$^{e, f}$	3.31±0.09^{a}	0.61±0.02$^{e, f}$	3.9±0.1$^{f, g, h, i}$
BP19	1.66±0.01$^{c, d}$	0.90±0.02$^{e, f, g}$	2.57±0.01$^{c, d}$	0.64±0.01^{a}	0.77±0.01$^{h, I, j}$	1.41±0.02$^{a, b, c}$
BP20	1.88±0.03$^{d, e, f}$	1.76±0.09^{m}	3.6±0.1^{g}	0.811±0.002^{a}	1.208±0.006^{o}	2.017±0.008$^{a, b, c, d, e, f, g}$
BP21	3.92±0.05$^{l, m}$	1.05±0.02^{i}	4.98±0.08^{k}	1.45±0.02^{a}	0.589±0.006$^{d, e}$	2.05±0.03$^{a, b, c, d, e, f, g}$
BP22	1.59±0.03^{c}	0.810±0.009$^{d, e}$	2.41±0.04^{c}	0.738±0.008^{a}	0.649±0.003$^{e, f, g}$	1.386±0.006$^{a, b, c}$
BP23	1.67±0.04$^{c, d}$	1.31±0.001^{k}	2.94±0.04$^{e, f}$	0.83±0.07^{a}	1.03±0.04^{n}	1.8±0.1$^{a, b, c, d, e}$
BP24	2.25±0.02$^{g, h}$	0.55±0.02^{b}	2.80±0.04$^{d, e}$	0.96±0.02^{a}	0.36±0.02^{a}	1.32±0.03$^{a, b, c}$
BP25	6.7±0.13^{s}	0.52±0.02^{b}	7.2±0.15^{n}	4.5±0.3^{a}	0.42±0.02$^{a, b}$	4.9±0.3^{i}
BP26	3.43±0.01^{k}	1.185±0.004^{j}	4.61±0.01$^{i, j}$	1.12±0.03^{a}	0.84±0.03$^{j, k, l, m}$	1.95±0.06$^{a, b, c, d, e, f}$
BP27	4.59±0.01$^{o, p}$	0.791±0.005^{d}	5.3±0.01^{l}	2.97±0.04^{a}	0.780±0.008$^{i, j, k}$	3.75±0.04$^{e, f, g, h, i}$
BP28	4.7±0.2$^{p, q}$	1.47±0.08^{l}	6.22±0.37^{m}	2.20±0.04^{a}	0.83±0.01$^{j, k, l, m}$	3.03±0.1$^{b, c, d, e, f, g, h, i}$
BP29	2.084±0.001$^{e, f, g}$	2.849±0.001^{n}	4.933±0.001$^{j, k}$	0.77±0.01^{a}	0.793±0.009$^{i, j, k, l}$	1.57±0.02$^{a, b, c, d}$
BP30	4.9±0.1^{q}	0.88±0.02$^{d, e, f, g}$	5.8±0.1^{m}	101±171^{a}	1.06±0.05^{n}	4.0±0.1$^{g, h, i}$

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

Most of the carbohydrates found in potatoes are in the form of starch, which is an assay that is expected to be performed in the near future. Still, some carbohydrates are found in the form of soluble sugars. Both in the pulp and peels, two soluble sugars were found, namely fructose and glucose. Once again, due to the high number of samples, most of the classifications are overlapping and thus only the antipodes are discernible. Still, considering the pulp, BP1 and BP25 (highland burgundy red and lilly rose – Europe) showed the highest amount of fructose, being BP25 the sample with highest amount of total sugars, mainly from fructose, due to the low amount of glucose found in this sample. The Bolivian sample, pink of Bolivia (BP28) showed the highest amount of glucose while purple of Congo showed the least amount, which is quite interesting, due to the European samples showing intermediate values of this sugar. Two German samples, BP15 and BP16 (blaue tannenzapfen and blaue bamberger hörnchen) showed the lowest amount of glucose. This influenced the total amount of sugars in the pulp, where BP16 showed the least amount in exequo with another German sample blaue bamberger hörnchen (BP17). Considering the peel, for fructose, interestingly, no differences were sought between the samples showing values of 0.4 to 3 g/100g. For glucose, statistical differences could be sought, although overlapping was also present in these samples. The Austrian

kefermarkter zuchtstamm (BP24) showed the least amount while BP3 (blaue st galler) and BP20 (blaue veltlin), both European samples showed the highest amount. Finally, considering the total sugars of the peel, BP25, lilly rose showed the highest amount and BP16 (blaue bamberger hörnchen) the lowest amounts.

4.2. Physical Analysis

The physical analysis of the potatoes encompassed the color, measured with a portable colorimeter, of both the flesh and peel in fresh samples and ones subject to a freeze-drying process, as well as texture analysis of the fresh pulps. Old or unsuitable colored potatoes are usually discarded in food processing plants and could constitute an abundant source of natural colorants. Still, most natural colorants are unstable and tend to change their color when dried, hence the comparison between fresh and freeze-dried samples. The peels are also quite rich in coloured compounds and thus were also analysed for their colors. **Table 5** shows the L*, a* and b* values of the pulp of the potatoes in both fresh and freeze-dried forms.

Table 5. L*, a* and b* coordinates of the fresh and freeze-dried potato pulps.

	Pulp					
	Fresh			Freeze-Dried		
	L*	a*	b*	L*	a*	b*
BP1	$64.7\pm0.4^{f, g, h}$	$8\pm2^{a, b, c, d, e}$	$15.6\pm0.2^{f, g}$	90.5 ± 0.8^{p}	10.4 ± 0.1^{h}	10.9 ± 0.5^{r}
BP3	$30\pm2^{a, b}$	$13.0\pm0.3^{c, d, e, f, g, h}$	$-4.3\pm0.4^{a, b}$	$53.57\pm0.05^{c, d}$	16.30 ± 0.02^{r}	-8.44 ± 0.02^{c}
BP4	$37\pm1^{a, b, c, d}$	$15\pm1^{c, d, e, f, g, h, i}$	$-3.0\pm0.9^{a, b, c}$	6074 ± 1^{h}	11.53 ± 0.08^{j}	-4.77 ± 0.04^{g}
BP5	$50\pm6^{a, b, c, d, e, f, g, h}$	$19\pm6^{g, h, i, j}$	$7\pm2^{c, d, e, f}$	$54.4\pm0.1^{d, e}$	7.81 ± 0.04^{f}	19.52 ± 0.03^{u}
BP6	$39\pm5^{a, b, c, d, e}$	$15\pm2^{c, d, e, f, g, h, i}$	-5 ± 1^{a}	63.80 ± 0.008^{j}	11.6 ± 0.01^{j}	-4.76 ± 0.01^{g}
BP7	$28\pm5^{a, b}$	$12\pm4^{c, d, e, f, g, h}$	$-2.8\pm0.9^{a, b, c}$	$52.62\pm0.09^{b, c}$	16.64 ± 0.02^{s}	-8.70 ± 0.01^{c}
BP8	$50\pm22^{a, b, c, d, e, f, g, h}$	$6\pm5^{a, b, c, d}$	$5\pm8^{b, c, d, e, f}$	63.8 ± 0.1^{j}	9.58 ± 0.04^{g}	0.13 ± 0.01^{i}
BP9	$38\pm4^{a, b, c, d}$	$17\pm1^{e, f, g, h, i, j}$	-5.5 ± 0.8^{a}	63.5 ± 0.4^{j}	12.3 ± 0.6^{k}	-4.95 ± 0.2^{g}
BP10	$33\pm2^{a, b}$	$12\pm2^{c, d, e, f, g, h}$	$0.1\pm0.9^{a, b, c, d}$	$54.4\pm0.3^{d, e}$	14.45 ± 0.05^{n}	$-5.82\pm0.04^{e, f}$
BP11	$39\pm7^{a, b, c, d, e}$	$14.9\pm0.4^{c, d, e, f, g, h, i}$	$-3\pm1^{a, b}$	$62.79\pm0.05^{i, j}$	12.33 ± 0.01^{k}	-5.60 ± 0.01^{f}
BP12	$51\pm1^{b, c, d, e, f, g, h}$	$21\pm4^{h, i, j}$	$11\pm8^{d, e, f, g}$	70.83 ± 0.08^{m}	17.61 ± 0.01^{t}	4.55 ± 0.01^{l}
BP13	$60\pm5^{d, e, f, g, h}$	$2\pm2.^{a, b}$	19 ± 4^{g}	71.1 ± 0.2^{m}	6.41 ± 0.01^{e}	2.52 ± 0.01^{j}
BP14	$62\pm5^{e, f, g, h}$	$6\pm5^{a, b, c}$	$11\pm5^{e, f, g}$	76.25 ± 0.09^{o}	5.41 ± 0.01^{d}	5.131 ± 0.009^{m}
BP15	$46\pm19^{a, b, c, d, e, f, g}$	$8\pm5^{a, b, c, d, e, f}$	$2\pm7^{a, b, c, d, e}$	$55.0\pm0.1^{e, f}$	13.60 ± 0.01^{m}	-6.03 ± 0.02^{e}
BP16	$68\pm6^{g, h}$	$1\pm4^{a, b}$	$14\pm5^{f, g}$	72.30 ± 0.4^{n}	4.16 ± 0.01^{a}	7.51 ± 0.01^{n}

