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UNLOCKING THE POTENTIAL OF ALUGBATI (*Basella alba L.*) POWDER: A NUTRITIONAL AND FUNCTIONAL FOOD INGREDIENT

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ABSTRACT
Alugbati, or Basella alba, is an underutilized yet widely consumed vegetable in Asia, particularly in the Philippines. This review explores the production, characterization, and potential applications of alugbati powder as a functional food ingredient. The drying process is critical for preserving the nutritional and functional properties of alugbati powder, with methods such as freeze drying, oven drying, and air drying each offering distinct advantages and limitations. Alugbati powder is rich in dietary fiber, vitamins, and minerals, making it suitable for incorporation into various food products to enhance their nutritional profiles. Additionally, its high antioxidant activity and natural pigments position it as a valuable ingredient for health-focused products and natural colorants. Despite its potential, challenges remain in optimizing production methods and standardizing quality control to ensure consistent product quality. Further research is necessary to validate the health benefits of alugbati powder and explore its applications in the food industry, particularly in addressing nutritional deficiencies in developing regions

KEYWORDS: *Alugbati Powder, Functional Food Ingredient, Drying Process, Nutritional Properties, Antioxidant Activity*

INTRODUCTION
Alugbati, as locally called in the Philippines and recognized as *Basella alba* worldwide, is a relatively understudied yet widely consumed vegetable grown in Asia. *Basella alba* belongs to the family Basellaceae, and commonly known as malabar spinach, indian spinach, ceylon spinach and vine spinach (Kumar et al., 2013). It comprises the green-stemmed (*Basella alba* var. *alba*) and purple-stemmed (*Basella alba* var. *rubra*) *Basella alba* forms (Saroj et al, 2012).

Basella alba is an underutilized vegetable often cultivated in home gardens (Bolaji et al., 2022) and used for culinary and medicinal purposes. This plant is very popular in the central and southern Philippines and is often a common component of a concoction vegetable dish called "laswa, las ay or law-oy" with its characteristic jelly-like consistency. It can be directly used in salads or can be used as a standalone vegetable for making soups, stews, steamed and oil fried items. In India, it is also being used to make snacks called as pakoda (Singh,et al, 2018). In addition, alugbati is recognized as a medicinal plant known for its antioxidant, antibacterial and anticancer potentials (Sushila et al., 2010). The leaves and stem of alugbati have been used in Indian Ayurvedic treatments for curing diseases such as melanoma, leukemia and oral cancer. It is useful as medicinal plant in the treatment of various ailments including anaemia (Rahmatullah et al., 2010), pelvic inflammation disease, threatened abortion (Focho et al., 2009), hypertension (Olowokudejo et al., 2008), earache and sore throat (Chatchawal et al., 2010; Paul et al., 2011), gonorrhoea (Singh et al., 2010), diabetes (Shantha et al., 2016) and ulcer (Dixit and Goyal, 2011).

The traditional use of alugbati has been attributed and correlated to the presence of bioactive phenolics and flavonoids in the plant (Adhikari et al., 2012). In addition, the fresh leaves and stems of both Basella species were found to be rich in protein, vitamin A, vitamin C, Ca, Fe, Mg, P, K, Na, Zn, Cu, Mn and Se and also having essential amino acids and flavones, making it a valuable addition to diets, especially in areas facing nutritional deficiencies (Singh,et al, 2018).

While alugbati presents numerous benefits, its potential remains underexplored. The greatest challenge lies in preserving fresh produce due to its limited shelf life. Hence, the transformation of alugbati into a powdered form offers a viable solution for extending its usability while preserving its nutritional benefits. Alugbati powder has the potential to be incorporated into food formulations as a functional food ingredient, contributing to improved health outcomes. This review explores various aspects of the characterization of alugbati powder, including its production methods, nutritional composition, bioactive components, and functional properties, alongside its potential applications in food systems.

