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Advanced Processing Techniques and Applications for Value-Added Sweet Potato Products

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Abstract Sweet potato, a versatile crop, plays a significant role in both food production and industrial applications due to its nutritional value and functional properties. This study provides a comprehensive overview of sweet potato composition, including carbohydrates, proteins, fibers, and antioxidants, and discusses the physicochemical properties influencing processing outcomes across different cultivars. Key primary processing techniques, such as washing, peeling, slicing, drying, and freezing, are examined alongside advanced methods like extrusion, fermentation, starch modification, and high-pressure processing for value-added products. Emerging innovations, including pulsed electric field technology, microwave-assisted processing, enzyme-assisted extraction, and 3D food printing, are explored for their potential to enhance production efficiency. A case study on industrial-scale sweet potato flour production is provided, covering the processing steps, quality control, and market impact. This study also addresses challenges in processing, such as seasonal variability, shelf-life limitations, and environmental concerns, with recommendations for overcoming these barriers, and concludes by highlighting future trends, including functional food development, sustainable practices, and the integration of genetic engineering to optimize processing outcomes. This study aims to provide insights for stakeholders to leverage sweet potato's potential and foster innovations in industrial applications.
Keywords Sweet potato processing; Value-added products; Emerging technologies; Food industry applications; Sustainable processing practices

1 Introduction

Sweet potato (*Ipomoea batatas* L.) is a globally significant crop, cultivated extensively in regions such as southern and eastern Africa, including Ethiopia (Mekonen et al., 2022). In water rich areas such as Zhejiang, where rice cultivation is the main crop, but sweet potatoes are the main food crop for residents in mountainous and semi mountainous areas as well as coastal islands due to the lack of freshwater resources.It is recognized for its rich nutritional profile, which includes complex carbohydrates, vitamins, minerals, and bioactive compounds (Escobar-Puentes et al., 2022; Laveriano-Santos et al., 2022). The tubers are not only a staple food source but also possess various health-promoting properties, such as antioxidant, anti-inflammatory, and anticancer activities (Bach et al., 2021; Yvonne and Pontsho, 2023). Additionally, sweet potato leaves, often discarded during harvesting, have potential for upcycling into high-value food products due to their bioactive constituents (Toy et al., 2022).

Sweet potato's versatility extends beyond its role as a food crop. It serves as a source of slowly digestible and resistant starch, making it valuable for the food industry (Bach et al., 2021). The crop's bioactive compounds, including carotenoids, polyphenols, and anthocyanins, contribute to its health benefits, which include cardiovascular protection and metabolic disorder management (Alam, 2021; Yvonne and Pontsho, 2023). Furthermore, sweet potato by-products, such as leaves, can be utilized to combat obesity through their lipase inhibitory activity (Toy et al., 2022). The diverse applications of sweet potato in food and industrial sectors underscore its importance as a multifunctional raw material.

This study provides a comprehensive overview of various processing techniques for sweet potatoes and their impact on nutritional and functional properties, examining methods such as boiling, frying, baking, and steaming to highlight how these processes affect macronutrients, vitamin content, and bioactive compounds across different sweet potato varieties, while also exploring the potential of sweet potato by-products in industrial applications to emphasize the importance of innovative processing methods for maximizing value.

2 Overview of Sweet Potato Composition and Properties

2.1 Chemical composition: carbohydrates, proteins, fibers, and antioxidants

Sweet potatoes are rich in a variety of bioactive compounds, including carbohydrates, proteins, fibers, and antioxidants. The carbohydrate content, primarily in the form of starch, ranges significantly among different cultivars, with values reported between 31.68% and 69.21% of dry weight (DW). Proteins in sweet potatoes also vary, with an average content of around 5.41 g/100 g DW, but can range from 2.36% to 8.60% DW depending on the cultivar (Kourouma et al., 2019; Zhang et al., 2022).

Fibers, both soluble and insoluble, are another important component, contributing to the dietary benefits of sweet potatoes. The fiber content can range from 1.00% to 14.35% DW (Kourouma et al., 2019; Shaari et al., 2021). Antioxidants such as polyphenols, flavonoids, carotenoids, and anthocyanins are abundant in sweet potatoes, with significant variations across different cultivars. For instance, the total polyphenol content can be as high as 9.38 mg GAE per g DW in some cultivars. Carotenoids, particularly β-carotene, are notably high in orange-fleshed varieties, while anthocyanins are more prevalent in purple-fleshed varieties (Kim et al., 2015; Alam, 2021).