BP17	41±5$^{a, b, c, d, e, f}$	15±1$^{c, d, e, f, g, h, i}$	-4±1$^{a, b}$	66.6±0.2^{k}	9.52±0.03^{g}	-1.94±0.01^{h}
BP18	40±11$^{a, b, c, d, e}$	14±3$^{c, d, e, f, g, h, i}$	-2±3$^{a, b, c}$	55.93±0.01^{f}	4.4±0.2^{b}	17.307±0.007^{t}
BP19	48±4$^{a, b, c, d, e, f, g, h}$	14±0.2$^{c, d, e, f, g, h, i}$	2±1$^{a, b, c, d, e}$	76.03±0.01^{o}	4.40±0.02^{e}	2.466±0.006^{j}
BP20	27±2^{a}	16±1$^{d, e, f, g, h, i, j}$	-5.6±0.6^{a}	51.68±0.01^{b}	6.5±0.01^{p}	-9.66±0.02^{b}
BP21	47±3$^{a, b, c, d, e, f, g}$	11±2$^{b, c, d, e, f, g}$	0.6±2$^{a, b, c, d, e}$	61.88±0.2$^{h, i}$	11.71±0.02^{j}	-4.76±0.01^{g}
BP22	70±1^{h}	-0.4±0.6^{a}	15.3±0.9$^{f, g}$	67.9±0.3^{l}	4.6±0.1^{c}	13.1±0.1^{s}
BP23	31±1$^{a, b}$	18.3±0.8$^{f, g, h, i, j}$	-5.9±0.1^{a}	52.3±0.1^{b}	15.995±0.009^{q}	-8.585±0.009^{c}
BP24	57±4$^{c, d, e, f, g, h}$	13±3$^{c, d, e, f, g, h}$	10±1$^{d, e, f, g}$	79.3±0.1^{n}	11.14±0.03^{i}	9.77±0.01^{q}
BP25	45±2$^{a, b, c, d, e, f, g}$	24±2$^{i, j}$	14±2$^{f, g}$	65.6±0.1^{k}	19.90±0.01^{v}	8.868±0.007^{p}
BP26	63±3$^{e, f, g, h}$	6±3$^{a, b, c, d}$	8±2$^{d, e, f}$	75.18±0.04^{o}	6.38±0.01^{e}	3.779±0.007^{k}
BP27	28±4$^{a, b}$	14±2$^{c, d, e, f, g, h, i}$	-3.1±0.4$^{a, b, c}$	45.52±0.03^{a}	18.64±0.02^{u}	-10.368±0.017^{a}
BP28	48±3$^{a, b, c, d, e, f, g, h}$	26±2^{j}	5.9±0.9$^{b, c, d, e, f}$	61.45±0.05^{h}	16.72±0.02^{s}	8.36±0.01^{o}
BP29	33±3$^{a, b}$	14±2$^{c, d, e, f, g, h, i}$	-4.4±0.6$^{a, b}$	54.7±0.1^{e}	15.10±0.04^{o}	-6.97±0.02^{d}
BP30	36±7$^{a, b, c}$	14±2$^{c, d, e, f, g, h, i}$	-31±2$^{a, b}$	59.79±0.09^{g}	13.38±0.04^{l}	-6.06±0.01^{e}

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

Once again, due to the high number of samples, overlapping of classifications made it unfeasible to classify or group the samples, thus, only the color limits are discussed. Thus, considering the fresh pulps, the darkest sample was BP20 (blaue veltin) while the lightest one was BP22 (blaue ajanhuiri), which was also the greener sample of all, while the reddest was the other Bolivian sample BP28 (pink of Bolivia). Considering b* coordinates, the bluest samples were BP6, BP9 and BP23 (königsbau, blue star and blaue beuseeländer, two European samples and one from New Zealand). Then after freezedrying the samples, considerable changes were sought for the colors, namely the highland burgundy red (BP1) became the lightest sample the darkest was BP27 (purple rain), which was also the reddest and bluest sample, which overall showed a very dark tone. The greenest freeze-dried sample was BP16 (blaue tannenzapfen), while the yellowest was BP5 (königspurpur). To visually understand the effect of the freeze-drying process on the color of the samples, **Figure 20** shows the colors of the pulps in fresh and freeze-dried samples.

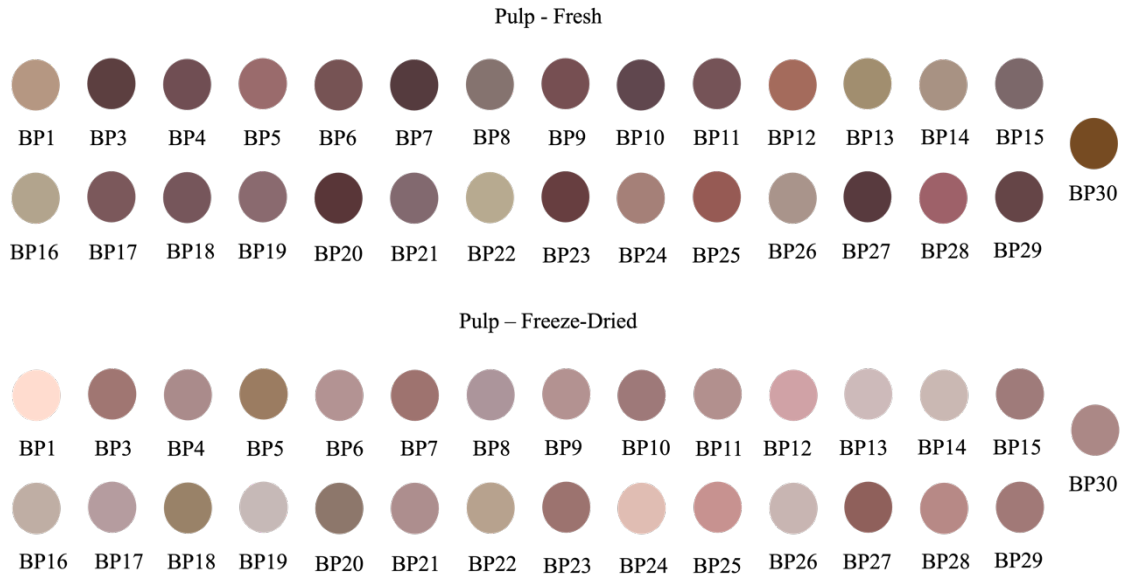

Figure 20. Color of the pulps of the potatoes when fresh and freeze-dried.

As can be noted from **Figure 20**, most samples showed a reduction in color intensity, becoming pastel colors, but still show interesting tones that could be used as natural food colorants, especially due to the high abundance of potatoes due to its consumption throughout the whole world.

