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OPTIMIZATION OF TOMATO PEEL INCORPORATION IN PASTA HACCP Approach and Food Safety

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Abstract

This study investigates the valorization of tomato peel, a nutrient-rich agro-industrial by-product, through its optimized incorporation into pasta as a functional ingredient, focusing on nutritional enhancement, technological functionality, sensory acceptability, and food safety assurance.

Control of raw material ensured the quality of tomato peel powder (TPP), characterized by its high dietary fiber and very high antioxidant activity (AA), directly correlated with its elevated total phenolic content. Different pasta formulations were developed by substituting durum wheat semolina with TPP (10%, 15%, 20%).

Evaluations revealed significant functional and technological properties: increasing TPP levels enhanced dough water binding capacity and lipid retention, while contributing to better AA in the final product. The resulting pastas were assessed for physical, chemical, cooking quality, and antioxidant properties.

Sensory evaluation identified the pasta with 15% TPP substitution (P2) as the most sensorially acceptable formulation. To ensure comprehensive food safety and hygiene, a preventive control system based on hazard analysis principles was implemented throughout production, identifying and managing critical control points (CCPs).

The findings demonstrate that optimized TPP incorporation (notably at 15%) significantly improves the nutritional profile (dietary fiber, antioxidants) and functional properties of pasta without compromising its quality, safety, or consumer acceptability. This approach offers a sustainable strategy for reducing food waste and developing value-added functional foods.

Key words:Tomato peel powder (TPP), Pasta fortification, Antioxidant activity, Total phenolics, Functional properties, Sensory evaluation, Food safety, HACCP, Sustainable food waste valorization.

Résumé

Cette étude explore la valorisation de la peau de tomate, un coproduit agro-industriel riche en nutriments, grâce à son incorporation optimisée dans les pâtes en tant qu'ingrédient fonctionnel, en mettant l'accent sur l'amélioration nutritionnelle, la fonctionnalité technologique, l'acceptabilité sensorielle et la garantie de la sécurité sanitaire des aliments.

Le contrôle de la matière première a assuré la qualité de la poudre de peau de tomate (PPT), caractérisée par sa teneur élevée en fibres alimentaires et par une très forte activité antioxydante (AA), directement corrélée à sa teneur élevée en composés phénoliques totaux**. Différentes formulations de pâtes ont été développées en substituant partiellement la semoule de blé dur par de la PPT (10%, 15%, 20%).

Les évaluations ont révélé d'importantes propriétés fonctionnelles et technologiques : l'augmentation du taux de PPT a amélioré la capacité de liaison d'eau de la pâte et la rétention des lipides, tout en contribuant à une meilleure AAdans le produit final. Les pâtes obtenues ont été évaluées pour leurs propriétés physiques, chimiques, leur qualité de cuisson et leur activité antioxydante.

L'évaluation sensorielle a identifié la pâte avec 15% de substitution par PPT (P2) comme la formulation la plus acceptable sur le plan sensoriel. Pour assurer une sécurité sanitaire et une hygiène alimentaire complètes, un système de maîtrise préventif basé sur les principes de l'analyse des dangers (type HACCP) a été mis en œuvre tout au long de la production, identifiant et gérant les points critiques pour leur maîtrise (CCP).

Les résultats démontrent qu'une incorporation optimisée de PPT (notamment à 15%) améliore significativement le profil nutritionnel (fibres alimentaires, antioxydants) et les propriétés fonctionnelles des pâtes sans compromettre leur qualité, leur sécurité ou leur acceptabilité par les consommateurs. Cette approche offre une stratégie durable pour réduire le gaspillage alimentaire et développer des aliments fonctionnels à valeur ajoutée.

Mots-clés : Poudre de peau de tomate (PPT), Enrichissement des pâtes, Activité antioxydante, Phénols totaux, Propriétés fonctionnelles, Évaluation sensorielle, Sécurité des

aliments, HACCP, Valorisation durable des déchets alimentaires.

الملخص

تستكشف هذه الدراسة تعزيز القيمة الغذائية لقشور الطماطم، باعتبارها منتجًا ثانويًا زراعيًا وصناعيًا غنيًا بالمغذيات، من خلال دمجها بشكل أمثل في المعكرونة كمكون وظيفي، مع التركيز على التحسين الغذائي، والوظيفة التكنولوجية، والقبول الحسي، وضمان سلامة الأغذية.

تم ضبط جودة المواد الخام في مسحوق قشور الطماطم ، الذي تميز بمحتواه العالي من الألياف الغذائية ونشاطه المضاد للأكسدة المرتفع جدًا ، المرتبط ارتباطًا مباشرًا بمحتواه المرتفع من إجمالي الفينولات. تم تطوير تركيبات مختلفة للمعكرونة عن طريق استبدال سميد القمح القاسي جزئيًا بـ بنسب متباينة 10%، 15%، 20%

كشفت التقييمات عن خصائص وظيفية وتكنولوجية مهمة: حيث أدت زيادة مستويات مسحوق قشرة الطماطم إلى تعزيز قدرة العجين على ربط الماء والاحتفاظ بالدهون، مع المساهمة في نشاط مضاد للأكسدة أفضل في المنتج النهائي. تم تقييم المعكرونة الناتجة من النشاط المضاد للأكسدة.(AAحيث الخصائص الفيزيائية والكيميائية، وجودة الطهي،، (

حدد التقييم الحسي المعكرونة المحتوية على 15% من قشر طماطم باعتبارها التركيبة الأكثر قبولاً من الناحية الحسية. لضمان سلامة الغذاء وصحته بشكل شامل، تم تطبيق نظام رقابة وقائي مبني على مبادئ تحليل المخاطر ونقاط التحكم الحرجة (نظام HACCP) (طوال عملية الإنتاج، لتحديد وإدارة نقاط التحكم الحرجة (CCPs).

تظهر النتائج أن الدمج الأمثل لـ قشر الطماطم (خاصة بنسبة 15%) يحسن بشكل كبير الملف الغذائي (الألياف الغذائية، مضادات الأكسدة) والخصائص الوظيفية للمعكرونة، دون المساس بجودتها أو سلامتها أو قبول المستهلك لها. يقدم هذا النهج استراتيجية مستدامة للحد من هدر الطعام وتطوير أغذية وظيفية ذات قيمة مضافة.

الكلمات المفتاحية:

تدعيم المعكرونة، النشاط المضاد للأكسدة، إجمالي الفينولات، الخصائص الوظيفي ،(TPPمسحوق قشور الطماطم (

تعزيز قيمة مخلفات الطعام المستدامة ،التقييم الحسي، سلامة الأغذية، نظام الهاسب (HACCP).

Table of contents

<u>Abbreviation List</u>

HACCP: Hazard Analysis and Critical Control Points

TPP: Tomato Peel Powder

WTP: Whole Tomato Powder

FBPs: Fruit By-Products

FAO: Food and Agriculture Organization

WHO: World Health Organization

UN: United Nations

UAE: Ultrasound-Assisted Extraction

MAE: Microwave-Assisted Extraction

HPLC: High-Performance Liquid Chromatography

UV-Vis: Ultraviolet–Visible Spectrophotometry

UV Treatment: Ultraviolet Treatment – Non-thermal microbial reduction method

DPPH: 2,2-Diphenyl-1-picrylhydrazyl (used in antioxidant testing)

Na_2CO_3: Sodium Carbonate

TPC: Total Phenolic Compounds

TFC: Total Flavonoid Content

AA: Antioxidant Activity

PP: Polyphenols

Vitamin C: Ascorbic Acid

GAE: Gallic Acid Equivalents

mg GAE/g: Milligrams of Gallic Acid Equivalents per gram of sample

HMMAs: High Moisture Meat Analogues

ISO 9001: International Standard for Quality Management Systems

AFNOR: Association Française de Normalisation

AOAC: Association of Official Analytical Collaboration

OECD: Organisation for Economic Co-operation and Development

C.I.E.: International Commission on Illumination

pH: Potential of Hydrogen

°C: Degrees Celsius

mg: Milligram

g: Gram

L: Liter

mL: Milliliter

µm (um): Micrometer

WHC: Water Holding Capacity

OHC: Oil Holding Capacity

TDF: Total Dietary Fiber

IDF: Insoluble Dietary Fiber

SDF: Soluble Dietary Fiber

DNA: Deoxyribonucleic Acid

B2: Riboflavin

B3: Niacin

B9: Folic Acid

et al.: and others

e.g.: exempli gratia (for example)

P, P1, P2, P3: Product samples or treatments

SARL SOPI (Couscous Mama): Agri-food company producing couscous, pasta, and semolina

OCRIM: Machinery manufacturer for semolina production

SSSE: Semolina Smaller than Sieve Extraction at 280 µm

B.I.: Brown Index

Y.I.: Yellow Index

L (lightness): Lightness value from the CIE color scale

DGS: Dried Gluten Substance (Dried Wet Gluten)

OCT: Optimal Cooking Time

Figures list

Tables list

INTRODUCTION

The agri-food industry generates tons of vegetable waste annually, a significant portion of which comes from tomato processing. Indeed, the production of tomato concentrate, sauces, or juices leads to the massive disposal of peels, representing up to 5 to 10% of the fruit's total weight. These often-overlooked residues pose a real environmental problem when not adequately valorized **(Gómez et al., 2014).**

However, tomato peels boast remarkable nutritional richness. They are particularly concentrated in dietary fibers, natural antioxidants like lycopene, as well as essential vitamins and minerals. These properties give them high potential as a functional ingredient in various food products (**Barros et al., 2010).**

The nutritional improvement of pasta formulations may considerably impact the quality of the diet in many parts of the world. Indeed, nowadays a great variety of products are available on the market that respond to constant changes in consumers' behaviors and needs. Nevertheless, the inclusion of non-conventional ingredients in pasta products faces multiple challenges, requiring different technological approaches and innovation to preserve product acceptability in terms of structural and sensory properties **(Alemayhu et al., 2016).**

Given this reality, the valorization of by-products from the agri-food industry is becoming a priority. Different valorization approaches are currently available: composting, extraction of bioactive compounds, or direct incorporation into food matrices. Among these methods, incorporation into processed products such as pasta stands out for its simplicity of implementation, reasonable cost, and nutritional added value **(Reboul, 2017).**

In this context, applying an HACCP (Hazard Analysis and Critical Control Points) approach is essential to guarantee the food safety of products incorporating these vegetable residues. It is therefore crucial to assess the potential risks associated with this incorporation while ensuring microbiological stability and compliance with food safety standards **(Mortimore& Wallace, 2013).**

Thus, a central question arises: Can the incorporation of tomato peels into pasta be optimized while ensuring their safety and nutritional quality through a rigorous HACCP approach?

This work addresses this question, focusing on the development of pasta enriched with tomato peels through an optimization study of their incorporation, coupled with a risk analysis using the HACCP method. The manuscript comprises three parts: a literature review, the materials and methods used for the study, and finally the results obtained accompanied by their discussion, concluded by a general conclusion **(Silva et al., 2019).**

LITERATURE SECTION

CHAPTER I
Pasta production

CHAPTER I: Pasta production

I.1. History

Pasta is said to have originated in China and was brought to Italy by *Marco Polo*. It was introduced in France by Italian cooks during the Renaissance.

The oldest pasta recipe is found in a Mesopotamian culinary treatise dating from 1700 BC, which should not be surprising since wheat cultivation began in Mesopotamia around 8000 BC.

The Mesopotamians ate risnatu, pasta made with wheat flour and water, grated or crumbled in a boiling liquid. Grated pasta is the oldest known form. In Italy, a similar type called *pasta grattugiata* exists, while in Alsace, Spätzle is made in a similar manner (Cesari,2022).

You have provided a table of contents in French and asked me to translate it to English. Here is the translated version of the table of contents:

I.2. Definition of pasta

Pasta is a food product that play an important role in human nutrition. It is popular with consumers due to its easy handling, storage and preparation. In addition to its high content of complex carbohydrates with a low glycaemic index, pasta also contains proteins. The quality of a protein is substantially related to its composition in essential amino acids and its digestibility. High-quality proteins contain all the essential amino acids at levels equal to or higher than those of the reference amino acid pattern established by theFAO/WHO/UN (FAO/WHO , 2013).

I.3. Classification

According to BOUDREAU and MENARD (1992), pasta comes in very varied forms. However, they can be classified into two very distinct categories following the machines from which they come: extruded pasta and laminated pasta.

- **Extruded pasta:**

These are types of pasta prepared using presses fitted with dies that shape
long pasta, such as macaroni and spaghetti, with an uncooked length of approximately 25 cm. They also include short or cut pasta, with a maximum length of 6 to 8 cm, such as rings, various types of elbows, and certain kinds used in soups.

Figure 1: Extruded pasta (Anonymous, 2022)

- **Laminated pasta:**

As for them, they are previously manufactured by presses equipped with a die, a slot or special mixers capable of forming the dough into thin sheets . This category includes soup pasta, ribbon pasta, stuffed pasta, and other similar varieties.

Figure 2: Laminated pasta (Anonymous, 2022..)

I.4. Pasta production

The steps preceding pasta production include receiving the semolina at the factory, storing it in silos where both the external and internal temperatures are strictly monitored to prevent water condensation inside the silo, dosing the semolina by volume or mass, mixing (in the case of semolina and farina) and transporing it to the manufacturing location.

