# Preparation and Functional Properties of Hydroxypropylated Sweet Potato (*Ipomoea batatas* L.) Starch

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Sweet potato (*Ipomoea batatas* L.) is an underutilized tuber in Nigerian industries. Its starch has diverse culinary and non-food applications. In this study, locally sourced sweet potato starch was isolated and hydroxypropylated using propylene oxide. The percentage of hydroxypropyl groups added and the degree of substitution were determined. Functional groups and morphological characteristics of both native and modified starches were analyzed using FT-IR and scanning electron microscopy (SEM). Functional and pasting properties were also examined. The degree of substitution and hydroxypropyl content fell within acceptable food application limits. SEM showed that granule structure remained intact after surface modification. Hydroxypropylated starches exhibited higher swelling and solubility than native starch from 50 to 90 °C. Both properties increased with greater molar substitution. Hydroxypropylation reduced storage turbidity and syneresis. Peak viscosity increased, while pasting and peak temperatures decreased after modification. Hydroxypropylated starches also had lower setback values. These results indicate enhanced functional properties in modified starch. The modified starch showed industrial potential for use in confectioneries, salad cream, mayonnaise, as well as in roles such as texturizers, thickeners, stabilizers, fillers, flavor carriers, and ingredients in beverages and bakery products, all with energy-efficient processing advantages.

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## INTRODUCTION

Starch is the most common naturally growing bio-degradable polymeric carbohydrate reserve; it is relatively inexpensive and widely available in various plant leaves, fruits, and seeds, while different stems and roots also contain this material (Saeed *et al.* 2021). Starch is a polysaccharide composed of glucose chain units. The branched and unbranched forms of starch are amylose and amylopectin, respectively. As reported by Wang *et al*. (2020a) both starch polymers exist as semi-crystalline granules in all

higher plant species. Starch is an odorless and tasteless white crystalline solid powder. Starch can dissolve in water and produces a colloidal mixture that transforms into a gel upon refrigeration, thus leading to specific physical attributes (Salwa *et al*. 2010). Multiple research outlets identify starch as the primary dietary caloric component in global nutrition because it appears in cereals including rice, maize, corn, wheat, barley, tiger nut, millet, chestnuts, mung beans, peas, chickpeas, and several additional plant types as well as tuber crops (yam, cassava, potatoes, cocoyam) (Chandrasekara and Kumar 2016). The functional properties of starch depend on the ratio of amylose to amylopectin, including the viscosity, shear resistance, gelatinization, solubility, gel stability, and retrogradation (Afolayan *et al.* 2014; Bashir and Aggarwal 2016). Food manufacturers employ starch as a component that affects food characteristics such as appearance properties, in addition to regulating moisture content, product consistency, and shelf life. Starch offers a variety of functional properties that facilitate binding, as well as expansion and densification or opacity creation and moisture absorption or prevention. Starch granules vary in size and shape according to the botanical source and processing methods. The structure of starch granules impacts their effectiveness in various applications, including industrial and food processing (Li *et al.* 2020a; Chen *et al.* 2021).

Starches derived from different plant sources often display differences in the composition and structural characteristics, resulting in variations in their physicochemical properties such as swelling, hydrolysis, degradation, rheology, solubility, and thermal behavior. These differences are crucial for the development and production of starch-based products. Moreover, the diverse features of the starch structure typically dictate the functional properties of starch granules, including swelling power, solubility, gelatinization, retrogradation, syneresis, and rheological behavior (Wang *et al.* 2020b; Thanyapanich *et al.* 2021; Yang *et al*. 2022; Hou *et al.* 2023; Obadi *et al.* 2023; Yan *et al.* 2024; Liu *et al.* 2024). However, native starch has particular drawbacks in industrial applications. Native starch granules undergo rapid hydration followed by swift swelling and rupture, leading to a loss of viscosity and the formation of weak-bodied cohesive pastes (Zia-ud-Din *et al.* 2017). There is a need to overcome these drawbacks by developing modified starches with enhanced functional properties.

Starch can be modified physically, chemically, enzymatically or by a combination of these methods. To address the undesirable properties of starches, modifications are performed (Granza *et al.* 2015). The changes in intra- and inter-molecular bonding patterns during chemical modification can lead to variations in starch functional properties and physicochemical characteristics (Iftikhar and Dutta 2019). Chemical modification techniques, which include oxidation, esterification, and etherification enable bonding associations between the reactive hydroxyl groups of starch and new chemical groups thus changing the chemical properties of starch (Wang *et al*. 2021).