Table 6 details the color coordinates of the peels of the 29 potatoes in both fresh and freeze-dried form. Once again, considerable overlapping occurred in most samples, allowing for very slight considerations in relation to the color of the samples. Regarding the fresh peels, the lightest sample was the peel of BP1 (highland burgundy red) while the darkest was the peel of BP3 (blaue st galler). Considering the red-greenness, several potatoes showed no statistical differences in the greenness, namely BP8, BP9, BP11, BP16, BP20, BP28 and BP30 (black princess, blue star, violine de boree, blaue tannenzapfen, blaue veltin, pink of Bolivia, and blue from Peru).

Table 6. L*, a* and b* coordinates of the fresh and freeze-dried potato peels.

	Peel					
	Fresh			**Freeze-Dried**		
	L*	**a***	**b***	**L***	**a***	**b***
BP1	53.1 ± 0.6^{d}	$9\pm1^{b, c}$	21 ± 0^{c}	65 ± 2^{q}	13.7 ± 0.1^{o}	4.9 ± 0.8^{l}
BP3	19 ± 5^{a}	$13\pm1^{c, d}$	1 ± 1^{a}	$49\pm1^{c, d}$	$11.3\pm0.2^{k, l}$	$-2.2\pm0.4^{e, f}$
BP4	$43\pm2^{b, c, d}$	$5\pm1^{a, b}$	$12.6\pm0.2^{b, c}$	$63\pm1^{n, o, p, q}$	$7.3\pm0.1^{d, e}$	1.6 ± 0.1^{i}

BP5	39±8^{b}	19±1$^{e, f}$	13±5$^{b, c}$	53±2$^{e, f, g, h}$	15.8±0.3^{q}	5.5±0.8$^{l, m}$
BP6	42±3$^{b, c, d}$	17±5$^{d, e, f}$	15±2$^{b, c}$	55±1$^{h, I, j}$	6.33±0.06$^{a, b}$	7.1±0.3^{n}
BP7	42±1$^{b, c, d}$	6±1$^{a, b}$	11.8±0.1^{b}	53.7±0.2$^{f, g, h}$	7.7±0.2$^{f, g}$	9.11±0.01^{p}
BP8	44±4$^{b, c, d}$	3±3^{a}	3±1$^{a, b}$	53.2±0.1$^{e, f, g, h}$	8.18±0.03^{h}	5.4±0.1$^{l, m}$
BP9	45±1$^{b, c, d}$	3±1^{a}	11±1^{b}	54.92±0.04$^{h, i}$	9.64±0.03^{j}	-0.23±0.02^{h}
BP10	45±1$^{b, c, d}$	6±4$^{a, b}$	10.0±0.4$^{a, b}$	50.94±0.03$^{d, e, f}$	12.65±0.02$^{m, n}$	-3.04±0.01$^{d, e}$
BP11	46±4$^{b, c, d}$	2±3^{a}	8.0±0.9$^{a, b}$	59.40±0.02$^{k, l, m}$	9.09±0.01^{i}	-1.62±0.01^{f}
BP12	45±2$^{b, c, d}$	5±2$^{a, b}$	11.1±0.4^{b}	64.06±0.09$^{o, p, q}$	15.74±0.04^{q}	7.09±0.02^{n}
BP13	47±0$^{b, c, d}$	15±2$^{d, e, f}$	14.3±0.9$^{b, c}$	62.20±0.01$^{m, n, o, p}$	6.51±0.02^{b}	5.79±0.01^{m}
BP14	52±4$^{c, d}$	6±5$^{a, b}$	16.9±3$^{b, c}$	61.30±0.03$^{m, n, o}$	6.07±0.02^{a}	7.42±0.001$^{n, o}$
BP15	47±1$^{b, c, d}$	4±1$^{a, b}$	11.3±0.5^{b}	45.21±0.2^{b}	11.63±0.05^{l}	-3.60±0.08$^{c, d}$
BP16	42±0$^{b, c}$	1.5±0.6^{a}	1.5±0.1$^{a, b}$	60.59±0.03$^{l, m, n}$	7.88±0.006$^{g, h}$	0.45±0.01^{h}
BP17	45±2$^{b, c, d}$	4±1 $^{a, b}$	9±1$^{a, b}$	64.98±0.04$^{p, q}$	7.41±0.01$^{d, e}$	1.54±0.01^{i}
BP18	43±3$^{b, c, d}$	6±1$^{a, b}$	7±1$^{a, b}$	57.92±0.02$^{j, k, l}$	9.586±0.005^{j}	-1.37±0.01^{f}
BP19	46±5$^{b, c, d}$	6±7$^{a, b}$	12.3±0.6$^{b, c}$	50.71±0.02$^{d, e}$	6.92±0.02^{c}	8.17±0.02^{o}
BP20	44±2$^{b, c, d}$	3±1^{a}	3.4±0.3$^{a, b}$	46.45±0.01^{b}	12.907±0.001^{n}	-7.084±0.007^{a}
BP21	43±1$^{b, c, d}$	3.0±0.5$^{a, b}$	7±1$^{a, b}$	61.22±0.004$^{m, n, o}$	8.83±0.01^{i}	-1.19±0.01^{f}
BP22	45±1$^{b, c, d}$	5±2$^{a, b}$	11±1^{b}	51.38±0.09$^{d, e, f}$	7.44±0.02$^{e, f}$	3.523±0.007^{k}
BP23	47±3$^{b, c, d}$	5±2$^{a, b}$	12.2±0.7^{b}	47.82±0.01$^{b, c}$	12.47±0.01^{m}	-5.15±0.02^{b}
BP24	45±4$^{b, c, d}$	3±7$^{a, b}$	10±0.9$^{a, b}$	57.60±0.02$^{i, j, k}$	16.55±0.03^{r}	9.887±0.003^{p}
BP25	51±1$^{c, d}$	20.1±0.3^{f}	12±1^{b}	56.62±0.02$^{i, j, k}$	11.07±0.01^{k}	18.81±0.01^{q}
BP26	47.9±0.9$^{b, c, d}$	14.2±0.7$^{d, e}$	15±2$^{b, c}$	54.44±0.04$^{i, j, k}$	7.10±0.01$^{c, d}$	2.71±0.02$^{j, k}$
BP27	47±1$^{b, c, d}$	3.0±0.3$^{a, b}$	11.1±0.3^{b}	37.24±0.09^{a}	14.85±0.08^{p}	-4.3±0.1^{c}
BP28	44±4$^{b, c, d}$	2±2^{a}	7±0.4$^{a, b}$	54.782±0.005$^{g, h, i}$	17.72±0.02^{s}	7.62±0.01$^{n, o}$
BP29	46±2$^{b, c, d}$	13±1$^{c, d}$	12.6±0.8$^{b, c}$	52.006±0.005$^{d, e, f, g}$	11.62±0.02^{l}	1.375±0.008^{i}
BP30	40±2^{b}	3±1^{a}	8±1$^{a, b}$	62.84±0.02$^{n, o p, q}$	6.99±0.01^{c}	2.657±0.008^{j}

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

While the reddest sample was the peel of lilly rose (BP25). The b* revealed that the yellowest peel was BP3 (blaue st galler), while the bluest was highland burgundy red (BP1). Considering the peels after freeze-drying, the lightest remained the highland burgundy red, while the darkest sample was the peel of BP27 (purple rain). The a* coordinates showed that the greenest sample was BP14 (linzerblaue) and the reddest was kefermarkter zuchtstamm (BP24), which also showed the yellowest values. The bluest sample was BP20 (blaue veltin). **Figure 21** shows the color change from the peels from the fresh samples to the freeze-dried ones. Due to the lower water content of the peels, the shift in color of the peels is overall less notorious than the one registered for the pulps, proving that the peels are strong candidates to be used as natural colorants in the industry, once again due to it being one the most produced food residues around the planet.