2.2 Physicochemical properties affecting processing techniques

The physicochemical properties of sweet potatoes, such as moisture content, ash, protein, fat, carbohydrate, and fiber, significantly influence their processing techniques. Moisture content, which ranges from 5.93% to 7.86%, affects the drying and storage stability of sweet potatoes (Shaari et al., 2021). The ash content, indicative of mineral content, varies from 1.95% to 8.11% DW, influencing the nutritional quality and processing behavior (Kourouma et al., 2019).

Color parameters (L, a*, b*) are crucial for consumer acceptance and processing quality. For instance, the lightness (L) value ranges from 68.0 to 89.2, which can affect the visual appeal of processed products (Shaari et al., 2021). The viscosity properties, such as peak viscosity (PV), hot paste viscosity (HPV), and cold paste viscosity (CPV), are essential for determining the suitability of sweet potato flours in various food applications. These values range from 90.7 to 318.8 RVU, 77.3 to 208.3 RVU, and 102.6 to 272.7 RVU, respectively (Zhang et al., 2022; Guo, 2024).

2.3 Variability across different cultivars and growing conditions

The chemical composition and physicochemical properties of sweet potatoes exhibit significant variability across different cultivars and growing conditions. For example, orange-fleshed sweet potatoes (OFSP) are rich in β-carotene, while white-fleshed sweet potatoes (WFSP) have higher carbohydrate and phenolic contents (Alam, 2021). The genetic diversity among sweet potato varieties leads to differences in nutrient availability and bioactive compound profiles (Shekhar et al., 2015; Zhang et al., 2022).

Growing conditions, including soil type, climate, and agricultural practices, also play a crucial role in determining the nutritional and physicochemical properties of sweet potatoes. For instance, Sweet potatoes grown in the hilly and mountainous areas of Jinhua, Zhejiang have brighter colors and higher dry matter content, which is more conducive to processing (Figure 1); sweet potatoes grown in Shanxi province showed higher polyphenol and flavonoid contents compared to other regions (Kourouma et al., 2019). Postharvest storage and processing methods further influence the retention of bioactive compounds and overall quality. For example, home-processing methods such as baking, boiling, and steaming can lead to significant losses in carotenoid content, while also affecting the antioxidant capacity (Kim et al., 2015; Vizzotto et al., 2017).

3 Primary Processing Techniques

3.1 Washing and peeling

Washing and peeling are fundamental steps in the processing of sweet potatoes, ensuring the removal of dirt, pesticides, and the outer skin. These steps are crucial for maintaining the quality and safety of the final product.

Automated systems for washing and peeling have been developed to enhance efficiency and consistency in industrial applications (Vithu et al., 2019). The use of advanced equipment, such as PLC-based control systems, has optimized these processes, reducing labor costs and improving throughput (Xiao and Xuan, 2018).

Figure 1 Sweet potato under good planting environment

3.2 Cutting and slicing methods

Cutting and slicing are essential for preparing sweet potatoes for further processing, such as drying or frying. The size and shape of the slices can significantly impact the drying kinetics and the quality of the final product. Various cutting and slicing techniques, including the use of automated slicers, have been optimized to ensure uniformity and efficiency (Onwude et al., 2018; Vithu et al., 2019). The thickness of the slices, typically ranging from 3 to 7 mm, plays a critical role in subsequent processing steps, such as drying and blanching (Song et al., 2021).

3.3 Blanching and pre-treatments

Blanching is a pre-treatment process that inactivates enzymes, such as peroxidase, which can cause quality degradation during storage and processing. Traditional hot water blanching (HB) and novel methods like conveyor belt catalytic infrared blanching (CBCIRB) and radio frequency (RF) blanching have been studied for their effectiveness in enzyme inactivation and quality preservation (Jiang et al., 2020). CBCIRB, for instance, has shown superior results in maintaining the hardness and phytochemical content of sweet potato slices compared to HB (Song et al., 2021). RF blanching combined with hot water blanching has also demonstrated improved color and texture retention.

3.4 Drying and dehydration processes

Drying is a critical process for extending the shelf life of sweet potatoes and producing various dried products. Several drying methods, including convective hot-air drying (CHAD), infrared drying (IRD), and combined infrared and convective-hot-air drying (IR-CHAD), have been explored for their efficiency and impact on product quality (Figure 2) (Rashid et al., 2022). Combined IR-CHAD has been particularly effective, offering higher drying rates and better energy efficiency compared to traditional methods (Onwude et al., 2018). Additionally, advanced techniques like ultrasound-assisted osmotic dehydration have been optimized to enhance drying efficiency and product quality (Oladejo and Ma, 2016).