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PRODUCTION OF ALUGBATI POWDER

2.1 Drying Methods

The drying process is critical in producing Alugbati powder, as it influences the retention of nutrients and functional properties. Various drying techniques are utilized, each with its own advantages and limitations:

- **Air Drying.** One of the simplest and most cost-effective methods, air drying involves exposing Alugbati leaves to heated airflow at controlled temperatures. Although efficient, it may lead to the degradation of heat-sensitive nutrients such as vitamin C. In a study utilizing Alugbati leaves powder for development of fortified fresh egg noodles, the washed and air dried Alugabti leaves were dried in a food dehydrator at 70ºC for 7hours. Results indicated that the powder has a high protein content (21.38%), making it suitable for addressing Protein Energy Malnutrition. The powder also exhibited a high ash content (16.17%), which can be attributed to the presence of minerals like calcium, magnesium, and iron in the vegetable. Moreover, the Total Carotenoid Content of the Alugbati leaves powder was found to be 11490 micrograms (µ) corresponding to 957.50 micrograms Retinol Equivalent per gram (µ RE/g). Based on the Philippine Dietary Reference Intake tables for vitamins, the Recommended Dietary Allowance (RDA) for vitamin A ranges only from 400–800 µg RE depending on the ag-e group and gender (FNRI 2015b). This suggests that the µg RE of 1 g 'alugbati' leaves powder from this study exceeds the RDA for vitamin A by at least 20%. Hence, the 'alugbati' leaves powder can be utilized for vitamin A fortification in certain products such as egg noodles (Soriano et al., 2020).
  Meanwhile, another study on development of powder from similar leafy vegetable, spinach (Spinacia oleracea), the leaves were dried in a convective hot air dryer. Results showed that better nutritional and functional properties (i.e. moisture content, protein, fat, ash, fiber, carbohydrate, colour L, a, b water absorption capacity, wettability) of dried spinach powder have been observed at 45ºC at 8.5 hours compared to those spinach powder dried from higher temperatures of 50ºC and 60ºC at 6 hours and 5 hours, respectively (Sargar et al., 2023).
- **Freeze Drying**: Freeze drying is considered the gold standard for preserving the nutritional and bioactive components of leavy vegetables (Saini et al., 2014). The process involves freezing the leaves and then sublimating the water under low pressure (Joshi et al., 2010). Freeze drying maintains the integrity of vitamins, antioxidants, and color (Saini et al., 2014), but it is energy-intensive and costly (Fellows, 2000).
  A study performed on development of water spinach (*Ipomea aquatica*) powder, freeze-dried samples showed better nutritional content and color retention compared to those samples under sun-drying and tray-drying methods (Joshi et al, 2021).
- **Oven Drying**: Oven drying is a moderate-temperature drying method that offers a balance between cost-effectiveness and nutrient retention. Oven drying at temperatures between 40°C and 60°C can preserve most nutrients, although prolonged exposure may reduce the levels of certain vitamins (Djuikwo et al, 2011).
  In a study on the sensory and nutritional analysis of spinach powder fortified biscuits, spinach (*Spinacia oleracea* L) leaves were dried in the shade for 6 to 8 hrs. to remove excess moisture followed by oven drying at 40-45ºC till complete drying (Sangwan & Jood, 2022). Based on the results of this study, it was concluded that spinach biscuits were found organoleptically and nutritionally superior in terms of protein, fibre, ash, mineral and antioxidant activity contents. Spinach leaves powder yield better functional characteristic and has the potentials of adding value to products like biscuit and similar products.
- **Sun Drying**: Sun drying is the conventional method used to obtain dried leafy vegetables, requiring only low capital, simple equipment and low energy input (Sobukola et al., 2007). Widely used in rural areas, sun drying is an inexpensive but less reliable method due to potential contamination and nutrient degradation from uncontrolled temperature and humidity.

  A study on dried *Moringa oleifera* leaves reportedly had a 63% decrease in carotenoid content upon sun drying (Sriwichai et al., 2017). Direct light exposure is hypothesized to induce the oxidation reaction of heat-sensitive phytochemical compounds in green leafy vegetables (Saini et al., 2014)

2.2 Powdering and Particle Size Reduction

Once the leaves are dried, they are ground into powder using mechanical grinders or hammer mills. In the study on Alugbati powder-fortified noodles, dried Alugbati leaves were blended to a fine powder using a blender (Soriano et al., 2020) while on the application of spinach powder on biscuits, dried leaves were ground in an electric grinder to obtain a fine powder (Sangwan & Jood, 2022). In both studies, however, controlling particle size was not mentioned.