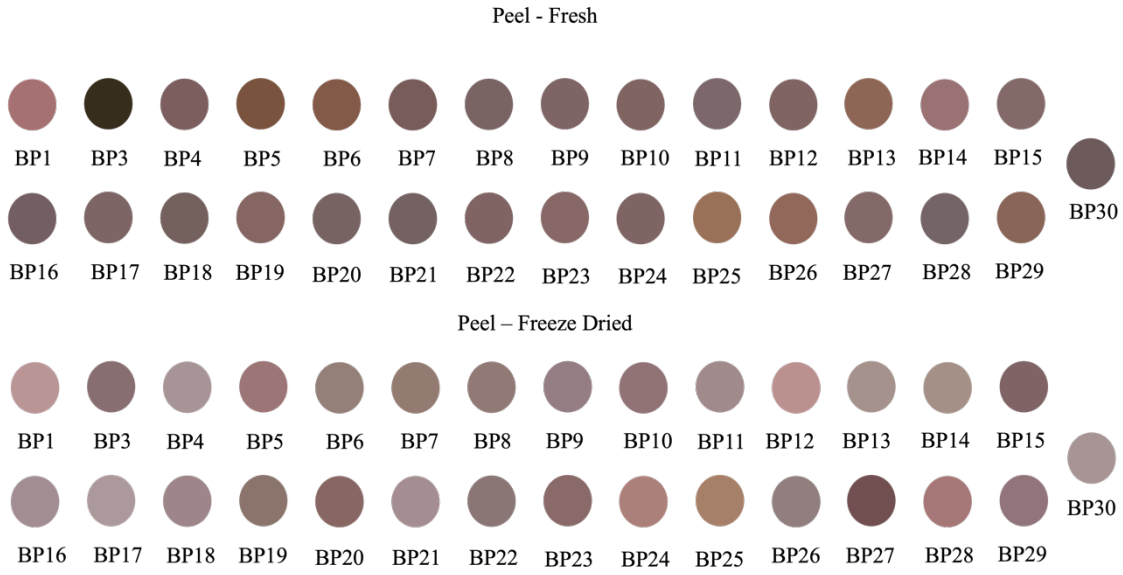

Figure 21. Color of the peels of the potatoes when fresh and freeze-dried.

Regarding the texture analysis, pH, and water activity, these were only performed in the potato pulps, and are presented in **Table 7**.

Table 7. Texture profile, pH and a_w from the potato pulps.

	Hardness (g)	**pH**	**aW**
BP1	18158±5044$^{a, b}$	6.050±0.006$^{c, d, e}$	0.992±0.004^{b}
BP3	26411±7406$^{a, b, c}$	6.33±0.01^{l}	0.984±0.002$^{a, b}$
BP4	22565±3149$^{a, b, c}$	6.02±0.01$^{c, d}$	0.988±0.005$^{a, b}$
BP5	22904±845$^{a, b, c}$	6.10±0.05$^{d, e, f, g, h}$	0.985±0.002$^{a, b}$
BP6	28405±2299$^{b, c}$	6.06±0.04$^{c, d, e, f}$	0.988±0.003$^{a, b}$
BP7	14687±2732^{a}	6.02±0.02$^{c, d}$	0.983±0.003$^{a, b}$
BP8	30853±5743$^{b, c}$	6.02±0.04$^{c, d}$	0.983±0.003$^{a, b}$
BP9	30073±2310$^{b, c}$	6.283±0.006$^{k, l}$	0.986±0.003$^{a, b}$
BP10	25971±304$^{a, b, c}$	6.25±0.02$^{j, k, l}$	0.999±0.003$^{a, b}$
BP11	23688±3728$^{a, b, c}$	6.13±0.02$^{e, f, g, h, i}$	0.987±0.003$^{a, b}$
BP12	23365±1271$^{a, b, c}$	6.06±0.03$^{c, d, e}$	0.988±0.002$^{a, b}$
BP13	21664±5126$^{a, b, c}$	6.18±0.05$^{g, h, I, j, k}$	0.988±0.002$^{a, b}$
BP14	29449±3760$^{b, c}$	6.17±0.07$^{f, g, h, I, j}$	0.987±0.005$^{a, b}$
BP15	31815±2566^{c}	6.11±0.06$^{d, e, f, g, h}$	0.985±0.001$^{a, b}$
BP16	28287±4373$^{b, c}$	6.20±0.01$^{h, i, j, k}$	0.982±0.003^{a}
BP17	21416±6112$^{a, b, c}$	6.06±0.04$^{c, d, e}$	0.983±0.002$^{a, b}$
BP18	25986±1804$^{a, b, c}$	6.26±0.02$^{j, k, l}$	0.983±0.003$^{a, b}$
BP19	32689±7050^{c}	6.24±0.02$^{i, j, k, l}$	0.984±0.003$^{a, b}$
BP20	32689±7050^{c}	5.88±0.01$^{a, b}$	0.988±0.005$^{a, b}$

BP21	22387±7154[a, b, c]	6.20±0.03[h, i, j, k]	0.985±0.001[a, b]
BP22	30189±715[b, c]	6.24±0.02[i, j, k, l]	0.982±0.002[a]
BP23	31647±4291[c]	5.83±0.03[a]	0.982±0.001[a]
BP24	17855±2724[a, b]	6.09±0.01[d, e, f, g]	0.984±0.001[a, b]
BP25	22877±362.[a, b, c]	5.97±0.03[b, c]	0.985±0.002[a, b]
BP26	33877±2352[c]	6.21±0.05[h, i, j, k]	0.986±0.001[a, b]
BP27	22373±1502[a, b, c]	6.183±0.006[g, h, i, j, k]	0.984±0.003[a, b]
BP28	24052±1828[a, b, c]	5.97±0.01[b, c]	0.985±0.002[a, b]
BP29	23682±4674[a, b, c]	6.02±0.01[c, d]	0.982±0.001[a]
BP30	27311±3837[a, b, c]	6.037±0.01[c, d, e]	0.985±0.003[a, b]

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

The potato pulps showed quite high values of hardness, averaging about 20 Kg of force, being the New Zealand sample (BP23) the hardest at 31.6 Kg and blaue anneliese (BP7) the softest at 14.6 Kg. In terms of pH, the most alcaline pulp was BP3 (blaue st galler) and the most acidic was blaue neuseeländer from Newzealand (BP23), which also showed the lowest water activity, *in exequo* with BP16, BP22, BP29 (blaue tannenzapfen, blaue ajanhuiri and purple from Congo). The sample with the highest water activity was BP1 (highland burgundy red). Still, both in terms of pH and a_w, the variations were very slight, ranging from 5.83 to 6.33 for pH and 0.982 to 0.992 for aW.

4.3. Bioactivity Analysis

The bioactivity analysis encompassed the antioxidant activity through the TBARS assay as well as the antimicrobial activity through the microdilution assay. Regarding the antioxidant activity, only the five samples with the best activity were selected due to many of them not showing any relevant results. **Table 8** shows the EC_{50} values obtained for the pulp and peel, detailing that for the pulp, the samples with the best antioxidant activity were BP16, BP17, BP22 and BP30 (blaue tannenzapfen, blaue bamberger hörnchen, blaue ajanhuiri and blue from Peru) in exequy, while BP15 (schwarzer teufel) showed statistically higher values of EC_{50}, thus lower antioxidant activity. Regarding the peels, the one with highest antioxidant activity was BP13 (purple fiesta), followed by BP16 and BP30 (blaue tannenzapfen and blue from Peru). Overall, BP30 was the potato with the best antioxidant properties both in the peels and pulps, reaching very low EC_{50} values.

Interestingly this sample is from Peru which is considered by many the origin of potato cultivation.

Table 8. TBARS assay of the pulp and peel of the five best potato samples.

