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Research Article
Industrial Utilization of Pumpkin (*Cucurbita pepo* L.) Starch: Its Physicochemical and Pasting Properties

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Abstract

Background and Objective: Pumpkin starches could be used in the food industry as free gluten starch. In this study, the physicochemical and pasting properties of pumpkin (*C. pepo* L.) starch were analyzed to determine the industrial application of pumpkin starch in food industry. Several studies have been carried out on the thermal and rheological properties of pumpkin but they remain less regarded and under-utilized. **Materials and Methods:** Pumpkin was cultivated and harvested on farmland in Ijero-Ekiti, Nigeria. The 500 g of pumpkin pulp from pumpkin (*C. pepo* L.) was washed with clean water at room temperature, milled and filtered. The residue was dried, while the slurry was centrifuged at 3000 rpm for 15 min. The lower sediment portion (starch) was washed three times with distilled water, air-dried at room temperature, milled and stored. The physicochemical properties (carbohydrate, crude protein, crude fat, moisture, starch yield and colour content), functional and pasting properties were analyzed. The values were reported in triplicates and presented as Means±SD, the statistical difference between the means was determined using a One-way Analysis of Variance (ANOVA) Statistical Package for Social Science (SPSS). **Results:** The results analyzed were 1.24, 0.84, 0.75, 70.69 and 1.69 g/100 g for total ash, crude fat, crude protein, carbohydrate and starch yield, respectively. The color parameters revealed the values for lightness (L*), red-green (a*), yellow-blue (b*), chroma (c*) and hue (h) were 86.52, 2.13, 9.69, 9.92 and 77.89, respectively with an average particle size of 236.50 µm. The water absorption capacity (WAC) was 11.6%, the oil absorption capacity (OAC) was 0.87 g/g, the foaming capacity (4.24%) and the swelling index (145.87 g/mL). The comprehensive examination of the starch's pasting (rheological) properties revealed a peak viscosity of 574.67 RVU and a breakdown viscosity of 224.00 RVU. Additionally, the starch displayed a peak temperature of 84.53°C and a time of 5.22 min. **Conclusion:** The starch from pumpkin pulp shows a high level of purity and better pasting properties, thus pumpkin starch could be recommended as by-product in the food industry.

Key words: Pumpkin pulp, starch, pasting temperature, color parameters, starch yield functional properties, protein

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pumpkin (*Cucurbita pepo* L.), known as Elegede in the Southwest of Nigeria[1], has fruit with a thick yellow pulp containing approximately 90% water, it is a valuable source of beta-carotene, a precursor of vitamin A[2] and dietary fiber with other bioactive compounds[3]. Starch constitutes a major component of pumpkin flesh, reaching up to 60% of the dry weight[4].

Starch is a tasteless, odorless, white polysaccharide found in the tubers and seeds of plants. It is produced in plant cells' chloroplast and amyloplast through photosynthesis and stored during tuber sprouting, seed germination and fruit maturation[5]. Starch plays a role in thickening, preserving and enhancing quality in various foods, including baked goods, confectioneries, pasta, soups and sauces and mayonnaise[6]. Starch is also used as a stabilizer in the yogurt industry to manage texture and decrease whey separation[7]. The functional behavior of starches depends on the morphological, thermal, rheological and physicochemical properties[8]. The rheological properties of starch pastes can be examined using the rapid visco analyser (RVA) or rheometer. Upon heating, starch granules undergo swelling and bursting, leading to the leaching of amylose and the formation of a viscous paste[9]. Pasting properties are crucial in terms of viscosity, including peak, final, breakdown and setback viscosity[10].

According to Przetaczek-Rożnowska[11], pumpkin starch pastes have more than four times higher final viscosity compared to corn starch pastes and pumpkin starch gels show significantly better texture properties than potato and corn starch gels. Prior research has shown that pumpkin fruit contains varying levels of starch, ranging from 0.49-9.22 g/100 g for low starch content and 9.76-16.27 g/100 g for high starch cultivars[12]. The structural and functional properties of starches from different varieties of pumpkin fruits have been examined[13]. Despite these attributes, pumpkin starch remains underutilized. Its economic potential has not been fully explored and is predominantly used locally[14]. This research aims to evaluate the physicochemical, functional and pasting properties of pumpkin starch and its potential applications in industries.

