STUDIES ON THE PHYSICOCHEMICAL AND PASTING PROPERTIES OF OXIDIZED SWEET POTATO *(Ipomoea batatas L. (Lam)* STARCH

[1]N. O. Sanyaolu, [1]L. K. Babalola, [2]M. O. Alabi-Abass, [1]A. A. Ibikunle and [1]S. T. Yussuf

Department of Chemical Sciences, Olabisi Onabanjo University, P.M.B. 2002, Ago-Iwoye, Ogun State Nigeria.

Department of Chemistry, Federal University of Agriculture, Alabata, Abeokuta,Ogun State, Nigeria.
Correspondent Author: alabiabassmuibatala@gmail.com

ABSTRACT

Starch isolated from sweet potato (Ipomoea batatas L.) was chemically modified by sodium hypochlorite (NaOCl). The physicochemical and pasting properties of the native and oxidized sweet potato starches (NSPS and OSPS) were investigated and they were also characterized by Fourier Transform Infrared Spectroscopy. In addition to the pH change from 6.40-7.40 on oxidation, other physicochemical properties such as; foaming capacity, water and oil absorption, moisture content, dispersibility, peak viscosity (PV), trough holding viscosity (TV) and final viscosity (FV) values increased by 2.27%, 0.83 and 0.46mL, 2.02%, 0.76%, 44.34 RVU, 138.34 RVU and 120.33 RVU respectively. However, the breakdown viscosity (BV) and setback viscosity (SV) experienced a decreased in value by 94.7 RVU and 18 RVU respectively following the oxidation process. In all, higher stability and reduced retrogradation to the starch characterized the oxidation process. The improved properties of the oxidized sweet potato starch (OSPS) are some of the essential properties in starch for its application in the pharmaceutical and other biodegradable industries which are lacking in native sweet potato starch (NSPS).

Keywords: native starch, oxidized starch, physicochemical properties, sweet potato, sodium hypochlorite.

INTRODUCTION

Starch is a renewable and biodegradable raw material available in abundance all over the world. It is a polysaccharide comprising glucose monomers joined by α-1, 4 linkage. Starch molecules contain hydrophilic -OH groups in the unmodified form which constitute intermolecular and intramolecular hydrogen bonds that limits its application for certain purposes. A major way to improve the limiting applications of starch is by modification which changes the chemical structures [10]. Introducing some oxidizing agents such as sodium hypochlorite, hydrogen peroxide and permanganate with different redox potentials have been used to modify starch by introducing -COOH and -CHO groups into the glucose chain by substitution of the -OH groups [4, 5, 10, 14, 16, 31]. The result of the oxidation process, produces oxidized starches of low retogradation [26].

Sweet potato (*Ipomoea batatas L*) ranks one of the most important amongst the tropical root and tuber crops species that are cultivated in large quantities on marginal soils. Economically, sweet potato has high nutritional content of starch ranging between 58-76 % (on a dry basis). Oxidized starch has gained enormous applications in several industries especially in the textile, paper and building materials industries where surface sizing and coating properties are highly essential. Some of the additional unique characteristics of oxidized starch are low viscosity, high stability, film forming and binding properties which makes it important in the food industry. In confectionaries as well, oxidized starch serves as an emulsifier, replaces gum arabic and a binding agent in batter productions [17].

Several researches have been carried out on isolation and oxidative modification of starches from different substrates such as corn, barley, potato, cassava, and beans [29, 30, 31]. In addition, some studies using oxidized starches to produce biodegradable films, characterization of starch with different oxidizing agents, effect of different catalyst concentrations at low levels of active chlorine on the physicochemical and morphological properties have been done [31]. However, there is little or no researches available to us on the isolation and oxidative modification of starch from Sweet potato (*Ipomoea batatas L*) substrates. Therefore, the aim of this research is to study the physicochemical and pasting properties of oxidized sweet potato starch.

MATERIALS AND METHODS

Sample collection

Tubers of sweet potato (*Ipomoea batatas L*) were purchased from a local market at Ago-Iwoye, Ogun State, Nigeria. The samples were verified by Chemical Sciences Department of Olabisi Onabanjo University Ago-Iwoye, Ogun State. Analytical graded reagents were used for this research.