3.5 Freezing and cold storage technologies

Freezing and cold storage are essential for preserving the quality of sweet potatoes over extended periods. These technologies help maintain the nutritional value and sensory attributes of the product. The use of controlled atmosphere storage and advanced freezing techniques can significantly reduce post-harvest losses and extend the shelf life of sweet potatoes (Vithu et al., 2019; Rashid et al., 2022). Proper storage conditions, including optimal temperature and humidity levels, are crucial for preventing spoilage and maintaining product quality.

The industrial processing of sweet potatoes involves a series of well-coordinated steps, each critical for ensuring the quality and safety of the final product. From washing and peeling to advanced drying and storage techniques, each process has been optimized to enhance efficiency and product quality. The integration of novel technologies, such as infrared and radio frequency blanching, as well as combined drying methods, has significantly improved the processing outcomes, making sweet potato products more competitive in the market.

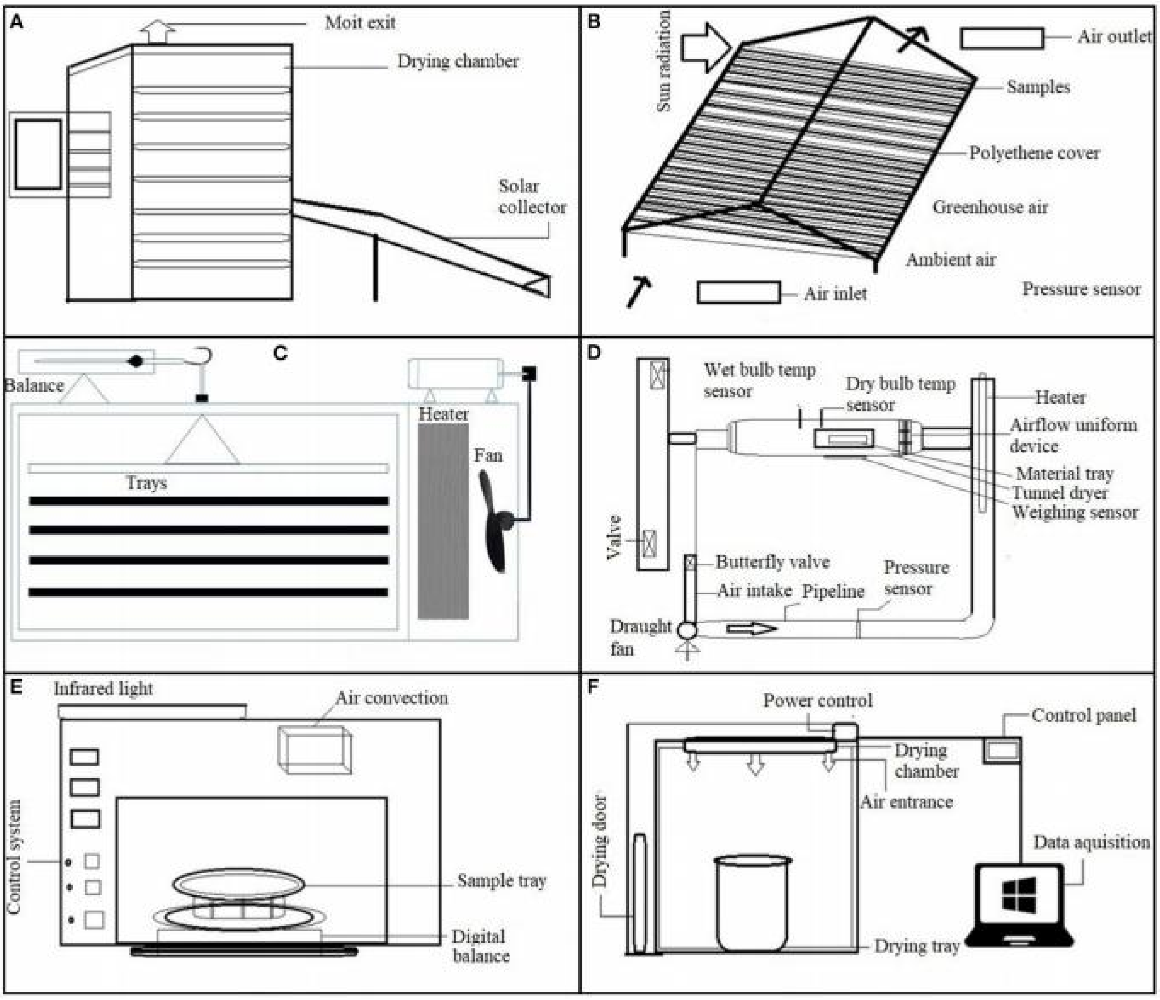

Figure 2 Drying techniques used for sweet potatoes (Adopted from Rashid et al., 2022)
Image caption: (A) Indirect solar dryer. (B) Greenhouse dryer. (C) Cabinet dryer. (D) Drying system. (E) Infrared drying equipment. (F) Mid-infrared dryer (Adopted from Rashid et al., 2022)