MATERIALS AND METHODS

Study area: Pumpkin was grown and harvested in September, 2023 at a farmland in Ijero Ekiti, Ekiti State, Nigeria. The pumpkin was authenticated and the research was carried out at the Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.

Production of pumpkin starch: The 500 g of pumpkin pulp from pumpkin (*C. pepo* L.) was washed with clean water at room temperature, milled and filtered. The residue was dried, while the slurry was centrifuged at 3000 rpm for 15 min. The upper portion of the sediment was discarded and the lower sediment portion containing starch was washed three times with distilled water. The starch was air-dried at room temperature, milled with a blender and stored in an airtight container at 10°C[15].

Physicochemical analysis of pumpkin starch: The standard method was used to determine the moisture, total ash, crude fat, crude protein and carbohydrate content of the starch[16]. The colour content of pumpkin pulp starch was determined using a colour meter PCE-CSM 2 (Deutschland GmbH) connected to a CQCS3 software, Version NR20XE (PCE Instruments UK Ltd., United Kingdom)[17].

Functional properties of pumpkin starch: Water absorption capacity (WAC) is an index of the amount of water retained within a food matrix under certain conditions and oil absorption capacity (OAC) is an index of the amount of oil retained within a food matrix under certain conditions. About 10 mL of distilled water was added to 1 g of the sample weighed into a dry centrifuge tube and stirred vigorously. The resulting suspension was centrifuged for 30 min at 4000 rpm. The supernatant was poured into a plate and the residue was measured[18].

The foaming capacity (FC) and bulk density were determined according to the method of Onwuka[19]. The samples were carefully placed in a 25 mL graduated cylinder and then packed by tapping the cylinder on the bench top 10 times from a height of 5 cm. The volume of the sample was then recorded. This process was repeated three times for each sample and the bulk density was calculated in g/mL for each sample.

The solubility power and swelling capacity of each sample were also calculated as a multiple of the original volume according to Aluge *et al*.[20]. A clean, dry graduated cylinder (50 mL) was used to transfer 1 g of each flour sample. After gently leveling the flour samples in the cylinder, the volume was recorded. Subsequently, 10 mL of distilled water was added to each sample. The cylinder was then swirled and left to stand for 60 min, during which the volume change (swelling) was recorded every 15 min.

Pasting properties of pumpkin starch: The starch pasting characteristics were determined using a rapid visco analyser (RVA Super 3, Newport Scientific Pty. Ltd., Australia). About 3 g of sample was combined with 25 mL of water in a sample canister. The sample was thoroughly mixed and placed into the RVA using the 12 min profile. The slurry was heated at 50°C with a 2 min holding time. The heating and cooling were conducted at a constant rate of 1500 rpm at 11.25°C/min. The corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile were recorded using a computer connected to the RVA[21].

Statistical analysis: All values were carried out in triplicate. The results were presented as Means±SD and the statistical difference between the means was determined using a One-way Analysis of Variance (ANOVA). Statistical Package for Social Science (SPSS) version 21 for Windows was used for the statistical analyses. The result were obtained at $p<0.05$.

RESULTS AND DISCUSSION

The physicochemical properties of pumpkin starch were detailed in Table 1, which includes information on its composition, starch yield and color parameters. Starch is a vital biomaterial used in various industries and as a food product[21] and plays a significant role in numerous applications.

The study revealed that the moisture content of pumpkin starch is 12.29%, slightly higher than the 9.07% reported by Ojo *et al.*[22]. However, this moisture content falls within the acceptable range for effective storage and resistance to microbial growth[23]. Furthermore, the crude fat (0.84%) of pumpkin starch was higher than the 0.31% obtained for taro starch[24] and the report of Ojo *et al.*[22] for crude fat (0.34%) of cassava starch. Lipids in starch granules can increase their functionality and significantly reduce the swelling capacity of the starch paste. Lipids are one of the major constituents of foods and are important in our diet. They are major sources of energy and play a major role in determining the overall physical characteristics, such as flavor, texture, mouth feel and appearance[25].