Starch Isolation

A method similar to Lawal (2004) [20] was followed with some modifications. The sweet potato tubers were washed and peeled. The initial and final weights of the tubers were recorded before and after peeling and it was milled with a local electric blender. The homogenate was consecutively sieved, washed thoroughly in distilled water and the mixture was kept for about 3-4 hours to sediment. The sediments was decanted and the starch obtained was air dried and stored at room temperature. The starch isolate here is regarded as native sweet potatoe starch (NSPS).

Starch Oxidation

Starch oxidation was carried out according to the method described by Wang *et al.*, (2003b) [32], with slight modifications. 100 grams of native sweet potato starch was mixed with 500 mL of distilled water and the pH of the mixture was adjusted to 9.5 with 4.0 M NaOH. 10 grams of NaOCl was added to the slurry over a period of 30 minutes with constant stirring while maintaining a pH range of 9.0 – 9.5. The reaction was allowed to mix continuously for 10 minutes after all the NaOCl has been added. Subsequently, the pH was adjusted to 7.0 with 1 M H_2SO_4 and the oxidized starch was filtered using a Buchner filter funnel (Whatman filter No. 4) , washed severally with distilled water and air dried at room temperature for 48 hours to about 10% moisture content. The starch isolate here is regarded as oxidized sweetpotatoe starch (OSPS)

ISSN 0795 - 22066

Physicochemical Properties of Starch

Percentage yield of starch

The percentage yield was derived using the equation (1) below (Yussuf et al 2018) [33].

$$\text{Starch yield (\%)} = \frac{W_1\,(g)\ X\ \ 100}{W_2\,(g)} \qquad \textbf{(1)}$$

Where,

W_1= Quantity of starch isolated

W_2= weight of sample after peeling.

Foam capacity of starch

The foaming capacity was evaluated according to the method reported by Omojola *et al.*, (2010) [23]. 2 g samples each of the native sweet potato starch and modified starch were homogenized in 100 mL of distilled water and stirred vigorously using a magnetic stirrer for 5 minutes. The homogenate was poured into a 250 mL measuring cylinder and the volume occupied were recorded after 30 seconds. The foam capacity was expressed as the percent increase.

$$\text{Foam capacity} = \frac{\textit{average change in volume}}{\textit{initial volume}} \times 100 \qquad \textbf{(2)}$$

pH Determination

The pH was determined by a procedure practiced by Benesi (2005) [3]. 10 g samples of sweet potato starch was weighed in triplicate into a 100 mL beaker and mixed with 40 mL of distilled water. The resulting suspension was stirred for 5 minutes and allowed to settle for 10 minutes. A calibrated pH meter was used to measure the pH of the supernatant.

Dispersibility

This was determined by the method described by Ashogbon *et al.*, (2000) [2]. 10 g samples of sweet potato starch was suspended in 100 mL measuring cylinder and distilled water was added to make a volume of 100 mL, the solution was stirred vigorously for 10 minutes and allowed to sediment for 3 hours. The volume of sedimented starch was subtracted from 100 and the difference was recorded as percentage dispersed.

Water and oil absorption capacity

The method of Beuchat [36] with little modification was adopted in the determination of oil and water absorption capacity. 1 g sample each of native sweet potato starch (NSPS) and oxidized sweet potato starch (OSPS) were weighed in triplicate into test tubes, 10 mL of distilled water and 10 mL of groundnut oil were added in different test tubes. They were heated in a water bath for 30 minutes at 60 °C. The starch slurry was centrifuged at 1000 rpm for 15 minutes and the supernatant carefully decanted and the weight of the starch paste taken.

$$\frac{\text{WAC}}{\text{OAC}} = \frac{\text{weight of starch paste in g}}{\text{1 g of dry starch sample}} \qquad \textbf{(3)}$$

WAC = water absorption capacity

OAC= oil absorption capacity

Bulk Density

The bulk densities were measured using the method of Manek *et al.*, (2012) [21]. 50 g sample of starch was measured into a 250 ml measuring cylinder and the volume occupied by the sample without tapping was recorded. The cylinder was then subjected to tapping for 100 times respectively and the volume occupied after tapping was recorded as well. The bulk density was calculated as the ratio of the weight to volume occupied.