4 Advanced Processing Techniques for Value-Added Products

4.1 Extrusion processing for sweet potato-based snacks

Extrusion processing is a versatile technique widely used in the food industry to produce snacks, pasta, and other food products. This method involves forcing sweet potato-based mixtures through a die under high pressure and temperature, resulting in expanded and texturized products (Figure 3). Studies have shown that extrusion can significantly enhance the functional properties of sweet potato residues, such as increasing soluble dietary fiber content and improving water and oil retention capacities (Qiao et al., 2020). Additionally, extrusion allows for the incorporation of various by-products, which can enhance the nutritional profile and sustainability of the final products (Grasso, 2020; Leonard et al., 2020). For instance, the substitution of purple sweet potato with kidney bean flour during extrusion has been shown to improve protein and fiber content while reducing the glycemic index (Palupi et al., 2023).

Figure 3 Sweet potato foods produced by Jinhua Jinling Agricultural Technology Co., Ltd

4.2 Fermentation processes for alcohol, vinegar, and enzymes

Fermentation is a traditional method used to convert sweet potato starch into various value-added products such as alcohol, vinegar, and enzymes. The process involves the breakdown of starch by microorganisms, which can be optimized to enhance yield and efficiency. For example, a novel method combining preheating with simultaneous viscosity reduction, hydrolysis, and fermentation (P-SVHF) has been developed to produce ethanol more efficiently from sweet potato starch, achieving an ethanol conversion efficiency of about 93% (Schweinberger et al., 2018). Spontaneous fermentation has also been shown to modify the physicochemical properties of sweet potato starch, making it suitable for different industrial applications (Ye et al., 2019).

4.3 Starch extraction and modification techniques

Sweet potato starch is a valuable raw material for various industrial applications, including food, biofuel, and dietary supplements. Advanced techniques such as twin-screw extrusion and biotechnological methods like CRISPR/Cas-based genome editing are being explored to enhance the functional properties of sweet potato starch. Twin-screw extrusion has been shown to improve the solubility, thermal stability, and functional properties of sweet potato starch, making it a suitable additive for diverse food products (Qiao et al., 2020). Genome editing techniques offer the potential to precisely modify starch properties, thereby optimizing its industrial applications (Lyu et al., 2021).

4.4 Puree and paste production for food industries

The production of sweet potato puree and paste involves processes such as peeling, cooking, and mashing, which can be optimized to retain the nutritional and sensory qualities of the final product. These products are widely used in the food industry as ingredients in baby foods, bakery products, and sauces. The comprehensive utilization of sweet potato, including the production of puree and paste, offers significant benefits such as local processing and wide applicability. The development of efficient processing techniques can enhance the commercial viability and health benefits of sweet potato-based products.

4.5 High-pressure processing (HPP) for preservation

High-pressure processing (HPP) is an advanced preservation technique that uses high pressure to inactivate microorganisms and enzymes without the need for high temperatures. This method helps retain the nutritional and sensory qualities of sweet potato products while extending their shelf life. Although specific studies on HPP for sweet potato are limited, the technique has been successfully applied to other food products, suggesting its potential for sweet potato preservation. The application of HPP could address some of the challenges in small-scale sweet potato processing by improving product quality and safety (Vithu et al., 2019).

The advanced processing techniques discussed in this study highlight the potential for enhancing the value and utility of sweet potato in various industrial applications. Extrusion processing, fermentation, starch modification, puree production, and high-pressure processing each offer unique benefits that can be leveraged to produce high-quality, nutritious, and sustainable sweet potato-based products. Continued research and development in these areas will further optimize these processes, contributing to the growth and sustainability of the sweet potato industry.

5 Emerging Processing Technologies and Innovations

5.1 Application of pulsed electric field (PEF) technology

Pulsed electric field (PEF) technology has emerged as a promising non-thermal method for food processing, offering numerous advantages over traditional thermal methods. PEF involves the application of short bursts of high voltage to food products, which can lead to cell membrane permeabilization, enhancing the extraction of valuable compounds and improving textural properties. Studies have shown that PEF can significantly reduce the energy required for cutting and frying sweet potatoes, as well as lower the oil content in fried products (Figure 4) (Liu et al., 2017; Niu et al., 2020; Parniakov et al., 2022). Additionally, PEF treatment can improve the quality of sweet potato products by reducing browning and enhancing the uniformity of frying (Barba et al., 2015). The technology has been successfully implemented in the potato processing industry, demonstrating its potential for broader applications in sweet potato processing (Fauster et al., 2018).

