Effect of Pre-Treatment and Drying Techniques on the Functional and Sensory Attributes of Potato Flour

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Abstract: ***This study investigates the impact of different pretreatment methods—boiling water blanching, immersion in 1% acetic acid, and 1% sodium bicarbonate—and two drying techniques (sun drying and room temperature drying) on the functional and sensory properties of potato flour made from the Cruz variety. Functional properties such as bulk density, foaming capacity, emulsifying capacity, and pH were measured, along with sensory evaluations of taste, color, texture, and overall acceptability. The results revealed that bulk density was significantly ($P \leq 0.05$) influenced by both pretreatment and drying methods, ranging from 0.720% to 0.914%. The highest values were recorded for samples treated with boiling water blanching and dried under the sun or at room temperature. In contrast, the lowest value was observed in samples treated with acetic acid and sun-dried. Foaming and emulsifying capacities were also significantly ($P \leq 0.05$) affected, showing higher values (27.5% and 19.39%) in samples treated with sodium bicarbonate and sun-dried, and lower values (13.33% and 6.42%) in samples treated with boiling water blanching and dried at room temperature. Furthermore, sensory evaluation indicated that pretreatment and drying method had a significant ($P \leq 0.05$) impact on texture, flavor, color, and overall acceptability. The best sensory scores were obtained from samples treated with sodium bicarbonate and sun-dried, whereas the lowest was observed in those treated with boiling water blanching and dried at room temperature. In conclusion, pretreatment with sodium bicarbonate followed by sun drying improved both the functional and sensory properties of potato flour.***

Keywords: potato flour, pretreatment methods, drying techniques, functional properties, sensory evaluation

1. Introduction

The potato (Solanum tuberosum L.) ranks as one of the world's most important food crops, following rice, wheat, and maize [1]. It is the leading tuber crop globally and belongs to the family Solanaceae. Potatoes play a vital role in global food security due to their wide availability and affordability. They are a versatile food source rich in carbohydrates, consisting of approximately 80% water and 20% dry matter when freshly harvested. Of this dry matter, starch accounts for 60–80%. On a dry weight basis, potato proteins exhibit a well-balanced amino acid profile, superior to that of cereal proteins [2]. Moreover, the total vitamin and mineral contents of potato flour are higher than those found in wheat flour.

Potatoes are also considered the third most significant source of phenolic compounds—particularly chlorogenic acid—after apples and oranges [3]. In addition, they contain various bioactive phytochemicals, including flavonoids, polyamines, and carotenoids, which are valued for their health-promoting properties [4]. Potato proteins are notable for their non-allergenic nature, high digestibility, and balanced amino acid composition, making them valuable functional ingredients in food systems. Furthermore, their excellent water solubility, especially at low pH values, enhances their suitability for incorporation into acidic beverages [5,6].

In terms of techno-functional attributes, potato proteins demonstrate superior properties such as water solubility, gel formation, emulsification, and foaming capacity [7]. According to the U.S. Food and Drug Administration, these proteins have diverse industrial applications, functioning as emulsifiers in spreads, sauces, desserts, and dressings; as water binders in meat and sausage products; and as foaming agents in confectionery, bakery, and dairy formulations [8].

The preparation of potato flour involves several processing steps [9]. Among these, drying is one of the most widely applied techniques [10]. The physicochemical characteristics of potato flour are significantly influenced by the processing conditions employed, particularly the pretreatment and drying methods used [11].

Pretreatment refers to the application of specific physical, thermal, or chemical processes to raw materials before subsequent processing. It is commonly employed prior to drying to enhance the drying rate, inactivate enzymes, reduce processing time, prevent discoloration, and improve the overall quality of the final dried product [12,13]. Generally, pretreatments are categorized into three main types: thermal, physical, and chemical. Thermal branching is widely used in the food industry as a pre-drying technique. This process facilitates enzyme inactivation responsible for quality deterioration in fresh produce, softens tissues to accelerate moisture removal, expels intracellular air that promotes oxidation, and reduces microbial load, thereby improving product stability [12].