Additionally, the total ash content of pumpkin starch (1.24%) surpasses that reported for cassava starch (0.32%)[22] and various maize starches[26], the ash content in the pumpkin starch indicated a good source of minerals preserved and might be suitable for consideration in food production. Total ash is an inorganic residue representing the total minerals contents of a food, this result agreed with the report of Kasaye *et al.*[27].

The crude protein of the pumpkin starch was 1.75%. The result of the study is higher than the result obtained by Bustillos-Rodríguez *et al.*[26] who reported 0.55% total crude protein of different maize starches. Comparatively, Ojo *et al.*[22] reported a higher value of 1.1% for the total crude protein content of cassava starch. The crude protein (1.75%) for pumpkin starch is significantly higher than the 0.04% reported for the crude protein of pumpkin starch[28]. The high crude protein content obtained in the present pumpkin starch study is beneficial as protein helps to promote growth and development.

The carbohydrate value of 70.67% obtained for pumpkin starch was lower than the 83.8% reported for taro starch[24]. The lower carbohydrate content could be beneficial for diabetic patients, as carbohydrates serve critical functions in energy storage and structural components.

The percentage yield of the pumpkin starch was 1.69%, similar to the range (0.49-9.22 g/100 g) for low starch cultivars in pumpkin fruit[14]. The color parameters, including lightness (L*), red-green (a*), yellow-blue (b*), chroma (c*) and hue (h), were 86.52, 2.13, 9.69, 9.92 and 77.89, respectively, with an average particle size of 236.50 µm. These values depicted the color characteristics of the pumpkin starch samples in comparison to other starches[26]. The colour of finished starch is an important attribute that determines their industrial application[29].

Functional properties are the essential physical and chemical attributes that represent the complex interactions between the composition, structure, molecular conformation and characteristics of food components within their environment, as observed and measured[30].

The functional properties of pumpkin starch were detailed in Table 2. The water absorption capacity of pumpkin starch was 11.60%. Lawal[31] suggested that starch with a higher amorphous material content would likely have more water-binding sites, leading to increased water absorption. A lower water absorption capacity for pumpkin starch indicates a reduced proportion of amorphous material, resulting in fewer water-binding sites and lower water absorption.

The oil absorption capacity (OAC) obtained for pumpkin starch was 0.87%. This value is lower than the reported OAC of 3.80% for native Jack bean starch[32] and tiger nut starch[33]. The OAC signifies the product's ability to entrap oil, an important attribute for various applications such as meat replacers and extenders, playing a key role as a flavor retainer and enhancer of food texture[34].

The bulk density of the starch was 1.05 g/mL. Bulk density serves as an indicator of flour expansion and a measure of food product porosity[35]. It is influenced by initial moisture content, particle size and starch content. The high bulk density of pumpkin starch suggests that its suitability for a wide range of food preparations, including liquid, semisolid and solid foods[36].

Table 1: Physicochemical properties of pumpkin starch

Parameter	Composition
Moisture (g/100 g)	12.29±0.06
Crude fat (g/100 g)	0.84±0.11
Total ash (g/100 g)	1.24±0.25
Crude protein (g/100 g)	0.75±0.03
Carbohydrate (g/100 g)	70.67±0.69
Starch yield (%)	1.69±0.13
L*	86.52±4.04
a*	2.13±0.94
b*	9.69±3.14
c*	9.92±3.27
H	77.89±1.27
Average particle size (μm)	236.50±3.89

L*: Lightness, a*: Red-green, b*: Blue-yellow, c*: Chroma, H: Hue and Mean±Standard Deviation

Table 2: Functional properties of pumpkin starch

Parameter	Composition
Water absorption capacity (g/g)	11.60±0.09
Oil absorption capacity (g/g)	0.87±0.02
Bulk density (g/mL)	1.05±0.01
Foaming capacity (%)	4.24±0.02
Wettability (min)	4.37±0.01
Solubility (%)	10.35±0.02
Swelling capacity (g/mL)	145.87±0.03