	Pulp (EC_{50} mg/mL)		**Peel (EC_{50} mg/mL)**
BP15	0.37 ± 0.03^{b}	BP3	0.343 ± 0.009^{b}
BP16	0.076 ± 0.009^{a}	BP10	$0.32\pm0.02^{a, b}$
BP17	0.07 ± 0.016^{a}	BP13	0.305 ± 0.008^{a}
BP22	0.07 ± 0.016^{a}	BP28	0.38 ± 0.04^{c}
BP30	0.07 ± 0.01^{a}	BP30	$0.33\pm0.03^{a, b}$

Different letters in each row mean statistically different values, using a *p*-value of 0.05.

The antimicrobial activity, shown in **Figures 22** and 23, details the effect of the peel extracts of the potatoes on bacterial and fungi species, all of which known food contaminants. Only the peels were analysed in this assay due to being the part of the potato that shows more bioactive molecules, and thus, the most probable to show any kind antimicrobial activity. For the bacterial species, the two positive controls used were *ampicillin* and *streptomycin* which showed inhibitory activity between 0.04 and 0.75 (mg/mL). Regarding the upper section of **Figure 22**, no potato peel could come near the inhibition of the two antibiotics. Still, it would not be expected that they would have inhibition values near the positive controls, but BP1 and BP12 (highland burgundy red and red salad potato) showed interesting minimum inhibition concentrations (MIC) against *E. coli* and BP4 (hermans blaue) against *S. aureus.*

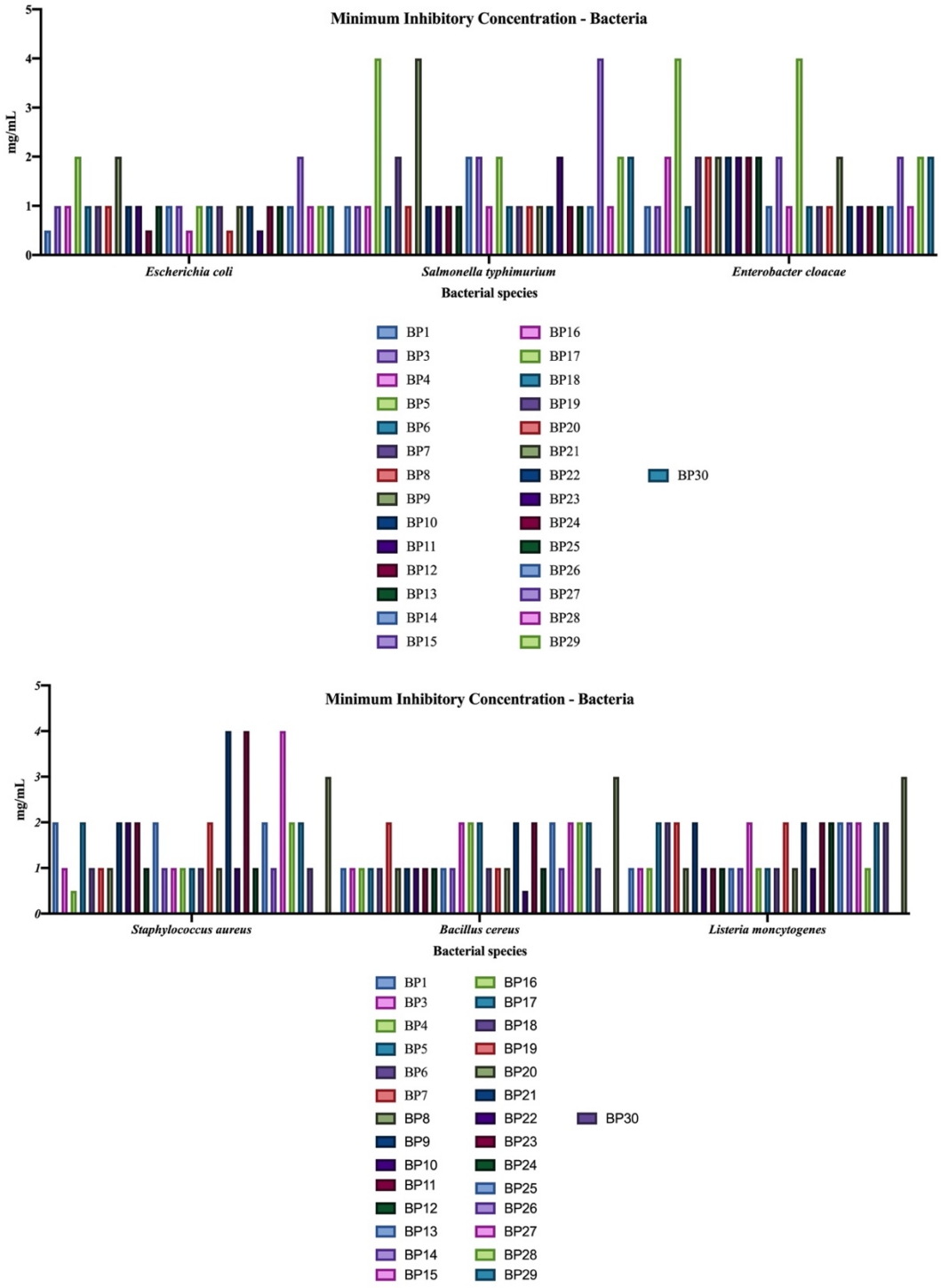

Figure 22. Minimum inhibitory concentration of bacterial species.

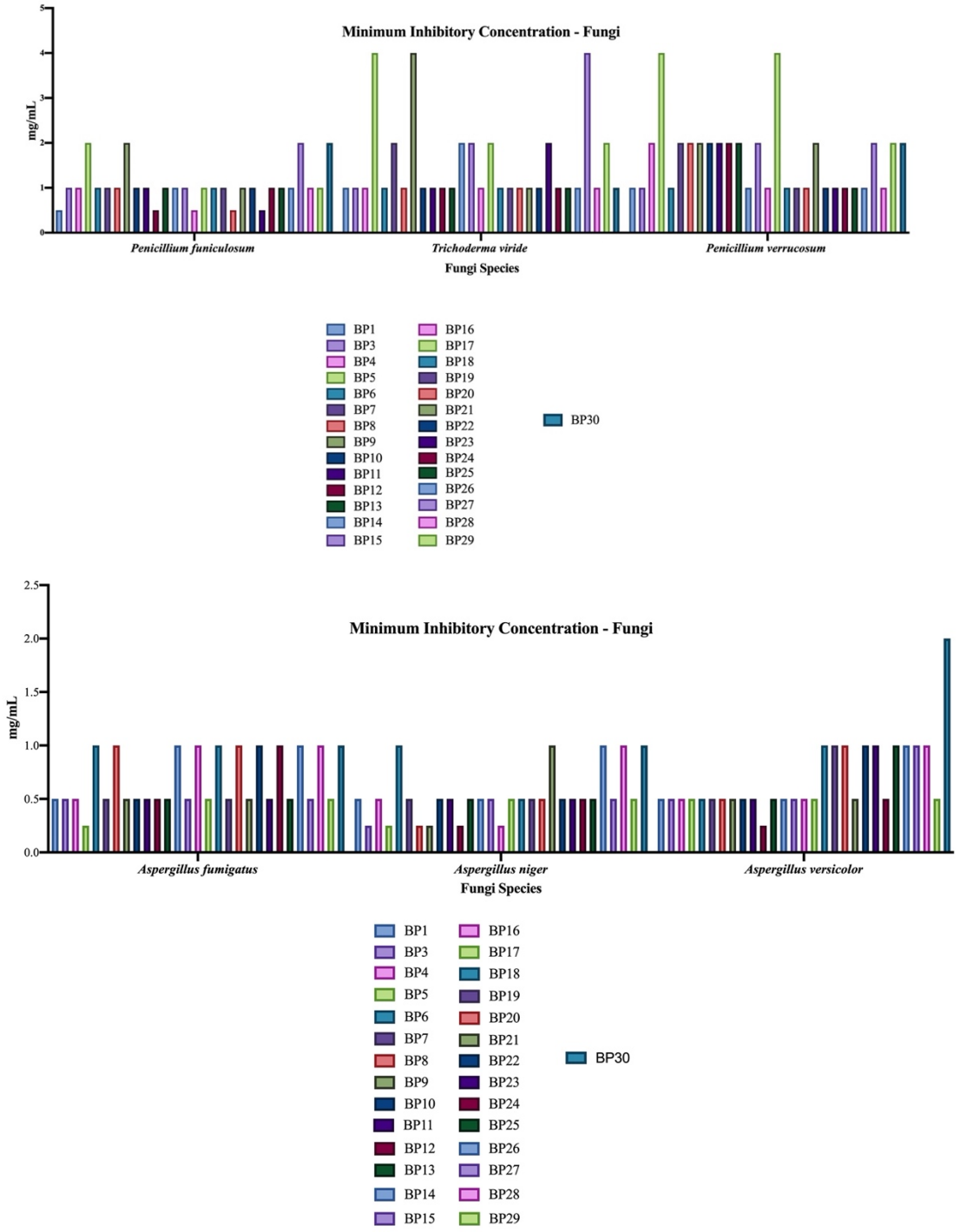

Figure 23. Minimum inhibitory concentration of the fungi species.