Pastification includes a certain number of successive operations (see figure No. 1) including the purification of semolina, mixing and deaeration, kneading, forming (drawing or rolling), drying and packaging (signagno and *al*.,2015)

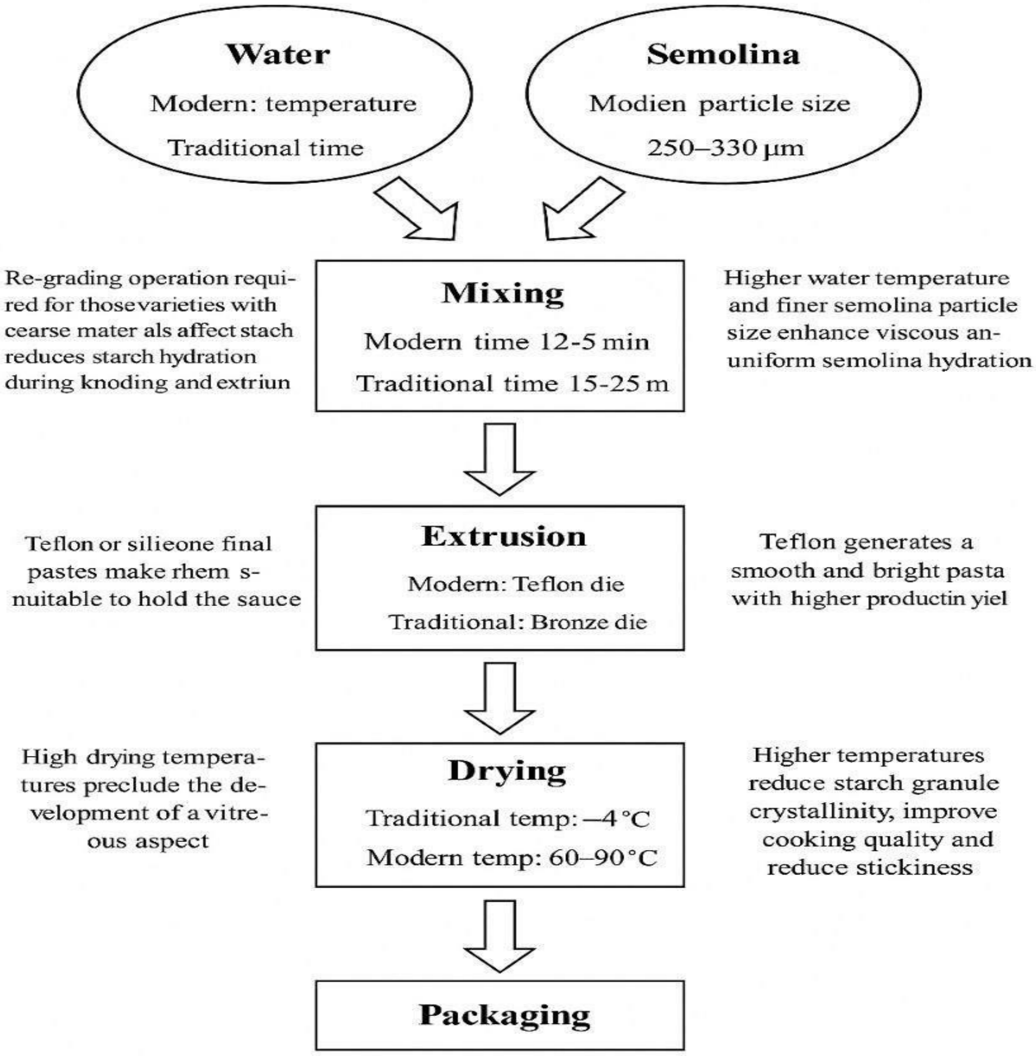

Figure 3: Diagram of production of pasta (signagno and al., 2015)

I.5. Pasta Processing Technology

pasta mainly made from coarse semolina milled from durum wheat, (*Triticum durum)*, which is mixed with water and then extruded through a metal die under pressure.

Pasta can be made into dried and filled products including spaghetti and macaroni, ravioli, and tortellini (Alemayehu, et *al* .,2016; Fuad& Prabhasankar,2010).

I.5.1. Hydration

Pasta is made by mixing water and semolina. In modern factories the proportions of ingredients are controlled automatically with dozers for determination of the quantity of water to add for quality optimal pasta (Alemayhu and *al* .,2016)

Through this step we seek to bring the humidity of the semolina which is approximately 14.5% of dry matter at a final humidity of 30% of dry matter.

I.5.2. Mixing

After hydrating our product, it is then kneaded for approximately 15 minutes using of a mixer in order to properly incorporate the water into the semolina so as to obtain lumps of different sizes while leaving at the press level a vacuum to reduce the oxidation of carotenoid pigments giving the pastes a bad color and on the other hand prevent the formation of air bubbles which degrade the quality of dough (sticky texture dough) (Fratianni et *al* ., 2023)

I.5.3. Extrusion

After kneading the semolina, the mixture obtained is extruded and passes through a matrix which makes it possible to exert pressure on the product inducing the elevation of the temperature and the formation of a gluten network in the dough which makes it elastic and translucent and in order to avoid the denaturation of its gluten networks in the event of a large rise in temperature the matrix is equipped with a cooling system water circulation (Fratianni et *al*.,2023).

I.5.4. Drying

Once the pastes are formed, they are transported to a drying chamber allowing the pasta to be well dried to high temperature processes for approximately 12 hours, from which this drying makes it possible to improve the organoleptic quality and to reduce bacterial contamination but on the other hand it reduces the value nutritional pasta which results in a lysine deficiency (Fratianni et *al*.,2023).

I.5.5. Packaging

Pasta is often packaged in polythene bags or cellophane or even in cardboard boxes. These packaging are intended to protect the finished product against any microbial damage or enzymatic and oxidative reactions as well as damage that may occur during delivery or storage (Da silva et *al*.,2023).

I.6. Nutritional quality

According to Da silva et *al.* (2023), the assessment of pasta's nutritional quality must take the following factors into account:

- A full plate of cooked pasta is equivalent of 60 to 70 g of dry pasta.
- During cooking, pasta absorbs almost twice its weight in water and lose 6 to 10% of its dry matter in the cooking water;
- Pasta is rarely eaten in plain form. It is often combined with fats (such as butter) and sometimes cheese or minced meat.
- Pasta is a good source of energy and proteins, while being low in fat. A ratio of 60 to 70g of raw pasta provides approximately 10% of daily calorie needs, equivalent to consuming 100g of bread.
    - ❖ The protein intake is significant; as 100 g of pasta contains 10 to 12 g of protein, increasing to 12 to 14 g in the case of egg pasta. However, like other grain-based products, pasta proteins are deficient in essential amino acids, particularly lysine.
    - ❖ Considering that the highest concentrations of minerals and vitamins in the grain are found in the

peripheral layers (pericarp, aleurone layer) which are removed during milling, the mineral and vitamin content of pasta is particularly low.

- The carbohydrates present are mainly complex carbohydrates that are easy to digest. Their energy release occurs over an extended period, providing a lasting sensation of satiety. These particularities explain why pasta is recommended for people requiring long-term energy, such as as endurance athletes (Kaur et *al* .,2023).

I.7. Different forms of pasta

Pasta comes in a wide range of shapes and sizes, each designed to pair with specific types of sauces or cooking methods.

Here are some of the most common types of pasta: (Table 1)

Table N°1: Most types of pasta and their characteristics.

Types	Characteristics
Spaghetti	Long, thin, and round pasta, commonly served with tomato-based sauces or meat sauces like Bolognese.
Penne	Short, tube-shaped pasta with angled edges, often used with thicker sauces like arrabbiata or creamy sauces.
Fusilli	Spiral-shaped pasta that holds onto sauces well, perfect for chunky or thick sauces.
Fettuccine	Flat, wide noodles typically paired with rich, creamy sauces like Alfredo or ragù.
Tagliatelle	Similar to fettuccine but thinner, commonly served with hearty sauces such as Bolognese.
Linguine	Long and narrow, often paired with seafood sauces or light tomato-based sauces.
Macaroni	Small, elbow-shaped pasta often used in baked dishes like mac and cheese or in pasta salads.
Lasagna	Large, flat sheets of pasta used in layered dishes, often with a filling of meat, béchamel, and cheese.
Ravioli	Square or round pockets of pasta filled with various ingredients such as cheese, meat, or vegetables, typically served with tomato or butter-based sauces.
Cannelloni	Large tubes of pasta, usually stuffed with fillings like ricotta cheese, spinach, or meat, and baked with sauce.

I.8. Innovation and Nutritional Improvement in Pasta Formulation

Pasta is a low-cost, versatile, nutritious food consumed globally on a daily basis by many populations. The growing consumer interest in staple foods with enhanced nutritional and technological characteristics has driven the industry to explore unconventional raw materials and innovative processes for pasta production.

Many studies have experimented the replacement of wheat flour/semolina in pasta formulation with functional ingredients such as barley flour, chickpea flour (Singh et *al*., 2023), aquatic fern (*Azolla sp*.) powder (Kaur et *al*., 2023b), small-sized fish (pangas) (Saini et *al*., 2023), asparagus pruning (da Silva et *al*., 2023) and green leafy vegetable wastes (Fratianni et *al*., 2023).

In fact, barley flour is a suitable ingredient for replacement of wheat in food formulation providing a vehicle for bioactive compounds such as beta-glucan.

In pasta formulation, Singh et *al*., 2023 combined barley flour with chickpeas flour, which, when used up to 20% supported a good quality of the final product, in parallel with an improvement of nutritional properties. Azolla sp. powder is a non-conventional and nutritionally valuable ingredient, that significantly influences the nutritional quality, cooking characteristics and sensory properties of semolina pasta (Kaur et *al*., 2023a, 2023b). Blends of semolina with fish pangas protein isolates (up to 5%) could enhance protein content and improve the amino acid profile without substantially affecting the sensory properties of pasta. Replacing wheat flour with asparagus pruning and green leafy vegetable waste provided bioactive compounds and antioxidant activity to pasta, improving its nutritional and cooking quality.

Lastly, the work by Zhao et *al*., 2023 studied the different combinations of protein isolates (soybean, whey and ovalbumin) with gluten-free ingredients, examining their impact on pasta quality. Indeed, as a staple food commodity in many countries, tailored approaches to pasta-making could expand the market for consumers affected by coeliac disease.

The nutritional improvement of pasta formulations may considerably impact the quality of the diet in many parts of the world. Indeed, nowadays a great variety of products are available on the market that respond to constant changes in consumer’s behaviours and needs. Nevertheless, the inclusion of non-conventional ingredients in pasta products faces multiple challenges, requiring different technological approaches and innovation to preserve product acceptability in terms of structural and sensory properties.

Tu le laisse pour la fin de l’introductionavant de parler sur la pelure de tomate

Chapter II: Tomato Peels Powder

Chapter II: Tomato Peels Powder

II.1. Definition

Tomato peel, the outer skin of the tomato fruit (Solanumlycopersicum), serves as the outermost protective layer of the tomato. Anatomically, it comprises an external epidermal layer covered with a waxy cuticle and two to four layers of collenchymatous cells. The epidermal layer is highly hydrophobic and crucial as the fruit's first defense against desiccation. ***(*Hetzroni*et al., 2011).***

II.1.1. Origin

Tomato belongs to the Solanaceae family, Sub-Family Soloanoideae, Tribe Solaneae, Genus Solanum and Species Solanumlycopersicum (TanujaBuckseth, 2023).Tomatoes are considered a fruit or vegetable depending on context. According to Encyclopedia Britannica, tomatoes are a fruit, labeled in grocery stores as a vegetable due to their taste and culinary purposes. Botanically, the tomato is a fruit berry, consisting of the ovary, together with its seeds, of a flowering plant. It has a much lower sugar content than culinary fruits, the tomato is native to Central, South, and southern North America, from Mexico to Peru(*Bionity, 2023*). Wild tomato plants come from the Andean region of South America. These plants belong to the plant group known as flowering plants or angiosperms, which have a sexual reproduction mode (Tomatosphere, 2023).

II.1.2. Botanical description of tomato

The tomato plant (*Solanumlycopersicum*) is a highly adaptable herbaceous species, typically cultivated as an annual but capable of biennial or perennial life cycles in favorable conditions. It exhibits diverse growth habits, from compact, determinate varieties to vigorous, indeterminate vines that can exceed 3 meters with support. Tomato stems are angular and covered in trichomes. Leaves are alternately arranged in a spiral pattern (137.5° phyllotaxy), varying from deeply lobed to dentate leaflets. Flowers are 1-2 cm wide with, appearing in cymes at the apical meristem. Botanically, the tomato fruit develops from the plant's fertilized ovary, with its fleshy part forming the pericarp (Swamy, K.R.M., 2023). Tomato fruits exhibit remarkable diversity in color (red, yellow, green, purple) and shape (spherical, oval, elongated, pear-shaped). Internally, they can be bilocular or multilocular, containing 50-200 small, lentil-shaped seeds, each encased in a gelatinous membrane and protected by a robust outer seed coat (OECD, 2008). Figure N°1 illustrates this details.

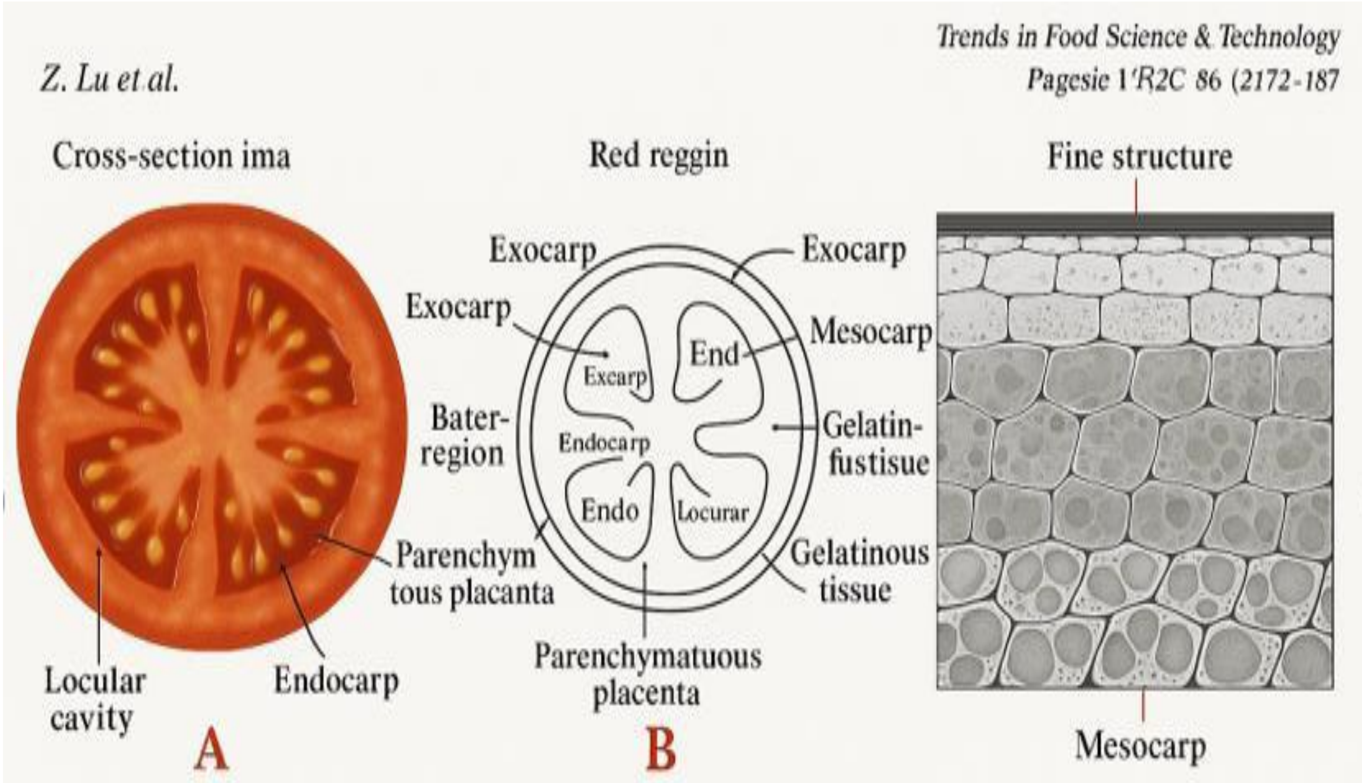

Figure 4: The cross-section image (A) of a tomato and its diagrammatic drawing (B) and the fine structure of the tomato outerlayer (C).

