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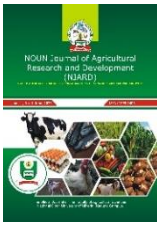

Original Article

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Functional Properties of Cassava Starch under Moist Sawdust and Trench Storage: Implications for Postharvest Management

Olaleye O. O [1*]., Banigbe S .A[1]., Adediran B.I [1]., Ogunjirin O. C [1]., Inana, M.E [2]., & Nze-Dike O.U [2].

[1]*Nigerian Stored Products Research Institute Ilorin, Kwara State, Nigeria.*
[2]*Nigerian Stored Products Research Institute Port Harcourt, Rivers State, Nigeria.*
**Corresponding Author: banigbesa@nspri.gov.ng contact: +2348062849360*

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ABSTRACT

This study investigated the impact of post-harvest storage methods (moist sawdust and trench storage) on the functional properties of starch extracted from bitter (TMS 30572) and sweet (TMS 4(2)1425) cassava varieties over a six-week period. Key functional properties analyzed included water absorption capacity, bulk density, swelling index, least gelation concentration (LGC), and pasting behavior using Rapid Visco Analyzer (RVA). Starch from both varieties showed no initial swelling potential (0 weeks) but exhibited gradual increases in swelling index during storage, influenced by starch-water hydrogen bonding and structural differences. Bulk density increased progressively across all samples, correlating with improved wettability and sink ability for industrial applications. Water absorption capacity remained lowest in starch products, attributed to variations in amylose/amylopectin ratios and granule size. LGC trends revealed divergent behavior: starch from sweet cassava stored in moist sawdust (SDSCS) showed consistent gelation improvement, while other samples fluctuated, reflecting interactions between starch constituents and storage-induced biochemical changes. Pasting properties demonstrated dynamic changes, with peak viscosity decreasing initially (0–2 weeks) due to microbial alteration of starch structure, followed by recovery (4–6 weeks). Moist sawdust storage better preserved functional integrity, particularly for sweet cassava, which displayed higher peak viscosity stability. Trench-stored samples exhibited greater variability, likely due to environmental exposure. The study concluded that moist sawdust storage optimizes functional properties for industrial use, mitigating post-harvest deterioration while enhancing starch quality. These findings provide actionable insights for small-scale farmers and cassava processors to reduce losses, improve food safety, and increase market value through tailored storage practices.

Keywords: *cassava, starch, post-harvest storage, trench, moist sawdust, functional properties*

INTRODUCTION

Cassava botanically called *Manihot esculenta* is a major starchy root crop widely cultivated in some parts of the tropical and subtropical regions of the world. Globally, cassava is known to serve as primary food source for over millions of people in some countries and particularly in Nigeria (Narina *et al.,* 2021; Mohidin *et al.,*2023; Gleadow *et al.,* 2023). Due to its high carbohydrate content cassava is indispensable in food security, economic empowerment, and industrial starch production (Borku *et al.*, 2025). Nigeria, known as the one of the world's largest producer of cassava, accounts for approximately 20% of global output (FAOSTAT, 2023). However, despite this production capacity of cassava, post-harvest losses are inevitable thus resulting to rapid physiological deterioration within 48 –72 hours after harvest, hence, poses a significant challenge to its utilization (Njoku *et al*. 2014; Martin, 2020). Starch is one of the most economically valuable derivatives of cassava, it constitutes 20 –35 % of the fresh root's weight of the cassava tuber. Starch has diverse use in food processing, pharmaceuticals, textiles, and bioethanol industries (Adeniji *et al*., 2005; Ogunmuyiwa *et al*., 2017; Egboduku *et al*., 2024). However, the quality of starch is significantly influenced by post-harvest storage conditions of the roots before processing (Oyagbohun, 2025). There are a combination of technologies and traditional knowledge of farming practices which could be explored and be of benefits to small-scale cassava farmers in Nigeria (FAO, 2013). Recent efforts to mitigate post-harvest losses of cassava have led to the exploration of modified storage technologies that create humid and sterile environments conducive to short- to medium-term root preservation (Uchechukwu-Agua *et al*., 2015). Among these, moist sawdust and trench storage have shown promise in maintaining cassava root quality, albeit with varied effects on biochemical composition and microbial load (Babarinsa *et al*., 2020). Moist sawdust, particularly when sterilized, can reduce microbial contamination and moisture loss in cassava, while trench storage offers a low-cost alternative that retains root firmness and slows down enzymatic browning (Babarinsa *et al*., 2020). Although these storage methods show promise, the differences in their effects on the functional properties of cassava starch like water absorption capacity, bulk density, swelling index, least gelation concentration, and pasting behavior, have not been thoroughly investigated. These properties are critical determinants of starch's suitability for diverse industrial applications and directly impact product quality and consumer acceptability (Mounir *et al*., 2024). This study investigated the influence of post-harvest storage methods, specifically moist sawdust and trench storage, on starch's functional properties derived from bitter and sweet cassava varieties. This research aimed to inform best practices for cassava root preservation and starch processing by elucidating the functional changes occurring during storage. The findings are expected to contribute to efforts that reduce post-harvest losses, improve food safety, and enhance the value chain for cassava-based industries