Regarding the antifungal activity, the two positive controls were ketoconazole and bifonazole, with MIC ranging between 0.10 and 0.20. Once again it was not expected for the pulps to show values of MIC near the positive controls, but some pulps showed interesting inhibition values. Against *P. funiculosum*, BP1, BP11, BP15 and BP18 and BP20 (highland burgundy red, violine de boree, Schwarzer teufel, fleuer bleue) showed interesting values, while BP3, BP5, BP8, BP9, BP12 and BP16 (blaue st galler,

königspurpur, black princess, blue star, red salad potato and blaue tannenzapfen) showed low MIC against *A. niger*. BP5 (königspurpur) showed a low MIC against *A. fumigatus* while BP11 (violine de boree) showed against *A. versicolor*.

4.4. Linear Discriminant Analysis

Due to the high number of samples, as seen above, quite a lot of overlapping in terms of classifications occurred, which hindered any deep analysis of the samples and their relationship. Thus, to overcome the classification limitation, a linear discriminant analysis (LDA) was performed with all analysis described above. This allowed a clustering of the samples that showed the most similarity, helping to understand further how the potatoes can be grouped. The LDA model defined 20 functions, although 99% of the variance was accounted for in the first 9 functions (Function 1–52.3%, Function 2–22.5%; Function 3–13.2%; Function 4–3.7%; Function 5–2.6%, Function 6–1.8%, Function 7–1.4%, Function 8–1.0% and Function 9–0.5%,) (**Figure 24**). Of all the different assays in the LDA, 19 showed discriminant ability, namely a* in the freeze-dried pulp, b* in the freeze-dried pulp, oxalic citric acids of the peels, oxalic and malic acids of the pulps, b* of the freeze-dried peels, L* of the of the freeze-dried pulps, a* of the freeze-dried peels, total organic acids of the pulps and the peels, glucose of the pulps, total sugars of the pulps, L* of the freeze-dried peels, glucose of the peels, pH, a* of the fresh peels, ash and L* of the fresh peels. Interestingly, the assays that were included were the colors, the organic acids and sugars, excluding the hardness and most of the nutritional profile. In terms of the correlation between the assays and each of the two functions, the first Function was highly correlated with the blue-yellow (b*) of the freeze-dried pulps, carbohydrates, kcal, fructose quantity in the peels and green-red (a*) in the freeze-dried peels, while Function 2 highly correlated with a* of the freeze-dried pulps, kJ, proteins, carbohydrates and fructose in the peels. Considering **Figure 24**, five clusters of potatoes can be sought, some mostly separated by Function 1 and others by Function 2. The most similar potatoes can be found in the middle-left cluster, including BP4, BP6, BP9 and BP11 which are, respectively from Germany, Czech Republic, The Netherlands, and France, which are neighbouring countries in Europe. The bottom left cluster grouped BP8 (black princess) and BP17 (blaue bamberger hörnchen) which are respectively from England and Germany, two countries that are also geographically nearby. The top-left cluster includes

the highest amount of varieties, and showed close to no differences among Function 2, except for BP29 (blue from Peru), the only sample from Peru, that did not cluster with any other sample, as expected. Regarding this mega-cluster, it included BP3, BP7, BP10, BP15, BP20, BP23, BP29 and BP30 (blaue st galler, blaue anneliese, violet queen, schwarzer teufel, blaue veltin, blaue neuseeländer, purple from Congo and blue from Bolivia). This mega-cluster encompassed potatoes from various backgrounds and geographic locations, as far as New Zealand, Africa, Europe, and South America. Very slight differences were found between them for the assays correlated with Function 2, namely the red-green values, calories, proteins and carbohydrates. Contrarily, the three left clusters are highly different based on these same assays, due to their distancing along Function 2. The two right clusters are more disperse than the left side clusters, both in terms of Function 1 and Function 2. The top right cluster included BP12, BP25 and BP28 (red salad potato, lilly rose and pink of Bolivia), two European potatoes and one South American. The pink of Bolivia a further higher on the Function 2 axis and it is clear that this cluster is looser than the others. The right lower cluster includes BP1, BP5 and BP24 (highland burgundy red, königspurpur, and kefermarkter zuchtstamm) which are potatoes from three neighbouring countries in Europe. Finally, under the bottom left cluster, two samples are almost overlapped, namely BP16 (blaue tannenzapfen) and BP19 (wildkartoffel) wich are both from Germany and show very similar values for all assays.

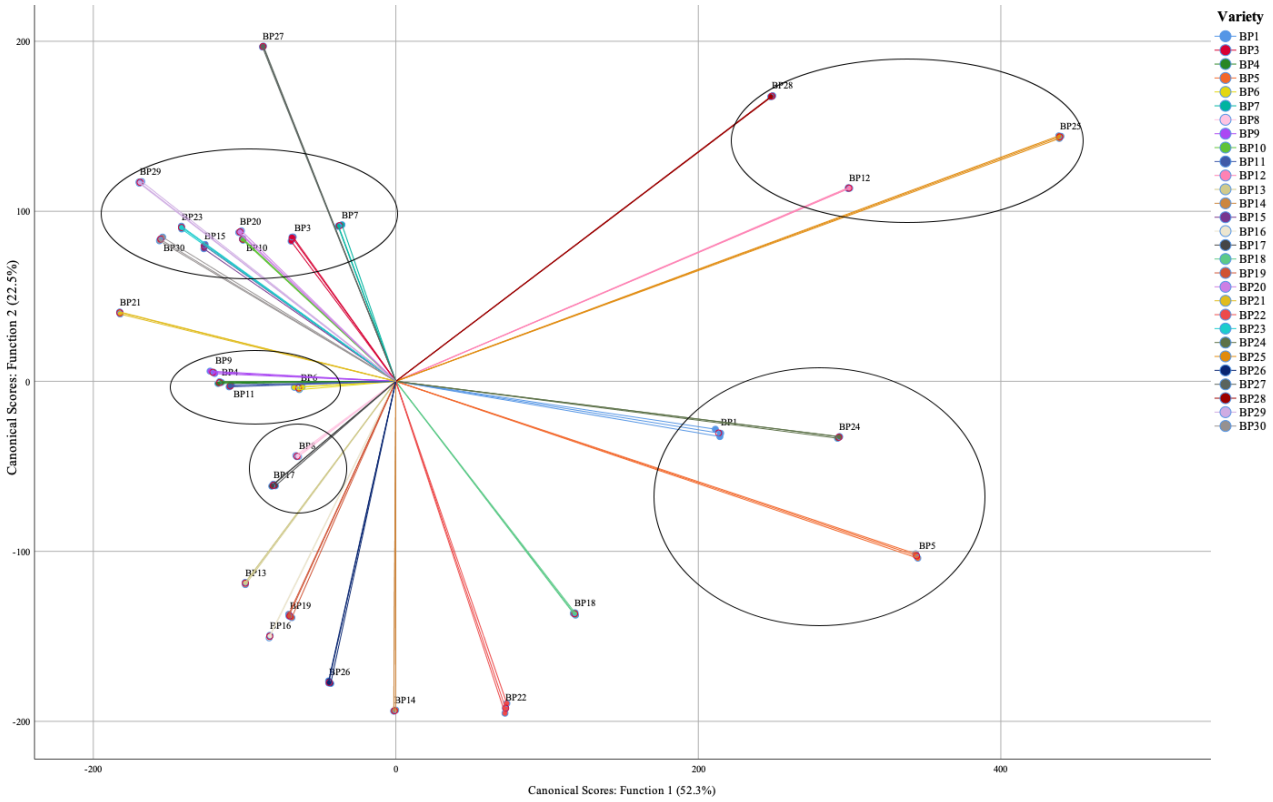

Figure 24. Linear discriminant analysis of the 29 potato varieties.