$$\text{Bulk Density Ratio} = \frac{\textit{weight of sample}(g)}{\textit{volume of sample}\ (ml)} \qquad \textbf{(4)}$$

ISSN 0795 - 22066

Moisture Content

The moisture content was analyzed by drying the starch powder at constant weight at 105 °C in dried and pre-weighed evaporating dishes. 5 g of starch was weighed into an evaporating dish placed in an automatic moisture analyzer and regulated at a temperature of 105 °C. After 5 hours of drying, the sample was withdrawn and placed in a desiccator to cool and then reweighed. A constant weight was obtained by repeating this process. The percentage of moisture in the starch was expressed as;

$$\text{Percentage moisture content} = \frac{(w_3 - w_2) x\ 100}{w_3 - w_1} \quad \textbf{(5)}$$

Where

W_1 = weight of dish

W_2 = weight of starch

W_3 = weight of cellulose and dish

Pasting Properties

The pasting properties of starch samples were determined using a Rapid Visco Analyzer (RVA-4. Newport Scientific Australia) with a Standard Analysis 1 profile. It is expressed in rapid visco units (RVU). 3.5 g of starch sample was weighed and 25 mL of distilled water was dispensed in a canister, paddle was placed into the canister and was joggled for a few seconds and then inserted into the RVA (Rapid visco analyzer). The measurement cycle was recorded at 960 rpm for 10 seconds.

Fourier Transform Infra-Red (FT-IR) Spectra of Starch

The IR spectra of the NSPS and OSPS were obtained from KBr (Potassium bromide) pellets using a 170SX FT-IR spectrophotometer (Nicolet, Madison, WI, USA) in the frequency range 4000-500 cm^{-1}. 200 mg of KBr pellets was added to 2 mg of starch sample and the mixture was crushed together. The mixture was transferred into a pellet forming-die, and then compressed using a pressing machine to form a pellet. After forming a pellet, it was transferred into a cell holder which was then inserted into a FTIR spectrophotometer.

RESULT AND DISCUSSION

Starch Yield (%)

Table 1 shows the results of the physicochemical properties of native sweet potato starch (NSPS) and oxidized sweet potato starch (OSPS). The quantity of starch obtained in both cases were not the sole objective of this research. The starch yield of NSPS was 12.62 % while that of OSPS was 12.67 %. The insignificant difference is probably due to the addition of sodium hypochlorite (NaOCl) during the modification process. The yield for the NSPS from the substrate was 12.62 %; a value lower than20-30% reported in literature [28]. The reason for the low yield is a variant of the technology employed in the isolation and the specie of the substrate [28].

ISSN 0795 - 22066

Table 1: Results of the physicochemical properties of native and oxidized sweet potato starch.

Parameters	Native	Oxidized
Starch yield (%)	12.62	12.67
Foam capacity (%)	3.8 ± 0.20	6.07 ± 0.09
pH	6.74 ± 0.057	7.40 ± 0.07
WAC (ml)	1.5 ± 0.41	2.33 ± 0.47
OAC (ml)	1.10 ± 0.082	1.56 ± 0.32
Dispersibility (%)	86.3 ± 0.50	87.06 ± 0.20
Moisture content (%)	16.82 ± 0.00	14.80 ± 0.00
Loose Density (g/ml)	0.5 ± 0.00	0.47 ± 0.0047
Tapped Density(g/ml)	0.68 ± 0.0082	0.70 ± 0.008

Table 2: Pasting properties of native and oxidized sweet potato starches.