3. CHARACTERIZATION OF ALUGBATI POWDER

3.1 Physical Properties

3.1.1 Particle Size Distribution

Powders possess physical and functional properties that are of significance in its usage notably powder structure, particle size distribution, powder density, bulk density, particle density, occluded air, interstitial air, flowability, rehydration (wettability, sinkability, dispersibility, solubility), hygroscopicity, heat stability, emulsifying ability, water activity, stickiness, caking, and others (Sharma et al., 2012). Specifically, for alugbati powder, the particle size affects its dispersibility, solubility, and texture. In a study on effects of particle size on physicochemical and functional properties of superfine black kidney bean (*Phaseolus vulgaris* L.) powder, flow properties, hydration properties, thermal stability, and cholesterol adsorption efficiency significantly improved with the reducing of particle size (Sun et al., 2019). Sieving methods are commonly employed to measure the particle size distribution (Allen, 2013), with fine particles

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being preferred for better solubility in liquid-based formulations. Thus, for alugbati powder fine particle sizes (below 200 microns) are preferable for use in beverages and instant foods, while coarser particles may be more suited to applications such as baked goods.

3.1.2 Moisture Content

Moisture content is crucial for the shelf stability of alugbati powder. A dry food product is less susceptible to spoilage caused by the growth of bacteria, molds, and insects (Solchansanj & Jayas, 2020). Moisture content is typically determined by oven drying or using a moisture analyzer.

3.1.3 Bulk Density and Flowability

Bulk density, which is one of the most important functional properties of a powdered product, is mainly affected by physical properties like morphology and particle size (Ding et al., 2020). On the other hand, powder flowability can be defined as the ability of a powder to flow under set environmental or processing conditions and it is ultimately determined by the type and extent of interparticle interactions (e.g., van der Waals and electrostatic interactions) occurring in the bulk powder (Camacho et al, 2022). While bulk density influences packaging and transportation), flowability is essential for industrial processing. Poor flowability can hinder mixing and dispensing in food manufacturing. These parameters are measured using standard techniques such as the angle of repose and bulk density testers (Bhandari et al, 2023).

3.2 Chemical Composition

3.2.1 Proximate Composition

The proximate composition of alugbati powder includes moisture, protein, fat, carbohydrate, ash, and fiber content. Typically, alugbati powder is rich in fiber and protein, with low fat content (Soriano et al, 2020). Standard AOAC methods are used to determine these values, which are crucial for nutritional labeling.

3.2.2 Phytochemicals and Antioxidants

Alugbati is known for its high phytochemical content, particularly flavonoids, alkaloids, phytosterols, tannins and triterpenoid. These compounds contribute to its antioxidant and anti-inflammatory properties (Reddy et al, 2023). Techniques such as high-performance liquid chromatography (HPLC) and spectrophotometry can used to quantify the levels of these bioactive compounds in alugbati powder. Also, alugbati powder exhibits significant antioxidant activity, and this could be determined by assays like DPPH (1,1-Diphenyl-2-picrylhydrazyl) and ABTS.

3.3 Functional Properties

3.3.1 Water Holding Capacity

Water holding capacity (WHC) refers to the ability to absorb and retain water, which is essential in products such as soups, sauces, and baked goods. Higher WHC enhances the textural properties of food products by improving moisture retention (Noguerol et al, 2021). WHC is mainly measured in 2 ways: (a) dispersing the sample in excess water in certain conditions (time-temperature), followed by the removal of the unabsorbed water using pressure, filtration or centrifugation and then measurement of the water bound by gravimetry or (b) measuring the water uptake in conditions of limited water. The water-holding capacity (WHC) can thus be estimated as the amount of water released from the sample also known water retention measurement or as the amount of water absorbed or bound by the sample, otherwise called water absorption measurement (Villemejane et al., 2013). The WHC of alugbati powder can be determined using modified methods (Heywood et al, 2002; Lin and Zayas, 1987).

3.3.2 Oil Holding Capacity

Oil holding capacity (OHC) is the amount of oil retained by the fibres after mixing, incubation with oil and centrifugation (Ozyurt & Ötles, 2016). This is important in fat-rich food formulations such as dressings, emulsions, and bakery products. Since alugbati contains sizeable amount of mucilage (Baskaran et al, 2015) and its mucilage can be utilized as a thickening agent and tablet binder (Kumar et al., 2013), alugbati powder's inherent mucilage content may contribute to its ability to bind fats, which can improve the texture and shelf life of many food products. The OHC of alugbati powder can be determined by using modified methods (Lin and Zayas, 1987).