II.2. Nutritional Content of Tomato Peel Powder

Tomato peel powder is a highly nutritious by-product of tomato processing, containing a wealth of bioactive compounds that provide various health benefits. It is particularly rich in dietary fiber, antioxidants, phenolic compounds, carotenoids, essential minerals, proteins, lipids, vitamins, organic acids, and other phytochemicals. These components make tomato peel powder an excellent ingredient for functional foods, pharmaceuticals, and nutraceuticals (Akubor&Owuse, 2020).

II.2.1. Dietary Fiber Content

Tomato peel powder is an exceptional source of dietary fiber, with total dietary fiber (TDF) content ranging from 62.79% to 88.53%. The insoluble dietary fiber (IDF) fraction is the predominant type, making up approximately 71.82% of TDF, while soluble dietary fiber (SDF) accounts for 15.31% (Navarro-González et al., 2011). Compared to other fruit peels, tomato peel powder has superior fiber content, making it valuable in food formulations for digestive health (Lu et al., 2019).

II.2.2. Lycopene and Other Carotenoid

Lycopene is the most abundant carotenoid in tomato peel powder and is known for its powerful antioxidant properties. It is responsible for the red pigmentation of tomatoes and plays a crucial role in reducing oxidative stress, preventing cellular damage, and lowering the risk of chronic diseases such as cardiovascular disorders and cancer. The lycopene content in tomato peel powder varies widely, ranging from 73.4 mg to 288 mg per 100 g, depending on the variety and processing methods used (Knoblich et al., 2005). Studies have shown that lycopene from tomato peel is more bioavailable when compared to that from raw tomatoes due to structural changes occurring during processing, which enhance its absorption in the human body (Benakmoum et al., 2008). Other carotenoids found in tomato peel powder include β-carotene, lutein, and zeaxanthin, which contribute to eye health and immune function (Elbadrawy&Sello, 2016).

II.2.3. Phenolic Compounds

Tomato peel powder contains a variety of phenolic compounds, including flavonoids and phenolic acids. The most abundant phenolic acids found in tomato peels are caffeic acid, chlorogenic acid, ferulic acid, and p-coumaric acid, which exhibit strong antioxidant and anti-inflammatory effects. Flavonoids such as rutin, quercetin, naringenin, and kaempferol further enhance the antioxidant capacity of tomato peel powder (Elbadrawy&Sello, 2016). The total phenolic content in tomato peels ranges from 157.8 mg to 1990 mg gallic acid equivalents (GAE) per 100 g (Navarro-González et al., 2011).

II.2.4. Vitamins

Tomato peel powder is a natural source of vitamins that contribute to its nutritional and functional properties. Vitamin C (ascorbic acid) is present in significant amounts, enhancing its antioxidant capacity and supporting immune function. Vitamin E (tocopherol) acts as a fat-soluble antioxidant, protecting cellular membranes from oxidative damage. Additionally, tomato peel powder contains B-complex vitamins such as niacin (B3), riboflavin (B2), and folate (B9), which play essential roles in energy metabolism and DNA synthesis (Knoblich et al., 2005).

II.2.5. Organic Acids

Tomato peels contain organic acids, including citric acid and malic acid, which contribute to their flavor, acidity, and preservative properties. Citric acid enhances mineral absorption and acts as a natural preservative, while malic acid plays a role in cellular energy production. These organic acids also contribute to the overall antioxidant activity of tomato peel powder (Lu et al., 2019).

II.2.6. Protein and Amino Acids

Tomato peel powder contains moderate levels of protein, ranging from 2.03 g to 11.13 g per 100 g. It includes essential amino acids such as lysine, leucine, valine, and phenylalanine, which are crucial for muscle growth and overall metabolism (Elbadrawy&Sello, 2016).

II.2.7. Lipids and Fatty Acids

The lipid content of tomato peel powder varies between 1.63% and 5.50%, with beneficial unsaturated fatty acids such as linoleic acid, oleic acid, and palmitic acid (Knoblich et al., 2005). The presence of these bioactive lipids also enhances the functional properties of tomato peel powder in food formulations (Benakmoum et al., 2008).

II.3. Extraction of valuable compounds of tomato peels powder

Extraction methods have evolved from traditional techniques like maceration, solvent extraction, and distillation to more advanced methods that address the increasing demand for efficiency, reduced energy consumption, and environmental safety.,

II.3.1. Solvent extraction

Solvent extraction for recovering antioxidant and bioactive compounds, particularly lycopene, from tomato peel is effectively achieved through the use of mixed-polarity solvent systems, researchers optimized the solvent composition, discovering that while n-hexane showed a strong affinity for lycopene, the swelling capabilities of ethanol and acetone were also crucial. The optimized n-hexane–ethanol–acetone mixture proved highly effective, achieving over 95% lycopene extraction yield (ANTONIO ZUORRO, 2020).

II.3.2. Ultrasound assisted extraction

Ultrasound assisted extraction (UAE)is a modern technique that enhances extraction yield while reducing processing time, energy, and solvent usage. It is considered a "green" alternative to conventional methods. UAE enhances the recovery of valuable food components by employing mechanisms like fragmentation, erosion, capillarity, detexturation, and sonoporation to disrupt plant cell structures and improve solvent penetration, utilizing either ultrasonic baths or probe-type devices (CHEMAT ET AL., 2017).Numerous studies investigated the UAE. of bioactive compounds from tomato pomace using acetone, ethanol, and ethyl acetate, optimizing parameters such as solvent-to-liquid ratio, temperature (to 30°C), and time (to 10 hours) (Flais and Oroian, 2024).

II.3.3. Microwave-assisted extraction (MAE)

Microwave-assisted extraction (MAE) is presented as an efficient technique for extracting bioactive compounds from industrial tomato waste (seed, pulp, and skin), offering faster extraction and less solvent use than traditional methods.[1]The process involves mixing tomato waste powder with a solvent, typically 95% ethanol, and microwaving it at specific power levels (180-450 W) for short durations (30-90 seconds) using a 2450 MHz microwave. Following heating and temperature recording, the supernatant is separated into hydrophobic and hydrophilic components using hexane with 0.1%. The hydrophobic fraction is then analyzed for carotenoids via HPLC after hexane evaporation and volume adjustment with n-hexane. The hydrophilic fraction is concentrated and adjusted with ethanol for determining total phenolic compounds (TPC) and total flavonoid content (TFC) using gallic acid and catechin as standards, respectively (Lasunon et al., 2021).

II.4. Functional and physicochemical properties of tomato peels

The physicochemical and functional properties of tomato peel powder make it a valuable ingredient for food applications. These properties include antioxidant activity, water and oil holding capacity, contributing to the stability and nutritional enhancement of foo products. (Donegà et al., 2015).

II.4.1. Antioxidant activity

Tomato peels are a valuable source of antioxidants and contribute significantly to the functional properties of the fruit. Studies show that tomato peels are rich in bioactive compounds. Compared to pulp and seeds, tomato peels contain higher concentrations of water-soluble and fat-soluble antioxidants, phenolics, lycopene, and ascorbic acid. The high antioxidant content in tomato peels significantly enhances the scavenging properties of tomato fruits. Specifically, the peel contributes a notable percentage to the total antioxidant capacity (51-63%), total phenolic content (56-65%), lycopene content (38-51%), and ascorbic acid content (41-47%). Removing the peel and seeds during consumption leads to a substantial loss of beneficial compounds (BIANCHI ET AL., 2023).

II.4.2. Water holding capacity

Tomato peels exhibit water holding capacity (WHC), which is crucial in food applications as it indicates their ability to bind water within food matrices. This property helps improve product texture and mouthfeel (e.g., in baked goods), reduce syneresis (water separation in gels or sauces), and enhance juiciness. WHC. can be determined by methods such as that developed by Pla et al. (2025). This method involves incubating samples in distilled water, centrifuging to separate the sediment, and calculating WHC based on initial and final weights. Water holding capacity (WHC) was determined according to the method developed by (Pla et al,2025).

II.4.3. Oil holding capacity

Tomato peels exhibit significant oil holding capacity (OHC), a functional property essential for food applications. This ability to bind and retain oil is mainly due to their high content of insoluble dietary fiber, whose porous structure and chemical composition offer a large surface area for oil entrapment. OHC contributes to improved texture and emulsion stability in food products like baked goods or meat formulations. Studies demonstrate that factors such as particle size and processing influence OHC, highlighting the potential of tomato peel as a valuable ingredient for oil retention and functionality.Oil holding capacity (OHC) was determined according to the method described by(Robertson et al,2025).

II.4.4. Thickening effect of tomato peels dried powders

Dried tomato peel powders exert a significant thickening effect in food formulations, attributed primarily to their high fiber content and excellent water holding capacity (WHC). Studies have shown that adding fine dried peel powder (e.g., up to 3.0% in rustic sauce) or rough dried peel powder (up to 1.0% in rustic sauce) can be organoleptically acceptable, even at concentrations where rheological properties allow for higher additions. The WHC of these powders enables them to absorb significant amounts of free water in sauces (e.g., 9.1% to 15.4%), increasing consistency and total solids without notably affecting Brix degree.

This capacity is particularly advantageous in the tomato industry, where it can reduce energy-intensive water evaporation during concentration, potentially replacing 20-25% of the water removal process and offering considerable cost savings. Furthermore, the fiber's ability to continue absorbing water during shelf life contributes to maintaining consistency over time, while re-inserting tomato peel into the production flow represents a valuable waste recovery strategy (Donegà et al., 2015).

II.5. Technological applications in food products

II.5.1. Use as Natural additive: Colorant and antioxidant

Tomato peels are a rich source of lycopene, imparting a deep red color that makes them a valuable natural food coloring agent. The extract, often termed "Lyco-red," primarily comprises lycopene along with other carotenoids like phytoene, phytofluene, beta-carotene, and lutein. Lyco-red provides shades from yellow to red and is suitable for diverse food products such as sauces, soups, snacks, pasta, baked goods, cereals, dairy, and beverages. Its advantages as a food colorant include stability to heat and extreme pH, effectiveness at low concentrations, absence of off-flavors, and its role as a natural antioxidant. The antioxidant activity of lyco-red, has several implications for food preservation techniques. It can inhibit the development of off-flavors in foods containing fats and oils by preventing the oxidation of unsaturated fatty acids (EffatM.Rizk et al 2014).

II.5.2. Use as Dietary fiber source

Tomato peels are rich in dietary fiber, particularly insoluble dietary fiber (IDF), which can be utilized to enhance the fiber content of various food products. Many studies analyzing tomato peel fiber found that it contains approximately 84.16 g/100 g of total dietary fiber, with IDF constituting 71.82 g/100 g. This high fiber content makes tomato peels suitable for incorporation into baked goods, snacks, and health bars to improve their nutritional profile (Inmaculada Navarro-González et all; 2011).

II.5.3. Functional ingredient in fortified foods

Tomato peel powder can be added to products like breads, pastas, cereals, or smoothies to boost their nutritional profile, especially for their antioxidant properties, vitamins (like vitamin C and E), and minerals (like potassium and magnesium). Research has explored the incorporation of tomato peel into butter cookies, demonstrating improved nutritional content and consumer acceptability. *(Navarro-González et al., 2011)*

II.5.4. Fat Replacer in Processed Foods

Tomato peel powder can be incorporated into processed meat products like sausages to replace fat content while maintaining texture and mouthfeel. A study investigated the effects of tomato peel as a fat replacement in sausages and found that it improved water holding capacity and sensory qualities, making it a viable fat substitute. *(Wang et al., 2017)*

II.5.5. Edible Films and Coatings

Extracts from tomato peels can be used to produce biodegradable edible films due to their polysaccharide and pectin content. These films can serve as coatings for fruits, vegetables, or meats, reducing moisture loss and microbial growth. A study developed hydrophobic edible films using cutin extracted from tomato peels combined with pectin, resulting in films with improved water resistance and mechanical properties. **(Chaparro-Hernández et al., 2019)**

II.6. Limitations and constraints of use

II.6.1. Sensory challenges

Incorporating whole tomato powder (WTP) or tomato peel powder (TPP) into food products like high moisture meat analogues (HMMAs) faces several constraints. Excessive WTP (20%) can negatively impact texture, leading to a hard, brittle product due to disrupted protein aggregation from lipids, sugars, and dietary fibers. TPP, on the other hand, produces a soft texture and uneven color distribution due to its high insoluble fiber content, which interferes with protein cross-linking and results in orange-red aggregates. Color stability is also a concern, particularly with TPP; boiling significantly reduces redness and yellowness, negating the initial color enhancement. This degradation occurs because lycopene and other pigments are heat-sensitive and break down during cooking. Although WTP increases total phenolic content

(TPC) and antioxidant capacity, these advantages diminish after boiling due to the decomposition of heat-labile phenolic compounds and the leaching of water-soluble substances. These textural and nutritional limitations influence the sensory experience and shelf life of TPP incorporated products. Further optimizations are needed to balance the benefits of tomato powder incorporation with these drawbacks (**Lyu et al., 2023).**

II.6.2. Lacking of sufficient researchers

There are still challenges to overcome in using fruit by-products (FBPs) despite the fact that they contain valuable compounds. More research is needed to fully understand the potential of these substances. Although studies have shown that food can be enriched with these compounds and that doing so can significantly change the food's nutritional composition, the long-term consequences of consuming these enriched foods have not been adequately studied. The synergistic effects of documented dietary habits are also lacking sufficient data. Furthermore, a particular chronic condition or age group may not be suitable for certain bioactive compounds or combinations thereof (Hasan et al., 2024).