Starch undergoes hydroxypropylation through its etherification reaction involving propylene oxide treatment under basic conditions. It is one of the chemical methods of modifying starch functionalities that has been less used by researchers. A few hydroxypropylated starch features include low gel opacity, improved freeze-thaw stability, lower gelatinization temperature, lower dissociation enthalpy, and higher cold-water solubility (Fu *et al*. 2019). The retrogradation tendency of gelatinized starch paste decreases after etherification treatment according to Wang *et al*. (2021). Experimental studies reveal that granule size does not influence the extent of hydroxypropylation in starch molecules (Yang *et al*. 2016). The reaction conditions result in greater

hydroxypropylation for potato starch amylose than amylopectin without affecting the size of amylopectin crystallites post-modification (Shi and BeMiller 2000).

The sweet potato plant (*Ipomoea batatas* L) belongs to the family of Convolvulaceae as a dicotyledonous species. Lebot (2009) identifies this plant as one of the most economically vital tropical root and tuber crops that successfully thrive in marginal soils, while Oolo *et al*. (2014) verify that the root contains more protein than other root and tuber crops, including cassava and yams. Chromophoric compounds found in specific varieties include β-carotene, anthocyanin, and phenolic compounds. Different sweet potato varieties exhibit distinct crystalline arrangements and amylose quantities while showing differences in gelatinization and pasting temperatures and water-binding strength as well as swelling capacity and degrees of solubility (Collado *et al*. 2001. Different growth environments can modify the fundamental characteristics of sweet potato starch materials. The physical characteristics of sweet potato starch including amylose content gelatinization temperature and average granule size showed increased levels when soil temperatures increased (Noda *et al*. 2002). The potential applications of starch expansion primarily depend on its physicochemical and functional properties (Iwe 2000; Akubor and Igba 2019).

Sweet potato is an underutilized source of starch for industrial applications despite its high percentage of starch content. The present research aimed to extract starch from sweet potato tuber harvested in the Ijebu-Ode, Ogun state in the western part of Nigeria and then modify it through hydroxypropylation to optimize its functionality for potential uses across food and non-food sectors.

## MATERIALS AND METHODS

### Starch Extraction

Starch extraction from sweet potato tubers was carried out using the method described by Senanayake *et al.* (2014). A manual peeling process was performed on cleaned sweet potato tubers following their washing under running tap water to eliminate surface soil. After peeling, the potatoes were ground through the food processor with clean water added at medium speed for 3 to 4 min. Extra extraction of the residue took place after adding water through the sieve. Muslin cloth was used to filter the obtained solution. The starch slurry was allowed to settle for a period of 2 to 3 h at room temperature. The supernatant was poured off. The materials in the starch suspension were withdrawn from the bottom of the container into water before filtration. This mixture was kept undisturbed for 2 h. The procedure to allow settling was performed three consecutive times. The sediment starch obtained was dried in an oven at 50 ºC and this temperature was maintained for 6 to 8 h before allowing it to reach room temperature. The dried starch was pulverized. The extracted starch was labeled NSPS and placed in an air-tight container for additional analysis. The starch yield was calculated as,

$$SY = {ES}/{ASP} X100 \quad (1)$$

where *SY* is the starch yield (%), *ES* denotes extracted starch (g), and *ASP* is the amount of sweet potatoes (g).

## Hydroxypropylation of Starch

About 100 g starch was mixed with a 500 mL solution containing 0.3% sodium tetraoxosulphate (VI). The solution was stirred before adding 0.5 mL of 0.5% propylene oxide solution drop-by-drop while maintaining a pH of 9.5 through the addition of 0.1M NaOH. The reaction was continued for 15 min before terminating by decreasing the solution pH to 5.5 using 0.5 N HCl. Each residue was subjected to multiple washing and drying cycles before proceeding with analysis. The dried sample was labeled as HSPS before storing it for analysis (Iftikhar *et al.* 2022).

## Hydroxyl Group Percentage and Degree of Substitution

About 0.1 g starch was taken in a volumetric flask and combined with 25 mL 1N tetraoxosulphate (VI) acid before placing it in a water bath to obtain a clear solution. The solution was then diluted to 100 mL with distilled water when the mixture reached room temperature. Approximately 1.0 mL of solution was withdrawn into a conical flask, followed by dropwise addition of 8 mL of concentrated tetraoxosulphate (VI) acid. The contents were allowed to heat in a boiling water bath for 20 min, then allowed to cool to room temperature, and then placed into an ice bath. After thorough mixing with 0.6 mL of the 3% ninhydrin reagent in 5% sodium metabisulphite solution, the mixture was stored at room temperature for 1.0 h. A UV spectrophotometer ((Shimadzu UV-3600 UV-Vis-NIR; Kyoto, Japan) was used to measure the absorbance at 590 nm after adding concentrated the acid to bring the total volume to 25 mL and native starch was used as the reference sample. Standard aqueous solutions with propylene glycol concentrations of 10, 20, 30, 40 and 50 µg/mL were used to create the calibration curve by preparing 1.0 mL aliquots (Iftikhar et al 2022).