MATERIALS AND METHODS

Material selection

The bitter cassava roots (TMS 30572) and sweet varieties (TMS 4(2)1425), both 15 months old, were sourced from Gede farm settlement in Ayede Ekiti, Nigeria. The sawdust utilized as moist material was collected from a sawmill situated on Olosun close in the Irewolede Area, near the second gate of the Nigerian Stored Product Research Institute (NSPRI) in Ilorin, Nigeria.

Harvesting and Post-Harvest Operations

Harvesting

The cassava plant's stems were trimmed, a short section above the ground was left before three weeks of harvest to enhance storability, as suggested by (Westby, 2021). The roots were harvested while the soil was moist following a heavy rain to reduce potential damage during extraction. A portion of the stem (ranging from 2 to 5 cm) was left attached to the roots to prevent rapid decay, as rotting typically begins at the neck, or the point where the root connects to the main plant.

Storage in moist sawdust

A cassava storage house, shown in Plate 1, measuring 2.0m x 2.0m x 2.5m, situated at NSPRI headquarters, Ilorin, was used for this research work. It has a concrete floor and the sides are made with brick blocks up to 1m in diameter. The remaining part is covered with wire mesh. The roof is covered with an iron sheet and the ceiling is covered with a mat. The storage method described by the Nigerian Stored Products Research Institute (2020), with slight modification, was employed. The two varieties of cassava roots were taken to the cassava storage house the same day as they were harvested and stored separately. Sawdust derived from a mahogany tree used as a moistening material was sterilized by using an autoclave set at a temperature of 121°C for 30 min. The sterilized sawdust was then moistened by mixing it with clean tap water at a solid-to-water ratio of 3:1, to give a moisture content of 38%. It was then spread on the floor of the cassava storage house, which had been previously swept, washed and cleaned with aseptic solution (Jik). About 250 kg each of carefully selected cassava tubers of the two varieties were kept there. One layer of undamaged cassava roots was carefully arranged on top of the moistened sawdust to prevent the root from touching each other, as shown in Plate2.

Plate: 1: Cassava storage warehouse

The roots were then covered with another layer of moist sawdust, followed by a second layer of roots; moist sawdust was packed between the roots and also at the top of the final layer of cassava roots. The storage house was inspected every 3 days throughout the storage period of six weeks to ensure that the sawdust was moist. The two cassava tubers varieties were collected at random separately from the cassava storage warehouse (moist sawdust) for analysis and processing every two weeks of storage.

Plate 2: Loading of unbruised cassava into the cassava storage warehouse

Storage in Trench

The method described by the Nigerian Stored Products Research Institute (2020) was used. A trench shown in Plate 3 of 2m x 1.5m x 1m in dimension was dug in a suitable site (close to the cassava storage house) in the premises of NSPRI. The dug trench was partitioned into two compartments with wood to accommodate the two varieties of cassava roots. 250kg each of harvested roots from pruned cassava plants of the two varieties were packed into each compartment of the dug trench, with alternate layers of palm leaves as shown in Plate 4.

Plate 3: Trench shed

Plate 4: loading of cassava roots into trench

Each batch of roots was covered with palm leaves, the last layer was covered with both leaves and soil. The trench was then covered by erecting a shed with thatched roof over it, to prevent excessive evaporation. The trench was sprinkled with some clean tap water every three days throughout the six-week storage period to keep it moist. The two cassava tuber varieties were collected separately at random from the trench for analysis and processing every two weeks of storage.

Determination of Functional Properties.