II.6.3. Stability and Pesticide Residues

Tomato peels are prone to microbial contamination and spoilage due to their high moisture content. Effective drying and stabilization methods are essential to ensure shelf stability and safety. There are insecticides, fungicides, and fertilizers use to fruits (tomato) in order to improve fruit production. Fruits are frequently treated with these substances by cultivars in order to prevent spoilage caused by insects, pests, rodents, bacteria, fungi, and occasionally viruses. Mycotoxins, aflatoxins, and fumonisins are examples of toxins that are created by biochemical processes and may pose a threat to the safety of food due to their pervasiveness and a variety of negative impacts on human health. If consumed, these toxins may develop in the byproducts and be harmful to human health (Hasan et al., 2024).

II.7. Processing Challenges

The fibrous nature of tomato peels necessitates size reduction (e.g., grinding) to facilitate their use in food formulations and enable efficient industrial-scale extraction of valuable compounds (Gerschen-son et al. 2015). This process, though potentially energy-intensive, is crucial as it creates smaller particles with a larger surface area. This increased surface area enhances water absorption, solubility, flavor release, improves mouthfeel, and boosts contact between the fibrous components and solvents during extraction, thereby significantly increasing reaction rates in biological and chemical processes. While both dry and wet grinding exist, optimizing the size reduction method is vital as it can significantly increase the yields of costly value-added component extraction. Therefore, size reduction is highly recommended as a pre-treatment before main extraction processes (Li et al. 2012; Arshadi et al. 2016).

II.8. Economic Feasibility and Waste Reduction

Research shows that adding tomato peel to food enhances nutrition and reduces waste. Sustainable processing methods, such as infrared peeling, improve efficiency while remaining cost-effective. Tomato peel pectin even has industrial applications, including corrosion inhibition. These innovations support the circular economy by transforming waste into valuable resources—lowering disposal costs, creating revenue, and reducing landfill and emissions pressure. Globally, tomato processing generates 3–7% waste by weight, primarily peels. For every 100 kg of tomatoes processed, 3–7 kg of peels are discarded. Large-scale processors handle millions of tons annually, resulting in thousands of tons of peel waste. The figure below illustrates tomato processing volumes and peel waste in major producing countries. By valorizing tomato peels, the agro-industry advances sustainability worldwide. (Almeida et al: 2024)

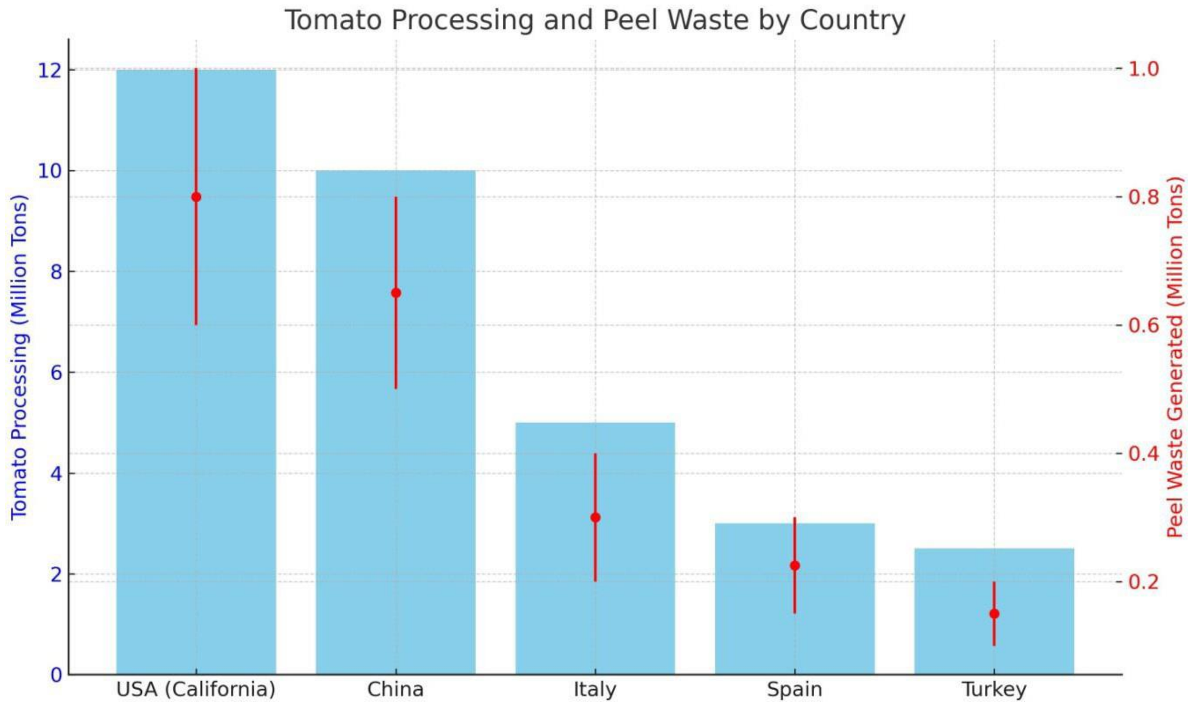

Figure 5: Quantitative Analysis of Tomato Peel Waste Generation in Industrial Processing by Country (Almeida et al., 2024 Modified).

Practical section

I. Material and Methods

I. Material and Methods

The Materials and Methods section outlines the experimental design, procedure, materials, and analytical techniques used in conducting the research. It provides a detailed and descriptive explanation of the conduct of research to enable reproducibility and transparency. The section has information on the source and preparation of material, equipment used, step-by-step methodologies, and data analysis protocols. By the clear enumeration of the steps taken, this part enables readers to judge validity and reliability of results and compare with related studies.

I.1. Introduction to the unit (SARL SOPI)

-History

SARL Sopi (private limited company by shares), trading as Couscous Mama, was founded in 1995 by professionals in the agri-food sector. It began production in 1997. Initially, the company produced couscous and pasta, and began producing durum wheat semolina after 2006.

The company has implemented a process of quality which will bring all its departments to the level of certification of the ISO 9001 standard, version 2000, in due course.

- **Storage Capacity:**

➢ **Raw Material.**

✓ Medium Semolina: 85 tons x4 (4: number of silos)

✓ Fine Semolina: 85 tons x3

✓ Flour (SSSF): 85 tons x2.

- **Production Capacity:**

Semolina: 300 tons/24 hours /Couscous: 4,500 kg/hour" Pasta: 1,400 kg/hour".

- **Resources:**

➤ Human Resources: 200 employees (all functions and statuses combined). ➤ Infrastructure: Factory for extension purpose production "OCRIM" machines for semolina production.

I.2. Study Design

The study was conducted between February 1 and May 11 in the laboratory of SOPI (pasta division), applying the HACCP method throughout the process. The samples analyzed included process water (used in pasta preparation) and durum wheat semolina.

I.2.1. Objective of study

The main objective of this study is to determine the feasibility and implications of employing tomato peels, an agri-food by-product rich in fiber and bioactive compounds, as a component of pasta products. The research goals are to:

➢ Enhance the value of a traditionally overlooked plant by-product from the perspective of sustainable development and circular economy;

➢ Enhance the nutritional value of pasta (fortification with fiber, antioxidants, etc.) without impacting its organoleptic or techno-functional quality.

➢ Analyze the effect of the addition of tomato peels on the physicochemical properties, texture, color, cooking behavior, and sensory acceptability of the end product.

I.3. Material

I.3.1. Equipment for Testing Raw Materials

Employed for analyzing water, semolina, flour, and other ingredients (See appendix):

- ✓ Analyzers for Moisture – Moisture content in flour/semolina.
- ✓ Glutomatic system – Quality and content of gluten.
- ✓ Falling number apparatus – Activity of enzyme alpha-amylase.
- ✓ Furnace for ash content (muffle furnace) – measuring minerals.
- ✓ Protein analyzers (Kjeldahl apparatus) – Determination of proteins.
- ✓ PH meter – Ingredients acidity.

I.3.2. Tools for Preparing and Testing Pasta Dough

These tools guarantee that the dough is mixed and tested under controlled laboratory conditions:

- ✓ Dough mixer/extruder at lab-scale – for studying the small-scale fabrication of pasta.
- ✓ Water activity meter – determines the level of moisture content to aid in shelf life preservation.
- ✓ UV-Vis spectrophotometer – analyzes the pigments and antioxidant activity of the pasta.

I.3.2. chemical Reagents

80% Methanol or ethanol (extraction solvent), DPPH, Folin–Ciocalteu reagent, Gallic acid (standard) Sodium carbonate (Na_2CO_3) solution, Distilled Water, etc.

I.4. Methods

I.4.1. Experimental Design

The formulation was carried out using a full factorial design with one factor (tomato peels) and three concentration levels. The objective was to study the effect of tomato peel concentration on the properties of pasta. The details are mentioned in the table below

Table N°2: Experimental design matrix

Factors	Concentration level		
Water	**60%**		
Tomato peels powder	**Min 10%**	**Center 15%**	**Max 20%**
Samples	**P1**	**P2**	**P3**

I.4.2. Process of preparation of Tomato peels powder

The preparation of tomato peel powder involves several key steps to ensure the preservation of its functional nutrients, such as lycopene (see the diagram N°1).

- First, the tomato peels are collected during the tomato crushing process.
- Then, the seeds are removed through sorting.
- The peels are washed thoroughly three times to eliminate impurities, followed by filtration to remove excess water.
- Next, the peels undergo drying for 2 to 24 hours at a controlledtemperature of 45°C, which helps preserve sensitive nutrients like lycopene.
- After drying, the peels are finely ground into powder.
- To ensure microbiological safety, the powder is sterilized using UV treatment.
- Finally, the powder is packaged, preferably in glass bottles, to protect itsantioxidant properties and maintain product quality.

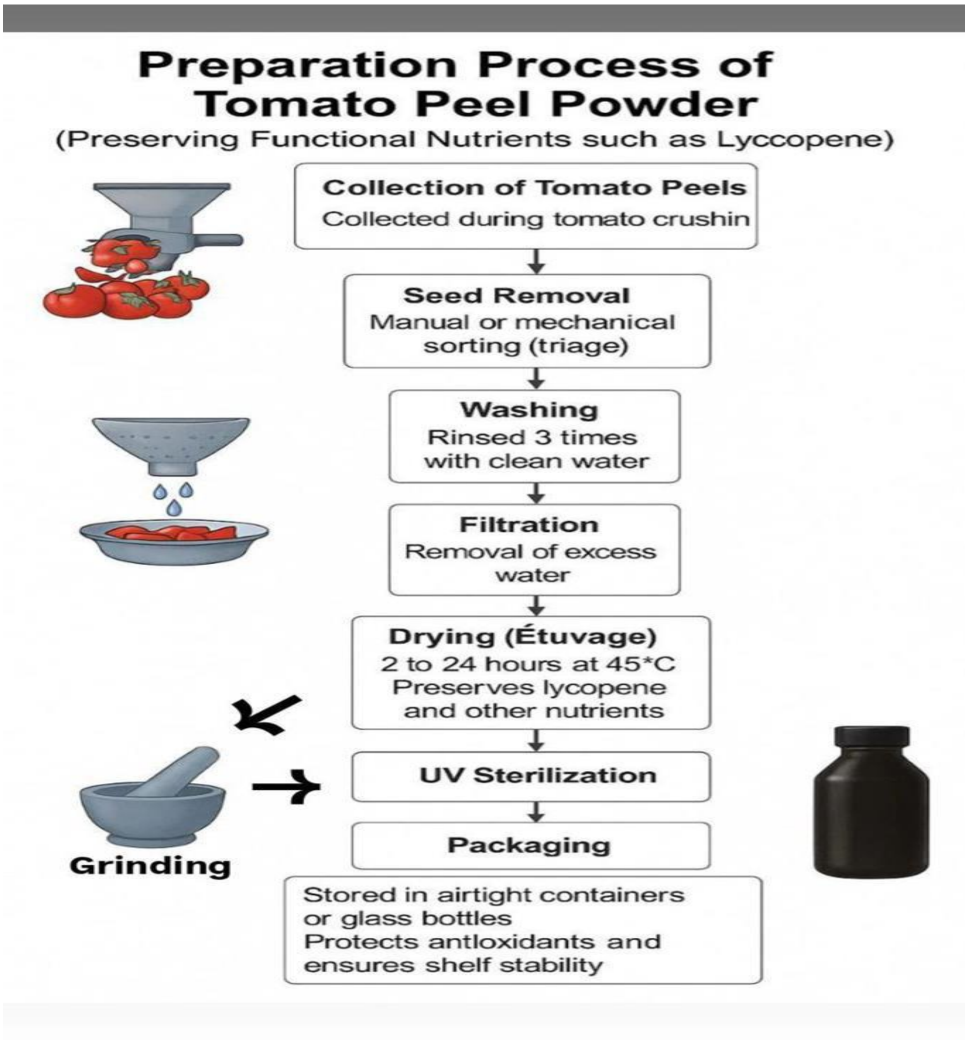

Figure N°6: Preparation Process of Tomato peels powder

I.5. Process of formulation of pasta incorporated of tomato peels

The manufacturing process of pasta enriched with tomato peel includes a set of steps similar to that of commercial industrial pasta except that the tomato peel powder was added at concentrations fixed by the experimental plan applied to this study; the details are mentioned in the figure below.