Overall, the LDA allowed to group samples by their similar chemical and physical parameters, allowing to discern the relationships between these 29 potatoes. Some samples are clustered with others from nearby countries, which is quite expected due to similar edaphoclimatic conditions while other clustered with samples from various countries from far flung latitudes. Still, most of the clustering was with species close to each other.

5. CONCLUSIONS

Potatoes are some of the most consumed vegetables around the world and constitute a high volume of residue that could be used and nutrition for incorporation in foods or even used and colorants or food preservatives. In this study, 29 varieties of potatoes and their peels were chemically and physically screened for different parameters. Due to the high number of samples, most of the values were overlapped and thus a LDA was used to cluster them by similarity. Five clusters were detected and allowed to join these potatoes by geographical location. Still, there is a high variation in chemical and physical

parameters. This study allowed to understand which are the most valuable potatoes in terms of caloric intake, coloring potential as well as changes that occur in the color when they are dried, which helps the industry know what to expect in terms of their use for colorants or dressings or food decoration. Has we seen some of them are good in Antioxidant, BP30, (Blue from Peru) as natural preservatives one of them is BP22. (Blaue Ajanhuiri)

Furthermore, it also allowed to understand which are the most acidic, hardest most alkaline, most resistant to different bacteria and fungi and also the most bioactive.

Further studies will determine the individual fatty acids, starch, and other parameters of the potatoes to better discriminate them and allow for a better understanding of their specific differences.

Overall, this study stands as a support for the food industry, academics, chefs and other players that can use the information and chose the most suitable variety for their specific needs.

Future work regarding this study focus on cultivating the samples in their native countries and comparing the results with the ones of this study. Furthermore, incorporating the peels and potatoes in foods to understand their coloring and preserving capabilities, as well as studying the nutrients which were not included in this work, namely the individual fatty acids, fibres, starch and solanine.

6. REFERENCES

Aaron KJ, Sanders PW. Role of dietary salt and potassium intake in cardiovascular health and disease: a review of the evidence. Mayo Clin Proc. 2013; 88:987-995.

Abel et al., 1986, Ríos et al., 2007, Duneto, 2018. "Dutch saltwater potatoes offer hope for world's hungry". M.phys.org. Retrieved 11 October 2018.

Aeschbach., r, Loliger, j., Scott, b.c., Murcia, a., Butler, j. et al. (1994), ‘Antioxidant actions of thymol, carvacrol, 6-gingerol, zingerone and hydroxyethyls’, Food and Chemical Toxicology, 32, 31 – 36.

Amado et al., 2014, Mohdaly, 2010. Optimization of antioxidant extraction from *Solanum tuberosum* potato peel waste by surface response methodology.

Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM. Dietary approaches to prevent and treat hypertension. A scientific statement from the American Heart Association. Hypertension. 2006;47: 296–308.

Baines, D., & Seal, R. (2012). Natrural food additives, ingredients and flavourings. Woodhead Publishing, Cambridge, UK

Boca, F. L. and Smoley, C. K. (eds). U.S. Food and Drug Administration. 1993. Everything Added to Food in the United States. CRC Press, Inc., New York.171pp.

Burt, S. (2004). Essential oils: their antibacterial properties and potential applications in foods – A review. International Journal of Food Microbiology, 94, 223-253.

Carocho, M., Morales, P., Ferreira, I.C.F.R., 2015. Natural food additives: *Quo vadis?* Trends in Food Science & Technology. Vol. 45, p. 284–295.

Carocho, M., Morales, P., Ciudad-Mulero, Fernández-Ruiz, V., Ferreira, E., Heleno, S., Rodrigues, P., Barros, L., Ferreira, I.C.F.R., 2020. Comparison of diferent bread types: Chemical and physical parameters. Food Chemistry. Vol. 310, p. 125954.

Charlie Nardozzi..The Editors of The National Gardening Association 2009.

Claude Duneton. « Le poids des mots - Le Figaro 31-1-2008.

Cotter, P.D., Hill, C., & Ross, R.P. (2005). Bacteriocins: Developing inn ate immunity for food. Nature Reviews, 3, 777-788.

Cotton PA, Subar AF, Friday JE, Cook A. Dietary sources of nutrients among US adults, 1994-1996. J Am Diet Assoc. 2004; 104:921-930.

Dahl WJ, Steward ML. Position of the Academy of Nutrition and Dietetics: Health Implications of Dietary Fiber. J Acad Nutr Diet. 2015; 115:1861-70.

Domingo Ríos, Marc Ghislain, Flor Rodríguez, David M. Spooner (2007). «What Is the Origin of the European Potato? Evidence from Canary Island Landraces». Crop Science Society of America (CSSA). Crop Science (em inglês). 47: 1271-1280.

Donald Ugent, Tom Dillehay, Carlos Ramirez (9 de junho de 1986). «Potato remains from a late pleistocene settlement in southcentral Chile». Economic Botany (em inglês). Springer New York. Consultado em 17 de junho de 2010.

Drewnowski A, Rhem CD. Vegetable cost metrics show that potatoes and beans provide most nutrients per penny. PLoS One, 2013;15;8(5).

Dilas et al., 2009, Yahia, 2010. Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization (2018).

Dietary Guidelines Advisory Committee 2015 Scientific Report. https://health.gov/dietaryguidelines/2015-scientific-report/Accessed December 27, 2018.

Edjabou, M.E., Petersen, C., Scheutz, C., Astrup, T.F., 2016. Food waste from Danish

households: generation and composition. Waste Manag. 52, 256e268.

EEA, 2009. Diverting waste from landfill. Effectiveness of waste-management policies in the European Union. European Environment Agency Report No 7/2009.

FAO. The United Nations Food and Agriculture Organization. The State of Food Insecurity in the World 2014 RESUME.

FAO. 2016. Climate change and food security: risks and responses. Rome (2016).

Garnett, T., 2006. Fruit and Vegetables & UK Greenhouse Gas Emissions: Exploring the Relationship. Working Paper Produced as Part of the Work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

Gropper S, S Smith JL, Carr TP. Advanced Nutrition and Human Metabolism. 7th ed. 2018. Boston, MA. Cegage Learning.

Guimarães, R., Barros, L., Dueñas, M., Calhelha, R. C., Carvalho, A. M., Santos-Buelga, C., Queiroz, M. J. R. P., & Ferreira, I. C. F. R., 2013. Nutrients, phytochemicals and bioactivity of wild Roman chamomile: A comparison between the herb and its preparations. Food Chemistry. Vol. 136, p. 718–725.

Gustavsson. Global food losses and food waste: extent, causes and prevention. Food and Agriculture Organization of the United Nations (2011).

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., Meybeck, A., 2011.

Habeebullah, 2010. Antioxidant Activity of Potato Peel Extracts in a Fish-Rapeseed Oil Mixture and in Oil-in-Water Emulsions.

HUANG, M. et al. Inhibitory effects of sweet potato leaves on nitric oxide production and protein nitration. Food Chemistry, v.121, n.2, p.480-486, 2010b. Available from: <http://www.sciencedirect.com/science/article/pii/S0308814609014885>. Accessed: January 12, 2017. doi: 10.1016/j.foodchem.2009.12.068.