The method described by Ogungbenle *et al.,* (2002) was used to determine the water absorption capacity, bulk density and the least gelation capacity While, swelling index was determined using the method as described by (Esheye, 2021)

Determination of Pasting properties

The pasting properties were determined using Rapid Visco Analyzer (RVA) model Super 4, manufactured by Newport Scientific Australia (Gaisford, 2015).

Results and Discussion

Effects of storage methods and period of storage on Functional properties of cassava root starch

Table 1: Effects of storage methods on functional and physical properties of cassava products made from cultivars of cassava stored for six weeks

Storage Methods	Bulk Density (g/cm^3)	Water Absorption Capacity (WAC)(g/cm)	Swelling Index(Cm^3)	Least Gelation Capacity (%)	pH	Titratable Acidity
TBCS	0.75±0.08^d	0.93±0.15^a	0.38±0.48^a	10.00±2.83^a	4.18±0.56^a	0.17±0.09^a
TSCS	0.69±0.10^{bcd}	1.34±0.35^{ab}	0.53±0.61^a	9.50±1.91^a	4.75±0.69^a	0.12±0.01^a
SDBCS	0.71±0.09^{cd}	1.15±0.06^{ab}	0.50±0.71^a	9.50±1.91^a	4.15±0.19^a	0.14±0.04^a
SDSCS	0.70±0.09^{bcd}	1.21±0.25^{ab}	0.63±0.48^a	9.50±1.00^a	4.98±1.01^a	0.11±0.01^a

Means in the same column with different letters are significantly different ($p < 0.05$)

TBCS=Trench bitter cassava starch, TSCS = Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Observation from Table 1 showed that there was significant difference ($p<0.05$) between the bulk density of starch produce from bitter cassava stored in sawdust and trench. while there was no significant difference ($p<0.05$) in the starch produce from sweet cassava stored in sawdust and trench. Also, there is significant difference in the bulk density of starch produce from different varieties of cassava stored in the same storage structures. The WAC of the starch produced from bitter cassava stored in the different storage structure differs significantly ($p<0.05$) from each other. Whereas, no significant difference was observed for starch produced from sweet cassava, stored in different storage structure. For swelling index, least gelation capacity, pH and total titratable acidity; there was no significant difference ($p<0.05$) between starch produced from different cassava varieties stored in different storage structure or in the same storage structures.

Figure 1: This figure shows the effect of the storage period on the swelling index of starch produce from stored cassava after storage. The starch extract from both bitter and sweet cassava root varieties (TBCS, TSCS, SDSCS, and SDBCS) that were stored in either trenches or moist sawdust shows no swelling potential when freshly prepared (0 weeks). During storage, the starch products from the cassava varieties and the different storage methods exhibit a slight increase in swelling power. Swelling power of starch depends on starch molecules to retain water through hydrogen bonding. Additionally, the varying degrees of swelling indicate structural differences among the different types of starch (Mweta, 2005).

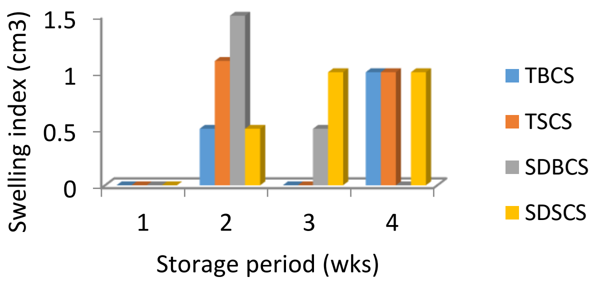

Figure 1: Effect of storage methods and period of storage on the swelling index value of cassava starch processed after storage.
TBCS=Trench bitter cassava starch, TSCS = Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

The effects of storage period and methods on the least gelation capacity of starch processed from two varieties of stored cassava roots are illustrated in Figure 2. Starch derived from sweet cassava roots (SDSCS) stored in moist sawdust shows a clear trend, with its gelation capacity increasing from the 0th to the 6th week. The variation of gelling properties of different flours may be attributed to differences in the ratios of carbohydrates, lipids, and proteins that compose the flours. Raikos, (2014) indicated that the interactions between these constituents significantly influence the functional properties of flour. A lower least gelation concentration (LGC) indicates a greater ability to form a gel or serve as a firming agent.