Figure 4 PEF treated sweet potato sticks (Adopted from Parniakov et al., 2022)

5.2 Microwave-assisted processing

Microwave-assisted processing is another innovative technology that has gained attention for its ability to rapidly heat food products, leading to reduced processing times and energy consumption. This method utilizes microwave radiation to generate heat within the food, which can enhance the efficiency of drying, blanching, and pasteurization processes. The application of microwave-assisted processing to sweet potatoes can improve the retention of nutrients and color, as well as reduce the overall processing time. This technology is particularly beneficial for industrial applications where time and energy efficiency are critical (Arshad et al., 2020).

5.3 Use of enzyme-assisted extraction methods

Enzyme-assisted extraction methods leverage the specificity and efficiency of enzymes to break down cell walls and release valuable compounds from plant materials. In sweet potato processing, enzymes such as pectinases and cellulases can be used to enhance the extraction of starch, pigments, and other bioactive compounds. This method offers a more environmentally friendly alternative to chemical extraction processes, reducing the need for harsh solvents and minimizing waste. Enzyme-assisted extraction can also improve the yield and quality of sweet potato-derived products, making it a valuable tool for industrial applications (Wang et al., 2018).

5.4 Integration of internet of things (IoT) and automation in processing

The integration of internet of things (IoT) and automation technologies in sweet potato processing can revolutionize the industry by enabling real-time monitoring and control of processing parameters. IoT devices can collect data on temperature, humidity, and other critical factors, allowing for precise adjustments to optimize processing conditions. Automation can streamline various stages of production, from sorting and peeling to cooking and packaging, reducing labor costs and improving consistency (Peña et al., 2021). The use of IoT and automation can also enhance traceability and quality control, ensuring that sweet potato products meet stringent safety and quality standards.

5.5 3D food printing with sweet potato ingredients

3D food printing is an emerging technology that allows for the creation of customized food products with intricate designs and precise nutritional content. By using sweet potato ingredients such as puree or flour, 3D food printing can produce novel and visually appealing products that cater to specific dietary needs and preferences. This technology offers opportunities for innovation in product development, enabling the creation of functional foods with enhanced nutritional profiles. Additionally, 3D food printing can reduce food waste by utilizing sweet potato by-products and creating value-added products from otherwise discarded materials (Vorobiev and Lebovka, 2022).

The adoption of emerging processing technologies such as PEF, microwave-assisted processing, enzyme-assisted extraction, IoT integration, and 3D food printing holds significant potential for enhancing the efficiency, quality, and sustainability of sweet potato processing. These innovations can address the growing consumer demand for high-quality, natural, and nutritious food products while also providing economic and environmental benefits for the industry. Continued research and development in these areas will be crucial for unlocking the full potential of these technologies and driving the future of sweet potato processing.

6 Case Study: Sweet Potato Flour Production for Industrial Use

6.1 Introduction to sweet potato flour applications

Sweet potato (*Ipomoea batatas*) flour has emerged as a versatile ingredient in the food industry due to its rich nutritional profile and functional properties. It is utilized in a variety of food products such as beverages, noodles, flakes, cookies, ice cream, yogurt, jams, and even as a natural dye (Histifarina et al., 2023). The high carbohydrate content, along with essential vitamins and minerals, makes sweet potato flour a valuable alternative to traditional flours, especially in regions where food diversification is crucial. Additionally, its low glycemic index and high fiber content make it suitable for diabetic-friendly products (Sabahannur et al., 2023).

6.2 Processing steps: washing, slicing, drying, and milling

The production of sweet potato flour involves several critical steps to ensure quality and functionality: Washing: The sweet potatoes are thoroughly washed to remove soil and impurities. Slicing: the cleaned sweet potatoes are sliced into thin pieces to facilitate uniform drying. Drying: various drying methods can be employed, including sun drying, oven drying, and microwave drying. Each method impacts the final quality of the flour differently. For instance, microwave drying has been shown to preserve the nutritional content better and reduce drying time compared to hot air drying (Sebben et al., 2017). Milling: the dried sweet potato slices are milled into fine flour. The milling process must ensure that the flour has a consistent particle size to maintain its functional properties (Figure 5) (Vithu et al., 2019; Belkacemi, 2022).