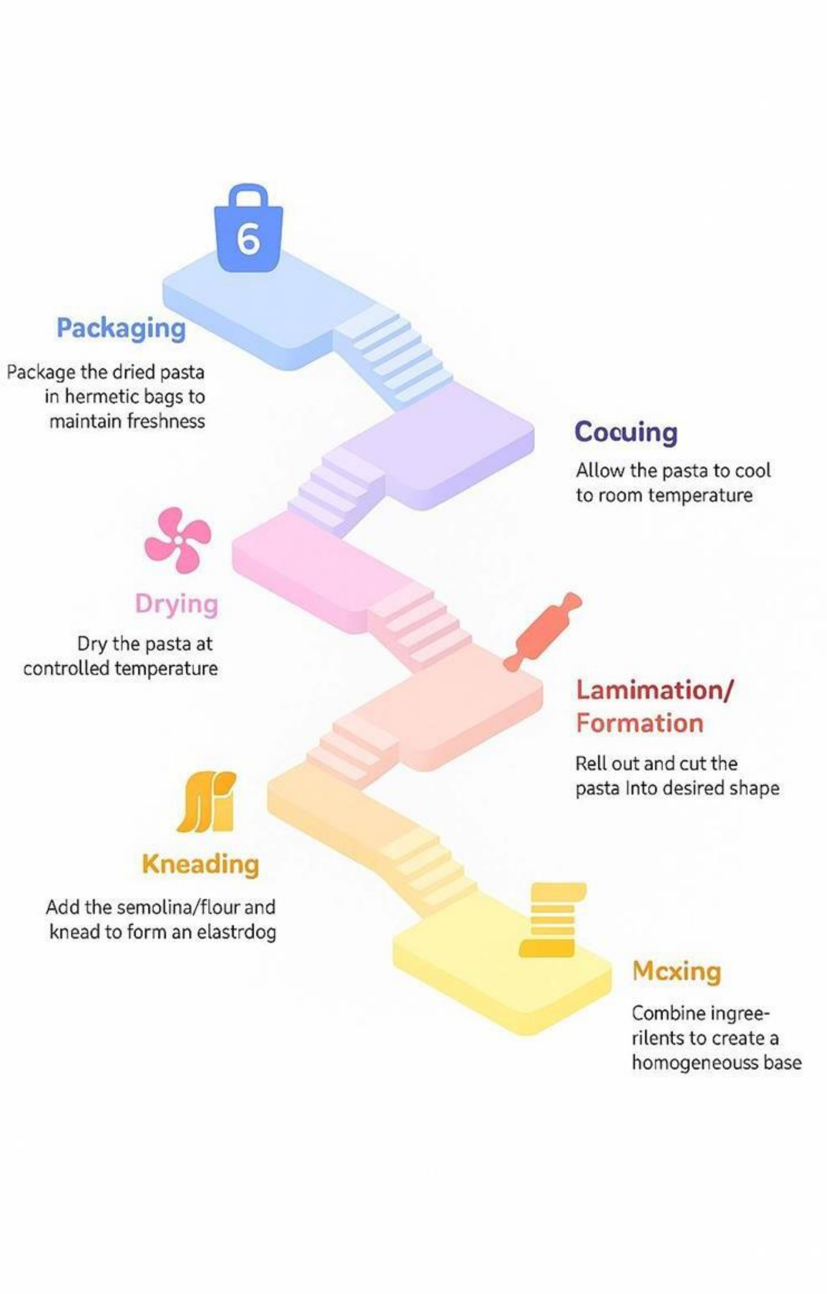

Figure N°7: Diagram of Pasta Fabrication (Sopi 2015)

I.6. Control of raw materials

I.6.1. Physicochemical control of Semolina

I.6.1.1. Determination of particle size

The method used is based on the AFNOR standard reference NF V03-703 of September 1997.

Principle:

The sizing of semolina particles is very important to achieve good hydration because hydration capacity depends on the surface area of the particles in contact with water and the homogeneity of the particles. Fine particles absorb water more quickly than coarse ones; therefore, it is necessary to measure the particle size composition of semolina before processing it into pasta**.(Arvaniti et al., 2014)**.

Apparatus:

→ Balance accurate to within 1 mg

→ 500 µm, 450 µm, 355 µm, 280 µm, 160 µm sieves

→ Sieve bottom

→ Laboratory plansifter.

Procedure:

- Utilize a 0.01 g balance to weigh out 100 g of semolina.
- After this, use a laboratory scale to dump the sample into the first sieve, which should have a total extraction of 500 µm mesh size.
- After that, close the lid tightly and get ready to start the operation for 5 minutes.
- After that, record the quantity of residue left on all of the sieves and track the extraction noted within the 280 µm sieve; this should be the SSSE (Semolina Smaller than Sieve Extraction at 280 µm).

I.6.1.2. Determination of color indices of semolina

The color of durum wheat semolina is a determining factor in the organoleptic quality of semolina and pasta. It is one of the characteristics to which consumers seem to attach great importance.

This involves assessing the color of semolina, which is characterized by two components: the brown index and the yellow index, using a spectrophotometer**. (Fratianni et al., 2005)**

1. **Purpose:**

The interest of the measurement is primarily commercial, the higher the yellow index, the more attractive and of high commercial quality.

2 Equipment:

▪ MINOLTTA spectrophotometer.

These conditions are those adopted by the International Commission on Illumination (C.I.E.).

3. Procedure:

Place approximately 50 g of semolina in a glass beaker, mix thoroughly, place the sample under the light source, and press the "measure" button. Ten successive measurements are taken, rotating the sample a quarter turn before each reading to limit the effects due to the heterogeneity of reflection on an uneven surface.

- **Expression of results:**

The results are expressed in the L, b system under the conditions adopted by the International Commission on Illumination (CIE).

Where:

- B.I: brown index.
- Y.I: yellow index
- L: lightness.
- B. I =100-L
- Y. I=b

➤ The more yellow the semolina, the higher the b index.

I.6.1.3. Determination of Dry Gluten Content by Rapid Drying

➤ **PURPOSE:**

The purpose of this procedure is to define the method to be followed to determine the quantity of gluten in flour and fine semolina.

➤ **SCOPE OF APPLICATION:** This procedure applies to flour and fine semolina samples collected during the production process of SARL SOPI.

➤ **Tools:** To measure the dry gluten residue obtained from dried wet gluten (DGS), a heating plate device (Glutork) is used. It consists of two plates coated with a non-stick material. An analytical balance accurate to 0.01 g is also required.

➤ **Operating Procedure:**

- Once the GREEN light on the glutork is on, open it and place the wet gluten ball in the center. Close the glutork and press it.
- the Glutimer light goes out, open the glutork.
- Remove the disc (the dried gluten) and weigh it to the nearest 0.01 g.

➤ **Expression of results:** The dry gluten content is the percentage of dried gluten obtained from the initial sample:

$$GS\% = Ms / M \times 100$$

Ms: mass of dry gluten

M: mass of the initial sample

I.6.1.4. Determination of the Swelling Index

Materials: Stopwatch Drinking Water, Balance accurate to 0.1g.

- **procedure:**

•Weigh 50g ±0.5g of semoulina.

•Empty by gravity into the test tube; V_1 is the occupied volume value read on the test tube.

•Fill a test tube with 200ml of drinking water.

•Quickly pour the test portion into the test tube.

•Stir two to three times; then place the test tube in place and start the stopwatch.

After 30 min ± 1 min, record the volume V2.

- **Expression of results:**

Swelling index, noted GI, after 30 min, is expressed as follows:

$$GI = V2 / V1$$

V1: Initial volume

V2: Volume after 30 min

I.6.1.5. Determination of Ash Content

- **Definition:**

An incombustible residue obtained from incineration using the procedures described in the method of **Algerian Standard NA733/1990.**

- **Principle:**

Burn a test sample until all organic residues are lost and weigh the resultant residue.

The residue is pulverulent after incineration at 550°C, while at 900°C it is glassy (Appendix VI)

- **Procedure:**

All tests will be done in triplicate.

- Heat the baskets for 15 minutes in the oven at 550 degrees centigrade.
- Balance your scales and set precisely 5 to 6 grams of semolina or wheat encapsulated in a baking dish with lid that has already been weighed.

- The dishes as well as their constituents are placed on the edge of the oven which is set to 550 degrees centigrade.

- Upon completion of flambéing, the dishes can be placed inside the oven with tongs.

➢ **Expression of result:**

The ash content is expressed as a percentage of the dry matter of the test sample, calculated using the following formula:

Ash content (%)= [(M1-M0)/ M] *100

Where:

- M0= mass of the empty dish (g)
- M1 = mass of the dish + ash after incineration (g)
- M= mass of the initial test sample (g)

I.6.1.6. Determination of moisture content

The moisture content of a sample corresponds to the amount of water it contains. It is determined by drying, that is, by heating the sample at 105 °C until a constant weight is achieved.

a) **Operating Procedure: AOAC (2016).**

Official Methods of Analysis of AOAC:

• Weigh a clean, empty crucible (recorded as P_0).

• Add approximately 5 g of a homogeneous sample (chicken or plant powder), then weigh again (recorded as P_1).

• Place the crucible containing the sample in an oven at 105 °C for 24 hours.

• Remove the crucible, place it in a desiccator to cool for 15 to 30 minutes, then weigh (recorded as P_2).

b) Moisture Content Calculation

• Moisture content (%) = $(P1-P2) / (P_1 - P_0) \times 100$

Where:

- **P_0**: mass of the empty crucible
- **P_1**: mass of the crucible + sample before drying
- **P_2**: mass of the crucible + dry sample after drying

I.6.1.7.pH of semolina

To determine the pH of semolina, you need to prepare a water extract of the semolina and then measure its pH using a pH meter. Here's a standard procedure commonly used in food analysis (ISO 7305:1998) :

Weigh 1 gram of semolina and place it into 10ml of distilled water

Stir thoroughly for 30 minutes at room temperature (use a magnetic stirrer or manually).

Let the mixture settle or filter it to remove solid particles (some protocols prefer measuring the supernatant or filtrate).

Calibrate the pH meter with standard buffers (pH 4.0 and 7.0 or 10.0).

Then insert the electrode into the semolina-water mixture or supernatant and record the pH.

I.6.2. Tomato Peels Control

I.6.2.1. Total Polyphenols content

- **Extraction of Polyphenols:**

a) Preparation of the extract:

The extraction of polyphenols tomato peels powders was carried out according to **Ngondo Blaise Pascal *et al.* (2023); Pascal, N. B., Joseph, M., &Attibayeba, M. N. C. (2023).**

- 0.1 g of powder was extracted in 10 ml of methanol.
- The mixture was stirred for 1 hour, then filtered.
- The extract was diluted at a 1:4 ratio (2 ml of extract + 8 ml of distilled water).

b) Preparation of the reaction mixture:

In a test tube:

- 0.2 ml of diluted extract
- 1.8 ml of distilled water
- 1.8 ml of diluted Folin–Ciocalteu reagent → wait for 5 minutes
- 0.2 ml of 7.5% sodium carbonate → mix using a vortex
- The test was performed in triplicate for each sample.

c) Incubation:

- 2 hours at room temperature, protected from light.

d) Reading:

- Absorbance was measured at 725 nm using a spectrophotometer.
- Results are expressed as gallic acid equivalents (GAE).

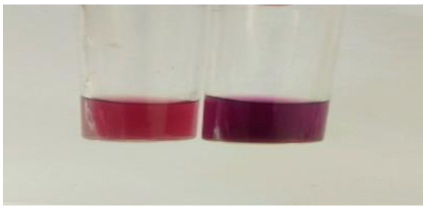

Figure N°8: Tomato Peel Extract

I.6.2.2. ADPPH antioxidant activity assay

The antioxidant activity assay of tomato peels powder was investigated with DPPH using UV-Visible spectrophotometer

1. **Procedure:**

The extraction of polyphenols from tomato peels powder was conducted as mentioned in previous section (I.6.2.1.a.).

The evaluation of antioxidant activity using DPPH was done following the protocol of Nabi et al. (2023).

• The solution of DPPH was prepared by dissolving 40 mg of DPPH in 100 g of methanol.

2. **Test**

• In a test tube, 1ml of each sample extract was added to 3 ml of DPPH and mixed.

• Capture capacity was measured at 515 nm with a spectrophotometer UV-Visible and compared to the blank value after incubating the tubes for 30 minutes at room temperature in the dark.

3. **Calculation:**

Antioxidant activity is calculated using the following formula:

$$AA\% = [(A_0 - A) / A_0] \times 100$$

Where:

- A_0: absorbance of the control (DPPH + methanol)
- **A**: absorbance of the sample (DPPH + extract)

I.6.2.3. Ash content

The Ash content of tomato peels powder was measured as described in Section ***I.6.1.5***

I.6.2.4. Moisture content

The moisture content in tomato peels powder was measured as described in Section ***I.6.1.6.***

I.6.2.5. pH

pH Of tomato peels powder was measured as described in Section ***I.6.1.7.***

I.6.3. Control of Chlorine level in process water

In the pasta-making business, process water shows up everywhere-from mixing the dough to rinsing machines and cooling hot lines-so its quality matters at every step. The measure of chlorine content was done according to WHO Guidelines **(2017).**

Principle of the standard method: DPD reacts with chlorine to produce a pink color, which is measured spectrophotometrically or visually using a color comparator.

- ✓ **Measured with**: Colorimeter or spectrophotometer (at 515 nm).
- ✓ Use a calibration curve or comparator chart to determine chlorine concentration
  Units: mg/100ml.

I.7. Functional and technological properties of pasta samples

The following tests were carried out on the three pasta samples formulated with different concentrations of tomato peel: P1 (10%), P2 (15%), and P3 (20%).

I.7.1. Cooking test

Procedure:

- Turn on the hotplate by setting the power knob to 1500W.
- Place the steel container containing 1L and 300ml of water on the hotplate.
- Bring to a boil, then add the sample and start the timer.
- Leave the container closed for the first minute.
- During the remaining time, move the lid slightly to the side.
- Stir with a fork 3 times for 10 seconds during cooking.

I.7.2. Determining the optimal cooking time (OCT)

2 minutes before the cooking time indicated on the package (or based on the standard cooking time assigned to the size), take a piece of pasta:

○Crush it between the crushing pads (for long, solid sizes).

○Cut at right angles with a knife (for short, hollow sizes).

- Repeat this process every 30 seconds until the visible white line in the center disappears.
- Once the pasta is cooked, cool the pasta (water + pasta) by adding 200 ml of tap water to the container.
- Immediately pour the pasta into a colander and drain by tapping the colander 3 times in 5 seconds.
- Place on a plate and let rest. After 5 minutes, evaluate the results.

I.7.3. Water and OIL Absorption Capacity (WAC- OAC)

- **Procedure:**

In this method, 1 g of sample was allowed to mix with 10 mL of distilled water for about 30 s. Sample was then allowed to stand at room temperature (25 ± 2 _C) for the next 30 min and centrifuged at 3,000 rpm (30 min).

The same procedure is conducted for OAC

- **Calculation**

Volume of the supernatant was determined and OAC and WAC (mg/mL) were calculated by formula

WAC=Vinitial _ Vfinal, where V is the volume of water (mL).

OAC=Vinitial _ Vfinal, where V is the volume of OIL (mL).

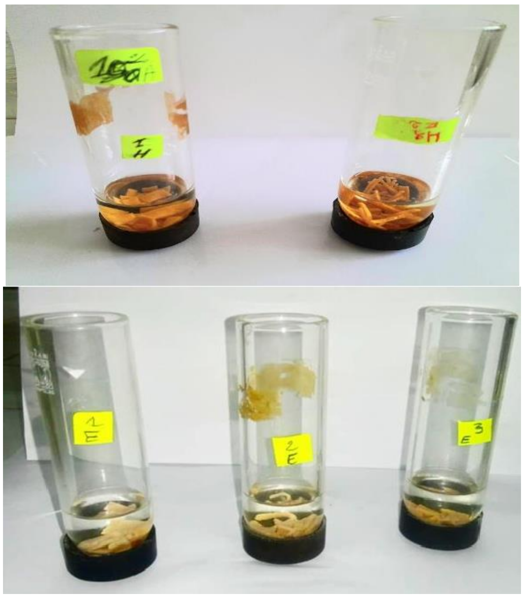

Figure N°9: Oil and water absorption capacity test

I.7.4. Antioxidant Activity percentage

Antioxidant Activity percentage of pasta samples was measured as described in Section I.6.2.2.