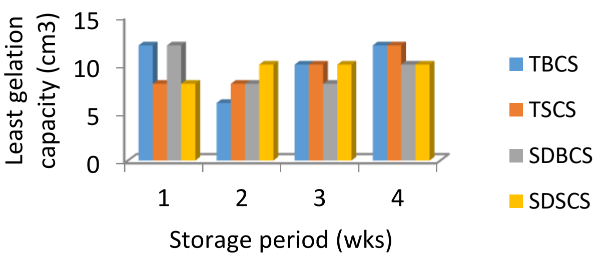

Figure 2. Effect of storage methods and period on the least gelation capacity value of starch after storage.
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

From Figure 3, it is observed that the bulk density of starch products was initially lower at the 0th week (fresh) and increased by the 6th week of storage. Bulk density (BD) indicates the weight a sample can support when placed directly on top of another. Higher bulk density results in improved wettability and water holding capacity of a product, as reported by (Olaseeni *et al.*, 2023). Additionally, Nnadozie, (2015) noted that an increase in bulk density enhances the sink ability of powder particles. This increased sink ability facilitates wetting by promoting dispersion.

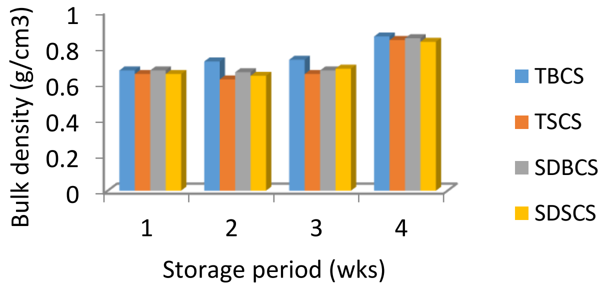

Figure 3. Effect of storage methods and period on the Bulk density value of starch after storage.
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

The effects of storage period and methods on the water absorption capacity (WAC) of starch produce from stored cassava after storage are illustrated in Figure 4. The observed differences in WAC among the products can be attributed to various factors, including particle size, the amylose-to-amylopectin ratio, and molecular structure. Generally, larger granule sizes result in greater WAC, while higher amylose content is associated with lower water binding capacity in starches (Azmah *et al.*, 2023; Zhang, et al., 2024).

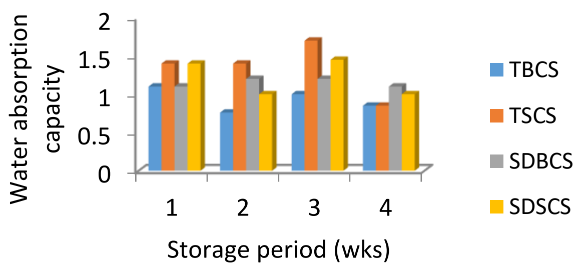

Figure 4. Effect of storage methods and period on the water absorption capacity value of starch after storage.

TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

The pH values of the starch processed after storage were presented in figure 5. It shows series of slight increase and decrease in the pH value. This shows that storage method had no significant effect on pH of starch produced from the different varieties of cassava. The pH value of starch products (3.6 - 6.4) falls within the recommended range of 5-7 as reported by the Nigeria industrial standard (2004). The pH of flour products is an important factor which affects their shelf life and the decrease in pH might not be unconnected with the duration and effectiveness of fermentation in the fermented products.

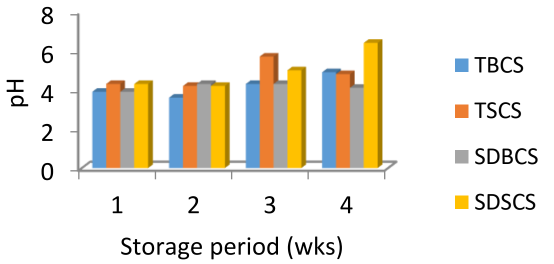

Figure 5: Effect of storage methods and period on the pH value of different cassava products processed after storage.
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Figure 6: shows the effects of storage period on titratable acidity (TTA) value of starch processed after storage. SDBCS and SDSCS show an increase in TTA from 0 to 6th week's storage period. Oyewole and Odunfa, (1989) reported that acidity might be due to the synthesis of lactates, acetates and some volatile organic acids. Hence the reduction in TTA values of some of the products might be due to loss of some volatile components like hydrocyanic acid (HCN) produced from the hydrolysis of the cyanoglucoside.