6.3 Quality control parameters in flour production

Quality control is essential in sweet potato flour production to ensure the final product meets industry standards. Key parameters include moisture content: optimal moisture content is crucial to prevent microbial growth and extend shelf life. Studies have shown that drying at 60°C produces flour with a moisture content of around 0.34% (Sabahannur et al., 2023). Nutritional composition: the flour should retain high levels of carbohydrates, vitamins, and minerals. For example, sweet potato flour can have carbohydrate content ranging from 64.83% to 66.90% (Histifarina et al., 2023). Functional properties: these include water absorption capacity, swelling power, and pasting properties. These properties are influenced by the drying method and pretreatment processes such as blanching and soaking in citric acid (Olatunde et al., 2015; Akinoso et al., 2021). Color and aroma: the color and aroma of the flour are important for consumer acceptance. Blanching and drying methods significantly affect these attributes, with boiling and drying at 60°C producing a yellowish-white flour with a slightly distinctive aroma.

6.4 Industrial adoption and market impact

The industrial adoption of sweet potato flour has been growing due to its functional benefits and nutritional advantages. It is increasingly used in bakery products, such as bread, to enhance β-carotene content and improve quality (Nogueira et al., 2018). The market impact is significant, as sweet potato flour provides a cost-effective and nutritious alternative to traditional flours, supporting food security and promoting health benefits (Dereje et al., 2020). Moreover, the use of sweet potato flour in various food products can drive demand for sweet potatoes, benefiting farmers and contributing to the agricultural economy (Vithu et al., 2019; Histifarina et al., 2023).