Despite the significance of these techniques, limited comprehensive studies have been conducted to compare the combined effects of different pretreatment and drying methods on the functional properties of potato flour. Given the increasing utilization of potato flour in various food formulations, it is essential to assess how these processing factors influence its functional and sensory characteristics.

Therefore, the objective of the present study was to investigate the effect of different pre-drying treatments—

specifically boiling water blanching, immersion in acetic acid, and sodium bicarbonate solutions—and two drying methods (sun drying and room temperature drying) on the functional and sensory properties of potato flour. This study contributes to optimizing potato flour processing methods, supporting food industry efforts to enhance product quality, reduce waste, and developing functional food ingredients with improved consumer acceptance

2. Material and Methods

Sample preparation

Potatoes were washed with fresh water to remove the adhering soil particles and peeled manually with the help of stainless-steel peelers. Peeled potatoes were cut into slices of 2 mm thickness using a hand operated stainless-steel slicer. Then potato slices were pre-treated.

Pretreatments and Drying Methods:

One kilogram of potatoes was sliced and blanched in boiling water for 10 minutes. The potato slices were then blotted dry with paper towels and divided into two portions: one was dried under sunlight at 35°C, while the other was dried at room temperature (22°C).

Another batch of one kilogram of sliced potatoes was immersed in a 1% acetic acid solution for 10 minutes, blotted dry with paper towels, and similarly divided into two portions: one dried under sunlight at 35°C, and the other at room temperature (22°C).

A third batch of one kilogram of sliced potatoes was soaked in a 1% sodium bicarbonate solution for 10 minutes, blotted dry with paper towels, and dried under the same two conditions: sun drying at 35°C and room drying at 22°C.

Bulk Density (B D)

The bulk density (BD) of the samples was determined using the method described by Oladele and Aina [14] . About 50 g flour sample was weighed in a 100 mL measuring cylinder. The sample was gently tapped continuously until a constant volume was obtained.

$$\text{bulk density, g/ml} = \frac{weight\ of\ sample}{volume\ of\ sample\ after\ tapping}$$

Foam Capacity (FC)

The foam capacity (FC) was determined using the protocol discussed by Naiker *et al.* [15]. FC is defined as the amount of interfacial area that can be produced by whipping the protein in food.

Foam capacity (FC)

$$= \frac{volume\ after\ homognization - volume\ before\ homogenization}{volume\ before\ homogenization} \times 100$$

Emulsion Capacity (EC)

The emulsion capacity was determined by the method described by Yasumatsu *et al.* [16] 1 g sample, 10 ml distilled water and 10 ml soybean oil) was prepared in calibrated centrifuged tube. The emulsion was centrifuged at 2000 × g for 5 min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage

Measurement of pH

Flour samples (0.25 g) were mixed with 25 mL of water and vortexed for 3 min. The mixture was held at room temperature for 1 h and centrifuged to separate phases. pH of the supernatant was measured using pH meter (Schott, Mainz, Germany) [17].

Sensory evaluation:

Twenty panelists from the Department of Food Science and nutrition, Faculty of Science at Bisha University, evaluated potatoes flour based on their sensory qualities. Using a 1–9 hedonic scale, panelists assessed taste, flavor, color, texture, and overall acceptability of prepared potatoes flour [18]. A score of 1 denoted dislike extremely whereas a score of 9 indicated like extremely

Statistical analysis

All data were subjected to statistical analysis using SPSS Vito means tested by analysis of variance Factorial design. Value of probability of 5% was used to indicate significance according to DMRT [19].