The percentage of hydroxypropyl groups and degree of substitution were calculated as follows,

$$HPG(\%) = \frac{APGx0.7763x10}{WS} \quad (2)$$

$$DS = \frac{162xHPG}{5800 - 58xHPG} \quad (3)$$

where *APG* is the amount of propylene glycol in µg/mL, *WS* is the weight of sample in g, and DS is degree of substitution.

## Fourier Transform Infrared Spectroscopy

Infrared spectra for native and modified starch samples were obtained by using a Fourier Transform Infrared (FTIR) spectrometer (Cary 630 Agilent Technologies, USA) operating at a resolution of 2.0 $cm^{-1}$ together with KBr optics in wave numbers from 650 to 4000 $cm^{-1}$

## Scanning Electron Microscopy

The native and modified starch samples' morphology was observed using a scanning electron microscope (SEM, EVO-18, Zeiss, Germany). Samples were vacuum dried, fixed on double-sided tape, sputter-coated with gold and observed at 5000x magnification.

## Swelling Power and Solubility

According to the methods presented by Paramitasari *et al.* (2024) and Dhull *et al.* (2021). A sample of 0.6 g starch was combined with 40 mL of water while heating the mixture at 50, 60, 70, 80, and 90 ºC for 30 min. The procedure included continuous stirring to avoid the formation of starch lumps. The sample was centrifuged at 3000 rpm for 15 min to separate the suspension into supernatant and residue. A 5 mL portion of supernatant was transferred into a pre-weighed petri dish, where it was dried for 2 h at 110 ºC before weighing. The result can be expressed as,

$$S = \frac{WSS}{WS} \tag{4}$$

$$SP = \frac{WSP}{WS - WSS} \tag{5}$$

where $S$ is solubility (%), WSS is the weight of soluble starch (g), $WSP$ is the weight of sediment paste (g), and $SP$ is the swelling power.

## Water and Oil Absorption Capacities

Water absorption measurements for starch solutions followed the procedure described by Jung *et al*. (2017). After mixing 1.0 g of starch powder with 10 mL of distilled water, the sample underwent centrifugation for 10 min at 4000 rpm. The water absorption capacity was expressed as,

$$WAC = \frac{WR}{WS} \tag{6}$$

where $WAC$ is the water absorption capacity, and $WR$ is the weight of residue in g. Starch samples underwent oil absorption capacity testing following by the method described in Ganiyat *et al.* (2017). A 10 mL olive oil sample was combined with 1.0 g of starch, followed by a 30 min room temperature incubation period and subsequent centrifugation at 3000 rpm for 15 min. The oil absorption capacity was
expressed as,

$$OAC = \frac{WR}{WS} \tag{7}$$

where $OAC$ is the oil absorption capacity.

## Freeze-thaw Stability

The starch samples underwent freeze-thaw testing based on the Iftikhar *et al*. (2022) method. 5% starch solutions were heated at 95 ºC under constant agitation for 30 min before weighing 10 g of paste into previously weighed centrifuge tubes and tightly capping them. The free water separation process for starch paste took place by centrifuging at 1000 rpm for 10 min. Tubes with starch paste were subjected to seven cycles of freezing at -18 ºC for 24 h, followed by thawing at 30 ºC for 4 h. The freeze-thaw process ended with centrifugation at 4000 rpm for 30 min. Each freeze-thaw cycle led to the calculation of syneresis, which represented the measured amount of water separation.

$$S = \frac{WWS}{WS} \tag{8}$$

In. Eq. 8, *S* is the syneresis, and WWS is the weight of water (g) separated.

### Paste Clarity

The evaluation of starch sample paste clarity followed Lawal (2011) with modifications. About 50 mg of starch was suspended in 5 mL of distilled water in test tubes. The test tubes were heated in a boiling water bath with periodic shaking for 30 minutes. The spectrophotometer measured the percentage transmittance at 650 nm against water as a blank solution after the solution reached room temperature. The starch samples were stored at 30 ºC for 1 to 5 days to measure transmittance at 650 nm every 24 hours.