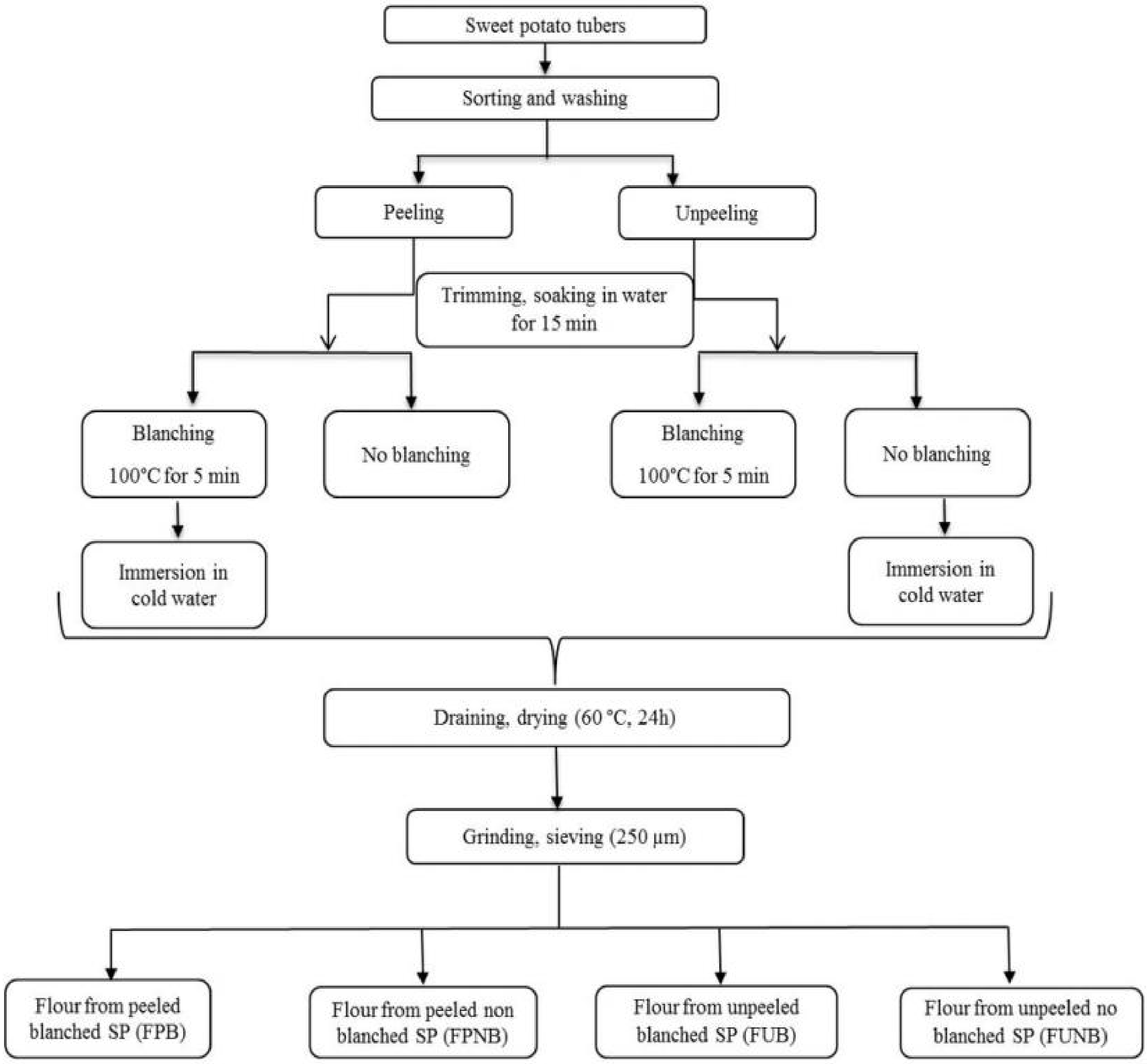

Figure 5 Flow chart for processing white fleshed sweet potato flours (Adopted from Belkacemi, 2022)

In conclusion, the production of sweet potato flour involves meticulous processing steps and stringent quality control to ensure a high-quality product suitable for various industrial applications. Its adoption in the food industry not only diversifies food products but also supports nutritional and economic goals.

7 Challenges and Limitations in Sweet Potato Processing

7.1 Impact of seasonal availability, post-harvest losses, and shelf-life issues

Sweet potatoes are highly susceptible to post-harvest losses due to inappropriate handling, storage, and delayed transit, leading to quality declines through microbiological and enzymatic activity. Seasonal availability complicates the supply chain, challenging the maintenance of consistent quality and quantity for industrial processing (Rashid et al., 2022). Shelf-life issues also arise with both fresh and processed products, as fresh sweet potatoes are prone to browning and oxidative damage, while processed products face challenges in nutrient retention and microbial stability, even with mitigation treatments such as ultrasound (Pan et al., 2020; Simões et al., 2020).

7.2 Energy, resource requirements, and environmental waste management

Sweet potato processing, especially drying, demands significant energy and resources (Rashid et al., 2022). Traditional drying methods like sun drying are inefficient and may reduce product quality, while advanced techniques like vacuum, infrared, and freeze drying, though more effective, require substantial energy inputs and sophisticated equipment. Furthermore, processing generates considerable waste, including peels and other by-products. Effective waste management strategies, such as bioprocessing to convert waste into bioethanol, microbial protein, and organic acids, require additional investment and infrastructure.

7.3 Regulatory, quality standards, and technological limitations

Meeting regulatory and quality standards presents another challenge in sweet potato processing. The industry must comply with stringent food safety regulations, quality control measures, and labeling requirements, which can be especially burdensome for small-scale processors. Additionally, adopting advanced non-destructive quality evaluation technologies, like imaging and spectroscopy, could enhance quality control, but high costs, specialized knowledge, and equipment needs limit widespread implementation (Sheikha and Ray, 2017; Sanchez et al., 2020).

7.4 Market, economic constraints, and profitability

The economic viability of sweet potato processing is influenced by market demand, pricing, and competition from other staple crops. Despite the health benefits and industrial applications of sweet potatoes, their market penetration remains limited compared to other crops, affecting the scalability and profitability of processing ventures (Laveriano-Santos et al., 2022). This economic constraint requires a multifaceted approach, including technological innovation, effective waste management, and adherence to quality standards to overcome the challenges and limitations in sweet potato processing.

8 Future Prospects and Trends in Sweet Potato Processing

8.1 Opportunities in functional food development

The bioprocessing of sweet potatoes offers significant opportunities for the development of functional foods. Sweet potatoes can be transformed into a variety of products such as sour starch, lacto-pickle, lacto-juice, soy sauce, acidophilus milk, sweet potato curd, yogurt, and alcoholic beverages through fermentation processes (Sheikha and Ray, 2017). The unique nutritional and functional properties of sweet potatoes, including bioactive carbohydrates, proteins, lipids, carotenoids, and anthocyanins, contribute to their health benefits, such as antioxidative, hepatoprotective, anti-inflammatory, antitumor, antidiabetic, antimicrobial, antiobesity, and antiaging effects (Wang et al., 2016). This makes sweet potatoes an excellent candidate for developing nutritionally enhanced and value-added food products that promote human health.

8.2 Prospects for bio-based industrial products from sweet potato

Sweet potatoes are not only valuable for food products but also for industrial applications. The starch from sweet potatoes can be used in food derivatives, dietary supplements, and as industrial raw materials (Lyu et al., 2021). Additionally, sweet potato residues can be utilized to produce biocomposites for packaging applications, which are characterized by their thermal stability and low environmental impact (Vannini et al., 2021). The potential for producing bioethanol from sweet potatoes further highlights their versatility as a bio-based industrial product (Sheikha et al., 2017). The integration of sweet potato processing into biorefineries can lead to the production of both ethanol and distilled beverages, contributing to the circular economy and reducing greenhouse gas emissions (Weber et al., 2020).