Mean±Standard Deviation

Table 3: Pasting properties of pumpkin starch

Parameter	Composition
Peak viscosity (RVU)	574.67±4.04
Trough (RVU)	352.67±2.52
Breakdown (RVU)	224.00±4.00
Final viscosity (RVU)	627.33±3.06
Setback (RVU)	273.33±2.89
Pasting temperature (°C)	5.22±0.23
Pasting time (min)	84.53±0.25

Mean±Standard Deviation

The foaming capacity of pumpkin starch was determined to be 4.24%. This measure gauges the interfacial area created by protein during foaming[37]. The low foaming capacity observed for pumpkin starch could be attributed to its low protein content.

Wettability denotes the time required for a sample to become completely wet[38]. The wettability of pumpkin starch was recorded at 4.37 min. This result suggests that the samples exhibited a shorter wetting time, indicating a stronger affinity for water. Wettability is linked to the ability of powdery particles to absorb water on their surfaces, thereby facilitating reconstitution, with particle size playing a significant role[39]. This outcome suggested that pumpkin starch would readily reconstitute in food systems upon hydration.

The solubility of pumpkin starch was 10.35%. The increase in solubility index during processing may be attributed to heightened moisture content, likely resulting from proper gelatinization and lateral expansion of the starch[40]. This solubility exceeded the values reported for different cassava cultivars[22] but was lower than the report for squashes[13].

The swelling capacity, an indicator of the starch's ability to imbibe water and swell, was determined to be 145.87 g/mL for pumpkin starch. The swelling index of granules reflects the extent of associative forces within the granules, with higher swelling indices associated with lower associative forces[41].

The properties of pumpkin starch during the pasting process were presented in Table 3. Factors such as amylose content, amylopectin molecular structure and molecular weight generally influence the characteristics of starch pasting[42]. The obtained pasting properties for pumpkin starch, including peak viscosity (574.67 RVU), trough (352.67 RVU), breakdown (224.00 RVU) and setback (273.33 RVU), were notably higher than those reported for pumpkin starch[28]. This suggests that pumpkin starch can endure heating and shear stress during cooking[40]. The final viscosity of pumpkin starch measured at 627.33 RVU indicates its ability to form a paste or gel after cooling. A higher final viscosity is often linked to increased breakdown, implying less stability in starch paste[33]. The setback value for pumpkin starch was 273.33 RVU, higher than the value reported for cassava starch[22]. Elevated setback values indicate lower retrogradation during cooling, which re-associates amylose and amylopectin chains into a more ordered structure, resulting in physical changes such as increased viscosity and gel formation[40]. With a trough viscosity of 352.67 RVU, pumpkin starch demonstrates its capability to withstand breakdown during cooling. The peak time and temperature obtained for pumpkin starch were 5.22 min and 84.53°C, respectively, aligned with the report for cassava starch[22]. The physical and chemical properties of pumpkin starch indicate its potential use in the food industry, especially as stabilizers. However, other methods of extracting starch from pumpkins should be explored and further research should be conducted on modifying pumpkin starch.

CONCLUSION

The properties of pumpkin starch, including its low-fat content and high protein levels, indicated a high level of purity. Additionally, the starch exhibited a high brightness value and strong pasting ability, making it potentially suitable for use as a stabilizer in the food industry. The study recommends investigating alternative extraction methods for purifying pumpkin starch and to potentially modifying the starch.

SIGNIFICANCE STATEMENT

The objectives of this study were to extract starch from the pulp of pumpkin and to examine its physicochemical, functional and pasting properties. Starch plays an important role as a stabilizing agent in the food industry. While previous research has covered the isolation of starch from pumpkin pulp, a comprehensive analysis of its physicochemical and pasting properties is still missing. It is important to assess the proximate composition, functional properties and paste characteristics of pumpkin starch to determine its potential applications and suitability in the food industry, especially as a stabilizer for yogurt production, which will be published subsequently. The research indicated that pumpkin starch demonstrates high purity and strong pasting properties, making it a promising food ingredient for the food industry. It is recommended that different methods of starch extraction should be employed to get the best starch yield in the future.

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