3. Results and Discussions

Bulk Density (BD)

Bulk density measures the heaviness of flour samples. It is a property that determines the porosity of a product which influences the design of package. It depends on the solid density, geometry, size, surface properties and the method of measurement. It also depends on particle density, its shape and way constituents are packed on positioned with respect to each other. As shown in Table 1 the highest values of bulk density was (0.914 g/ml) obtained for the sample pretreated with boiling water blanching and dried under the sun or at room temperature and the lower value (0.728 g/ml) was obtained for the sample pretreated with acetic acid and dried under the sun, bulk density was reported to be influenced by the structure of starch polymers, as loose structure of starch polymers are related to low bulk density[20] . Both pretreatments and drying methods had a highly significant effect on bulk density. The interaction effect was also significant, meaning the impact of pretreatments depended on the drying method. The high bulk flour density suggests their suitability for use in food preparation such as thickener in food products [21].

Foam capacity (FC)

Foam capacity of flour is measured as the amount of interfacial area created by whipping of flour. Protein is generally responsible for foam formation. Foam capacity generally depends on the interfacial films formed by the proteins which maintain the suspension of air bubbles and slow down the coalescence rate. The obtained result (Table 1) revealed that the foam capacity of potato flour was significantly affected by both pretreatment type and drying method ($p < 0.05$). Sodium bicarbonate with sun drying exhibited the highest foaming capacity (27.50), which was significantly greater than that of boiling water blanching with room drying (13.33). Acetic acid with sun drying (26.67) and sodium bicarbonate with room drying (25.00) also showed relatively high foaming capacities but their differences from other high-performing treatments were not significant. Boiling water blanching with room drying consistently showed the lowest foaming capacity and differed significantly from most other treatments. The extension of heat causes denaturation of protein thereby decreasing their foam capability [22].

Emulsion Capacity (EC)

Emulsion capacity is the ability of flour to bind both hydrophilic and hydrophobic compounds. As shown in table 1, both pretreatment and drying methods as well as their interaction significantly affected the emulsion capacity (EC) of potato flour. Sodium bicarbonate combined with sun drying recorded the highest EC (19.39) while boiling water blanching combined with room drying showed the lowest value (6.42). Treatments with acetic acid and boiling water blanching under sun dry exhibited intermediate capacities indicating a strong influence of both chemical and thermal pretreatments on protein functionality.

The higher emulsifying capacity observed in the sodium bicarbonate (weak base) treatments may be attributed to the neutral pH created during pretreatment. This neutral pH increases protein solubility and flexibility, enhancing their ability to function as emulsifiers. Moreover, it promotes the exposure of hydrophobic groups and reactive amino acid residues, which improves the ability of proteins to adsorb at the oil–water interface and stabilize emulsions. Similar findings were also reported by Mu *et al*. [23] who conclude that salt type is crucial factor influencing the emulsifying capacity of potato proteins and reported that the addition of 0.2 mol/L $CaCl_2$ improved the EC of the sweet potato proteins.

On the other hand, boiling water blanching pretreatment particularly when combined with room drying drastically reduces EC. This reduction could be due to protein denaturation and aggregation caused by heat treatment leading to a loss of solubility and interfacial activity. Denatured proteins often form insoluble aggregates which decrease their ability to form stable emulsions. This agrees with the observations of Baier & Knorr [24] who found that high temperatures can affect the surface hydrophobicity, flexibility, and MW distributions of potato proteins, thus impacting their ability to adhere to O/W interfaces and affects emulsifying activity [24]. Increase in emulsification activity is important for products like comminuted meat, salad dressing, frozen desserts and mayonnaise [25] . Emulsion capacity of potato flour pretreated with sodium bicarbonate and acetic acid was high and can be used in manufacturing food products requiring emulsion to stabilize colloidal food systems.

PH

As shown in table 1 the results indicate that both pretreatment type and drying method significantly affected the pH of potato flour. Sodium bicarbonate treatment resulted in higher pH values reflecting its alkaline nature which increases the overall alkalinity of the samples and stabilizes them during drying, while boiling water blanching treatment gave intermediate pH values suggesting that blanching helped maintain moderate acidity without major shifts. In contrast, acetic acid pretreatment caused a clear reduction in pH, due to the acidic environment which lowers the overall hydrogen ion concentration in the dried product.