3.3.3 Solubility

Solubility is the maximum concentration of a solute that can dissolve in a solvent at a given temperature (Lu et al, 2022). This is a critical factor in beverage formulations, where dispersibility in liquids is necessary. Fine alugbati powder tends to have good solubility, making it ideal for incorporation into smoothies, instant drinks, and powdered supplements. An advanced method of evaluating the solubility of powdered food ingredients is by using dynamic nuclear magnetic resonance (NMR) relaxometry. NMR relaxometry tracks the hydration and solubility of powdered food samples by measuring the relaxation time (T2) during mixing, while filtration and freeze-drying are used to physically separate and measure the soluble and insoluble fractions of the powder (Granizo et al., 2007).

3.3.4 Gelation and Viscosity

Alugbati contains mucilage, a polysaccharide that can form gels and increase viscosity in food formulations. This property is useful in thickening agents, stabilizers, and gelling agents in food applications (Kumar et al., 2013). Rheological testing can assess the gelation and thickening capacity of alugbati powder.

4. ALUGBATI POWDER AS A FUNCTIONAL FOOD INGREDIENT

4.1 Nutritional Enhancement

Alugbati powder is a potential valuable ingredient for boosting the nutritional profile of food products. Its high levels of vitamins, minerals, and fiber make it an excellent addition to fortify various food items, such as baked goods, beverages, soups, and snacks. It can also be used to enhance the micronutrient content of processed foods, addressing issues related to nutrient deficiencies, particularly in developing countries.

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4.2 Antioxidant-Rich Functional Foods

The significant antioxidant activity of alugbati powder makes it an ideal candidate for use in functional foods aimed at improving health outcomes. Antioxidants are linked to reducing oxidative stress, preventing chronic diseases, and enhancing overall well-being. Alugbati powder can be incorporated into health-focused products such as energy bars, granola, and smoothies to boost their functional value.

4.3 Natural Colorant

Alugbati powder, particularly from the purple-stemmed variety, contains natural pigments such as anthocyanins. These pigments can be used as natural food colorants, providing a clean-label alternative to synthetic dyes. This makes alugbati powder suitable for use in beverages, confectionery, and dairy products where vibrant natural colors are desired.

4.4 Dietary Fiber Source

Alugbati powder is an excellent source of dietary fiber, which is crucial for digestive health. Dietary fiber helps regulate bowel movements, lower cholesterol levels, and control blood sugar levels. Alugbati powder can be incorporated into fiber-rich products, such as cereals, crackers, and dietary supplements, to provide health benefits related to gut health.

4.5 Thickening and Gelling Agent

The mucilage in alugbati gives it potential as a natural thickening and gelling agent in food products. Its ability to form viscous solutions and gels can be applied in sauces, gravies, jellies, and low-fat products, offering an alternative to synthetic thickeners and stabilizers.

5. Challenges and Future Directions

5.1 Optimization of Drying and Processing Techniques

Improving drying methods is crucial for retaining the nutritional and functional properties of alugbati powder. Optimizing the balance between drying temperature, time, and cost will be key to producing high-quality alugbati powder on a commercial scale.

5.2 Standardization of Quality Control

Standardizing the quality of alugbati powder across batches is essential for its commercial use. Parameters such as particle size, moisture content, and bioactive compound concentration should be monitored consistently to ensure uniformity.

5.3 Development of Novel Applications

Research into novel food applications of alugbati powder is still in its early stages. Exploring its use in plant-based foods, meat substitutes, and functional beverages could unlock new markets. Further studies on the bioavailability of its nutrients and bioactive compounds are also necessary to establish its efficacy as a functional food ingredient.

6. CONCLUSION

Alugbati powder is a promising functional food ingredient with numerous potential applications in the food industry. Its rich nutritional profile, coupled with its antioxidant, anti-inflammatory, and antimicrobial properties, make it an ideal candidate for health-promoting food products. As interest in plant-based, natural ingredients continues to grow, *Alugbati* powder offers a sustainable, nutrient-dense option for the development of functional foods. However, further research is necessary to optimize its production, ensure consistency, and validate its health benefits in clinical settings.

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