I.8. Sensory evaluation

A sensory evaluation was conducted with a panel of thirty tasters, both male and female, aged between 20 and 55 years. Among them, ten were experts in pasta production and quality control from the SOPI MAMA processing unit, where the evaluation was held. The aim was to determine the most acceptable pasta formulation enriched with tomato peel powder. The samples tested included P1 (10%), P2 (15%), and P3 (20%) tomato peel powder.

Each participant was given a detailed evaluation sheet to rate key sensory attributes: color, odor, texture, and overall acceptability. A final score out of 10 was assigned to each product. This structured approach allowed for the objective comparison of the samples and the selection of the most preferred pasta formulation.

II. Results and discussion

II. Results and discussion

II.1. Control of raw material

I.1.1. Semolina color index

The Yellow Index (YI) critically assesses the visual and commercial quality of semolina by quantifying its natural yellow pigments, chiefly carotenoids such as lutein. Consumers generally favor a higher YI, indicating richer pigmentation and the desirable golden appearance in pasta.

Our measured YI of [20] corresponds to a [moderate] yellow intensity. These results are close to those reported by Brahami et al. (2021) and Saia et al. (2022), who found values of 17–25 and 20–27, respectively. Relative to these benchmarks, our YI is comparable, indicating a satisfactory level of natural pigmentation. Maintaining a high YI is important not only for aesthetic appeal but also for nutritional value, as carotenoids act as antioxidants. However, YI can be influenced by factors such as wheat variety, storage conditions, and heat generated during milling (Zhao et al., 2023).

II.1.2. Physicochemical control of Raw Materials Used in Pasta Formulation

Figure N° 10 presents the physicochemical characteristics of the three raw materials (semolina, process water, and tomato peels powder), including pH, moisture content, and ash content. For process water, the chlorine content was also determined. In addition, the particle size and swelling capacity of semolina were evaluated to better characterize its functional properties.

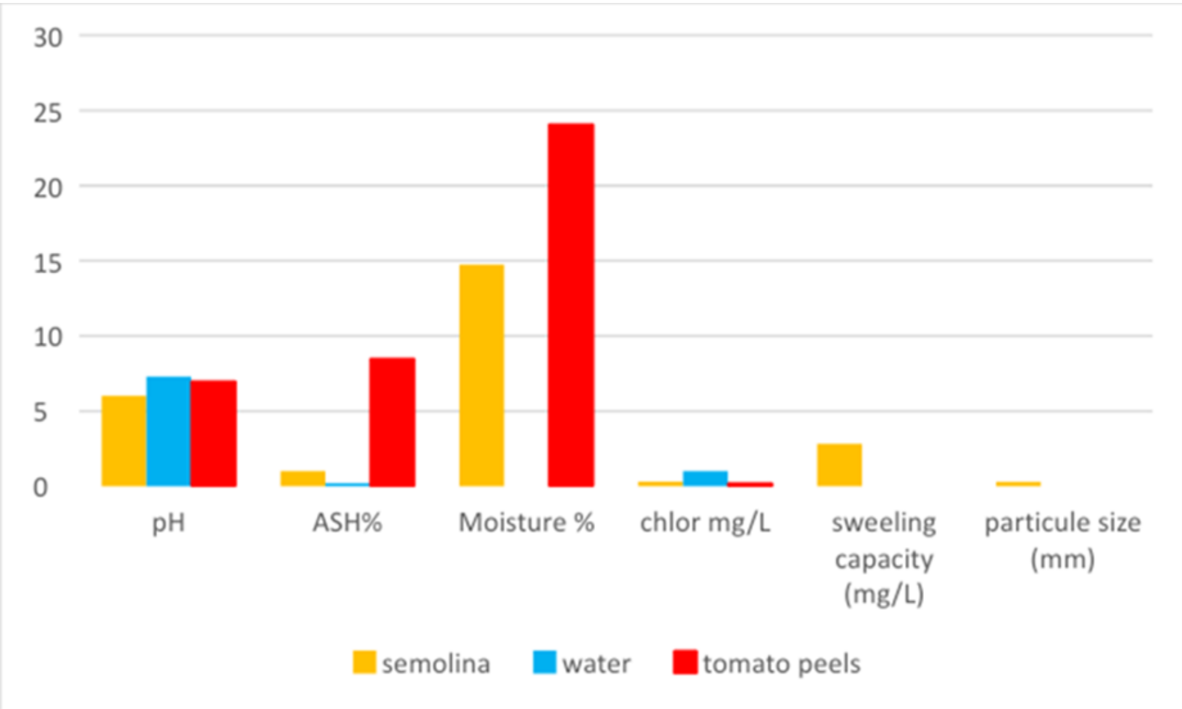

Figure N°10: Physicochemical Properties of Raw Materials Used in Pasta Formulation

II.1.2.1. pH.

- Semolina has a slightly acidic to neutral pH around 6.0, within the acceptable range for cereal-based products.
- Water and tomato peel powder both show near-neutral to slightly alkaline pH (7.9–8.0).
  This neutral-to-alkaline range for tomato peels is consistent with the findings of Aydemir et al. (2022), who reported that dehydrated tomato by-products exhibit pH between 7.5 and 8.2, depending on processing and variety. A higher pH in water may indicate low microbial activity and good quality, which is important for industrial processing (Kumar et al., 2015).

II.1.2.2. Ash Content

The ash content was approximately 8.5% in tomato peel powder, 1.0% in semolina, and 0.2% in process water.

Ash content reflects total mineral composition, which is much higher in tomato peel due to the presence of potassium, calcium, magnesium, and trace elements.

According to Pagani et al. (2012) and Ferrise et al. (2019), high ash content in raw materials enhances nutritional value but must be controlled to avoid negative sensory effects in final products.

This result makes tomato peel a valuable mineral-rich supplement in functional foods.

II.1.2.3. Moisture Content

- Regarding the results; Semolina has the highest moisture content (~13.5%), which aligns with regulatory standards (typically 12–15%).
- Tomato peel powder retains moderate moisture (~10.5%), which is normal for dried plant powders.

Lower moisture in tomato peel enhances its shelf stability. As per Zanoni et al. (2010), moisture under 12% ensures microbial safety in dried food products.

II.1.2.4. Chloride Content in process water

- Water shows the highest chloride concentration (~2 mg/L), which may reflect residual ions from municipal treatment or mineral content.This value is well below the maximum allowable limit set by Algerian standards (JORA), which is 200 mg/L for drinking water. Such a low level may reflect a minimal presence of residual ions from municipal treatment or naturally low mineral content.
- Semolina and tomato peel powder show very low levels, indicating no significant salt contamination in the solids. According to Cappa et al. (2017), low chloride in raw materials is desirable to avoid taste alteration and preserve product integrity.

II.1.2.5. Swelling Capacity for semolina

The result of swelling index of the fine semolina sample used for pasta formulation was 2.84 mL/g, which falls within the moderate range of typical values reported for durum semolina (generally 2.5–4.5 mL/g). This value suggests that the semolina has a reasonable water absorption capacity, which is essential for proper gelatinization during cooking. According to Carpentieri et al. (2024), semolina with moderate swelling behavior tends to form pasta with good textural integrity and lower stickiness, characteristics desirable in premium pasta products. Similarly, Patel et al. (2022) reported swelling index values between 1.98 and 2.90 mL/g when semolina was enriched with functional ingredients, highlighting that values in this range are considered suitable for maintaining both hydration and firmness.

Although swelling index can also be influenced by factors such as protein content and particle size, the result of 2.84 mL/g indicates that the semolina likely supports balanced cooking performance, making it well-suited for various wheat-based food applications.

II.1.2.6. Particle Size Distribution of Semolina

A particle size of 280 µm was recorded for the semolina sample, which falls within the typical range for standard durum semolina (250–450 µm), commonly used in pasta and couscous production. According to Carpentieri et al. (2024), semolina in this size range provides a good balance between hydration rate and structural integrity, leading to doughs with firm texture and controlled starch release during cooking. Additionally, Bouasla et al. (2022) also noted that semolina with particle sizes around 280–300 µm are ideal for producing pasta with desirable cooking quality, as they allow for uniform water penetration without excessive surface stickiness.

Farthermore, Patel et al. (2023) observed that coarser semolina particles tend to reduce swelling capacity compared to finer ones, which aligns with a more compact and elastic dough structure.

Therefore, a particle size of 280 µm suggests that the semolina is well-suited for high-quality pasta production, offering a good compromise between hydration behavior and mechanical strength in the final product.

II.1.2.7. Overall Discussion of Physicochemical Properties

These physicochemical differences are important when considering ingredient compatibility and food safety:

- Tomato peel powder, with its high ash and moderate moisture, is a nutrient-dense additive that also provides natural color and antioxidants (Garcia et al., 2019).
- However, its high ash content should be carefully dosed in formulations to avoid texture issues and off-flavors (Martinez et al., 2020).
- The moisture content of semolina ensures good processability for pasta but must be monitored to avoid microbial growth. The values here are within safe ranges as per FAO standards.
- pH neutrality across all samples indicates microbiological stability, essential in dry and semi-dry food systems. Reale et al. (2021) note that stability in pH reduces fermentation risk during storage.

II.1.2.8. Evaluation of Antioxidant Potential and Total Phenolics in Tomato Peel Powder

Figure N° **11** illustrates the antioxidant activity (measured by the DPPH method) and total phenolic content of tomato peel powder samples, expressed as percentages and mg GAE/g, respectively.

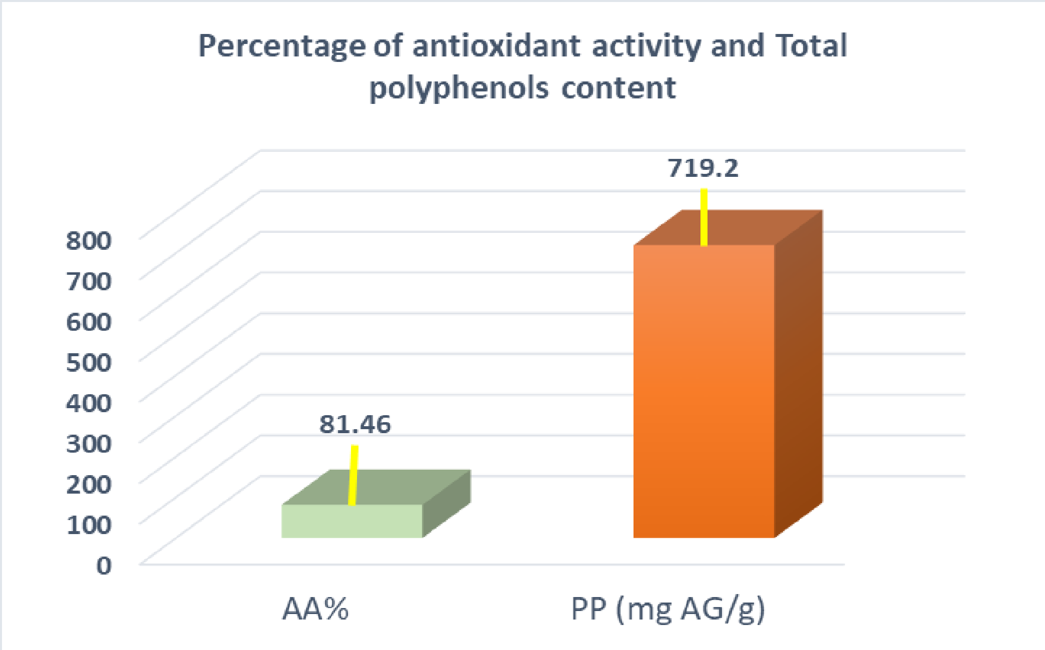

Figure N°11: Phenolic Content and Antioxidant Capacity of Tomato Peel Powder Samples.

The results obtained from our analysis indicate exceptionally high values for both antioxidant activity (AA%) and total polyphenol content (PP) in the tomato peel extract. Specifically, the antioxidant activity reached 81.46%, while the total polyphenol content measured approximately 719.2 mg AG/g. These values reflect the strong functional potential of tomato peel as a natural antioxidant-rich ingredient.

When compared to the findings of NinčevićGrassino et al. (2019), who reported total phenolic contents ranging from 248.5 to 406.4 mg/ g of tomato peel, the difference is significant.

Our recorded value is nearly two orders of magnitude higher. In parallel, Salem et al. (2020) reported a total polyphenol content of 848.52 mg AG/g in tomato peel extracts, which is even higher than our findings, reinforcing the notion that tomato by-products can yield rich concentrations of phenolic compounds when optimized extraction techniques are applied.

Similarly, another study recorded a total polyphenol content of 483.5 mg AG/g, which, while lower than our result, still demonstrates significant bioactive potential. The variation among studies highlights the importance of extraction parameters, raw material origin, and analytical methods in influencing the final yield of phenolics.

The antioxidant activity recorded in our extract (~81%) is consistent with data reported in similar works, such as Ouatmani et al. (2019), who recorded around 78% activity for tomato seed phenolic extracts. Taken together, these findings support the valorization of tomato processing by-products in the development of functional ingredients. Our extract, with its high polyphenol concentration and antioxidant activity, can serve as a powerful additive in the formulation of health-oriented foods or nutraceuticals.

II.2. Functional and technological properties of pasta samples

Figure N°12 presents a bar chart showing the results of antioxidant activity (AA%), cooking time, oil holding capacity, and water holding capacity for the three tomato peel pasta samples containing 10%, 15%, and 20% tomato peel powder, respectively.