8.3 Sustainable processing and circular economy practices

The concept of a circular economy is increasingly being applied to sweet potato processing. By utilizing sweet potato waste in biorefineries, it is possible to produce bioethanol and distilled beverages, thereby reducing food waste and greenhouse gas emissions (Weber et al., 2020). Additionally, the anaerobic co-digestion of sweet potato with dairy cattle manure can generate biogas and bio-fertilizer, enhancing the sustainability of agricultural practices (Montoro et al., 2019). The development of biocomposites from sweet potato residues for packaging applications also exemplifies the principles of a circular economy, closing the loop of sweet potato product and by-product valorization (Vannini et al., 2021).

8.4 Role of genetic engineering in optimizing processing outcomes

Genetic engineering holds promise for optimizing sweet potato processing outcomes. Advances in genome editing technologies, such as CRISPR/Cas9, allow for precise modifications of the sweet potato genome, potentially reducing breeding time, increasing yield, and optimizing starch properties (Lyu et al., 2021). These technologies can enhance the nutritional value of sweet potatoes and improve their suitability for various industrial applications (Hameed et al., 2018). The ability to target specific genes without altering the overall genetic makeup of the crop can lead to the development of sweet potato varieties with improved processing characteristics and resilience to environmental stresses (Nahirñak et al., 2022).

8.5 Public-private collaborations for innovation

Public-private collaborations are essential for driving innovation in sweet potato processing. These partnerships can facilitate the development and commercialization of new processing technologies and products. By combining the resources and expertise of both sectors, it is possible to address the challenges and opportunities in the sweet potato processing industry (Ma, 2019). Collaborative efforts can also support the scaling up of sustainable processing practices and the integration of sweet potato bioprocessing into the circular economy, ultimately contributing to economic growth and job creation in the agriculture and food sectors (Montoro et al., 2019; Weber et al., 2020).

The future of sweet potato processing is promising, with numerous opportunities for developing functional foods, bio-based industrial products, and sustainable processing practices. Advances in genetic engineering and public-private collaborations will play a crucial role in optimizing processing outcomes and driving innovation in the industry. By embracing these prospects and trends, the sweet potato processing industry can contribute to food security, environmental sustainability, and economic development.

9 Concluding Remarks

The review of sweet potato processing techniques for industrial applications has highlighted several critical aspects. Firstly, post-harvest processing practices such as grading, sorting, cleaning, peeling, drying, and storage are essential for extending the usability of sweet potatoes and enhancing their commercial value. The nutritional and health benefits of sweet potatoes, including their rich content of dietary carotenoids, polysaccharides, and secondary metabolites, are well-documented, with processing methods significantly impacting these bioactive compounds. Non-destructive quality evaluation techniques, such as imaging and spectroscopy, have proven effective in ensuring the quality and safety of sweet potatoes during processing. Additionally, advanced processing technologies like ultrasound-assisted osmotic dehydration and combined infrared and hot-air drying have been optimized to improve the efficiency and quality of sweet potato products. The potential of bioprocessing to create functional foods and beverages from sweet potatoes further underscores the crop's versatility and economic potential.

For industrial stakeholders, several recommendations can be drawn from this review. Adopting advanced processing technologies, such as ultrasound-assisted osmotic dehydration and combined infrared and hot-air drying, can enhance product quality and processing efficiency. Utilizing non-destructive quality evaluation, including imaging and spectroscopy techniques for quality assessment, helps maintain high standards and ensure consumer safety. Focusing on nutritional retention by selecting and optimizing processing methods minimizes the loss of bioactive compounds, preserving the nutritional and health benefits of sweet potatoes. Exploring bioprocessing opportunities by investing in relevant technologies can diversify product offerings and open new markets for functional foods and beverages derived from sweet potatoes. Tailoring sweet potato varieties and processing methods to meet the specific demands of different markets, such as the growing European market, can enhance competitiveness and market share.

The future of sweet potato processing holds significant promise, driven by ongoing advancements in technology and a growing understanding of the crop's nutritional and economic potential. Continued research into optimizing processing conditions and developing new bioprocessing applications will be crucial in unlocking the full value of sweet potatoes. As consumer demand for healthy, functional foods increases, the sweet potato industry is well-positioned to capitalize on these trends, provided that stakeholders remain committed to innovation and quality. The integration of advanced technologies and sustainable practices will be key to ensuring the long-term success and growth of the sweet potato processing industry.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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