### Gelation Properties

The procedure started with heating starch suspensions containing 2%, 4%, 6%, 8%, 10%, and 14% (w/v) of starch in 5 mL distilled water in boiling water for 1.0 h before rapidly cooling them under running water. The test tubes received additional cooling to 4 ºC for 2 hours. Least gel concentration (LCG) is the concentration at which the sample remains in its initial position when the test tubes are inverted (Lin *et al.* 2017).

### Pasting Properties

A Rapid Visco analyzer (Newport Scientific Pty Ltd, Warie-wood NSW 2102, Australia) was used to measure the pasting properties of starch samples. The procedure required weighing 3 g of dried starch samples into a dehydrated canister, followed by adding 25 mL of distilled water to this container. The experimental conditions followed Rapid Visco analyzer specifications, during which the suspension was properly mixed before placing the canister into its structure. The suspensions were heated for 1.0 min at 50 ºC, then to 95 ºC while maintaining 2 min of holding time, followed by the cooling stage reaching 50 ºC with an additional 2 min of holding time. The heating and cooling process occurred at an 11.8 ºC/min constant rate. Pasting parameters such as pasting temperature, peak viscosity, trough, breakdown, final viscosity, and set-back viscosity were recorded.

## RESULTS AND DISCUSSION

### Degree of Modification and Percentage of Substituent Groups

The analyzed values for hydroxypropyl group percentage (HPG) and degree of substitution (DS) of hydroxypropyl sweet potato starch amounted to 0.97% and 0.028%, respectively. The DS is the number of hydroxyl groups in the repeating unit that can be chemically altered. The results aligned with the Food application recommendations of 7% and 0.2%, respectively (Ochubiojo and Rodrigues 2012).

### Structural Evaluation by Infrared Spectroscopy

The FT-IR spectra in Fig. 1 compares the native and hydroxypropylated sweet potato starches. Specifically, the FT-IR spectra were used to compare the chemical structure of starch before (native sweet potato starches, NSPS) and after hydroxypropylated sweet potato starches (HSPS) modification with propylene oxide. In the unmodified starch (NSPS) spectrum, characteristic absorbance was observed, including a broad peak around 3460 $cm^{-1}$ corresponding to the O-H stretching vibration,

which can be due to the presence of starch or due to the presence of water (Mi and Meera 2020; Salim *et al*. 2020; Hashem *et al*. 2025).