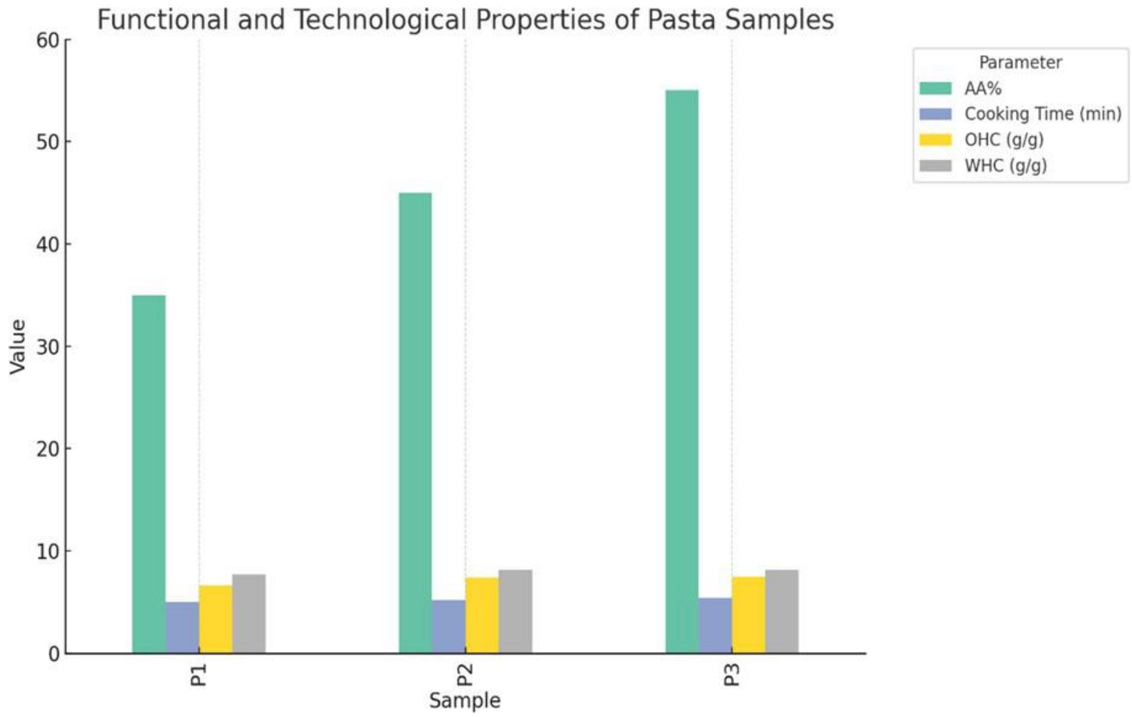

Figure N°12: Antioxidant Activity, Cooking Time, and Holding Capacities of Pasta with Tomato Peel Powder.

II.2.1. Antioxidant Activity percentage

Antioxidant capacity increases linearly from P1 to P3 (35% → 55%).

This is attributed to the progressive incorporation of polyphenol-rich tomato peels and psyllium, both known for their antioxidant properties.

This finding is consistent with the results of Aydemir et al. (2022) and Barros et al. (2010), who reported that tomato by-products are rich in potent antioxidants such as lycopene, flavonoids, and phenolic acids, which contribute to enhanced antioxidant activity in food products.

II.2.2. Cooking Time

The cooking time increases moderately from 5.0 min (P1) to 5.4 min (P3).

This rise reflects a denser and more hydrated matrix due to the hydrophilic fibers present in enriched samples. Likewise, Padalino et al. (2013) observed similar effects in pasta enriched with vegetable fiber, explaining that increased water absorption delays starch gelatinization and protein softening.

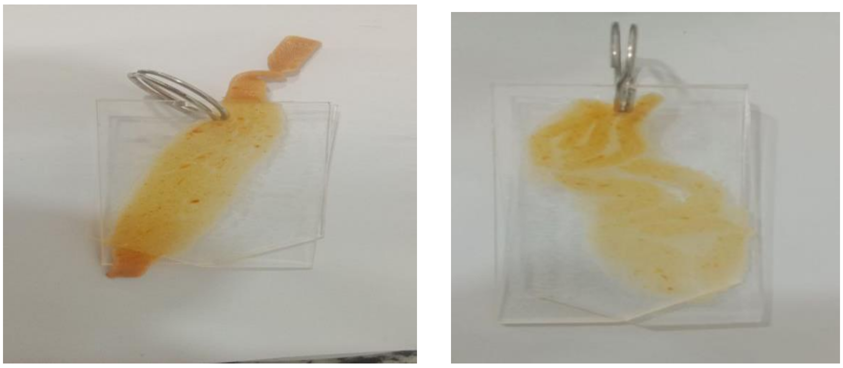

Figure N° 13: Test for Pasta Doneness: Sample Placed Between Glass Slides for Visual Assessment

II.2.3. Oil Holding Capacity (OHC)

Results shows that OHC increased with enrichment, from 6.64 g oil/g in P1 to 7.44 g oil/g in P3. This is advantageous for flavor retention and textural performance, particularly in pasta served with oil-based sauces.

Gómez et al. (2012) found that dietary fibers from vegetable sources enhance the emulsifying and fat-binding capacities of food matrices, thus improving mouthfeel.

II.2.4. Water Holding Capacity (WHC)

According to the results, WHC increases from 7.72 to 8.15 g water/g across the samples.

High WHC is important for dough elasticity, moisture retention during drying, and shelf-life stability. Mastromatteo et al. (2012) noted that the addition of insoluble fibers (like those from tomato peel) significantly boosts WHC without compromising product integrity.

II.2.5. Overall Discussion of functional and technological properties of pasta samples

The histogram demonstrates a positive correlation between functional enrichment and technological improvement in pasta products:

Antioxidant enhancement not only improves nutritional quality but also contributes to oxidative stability during storage.

The moderate increase in cooking time remains within acceptable sensory thresholds and does not hinder consumer convenience.

Improvements in OHC and WHC support product performance in terms of texture, mouthfeel, and rehydration, which are keys factors for consumer satisfaction.

These results are consistent with recent research: Reale et al. (2021) Found that enriched pasta with vegetable co-products showed improved WHC and antioxidant retention after cooking. Similarly, Milczarek et al. (2018) Highlighted that fiber-rich by-products help maintain microbiological and textural stability in cereal-based formulations. Martinez et al. (2020) Confirmed that moderate inclusion of antioxidant-rich by-products does not negatively affect the sensory or cooking characteristics of pasta.

II.3. Sensory evaluation of pasta formulated with tomato peels powder

The results of this evaluation are presented in the form of a bar chart see Figure N°14 showing the average scores given to each pasta sample (P1, P2; P3) for color, odor, texture, and overall acceptability.

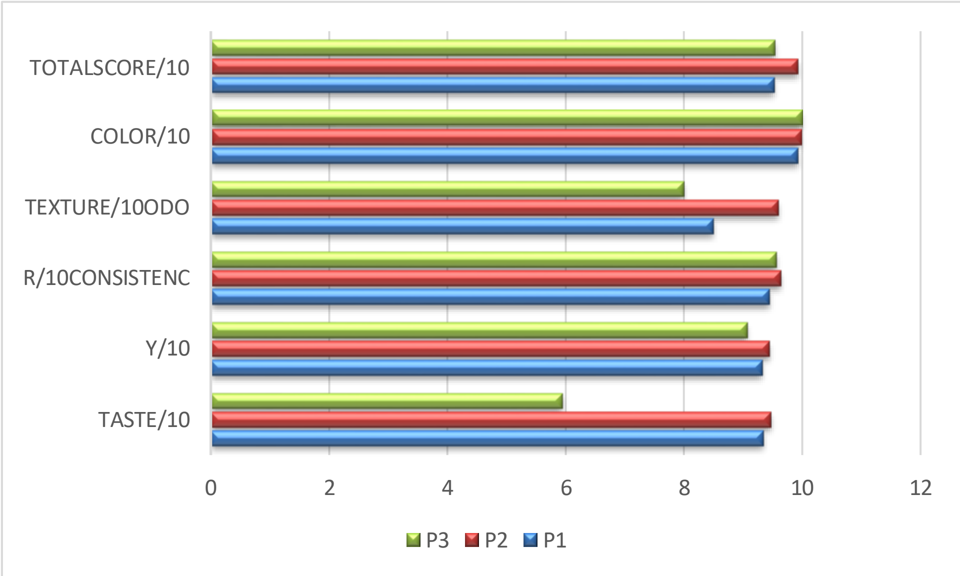

Figure N°14. A bar chart showing the Organoleptic test results of the three simples of the pasta.

The results reflect how ingredient variation particularly the incorporation of tomato peels affects the organoleptic quality of the final product.

- Sample P2 (15% TPP) exhibited the highest overall average score (9.63/10), with nearly perfect scores in color (9.98) and odor (9.64), and excellent ratings in taste and consistency (both 9.45). This sample appears to achieve the best balance between functional enrichment and sensory acceptability. The high color score is likely due to the presence of lycopene, a naturally occurring red pigment in tomato peels, known for its strong antioxidant properties and visual appeal (Aydemir et al., 2022).
- This outcome aligns with the findings of
- Padalino et al. (2017), who observed that incorporating 15 % tomato peel into pasta significantly enhances color and consumer-perceived freshness. Additionally, Martinez et al. (2020) reported that enrichment with antioxidant-rich tomato by-products improves both appearance and odor without negatively affecting taste when used in moderate concentrations.
- Although Sample P3 achieved perfect color (10.00) and high odor (9.57) and consistency (9.07), it received a significantly lower taste score (5.95). This discrepancy suggests that despite good visual and aromatic properties. Gómez et al. (2012) confirmed that incorporating vegetable fibers (from tomato, beetroot, or carrot) can negatively affect the taste of cereal-based products, especially at higher doses, even while improving texture and color.
- Furthermore, Martinez et al. (2021) highlighted that functional enrichment with fiber and phenolics can

impact flavor perception if not carefully dosed.

- Sample P1 achieved a strong overall score of 9.53, with excellent ratings in taste (9.35), odor (9.45), and color (9.93). While slightly lower than P2 in color and odor.

The incorporation of 10% tomato peel into the pasta did not result in a noticeable or appealing color change. This level of enrichment was insufficient to clearly indicate to consumers that the pasta had been fortified with tomato peel. Similar findings were also reported by Kadri et al. (2024).

II.4. Application of HACCP in pasta formulated with tomato peels powder

In the context of sustainable food innovation and waste valorization, this study explores the incorporation of tomato peel a by-product of the tomato processing industry into pasta formulation.

In our formulation, we successfully incorporated tomato peel powder into pasta dough, following precise measurements and hygienic conditions at every stage.

All handling, formulation, and processing steps were carried out with strict adherence to quality standards and HACCP principles, ensuring the reliability of the results. The outcomes of this study reflect the effects of tomato peel incorporation on the organoleptic, physical, and microbiological quality of pasta.

II.4.1. Advantages of Incorporating Tomato Peel

- **Improved Nutritional Value:**
  Tomato peel is rich in dietary fiber, antioxidants (like lycopene and polyphenols), and micronutrients, which enhance the nutritional profile of pasta.
- **Enhanced Functional Properties:** Incorporating tomato peel improves water-holding and oil-holding capacities, which can benefit the texture and shelf life of the pasta.
- **Color Acceptability:** The natural red pigment of tomato peel gives pasta an attractive, vibrant color, which may appeal to consumers looking for healthier or gourmet options.
- **Taste and Flavor:** Tomato peel can add a mild, pleasant tomato flavor that may enhance the overall sensory experience of the pasta.

II.4.2. Risks and Challenges Identified (Based on HACCP Principles)

According to the literature, adding tomato peel powder at levels ≥ 25% can negatively affect the texture of pasta, making it gritty or coarse.

Quality Concerns: The acidity of the pasta may increase due to the natural acids present in tomato peel, which could alter the taste and require pH monitoring or correction.

Physical Hazards: There is a risk of contamination by physical residues such as dirt, stones, wood fragments, or plant debris if the peel is not properly cleaned and sieved.

Chemical Hazards: Tomato peels may contain residues of pesticides or insecticides, especially if sourced from conventionally grown tomatoes. Proper washing and sourcing from safe suppliers is critical.

Biological Hazards: If the tomato peels are not properly dried and stored, they may promote the growth of microorganisms such as bacteria, molds, or yeasts, posing food safety concerns.

Table N°3: Hazard Analysis in the Formulation Process of Tomato Peel-Enriched Pasta

Hazard Type	Specific Risk	Degree of Danger (1–10)
Organoleptic	Texture defect (≥ 25% tomato peel)	6
	Change in taste/flavor (too sour or strong)	4
Quality	Increase in acidity	5
Physical	Dirt and soil particles in peel	3
	Stones or wood residues	4
Chemical	Pesticide/insecticide residues	7
Biological	Growth of microorganisms (mold, bacteria)	8
Functional	Poor oil/water absorption if peel is too coarse	3
Consumer Accept.	Color too dark or undesirable	2

II.4.3. Corrective and Preventive Measures in the HACCP Plan for Tomato Peel-Enriched Pasta

To ensure the safety, quality, and consumer acceptance of pasta enriched with tomato peel, the following practices are recommended:

- **Raw Material Safety**: Ensure proper washing, visual inspection, and microbiological testing of tomato peels. Source only from certified suppliers to minimize chemical contamination risks.
- **Controlled Incorporation Levels**: Limit tomato peel addition to below 25% to maintain acceptable texture and sensory properties. Use trial batches to determine the optimal level.
- **Decontamination Processes**: Apply sterilization methods such as steam treatment, drying at ≥60°C, or UV-C exposure to reduce microbial and biological hazards.
- **Physical Hazard Control**: Use sieving and mechanical sorting after grinding to eliminate foreign particles like stones or wood fragments.
- **Moisture and Shelf-Life Management**: Dry peel powder to <10% moisture and store in cool, dry, airtight conditions. Use desiccants and vacuum-sealed packaging when possible.
- **Process Optimization**: Monitor dough pH and adjust with natural buffering agents if necessary. Use sensory and consumer testing to validate product acceptance before scaling up.

Conclusion

This study demonstrates that tomato peel powder, an underutilized by-product of the tomato processing industry, can be successfully incorporated into pasta to improve its nutritional, functional, and sensory properties. The enriched pasta exhibited enhanced antioxidant activity, improved water and oil retention capacities, and an attractive natural color—particularly at 15% inclusion rate, which proved to offer the best compromise between enrichment and palatability.

By adhering to HACCP principles throughout the process, the formulation ensured product safety and compliance with food quality standards. Critical control points—including raw material selection, microbial decontamination, and dosage limits—were identified and mitigated to support product integrity. Ultimately, the valorization of tomato peel through its incorporation into pasta is a promising strategy to reduce food industry waste while responding to growing consumer demand for healthier, more sustainable food options. This innovation not only enhances the nutritional profile of a globally consumed staple but also contributes meaningfully to the future of sustainable food systems.