Parameters	NSPS	OSPS
Peak viscosity (RVU)	517.33	561.67
Trough holding viscosity (RVU)	233.08	371.42
Final viscosity (RVU)	289.42	409.75
Breakdown Viscosity (RVU)	284.42	190.25
Setback viscosity (RVU)	56.33	38.33
Pasting time (mins)	4.67	4.67
Pasting temperature (°C)	79.95	79.20

Foam Capacity

The foam capacity of native sweet potato starch (NSPS) and oxidized sweet potato starch (OSPS) were shown in Table 1 above. Oxidation with sodium hypochlorite increased the foam strength of NSPS **by 2.27%.** It can be deduced that the low fat content in the NSPS compared to OSPS is a factor contributing to the increase. It has also been reported by [33] that foam capacity is a direct indication of the fat content.

pH

The pH of the NSPS and OSPS are shown in Table 1. NSPS shows a pH of 6.74 which is in the acidic region while that of OSPS reveals a pH of 7.40 in the basic

ISSN 0795 - 22066

region. The basicity in pH of the OSPS is due to the use of sodium hydroxide during the modification process for neutralization. This results is similar to the submission of [12], for pH of sweet potato starch sample (NSPS at pH 6.70 and OSPS at pH 7.70). It is found to be within the pH range (3-9) accepted for starch and its derivatives used in the pharmaceutical, cosmetic and food industries [23].

Dispersibility

The results of dispersibility of NSPS and OSPS are presented in Table 1. Dispersibility is a measure of the ability of starch or starch blended in water to reconstitute [24]. Only a slight difference of 0.7% in dispersibility value was observed upon oxidation. It can be inferred that OSPS have better reconstitution property than NSPS as reported in literature that, the higher the dispersibility the better the reconstitution of starch in water [24].

Water and oil absorption capacity

Water and oil-absorption capacities of NSPS and OSPS are presented in Table 1. Water and oil absorption capacities increased after oxidation by 0.83 mL and 0.46 mL respectively. Increase in water and oil absorption capacity have been observed after the introduction of bulky functional group and their electrostatic repulsion facilitated the absorption of water within starch molecules [9]. Significantly, the oil-absorption capacity of OSPS (1.56 mL) increased than that of NSPS (1.1 mL) after oxidation.

Bulk Density

The results of the bulk densities of OSPS and NSPS are shown in Table 1. The bulk density of OSPS was recorded at (0.7±0.008) which is slightly higher than that of NSPS (0.68±0.0082). Bulk density measures the degree of coarseness of starch samples and particle size [17]. Particle size is inversely proportional to bulk density, invariably from the results OSPS particles are more coarsed than NSPS particles. These results are similar to that reported of white cocoyam (0.71 g/mL) [17].

Moisture content

Moisture content shows the percentage of water content of a material. As presented in Table 1, the moisture content value of OSPS recorded is lower than NSPS by 2.02%. Lower values has also been recorded for moisture content of oxidized starch in previous literatures [22]. This is an indication that OSPS have a better shell life than NSPS.

Pasting Properties

The pasting profile of the NSPS and OSPS are presented in Table 2. Pasting properties is observed when an aqueous suspension of starch is heated above a critical temperature, granules swell irreversibly and amylose leaches out into the aqueous phase, resulting into increased viscosity [37]. There were no observable changes in the pasting temperature of both NSPS and OSPS this trend was reported by [30]. However, the oxidized starch showed higher peak viscosity than the native starch and this is in conformity with the findings of [20] for cocoyam starches and also corroborated by[1]. The trough holding viscosity increased considerably with oxidation indicating that chemical modification is greatly influenced by shear thinning during the holding period. OSPS with higher value will have higher strength to withstand breakdown during

ISSN 0795 - 22066

cooling process than the NSPS. The breakdown viscosity which determines the fragility of starch decreased following oxidation. [8 and 20] also reported an increase in breakdown viscosity with oxidation. However, in this work a decrease in breakdown viscosity was observed, this showed that the OSPS has not been totally degraded. Therefore the integrity of the starch to withstand heating and shear stress is still maintained [26]. The final viscosity greatly increased after oxidation; this increase is due to the partial cleavage of the glycosidic linkages leading to an increase in molecular weight of the starch molecules after oxidation. The result indicates that the oxidized starch has greater stability to shear stress. Consequently, a reduction in the setback viscosity followed the oxidation process and this is due to the hindrance caused by carbonyl and carboxyl group [1].

Fourier transforms infra-red Spectroscopy (FTIR)

The FT-IR spectra of native sweet potato starch (NSPS) and its oxidized derivative (OSPS) are presented in Figure 1.