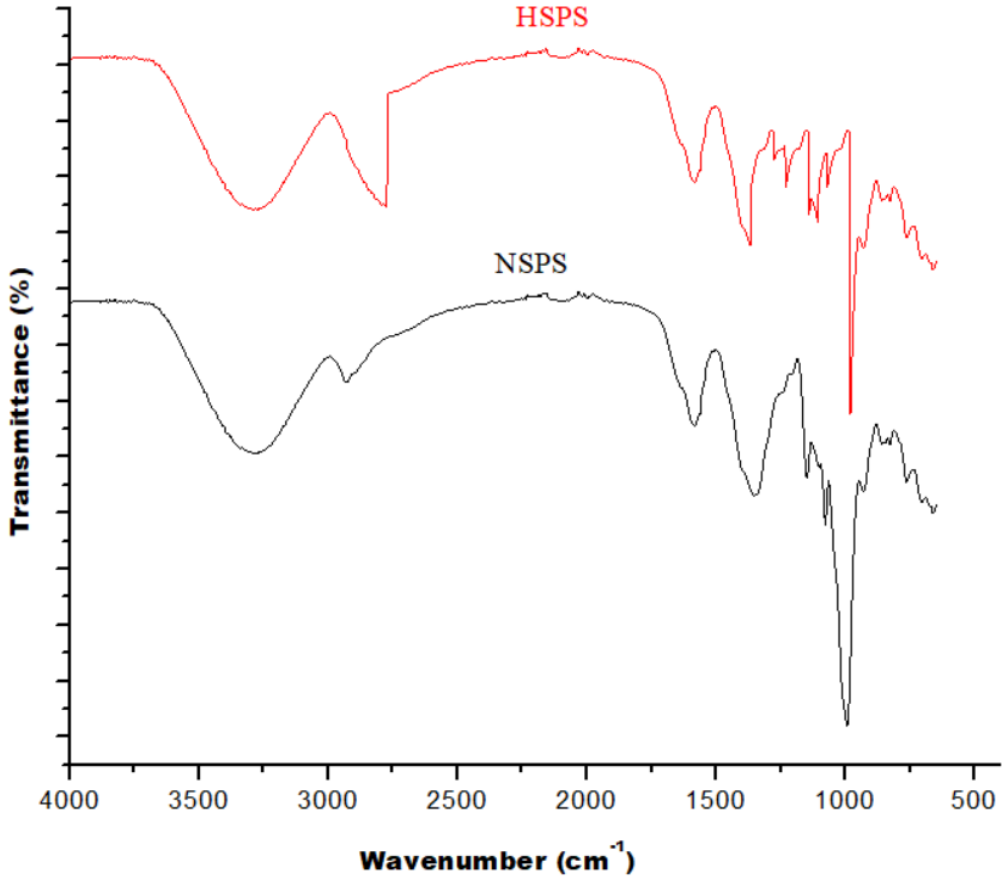


**Fig. 1.** FT-IR Spectra of native sweet potato starches and hydroxypropylated sweet potato starches.

Peaks in the region of 2980 $cm^{-1}$ correspond to C-H stretching vibrations (Granzal *et al.* 2015), while strong absorbance between 1030 and 1250 $cm^{-1}$ are be associated with C-O and C-C stretching in the glucose units of starch (Salim *et al*. 2020; Hashem *et al*. 2025). The peak at 1654 $cm^{-1}$ is typically attributed to the bending vibration of adsorbed water (H-O-H bending). Starch has a strong affinity for water, and this peak is often present due to moisture retention within the granules, while those seen at 1428 $cm^{-1}$ can be assigned to -C-H bending vibrations in the $CH_2$ groups of the starch backbone (Salim *et al*. 2020; Hashem *et al*. 2025). The presence of this peak after modification suggests some structural change in the starch polymer, likely due to the introduction of hydroxypropyl groups. After modification with propylene oxide (HSPS), notable changes were observed in the FT-IR spectrum. A shift and reduction in the intensity of the O-H stretching band (3340 $cm^{-1}$) suggest a decrease in hydrogen bonding, likely due to etherification. The appearance of new peaks around 2855 $cm^{-1}$ can be attributed to C-H stretching, confirming the introduction of hydroxypropyl groups. The peak associated with C-O stretching and C-H deformation in ether groups (-C-O-C-) was found at 1270 $cm^{-1}$, indicating successful starch etherification with propylene oxide. The increase in

intensity of this peak after modification confirms the incorporation of hydroxypropyl groups. The appearance of new peaks around 1233 $cm^{-1}$ and 1150 $cm^{-1}$ can be attributed to C-O-C stretching, confirming the introduction of hydroxypropyl groups. These modifications indicate the successful substitution of hydroxyl groups with hydroxypropyl groups, altering the starch's structure and properties. Overall, the FTIR spectra confirm the structural changes that occur due to propylene oxide modification, which likely improves the starch's solubility, stability, and functionality in various applications.

## Scanning Electron Microscopy

The SEM images compare the morphology of starch granules before and after modification with propylene oxide, as depicted in Fig. 2. Before modification (a), the native starch granules appeared irregularly shaped with rough and aggregated surfaces. There was significant agglomeration, with smaller granules adhering to larger ones, indicating a porous and non-uniform structure typical of unmodified starch. In contrast, after modification (b) the starch granules had undergone modification with propylene oxide, exhibiting a smoother, more rounded morphology with increased aggregation. The granules appeared more distinct and well-separated, likely due to the etherification process, which reduces intermolecular hydrogen bonding. This modification could enhance the dispersibility of the starch and alter its physicochemical properties. The clear structural differences between the two images highlight the significant impact of propylene oxide treatment on starch granules, which can enhance their applications in various industries.