Table 1: Effect of pretreatment and drying methods on some functional properties and pH

Pretreatment	Drying methods	Buck density (g/ml)	Foam Capacity%	Emulsifying capacity%	pH
Sodium bicarbonate	Sun drying	$0.852^{b} \pm 0.017$	$27.5\ ^{a}\pm 0.84$	$19.39^{a} \pm 1.75$	$6.43^{b} \pm 0.06$
Acetic acid		$0.728^{c} \pm 0.012$	$26.67^{a}\pm 1.67$	$11.77^{c} \pm 0.52$	$5.25\ ^{e}\pm 0.05$
Boiling water blanching		$0.914^{a}\pm 0.019$	$24.17^{a}\pm 0.84$	$13.66^{bc} \pm 1.35$	$6.10^{c} \pm 0.00$
Sodium bicarbonate	Room temp. drying	$0.852^{b} \pm 0.017$	$25^{a} \pm 1.67$	$15.11^{b} \pm 1.17$	$6.83^{a} \pm 0.06$
Acetic acid		$0.852^{b} \pm 0.017$	$22.5\ ^{b}\pm 2.5$	$10.50\ ^{c}\pm 1.50$	$5.73^{d} \pm 0.21$
Boiling water blanching		$0.914^{a} \pm 0.019$	$13.33^{c} \pm 1.67$	$6.42^{d} \pm 0.59$	$6.60^{b} \pm 0.10$
LSD		0.030	5.04	2.20	0.18

Mean (±SD) values bearing different superscript (s) in the same column are significantly different (P≤0.05) according to DMRT

Sensory evaluation

Table 2 describes the sensory evaluation (texture, flavor, taste, color, and general acceptability) of the prepared potatoes flour the tabulated data showed that pretreatment and drying technique, had a significant effect on the properties with a significant interaction between them ($p < 0.05$). The best texture, flavor, taste, color and overall acceptability were obtained with sodium bicarbonate pretreatment combined with sun drying while the lowest values were observed with boiling water blanching pretreatment under room temperature drying.

Table 2: Effect of pretreatment and drying methods on Sensory evaluation

Pretreatment	Drying methods	Texture	Aroma	Taste	Color	Overall acceptability
Sodium bicarbonate	Sun drying	$9\ ^{a}\pm0.0$	$7.5^{a}\pm0.1$	$8.1^{a}\pm0.35$	$8.4^{a}\pm0.1$	$8.5^{a}\pm0.3$
Acetic acid		$6.9\ ^{c}\pm0.\ 1$	$6.6^{b}\pm0.3$	$6.3^{b}\pm0.1$	$7.3^{b}\pm0.3$	$6.9^{b}\pm0.2$
Boiling water blanching		$7.5\ ^{b}\pm0.1$	$6.5^{c}\pm0.1$	$6.4^{b}\pm0.3$	$7.1^{b}\pm0.3$	$6.4^{c}\pm0.1$
Sodium bicarbonate	Room temp. drying	$7.7^{b}\pm0.2$	$6.4^{c}\pm0.0$	$6.4^{b}\pm0.1$	$6.7^{c}\pm0.3$	$6.2^{c}\pm0.2$
Acetic acid		$7.1^{c}\pm0.15$	$6.9\ ^{b}\pm0.1$	$5.9^{c}\pm0.1$	$7.2^{bc}\pm0.1$	$6.9^{b}\pm0.1$
Boiling water blanching		$4.3\ ^{d}\pm0.45$	$4.6^{d}\pm0.4$	$4.8^{d}\pm0.2$	$6.9^{bc}\pm0.1$	$3.9^{d}\pm0.1$
LSD		0.389	0.386	0.386	0.397	0.325

Mean (±SD) values bearing different superscript (s) in the same column are significantly different (P≤0.05) according to DMRT

4. Conclusion

This study demonstrates that pretreatment with sodium bicarbonate followed by sun drying significantly improves the functional and sensory characteristics of potato flour. These findings suggest a practical and efficient method for producing high-quality potato flour suitable for various food formulations. Further studies exploring long-term stability and nutritional variations across potato varieties are recommended

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