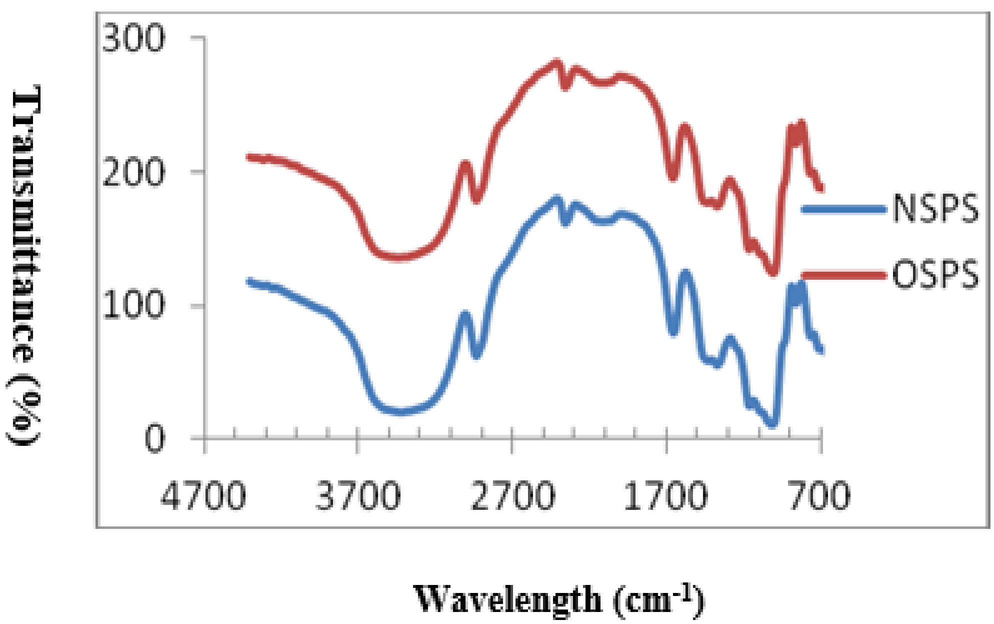

Figure 1: The FT-IR spectrogram of both native and oxidized sweet potato starches.

The broad band observed in the region 3300 – 3500 cm^{-1} is due to O-H stretching vibration giving the information of the presence of hydroxyl bonds within the starch molecules. The broad band in the OSPS is more intensed as a result of the depolymerized linkages present resulting from the oxidation process. A sharp peak at 2900 cm^{-1} is attributed to CH_2 symmetric stretching vibration. A distinctive peak at 1730 cm^{-1} is characteristic of C=O stretch of a carbonyl group produced by oxidation of hydroxyl group to aldehyde. The peaks generated at 1635 cm^{-1} indicates the vibration of water molecules adsorbed by the starch as reported by [11] and [35]. The absorptions at 1350 cm^{-1} is also responsible for C-H

ISSN 0795 - 22066

bending vibration [7, 19 and 25]. However, when the IR spectra of both the native and oxidized sweet potato starches were compared, no observable difference was detected. This is due to the fact that oxidation causes de-polymerization of starch molecules by breaking the glucoside linkages [28].

CONCLUSIONS

Oxidized sweet potato starch improves the starch and subject its molecules to depolymerization. The pasting properties showed decreased retrogradation, higher dispersibility, greater stability to shear stress, and low viscosity of the oxidized starches which are essential properties required in starch for its application in the pharmaceutical, confectionaries and other biodegradable industries such as textile and paper industries where surface sizing and coating properties are of great importance.

. **REFERENCES**

1. K. O. Adebowale and O. S. Lawal (2002). Effect of annealing and heat moisture conditioning on the physicochemical characteristics of Bambarra groundnut (Voandzeia subterranea) starch. *Food/Nahrung*, *46*(5), 311-316.

2. A. O. Ashogbon and E. T. Akintayo (2012). Morphological, functional and pasting properties of starches separated from rice cultivars grown in Nigeria.

3. I. R. M. Benesi (2005). *Characterisation of Malawian cassava germplasm for diversity, starch extraction and its native and modified properties* (Doctoral dissertation, University of the Free State).