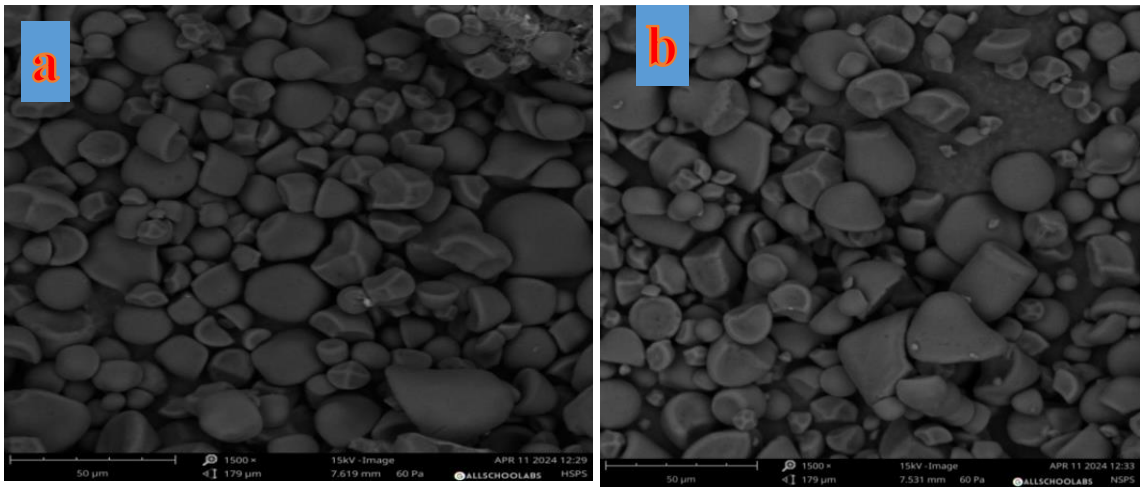


**Fig. 2.** SEM images of native sweet potato starches (a) and hydroxypropylated sweet potato starches (b)

## Swelling Power and Solubility

The swelling power values for NSPS spanned between 1.52 to 3.12, while hydroxypropylated starches ranged from 4.29 to 5.99 within a temperature range of 50 ºC to 90 ºC. Swelling power describes the starch's capacity to hydrate under particular cooking conditions. Starch swelling power depends on its ability to bind water molecules through hydrogen bonds and its behavior is controlled by three factors: the strength of micellar networks and the amylose content and the amylopectin molecular structure (Tang *et al*. 2005; Mehboob *et al*. 2015). The swelling power value of HSPS surpassed

native starch values because of its increased long-chain amylopectin structure, which aligns with findings on cassava starch (Saaki and Matsuki 1998). The solubility index measurements for native and hydroxypropylated sweet potato starches fell between 0.06 to 0.36 and 0.16 to 0.52, respectively. Solubility measurement reflects the hydrophilic nature of the modified starch.

The data in Table 5 displayed enhanced solubility of all starch samples when the temperature reached higher levels. A higher solubility index value in hydroxypropylated sweet potato starch resulted from its increased soluble amylose content as well as enhanced hydrophilic character (Lan *et al*. 2008). The hydrophilic hydroxypropyl group enhanced water absorption, which accelerated the swelling process of starch granules (Afolabi *et al.* 2012). The ability of starch to swell and its solubility rise after undergoing chemical modification, especially hydroxypropylation, agrees with Das *et al.* (2010), who studied starch derived from white yam.

## Water and Oil Absorption Capacities

Table 2 displays the effect of hydroxypropylation on water and oil absorption capacities of sweet potato starches. Hydroxypropylated starch achieved the maximum absorption values of 1.81 g/g as compared to 1.52 g/g recorded for native starch. According to Shah *et al.* (2017), water absorption capacity relies upon the molecular structure, crystalline and amorphous regions within the starch and distribution of granular size. According to Ikegwu *et al*. (2010), food products that effectively absorb water and oil result in improved sensory characteristics, including flavor retention and mouthfeel. The higher water and oil absorption of modified starch occurs because of the functional groups created on starch molecules allow better binding than native starch (Lawal 2004; Obioma *et al.* 2021).

## Freeze Thaw Stability

The freeze-thaw stability serves as an indicator of retrograde starch behavior (Hoover *et al*. 1997; Wang *et al*. 2023) based on measurements of the degree of syneresis, which indicates water release from gels over time or after refrigeration. The formulation process for refrigerated and frozen foods should include this factor as a fundamental consideration (Thomas and Atwell 1999).

**Table 1.** Effect of Freeze-thaw Cycles on Syneresis in NSPS and HSPS Samples

| Sample/ Cycle (%) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| NSPS | 4.3±0.75 | 7.5±0.57 | 13.8±0.35 | 14.8±0.35 | 15.8±0.10 | 18.6±0.15 | 20.2±0.30 |
| HSPS | 2.76±0.25 | 4.8±0.10 | 9.6±0.26 | 12.4±0.25 | 2.8±0.10 | 13.1±0.15 | 13.7±0.15 |

Values are expressed as mean ± standard deviation of triplicate determination. Where NSPS = Native sweet potato starch, HSPS = Hydroxypropylated sweet potato starch

**Table 2.** Water and Oil Absorption Capacities of the NSPS and HSPS Samples

| Samples | WAC (g/g) | OAC (g/g) |
|---|---|---|
| **NSPS** | 1.52±0.01 | 1.73±0.02 |
| **HSPS** | 1.81±0.02 | 2.15±0.02 |

WAC= Water Absorption Capacity, OAC = Oil Absorption Capacity, NSPS = Native Sweet Potato Starch, and HSPS = Hydroxypropylated Sweet Potato Starch

The freeze-thaw stability measurements for NSPS ranged between 4.3% and 20.2%, but HSPS exhibited stability values between 2.76% and 13.7%. After evaluation of total water release during all the cycles HSPS gels demonstrated the lowest syneresis behavior among the tested starches. Similar observations have been reported for hydroxypropyl finger millet starches (Lawal 2009) and Iftikhar *et al.* (2022), who studied the hydroxypropylation of rice starch.