Institute of Medicine. 2005. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: The National Academies Press. https://doi.org/10.17226/10490.

Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. 2000. Washington (DC): National Academies Press (US).

Institute of Medicine. 2004. Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate. Washington, DC: The National Academies Press. https://ods.od.nih.gov/factsheets/Potassium-HealthProfessional/

ISSN 1725-9177. https://www.eea.europa.eu/publications/diverting-wastefrom-landfill-effectiveness-of-waste-management-policies-in-the-europeanunion/download (Accessed 23 August 2021).

Juneja, V.K., Friedman, M., Mohr, T.B., Silverman, M., Mukhopadhyay, S. (2017). Control of Bacillus cereus spore germination and outgrowth in cooked rice during chillin by nonorganic and organic apple, orange, and potato peel powders. Journal of Food Processing and Preservation, 42, e13558.

Kader. Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce (2005).

Kenny. Health Benefits and Cons of *Solanum tuberosum* (2013).

Liang, Z., Tai-hua, M., Meng-mei, M., Ruo-fang, Z., Qing-hua, S., Yan-wen, X. (2019). Nutritional evaluation of different cultivars of potatoes (*Solanum tuberosum L.*) from China by grey relation analysis (GRA) and its application in potato steamed bread making. Journal of Integrative Agriculture, 18, 231-245.

Lockowandt, L., Pinela, J., Lobo, C., Pereira, C., Abreu, R. M. V, Calhelha, R. C., José, M., Barros, L., Bredol, M., & Ferreira, I. C. F. R., 2019. Chemical features and bioactivities of cornflower (Centaurea cyanus L.) capitula : The blue flowers and the unexplored non-edible part. Industrial Crops & Products. Vol. 128, 496–503.

Lutaladio et al., 2009, Narvaez-Cuenca et al., 2018, Stokstad, 2019. Potato biodiversity: A linear discriminant analysis on the nutritional and physicochemical composition of fifty genotypes (2009).

McGill CR, Kurilich AC, Davignon J. The role of potatoes and potato components in cardiometabolic health: A review. Ann Med. 2013;45(7):467-73.

National Academies of Sciences, Engineering, and Medicine. Dietary Reference Intakes for Sodium and Potassium. Washington, DC; The National Academies Press; 2019.

O'Neil CE, Keast DR, Fulgoni VL, Nicklas TA. Food sources of energy and nutrients among adults in the US: NHANES 2003–2006. Nutrients. 2012 Dec 19;4(12):2097-120.

Olivia M Kenny,Anti-inflammatory properties of potato glycoalkaloids in stimulated Jurkat and Raw 264.7 mouse macrophages. (2012)

Parfitt. Food Waste within Food Supply Chains: Quantification and Potential for Change to 2050(2010).

Potassium: Food Sources Ranked by Amounts of Potassium and Energy per Standard Food Portions and per 110 Grams of Foods. Available at: https://health.gov/our-work/food-nutrition/2015-2020-dietary guidelines/guidelines/appendix-10/

Pezeshk et al., 2015, Ojagh et al 2015., Alishahi, 2015. Utilization of potato peel as eco-friendly products: A review.

Romanucci, V., Fabio, G.D., Marino, C.D., Davinelli, S., Scapagnini, G., Zarrelli, A. Rachael Link (2018). Evaluation of new strategies to reduce the total contente of α - solanine and α chaconine in potatoes. Phytochemistry Letters, 23, 116-119.

Salaman, Redcliffe N.; Burton, W. G.; Hawkes, J. G. (1985). The history and social influence of the potato. Cambridge and New York: University of Cambridge. ISBN 9780521077835.

Sagar. Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization (2018).

Sampaio, S.L., Petropoulos, S.A., Alexopoulos, A., Heleno, S.A., Santos-Buelga, C., Barros, L., Ferreira, I.C.F.R. (2020). Potato peels as sources of functional compounds for the food industry: A review. Trends in Food Science & Technology, 103, 118-129.

Schieber, A., Stintzing, F. C., Carle, R., 2001. By-products of plant food processing as a source of functional compounds-recent developments. Trends in Food Science & Technology, 12: 401–413

Sokovic, M., Glamočlija, J., Marin, P. D., Brkić, D., Van Griensven, L. J. L. D. (2010). Antibacterial effects of the essential oils of commonly consumed medicinal herbs using an in vitro model. Molecules, 15, 7532–7546.

Sonia et al., 2016, Mini et al., 2016, Geethalekshmi et al., 2016, Tiwari ,2009.Chemical Treatment of Animal Feed and Water for the Control of Salmonella.

Sotillo, D.R., Hadley, M., Wolf-Hall, C. (1998). Potato peel extract a nonmutagenic antioxidant with potential antimicrobial activity. Journal of Food Science, 63, 007-910.

Storey ML, Anderson PA. Contributions of white vegetables to nutrient intake: NHANES 2009-2010. Adv Nutr. 2013: 4: 335S–344S.

Theron, M. M., Lues, J. F. R., 2011. Organic acids and food preservation. 1. CRC Press.

Ugent, Donald; Peterson, Linda W. (1988). «Archaeological Remains of Potato and Sweet Potato in Peru» (PDF). Centro Internacional da Batata. Circular. 16 (3)Harris, David R.; Hillman, Gordon C. (2014). Foraging and Farming: The Evolution of Plant Exploitation (em inglês). Londres e Nova Iorque: Routledge. ISBN 1317598296

Woolfe JA. The Potato in the Human Diet. 1987. Cambridge University Press.

Woolfe JA. The Potato in the Human Diet. New York: Cambridge University Press. 1987.

USDA standard reference 28, based on Reference Amounts Customarily Consumed (RACC).

USDA Dietary Guidelines for Americans. Available at: https://health.gov/our-work/food-nutrition/2015-2020-dietary-guidelines/guidelines/chapter-2/a-closer-look-at-current-intakes-and-recommended-shifts/

U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans, 2005. 6th Edition, Washington, DC: U.S. Government Printing Office.

U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at https://health.gov/dietaryguidelines/2015/guidelines/

7. PUBLISHED WORKS

Izamara de Oliveira,1,2# Christian Rodrigues,1, # Sandrina Heleno,1 Spyridon Petropoulos2, Alexios Alexopoulos4, Márcio Carocho1, *, Isabel C.F.R. Ferreira,

Lillian Barros1. Nutritional characterization, pH and Antioxidant activity of the Pulp of 29 Color-fleshed Potatoes.

Izamara de Oliveira1,2, Jonata M. Ueda1, Christian Rodrigues1, Sandrina Heleno1, Spyridon Petropoulos3, Alexios Alexopoulos4, Márcio Carocho1, *, Lillian Barros1, Isabel C.F.R. Ferreira1. Physical Properties of 29 Colored Potato Varieties.

Conference Participation

Christian T. Rodrigues, Izamara de Oliveira, Sandrina Heleno, Spyridon Petropoulos, Alexios Alexopoulos, Márcio Carocho, Isabel C.F.R. Ferreira, Lillian Barros. 7th Portuguese Young Chemists Meeting - Bragança, Portugal, from 19 a 21 May 2021. Nutritional characterization, pH and Antioxidant activity of the Pulp of 29 Color-fleshed Potatoes.

Poster

Izamara de Oliveira,1,2# Christian Rodrigues,1, # Sandrina Heleno,1 Spyridon Petropoulos3, Alexios Alexopoulos4, Márcio Carocho1, *, Isabel C.F.R. Ferreira, Lillian Barros1. Nutritional characterization, pH and Antioxidant activity of the Pulp of 29 Colored Potatoes.

Izamara de Oliveira1,2, Jonata M. Ueda1, Christian Rodrigues1, Sandrina Heleno1, Spyridon Petropoulos3, Alexios Alexopoulos4, Márcio Carocho1, *, Lillian Barros1, Isabel C.F.R. Ferreira1. Physical Properties of 29 Colored Potato Varieties.