4. P. L. Bragd, A. C. Besemer and H. van Bekkum (2000). Bromide-free TEMPO-mediated oxidation of primary alcohol groups in starch and methyl α-D glucopyranoside. *Carbohydrate Research*, *328*(3), 355-363.

5. A. R. G. Dias, E. da Rosa Zavareze, E. Helbig, F. A. de Moura, C. G. Vargas, and C. F. Ciacco (2011). Oxidation of fermented cassava starch using hydrogen peroxide. *Carbohydrate polymers*, *86*(1), 185-191.

6. M. Eames and M. Adebowale (2002). Sustainable development and social inclusion: Towards and integrated approach to research.

7. J. M. Fang, P. A. Fowler, J. Tomkinson, and C. A. S. Hill (2002). The preparation and characterisation of a series of chemically modified potato starches. *Carbohydrate polymers*, *47*(3), 245-252.

8. L. M. Fonseca, J. R. Gonçalves, S. L. M. El Halal, V. Z. Pinto, A. R. G. Dias, A. C. Jacques and E. da Rosa Zavareze (2015). Oxidation of potato starch with different sodium hypochlorite concentrations and its effect on biodegradable films. *LWT-Food Science and Technology*, *60*(2), 714-720.

9. Z. Gonzalez and E. Pérez (2002). Effect of acetylation on some properties of rice starch. *Starch Stärke*, *54*(3-4), 148 -154.

10. G. Hu, J. Chen, and J. Gao (2009). Preparation and characteristics of oxidized potato starch films. *Carbohydrate Polymers*, *76*(2), 291-298.

11. M. M. Ibrahim, W. K. El-Zawawy, Y. Jüttke, A. Koschella, and T. Heinze (2013). Cellulose and microcrystalline cellulose from rice straw and banana plant waste: preparation and characterization. *Cellulose*, *20*(5), 2403-2416.

12. M. C. Iheagwara (2013). Isolation, modification and characterization of sweet potato (Ipomoea batatas L (Lam)) starch. *J Food Process Technol*, *4*(1), 1-6.

ISSN 0795 - 22066

13. M. C. Iheagwara, I. H. Chibuzo, and J. C. Ibeabuchi (2019). Effect of tuber sections and processing conditions on the physicochemical properties of sweet potato (Ipomoea batatas L. (Lam)) flour. *Food Quality and Safety*, *3*(4), 273-278.

14. B. Klein, N. L. Vanier, K. Moomand, V. Z. Pinto, R. Colussi, E. da Rosa Zavareze, and A. R. G. Dias (2014). Ozone oxidation of cassava starch in aqueous solution at different pH. *Food chemistry*, *155*, 167-173.

15. S. A. Kolawole, N. C. Igwemmar and H. A. Bello (2013). Comparison of the physicochemical properties of starch from ginger (Zingiber officinale) and maize (Zea mays). *International Journal of Science and Research*, *2*(11), 71-76.

16. D. Kuakpetoon and Y. J. Wang (2001). Characterization of different starches oxidized by hypochlorite. *Starch-Stärke*, *53*(5), 211-218.

17. D. Kuakpetoon and Y. J. Wang (2006). Structural characteristics and physicochemical properties of oxidized corn starches varying in amylose content. *Carbohydrate Research*, *341*(11), 1896 1915.

18. D. Kuakpetoon and Y. J. Wang (2008). Locations of hypochlorite oxidation in corn starches varying in amylose content. *Carbohydrate Research*, *343*(1), 90-100.

19. D. K. Kweon, Choi, J. K., Kim, E. K., and Lim, S. T. (2001). Adsorption of divalent metal ions by succinylated and oxidized corn starches. *Carbohydrate Polymers*, *46*(2), 171-177.

20. O. S. Lawal (2004). Composition, physicochemical properties and retrogradation characteristics of native, oxidised, acetylated and acid-thinned new cocoyam (Xanthosoma sagittifolium) starch. *Food chemistry*, *87*(2), 205-218.

21. R. V. Manek, P. F. Builders, W. M. Kolling, M. Emeje, and O. O. Kunle (2012). Physicochemical and binder properties of starch obtained from Cyperus esculentus. *Aaps Pharmscitech*, *13*(2), 379-388.