## Paste Clarity

The utilization of starches in food industries depends heavily on the paste clarity, which determines both brightness and opacity in foods using them as thickeners (Mweta *et al*. 2015). Increased number of storage days resulted in a reduction of paste clarity across all sweet potato starch samples. Table 3 shows the percentage transmittance between the modified starch and the native starch samples. The experimental data indicated that modification improved starch paste clarity levels. The transmittance measurements for hydroxypropylated starch ranged between 98.3% and 90.5% according to Singh and Singh (2001) for potato starch. The high transmittance level of hydroxypropylated starch results from hydroxyl group substitutions in the starch molecule structure which create electrostatic repulsion between adjacent starch molecules while reducing inter-chain association and leading to enhanced percentage transmittance (Lawal 2004).

**Table 3.** Effect of Storage Time on Transmittance of NSPS and HSPS Samples

| Samples/Day (%) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **NSPS (%)** | 95.3±0.20 | 93.7±0.15 | 91.7±0.20 | 87.3±0.21 | 84.5±0.20 |
| **HSPS (%)** | 98.3±0.55 | 97.1±0.20 | 95.3±0.40 | 92.6±0.30 | 90.5±0.20 |

NSPS = Native sweet potato starch, and HSPS = Hydroxypropylated Sweet Potato Starch

## Gelation Properties

A reduced minimum gelation concentration indicates increased potential for structural support in various manifestation of superior gelation attributes. The starch gelation process, characterized by gelatinization, water absorption, and swelling, forms a multi-faceted, three-dimensional network that provides for different food applications. The NSPS sample demonstrated the least gel concentration value of 10% (w/v), but HSPS reached its least gel concentration at a concentration of 6% (w/v). Gelation properties result from a physical competition between starch gelatinization and protein gelation for available water (Singh and Singh 2001).

**Table 4.** Least Gel Concentration of the NSPS and HSPS Samples

| | | Sample Concentration (%w/v) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Samples** | **Remark** | 2 | 4 | 6 | 8 | 10 | 12 | 14 |
| **NSPS** | **Gelation** | - | - | + | + | + | + | + |
| | **State** | Liquid | Liquid | Viscous | Viscous | L.G.C | F.G | F.G |
| **HSPS** | **Gelation** | - | + | + | + | + | + | + |
| | **State** | Liquid | Viscous | L.G.C | F.G | F.G | V.F.G | V.F.G |

L.G.C = Least Gel Concentration, F.G = Firm Gel, V.F.G = Very Firm Gel, NSPS = Native sweet potato starch, HSPS = Hydroxypropylated sweet potato starch

**Table 5.** Swelling Power and Solubility indexes of NSPS and HSPS at Different Temperatures

| Samples/Temp | 50 ºC | 60 ºC | 70 ºC | 80 ºC | 90 ºC |
|---|---|---|---|---|---|
| **Swelling Power** | | | | | |
| **NSPS(g/g)** | 1.52±0.05 | 1.82±0.02 | 2.10±0.02 | 2.74±0.01 | 3.12±0.02 |
| **HSPS(g/g)** | 4.29±0.03 | 4.77±0.05 | 5.07±0.02 | 5.46±0.02 | 5.99±0.05 |
| **Solubility Index** | | | | | |
| **NSPS(g/g)** | 0.06±0.01 | 0.10±0.01 | 0.19±0.01 | 0.30±0.01 | 0.36±0.03 |
| **HSPS(g/g)** | 0.16±0.02 | 0.23±0.02 | 0.28±0.02 | 0.40±0.01 | 0.52±0.03 |

NSPS = Native sweet potato starch, HSPS = Hydroxypropylated sweet potato starch

The gelation properties of the native starch were reduced following succinylation and acetylation, according to Adebowale and Lawal's (2003) findings. According to Lawal (2005), the native new cocoyam starch's lowest gelation concentration was 8% (w/v). Similar findings regarding arrowroot starch gelation were documented by Okoye *et al*. (2010). The starch exhibited a lower least gel concentration than the native starch after hydroxypropylation.