Perspective

In light of these results, and while the quantification of potential insecticide residues is currently underway to ensure food safety, several future perspectives can be considered to support and expand the use of tomato peel powder in food applications:

- Optimize drying and milling processes to improve the bioavailability of functional compounds.
- Assess the shelf-life and storage behavior of tomato peel-enriched pasta.
- Incorporate this ingredient into public health strategies targeting micronutrient deficiencies.
- Investigate consumer perception and market acceptance on a larger scale.
- Extend applications to other cereal-based products using agro-industrial by-products.

Bibliographic References

Bibliographic References

A

1. Aider, M., & de Halleux, D. (2009). Application of UV radiation and drying for the microbial safety and shelf-life of tomato by-products. Journal of Food Safety, 29(3), 314–331.

2. Akubor, P. I., &Owuse, A. U. (2020). Chemical composition, functional and biscuit making properties of tomato peel flour. South Asian Journal of Food Technology and Environment, 6(1), 874–884. https://doi.org/10.46370/sajfte.2020.v06i01.01

3. Almeida, P. V., Gando-Ferreira, L. M., &Quina, M. J. (2024). Tomato residue management from a biorefinery perspective and towards a circular economy. Foods, 13(12), 1873. https://doi.org/10.3390/foods13121873

4. Alemayehu, D., Desse, G., Abegaz, K., Desalegn, B. B., &Getahun, D. (2016). Proximate, mineral composition and sensory acceptability of homemade noodles from stinging nettle (Urticasimensis) leaves and wheat flour blends. International Journal of Food Science and Nutrition Engineering, 6(3), 55–61.

5. Alemayhu, D., Jha, A., &Dharmendra, S. (2016). Functional and rheological properties of pasta enriched with vegetable and fruit flours: A review. Journal of Food Science and Technology, 53(5), 2151–2161.

6. Anonymous. (2022). Pasta extruder machine for macaroni processing line [Product page]. Dragon Extruder. https://www.dragonextruder.com/macaroni-processing-line/pasta-extruder.html

7. Aydemir, L. Y., Sagdic, O., &Ozturk, I. (2022). Effect of tomato processing by-products on functional and technological properties of food. Food Research International, 150, 110741. https://doi.org/10.1016/j.foodres.2021.110741

B

8. Barros, L., Ferreira, M. J., Queirós, B., Ferreira, I. C. F. R., &Baptista, P. (2010). Total phenols, ascorbic acid, β-carotene and lycopene in Portuguese wild edible mushrooms and antioxidant activities. Food Chemistry, 119(4), 1439–1446.

9. Benakmoum, A., Abbeddou, S., Ammouche, A., Kefalas, P., &Gerasopoulos, D. (2008). Valorisation of low quality edible oil with tomato peel waste. Food Chemistry, 110(3), 684–690. https://doi.org/10.1016/j.foodchem.2008.02.063

10. Bianchi, A. R., Vitale, E., Guerretti, V., Palumbo, G., De Clemente, I. M., Vitale, L., Arena, C., & De Maio, A. (2023). Antioxidant characterization of six tomato cultivars and derived products destined for human consumption. Antioxidants, 12(3), 761. https://doi.org/10.3390/antiox12030761

11. Boukid, F., Folloni, S., Sforza, S., Vittadini, E., &Prandi, B. (2021). Current trends in ancient grains-based food production: Insights into nutritional aspects and technological applications. Comprehensive Reviews in Food Science and Food Safety, 20(4), 3273–3306.

C

12. Cappa, C., Lucisano, M., &Mariotti, M. (2017). Influence of the addition of different fibers on dough properties and biscuits quality. Food Chemistry, 217, 193–200.

13. Cesari, L. (2022). A brief history of pasta: The Italian food that shaped the world. Profile Books.

14. Chandrasekara, A., &Shahidi, F. (2010). Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. Journal of Agricultural and Food Chemistry, 58(11), 6706–6714.

15. Chaparro-Hernández, S., Ruiz-Cruz, S., Márquez-Ríos, E., De Jesús Ornelas-Paz, J., Del-Toro-Sánchez, C. L., Gassos-Ortega, L. E., Ocaño-Higuera, V. M., López-Mata, M. A., &Devora-Isiordia, G. E. (2019). Effect of chitosan–tomato plant extract edible coating on the quality, shelf life, and antioxidant capacity of pork during refrigerated storage. Coatings, 9(12), 827. https://doi.org/10.3390/coatings9120827

D

16. Da Silva, D. S., Saraiva, B. R., Lazzari, A., et al. (2023). Valorisation of asparagus pruning waste as a new ingredient to improve pasta quality properties. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16738

17. Dehghan-Shoar, Z., Hardacre, A. K., & Brennan, C. S. (2011). The physicochemical characteristics of extruded snacks enriched with tomato lycopene. Food Chemistry, 125(4), 1561–1566.

18. Del Valle, J. M., Cámara, M., &Torregrosa, F. (2006). Valorization of tomato processing by-products: A review. Food Research International, 39(4), 395–401.

E

19. Eslami, E., Carpentieri, S., Pataro, G., & Ferrari, G. (2022). A comprehensive overview of tomato processing by-product valorization by conventional methods versus emerging technologies. Foods, 12(1), 166. https://doi.org/10.3390/foods12010166

20. Eslami, E., Landi, G., Benedetti, M., &Pataro, G. (2024). Economic and environmental impact analysis of innovative peeling methods in the tomato processing industry. Sustainability, 16(24), 11272. https://doi.org/10.3390/su162411272

F

21. FAO. (2020). FAOSTAT statistics database: Crops and livestock products. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat

22. FAO/WHO. (2013). Dietary protein quality evaluation in human nutrition (FAO Food and Nutrition Paper 92). Food and Agriculture Organization.
23. Feillet, P. (2000). Le grain de blé : Composition et utilisation. Éditions Quae.

24. Ferrise, R., et al. (2019). Influence of ash content on durum wheat quality and end-use products. Journal of Cereal Science, 86, 89–94.

25. Fratianni, A., Vitone, C., D'Agostino, A., Trivisonno, M. C., Falasca, L., &Panfili, G. (2023). Development of functional pasta enriched with green leafy vegetables: Impact on liposoluble compounds, nutritional, technological and sensorial quality. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16682

26. Fuad, T., &Prabhasankar, P. (2010). Role of ingredients in pasta product quality: A review on recent developments. Critical Reviews in Food Science and Nutrition, 50(8), 787–798. https://doi.org/10.1080/10408390903001693

G

27. Garcia, E., Martín, D., &Martínez, M. (2019). Effect of tomato peel powder on the quality and sensory properties of fresh pasta. Journal of Food Processing and Preservation, 43(2), e13850.

28. Gómez, B., Gullón, B., Remoroza, C., Schols, H. A., Parajó, J. C., & Alonso, J. L. (2014). Purification, characterization, and prebiotic properties of pectic oligosaccharides from tomato peel wastes. Journal of Agricultural and Food Chemistry, 62(40), 9769–9782.

29. Gómez, M., Jiménez, S., Ruiz, E., &Oliete, B. (2012). Effect of extruded wheat bran on dough rheology and bread quality. LWT – Food Science and Technology, 46(1), 102–107.

H

30. Hetzroni, A., Vana, A., &Mizrach, A. (2010). Biomechanical characteristics of tomato fruit peels. Postharvest Biology and Technology, 59(1), 80–84. https://doi.org/10.1016/j.postharvbio.2010.08.008

31. International Organization for Standardization (ISO). (1998). ISO 7305:1998: Durum wheat semolina and durum wheat flour — Determination of yellow pigment content.

K

32. Kalogeropoulos, N., et al. (2012). Chemical composition, antioxidant activity and antimicrobial properties of tomato peel extracts. Food Chemistry, 130(3), 667–672.

33. Kaur, A., Singh, A., Gupta, A., Surasani, V. K. R., & Dhaliwal, S. S. (2023). Utilisation of aquatic fern (Azolla sp.) powder for supplementing semolina pasta: Quality characteristics of produced pasta. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16582

34. Kaur, H., Bobade, H., Sharma, R., & Sharma, S. (2023). Influence of extruded whole wheat flour addition on quality characteristics of pasta. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16697

35. Knoblich, M., Anderson, B., &Latshaw, J. D. (2005). Analyses of tomato peel and seed byproducts and their use as a source of carotenoids. Journal of the Science of Food and Agriculture, 85(7), 1166–1170.

36. Kumar, P., Suri, S., & Malik, R. (2015). Evaluation of physicochemical and microbiological characteristics of wheat semolina during storage. International Journal of Food Science, 2015, Article 939167. https://doi.org/10.1155/2015/939167

L

37. Lu, Z., Wang, J., Gao, R., Ye, F., & Zhao, G. (2019). Sustainable valorisation of tomato pomace: A comprehensive review. Trends in Food Science & Technology, 86, 172–187. https://doi.org/10.1016/j.tifs.2019.02.020

M

38. Marquínez, X., & Moreno, G. (2012). Tomato peel (Solanumlycopersicum L.) colonization by the endophyte yeast Candida guilliermondii (Castellani) Langeron et Guerra. https://doaj.org/article/91455faf9f734009ba4f501f47e00e8a

39. Martinez, M. M., Gómez, M., & Navarro, A. (2020). Effect of dietary fiber enrichment on the physicochemical, functional and sensory properties of pasta. LWT – Food Science and Technology, 134, 110262.

40. Martinez, M. M., Navarro, A., & Garcia, E. (2021). Impact of antioxidant-rich ingredients on dough structure and sensory perception of functional pasta. Journal of Functional Foods, 85, 104663.

41. Mastromatteo, M., Spinelli, S., & Del Nobile, M. A. (2012). Textural characteristics of whole and fiber-enriched wheat pasta. Journal of Cereal Science, 56(2), 296–301.

42. Milczarek, M., Zadernowski, R., &Nesterowicz, J. (2018). Evaluation of nutritional quality and microbiological stability of cereal products enriched with vegetable residues. Food Chemistry, 240, 1023–1030.

43. Mortimore, S., & Wallace, C. (2013). HACCP: A practical approach (3rd ed.). Springer.

N

44. Navarro-González, I., García-Valverde, V., García-Alonso, J., &Periago, M. J. (2011). Chemical profile, functional and antioxidant properties of tomato peel fiber. Food Research International, 44(5), 1528–1535. https://doi.org/10.1016/j.foodres.2011.04.005

P

45. Padalino, L., Mastromatteo, M., & Del Nobile, M. A. (2013). Effect of tomato paste addition on the mechanical, color and sensory properties of durum wheat spaghetti. International Journal of Food Science & Technology, 48(6), 1225–1231.

46. Pagani, M. A., Lucisano, M., &Mariotti, M. (2012). Durum wheat and pasta quality. In Durum wheat: Chemistry and technology (pp. 223–261). AACC International Press.

47. Pasta fortification with tomato peel by-product: Impact on technological and antioxidant properties. (2024). Carpathian Journal of Food Science and Technology, 16(2), 169–180. https://doi.org/10.34302/crpjfst/2024.16.2.14

R

48. Radić, K., Galić, E., Vinković, T., Golub, N., &Čepo, D. V. (2024). Tomato waste as a sustainable source of antioxidants and pectins: Processing, pretreatment and extraction challenges. Sustainability, 16(21), 9158. https://doi.org/10.3390/su16219158

49. Reboul, E. (2017). Bioaccessibility and bioavailability of micronutrients and phytochemicals: Expected changes in an era of food reformulation and potential consequences for health. Food & Function, 8(1), 12–27.

50. Reale, A., Di Renzo, T., & Coppola, R. (2021). Impact of pH and moisture on microbial stability in functional pasta products. Journal of Food Safety, 41(5), e12956.

51. Rufián-Henares, J. A., & Morales, F. J. (2009). Functional value of melanoidins: In vitro antioxidant and antimicrobial activities. Food Chemistry, 114(4), 195–204.

S

52. Saini, M., Singh, A., Sharma, T., Surasani, V. K. R., Kumar, V., &Bobade, H. (2023). Enrichment of pasta with Pangasiuspangasius protein isolate for improved sustainability, nutrition, and quality. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16756

53. Silva, A. R. A., Cunha, L. M., & Lima, R. C. (2019). Optimization of functional pasta with fruit and vegetable by-products using response surface methodology. Journal of Food Processing and Preservation, 43(8), e14028.

54. Singh, G., Singh, B., Singh, A., Kumar, V., &Surasani, V. K. R. (2023). Development and characterisation of barley-based non-conventional pasta supplemented with chickpea flour. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16553

T

55. Tomažič, I., et al. (2016). Tomato processing by-products as a sustainable source of functional compounds in pasta. LWT - Food Science and Technology, 73, 152–160.

W

56. World Health Organization (WHO). (2017). Guidelines [General reference].

Z

57. Zanoni, B., Peri, C., & Bruno, D. (2010). Modelling of water activity and moisture content during pasta storage. Journal of Food Engineering, 99(4), 437–444.

58. Zhao, R., Zhao, R., Li, Q., et al. (2023). Improvement effect of different protein powder on cooking characteristics of gluten-free pasta and the establishment of quality evaluation based on principal component analysis. International Journal of Food Science and Technology. Advance online publication. https://doi.org/10.1111/ijfs.16728

Appendices

Appendices

Single-pan scales

Analytical balances

DRYERS

Muffle furnace for ash dosing

Multi-cell oven for water dosing

fra-tec Infrared: protein,……….water,..)

Glutorc for drying wet gluten

Plansifter with Sieve Particle Size .

O‘oo‘o‘o‘ **Spectro_ photo meter UV _1601**

RAW MATERIALS :

Water

Semoulina

Tomato peels **Tomato peels powder (TPP)**

Preparing Tomato Paste After mixing the raw ingredients :

1. After mixing ingredient

2. Making templates

3. Cooking Time.

4 .Organoleptique test

People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

Saad Dahlab University of Blida 1

Faculty of Natural and Life Sciences

Department of Food Science

Final Year Thesis
In Partial Fulfillment of the Requirements for the Master's Degree (Master II)
In Food Safety and Quality Assurance

OPTIMIZATION OF TOMATO PEEL INCORPORATION IN PASTA HACCP Approach and Food Safety

Conducted by:

-BOUTEBAL MOHAMED AMINE

-HADOU MOHAMED

-GHRIB MOHAMED ABDERREZAK

In front of the jury:

- President: Dr TLEMSANI A. (MCA) – University Blida 1

-Examiner: Dr BOUCHAKOUR R. (MCA) – University Blida 1

- Supervisor: Dr NABI I. (MAB) – University Blida 1

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