22. A. L. Muñoz-Celaya, M. Ortiz-García, E. J. Vernon-Carter, J. Jauregui-Rincón, E. Galindo and L. Serrano-Carreón (2012). Spray-drying microencapsulation of Trichoderma harzianum conidias in carbohydrate polymers matrices. *Carbohydrate polymers*, *88*(4), 1141-1148.

23. M.O. Omojola, Y.O. Akinkunmi, K.O. Olufunsho, H.O, Egharavba and E. O. Martin (2010). Isolation and Physicochemical Characterization of Cola-Starch Africa Journal of Food, Agriculture, Nutrition and Development .10 (7): 2884-2900.

24. J. Pal, R. S. Singhal and P. R. Kulkarni (2000). A comparative account of conditions of synthesis of hydroxypropyl derivative from corn and amaranth starch. *Carbohydrate Polymers*, *43*(2), 155 162.

25.

26. A. Para (2004). Complexation of metal ions with dioxime of dialdehyde starch. *Carbohydrate polymers*, *57*(3), 277-283.

27. K. S. Sandhu, M. Kaur, N. Singh, and S. T. Lim (2008). A comparison of native and oxidized normal and waxy corn starches: Physicochemical, thermal, morphological and pasting properties. *LWT-Food Science and Technology*, *41*(6), 1000-1010.

28. V. Singh, and S. Z. Ali (2000). Acid degradation of starch. The effect of acid and starch type. *Carbohydrate polymers*, *41*(2), 191-195.

29. B. Soison, K. Jangchud, A. Jangchud, T. Harnsilawat and K. Piyachomkwan (2015). Characterization of starch in relation to flesh

ISSN 0795 - 22066

colors of sweet potatovarieties. *International Food Research Journal*, *22*(6), 2302.

30. F. Spier, E. D. R. Zavareze, R. Marques e Silva, M. C. Elias and A. R. G. Dias (2013). Effect of alkali and oxidative treatments on the physicochemical, pasting, thermal and morphological properties of corn starch. *Journal of the Science of Food and Agriculture*, *93*(9), 2331 2337.

31. N. L. Vanier, E. da Rosa Zavareze, V. Z. Pinto, B. Klein, F. T. Botelho, A. R. G. Dias and M. C. Elias, (2012). Physicochemical, crystallinity, pasting and morphological properties of bean starch oxidised by different concentrations of sodium hypochlorite. *Food chemistry*, *131*(4), 1255 1262.

32. Y. J. Wang and L. Wang (2003a). Physicochemical properties of common and waxy corn starches oxidized by different levels of sodium hypochlorite. *Carbohydrate polymers*, *52*(3), 207 217.

33. V. D. Wang Truong and L. Wang (2003b). Structures and rheological properties of corn starch as affected by acid hydrolysis. *Carbohydrate Polymers*, *52*(3), 327-333.

34. S. T. Yussuf, A. A. Ibikunle, N. O. Sanyaolu, and A. A. Oderinde (2018). Proximate composition, physicochemical and pasting properties of a novel African star apple (Chrysophyllum albidum) seed nuts starch as supplement to industrial starch. *Journal of Chemical Society of Nigeria*, *43*(2).

35. E. D. R. Zavareze, V. Z. Pinto, B. Klein, S. L. M. El Halal, M. C. Elias, C. Prentice-Hernández, and A. R. G. Dias (2012). Development of oxidised and heat–moisture treated potato starch film. *Food chemistry*, *132*(1), 344-350.

36. S. D. Zhang, Y. R. Zhang, J. Zhu, X. L. Wang, K. K. Yang and Y. Z. Wang, (2007). Modified corn starches with improved comprehensive properties for preparing thermoplastics. *Starch‐Stärke*, *59*(6), 258-268.

37. L. R. Beuchat, (1977). Functional and electrophoretic characteristics of succinylated peanut flour protein. *Journal of Agricultural and Food chemistry*, *25*(2), 258-261.

38. P. Van Hung, and N. Morita, (2005). Physicochemical properties of hydroxypropylated and cross-linked starches from A-type and B-type wheat starch granules. *Carbohydrate polymers*, *59*(2), 239-246.

ISSN 0795 - 22066