## Pasting Properties

The pasting characteristics from Table 6 compare NSPS to acetylated and hydroxypropylated sweet potato starches. The process of heating starch and starch-based products with water treatment causes them to display different pasting profiles. Starch pasting properties represent essential features because they determine the way starch behaves as a paste material (Tsakama *et al*. 2010; Awolu *et al*. 2017). The pasting characteristics evaluate how starch behaves during and after cooking. Peak viscosity shows a transparent link with swelling power and breakdown viscosity among other factors, where amylopectin molecules with higher levels lead of substitution to superior swelling capacity (Ashogbon and Akintayo 2014). Research evidence combined with the tabular data supports that modified starch reached superior peak viscosity compared to native starch while also showing enhanced swelling action, according to Iftikhar *et al.* (2022). Hydroxypropylation led to a decrease both in starch pasting temperature and setback values. The high pasting temperature of starches makes them inappropriate for particular products because their preparation requires expensive energy consumption. Hydroxypropylated starch with a high pasting temperature takes an extended period to complete its gelatinization process during manufacturing operations (Afoakwa and Sefa-Dedeh 2002).

The low setback value of hydroxypropylated starch shows reduced retrogradation and indicates the addition of new substituent groups in modified starch derivatives that restrict starch molecule realignment after cooking, according to Moin *et al*. (2017). Hydroxypropylation of starch induced greater formation of viscous paste or gel after thermal cooling. The re-association tendency exhibited high levels in hydroxypropylated starch products based on the analysis results. After hydroxypropylation, the final viscosity of the samples increased in agreement with the study Obioma *et al*. (2022). Pasting time analysis revealed that hydroxypropylated starch required less cooking duration. The study showed a direct relationship between pasting time and pasting temperature because starches with lower pasting temperatures required shorter pasting times. The connection between pasting temperature and time produced practical energy-saving and time-saving benefits in industrial applications. The utilization of

hydroxypropylated starch with a quick pasting time and minimal pasting temperature will yield superior time and energy benefits during food preparation operations as compared to native starch samples.

**Table 6.** Pasting Properties of NSPS and HSPS Samples

| | RVA Parameters (cP) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Samples** | PV | T | BD | FV | SB | $P_{temp(^0c)}$ | $P_{time(min}$ |
| **NSPS** | 6947 | 3159 | 3788 | 3948 | 825.5 | 80.07 | 4.44 |
| **HSPS** | 6958 | 3260 | 3698 | 4025 | 765 | 79.95 | 4.34 |

PV = Peak Viscosity, T = Trough, BD = Breakdown, FV = Final Viscosity, SB = Setback Viscosity, $P_{temp}$ = Pasting Temperature, $P_{time}$ = Pasting Time, NSPS = Native sweet potato starch, and HSPS = Hydroxypropylated sweet potato starch

**Table 7.** Comparison of the Presented Study with other Hydroxypropylated Starches

| | **DS/MS** | **Swelling Power** | **Solubility Index** | **WHC** | **Paste Clarity** | **Reference** |
|---|---|---|---|---|---|---|
| Apio starch | 0.074 | 13.25 | 49.51 | 180.5 | 60 | Park and Kim 2020 |
| Cassava starch | Not determined | Not determined | 79.4 | 1.71 | | Mudiaga - Ojemu *et al.* 2023 |
| *Cajanus cajan* | 0.17 | 35.5-90 | - | - | 18.4 | Lawal 2011 |
| *Musa paradisiaca* | 0.028 | 15.66 | 69.21 | - | - | Metta and Sahoo 2024 |
| Potato cultivar | | 9.8 | 2.6 | | | Senanayake *et al*. 2014 |
| Potato | 0.071 | 5.99 | 0.52 | 1.81 | | Present study |

## CONCLUSIONS

This study investigated the functional properties, pasting properties, and characterization methods for native sweet potato starch (NSPS) and hydroxyethylated sweet potato starch (HSPS), and the following results were obtained:

1. The starch samples exhibited different functional and pasting characteristics, enabling their use in various food applications.
2. Native starch exhibited a higher syneresis value, which limits its use in frozen food applications, unlike hydroxypropylated starch.
3. Hydroxypropylated starch exhibited superior properties, such as, reduced syneresis, improved water and oil absorptions, better clarity, and enhanced swelling power and solubility.
4. These properties make hydroxypropylated starch ideal for both food and non-food applications.

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