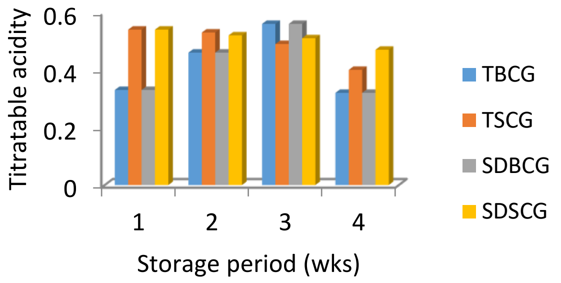

Figure 6: Effect of storage method and period on the titratable acidity value of different cassava products processed after storage.
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Effects of storage methods and period of storage on pasting properties of cassava root starch

Pasting properties of the starch produce from cassava roots stored in trench and moist sawdust for some parameter were significantly different ($p < 0.05$) from each other as can be seen in Table 2. However, the storage type had significant effect ($p<0.05$) on the pasting properties, except trough viscosity, peak viscosity, pasting temperature, peak time and setback viscosity for starch. This is demonstrating that storage type plays a crucial role on the pasting properties of the starch processed after storage except pasting time.

Table 2. Effect of storage methods on the pasting properties of cassava products made from two cultivars of cassava stored for six weeks (RVU)

STORAGE TYPE	PEAK VISCOSITY	TROUGH (HOT PASTE) VISCOSITY	BREAKDOWN VISCOSITY	FINAL VISCOSITY	SETBACK VISCOSITY	PEAK TIME(MIN)	PASTING TEMP(^{O}C)
TBCS	646.32±75.18^{bc}	226.57±21.14^{a}	419.80±58.00^{c}	300.67±25.18^{a}	73.55±10.67^{a}	4.05±0.09^{a}	71.40±0.86^{ab}
TSCS	624.07±85.02^{b}	234.65±29.49^{a}	389.45±61.48^{bc}	311.05±34.57^{a}	76.42±6.55^{a}	4.34±0.08^{a}	71.63±1.03^{ab}
SDBCS	601.35±48.33^{b}	214.67±12.60^{a}	386.72±38.28^{bc}	278.57±13.14^{a}	62.45±10.52^{a}	4.11±0.12^{a}	71.05±0.66^{ab}
SDSCS	619.75±80.89^{b}	238.22±33.45^{a}	381.70±63.18^{bc}	322.10±45.00^{ab}	84.05±25.32^{a}	4.36±0.16^{a}	69.09±4.26^{ab}

Means in the same column with different letters are significantly different ($p < 0.05$)
TBCS=Trench bitter cassava starch, TSCS = Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Figure 7: shows the effect of storage method and duration on the peak viscosity of starch processed after storage. Peak viscosity indicates the water-binding capacity, which refers to starch's ability to swell freely before undergoing physical breakdown (Sanni *et al*., 2004). This property is also influenced by fermentation and may correlate with the final product quality, helping to determine the viscous load that a mixer may encounter. According to Sandhu and Singh (2007), higher peak viscosity values can be as a result of differences in protein content. Loosely packed starch granules with a lower protein-to-starch ratio in finer fractions tend to hydrate and swell more quickly when heat is applied. Starch typically exhibits high peak viscosity values. The observed peak viscosity values decreased from week 0 to the end of the second week, followed by an increase until the sixth week. The initial decrease in peak viscosity may be due to alterations in the chemical structure caused by the activities of microorganisms isolated from the stored cassava roots. Over time, these activities can significantly change the chemical structure of the starch (Ray, 2000; Shil, et al., 2024).

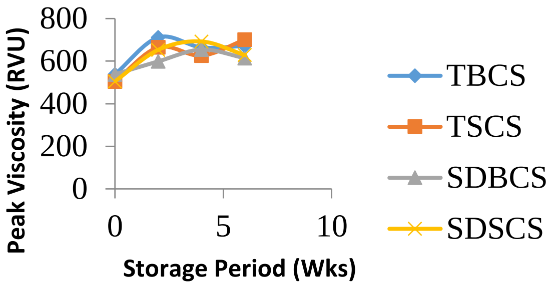

Figure 7: Effect of storage methods and period of storage on the peak viscosity value of different cassava products processed after storage
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Trough viscosity curve of starch products, including TBCS, TSCS, SDBCS, and SDSCS, is illustrated in Figure 8. The curve demonstrated a steady increase from the start to the sixth week of storage, contrasting with the other products, which exhibit a pattern of fluctuations with both increases and decreases. The hot paste viscosity and breakdown value indicate the heat resistance and paste stability of the cassava products processed after storage. Notably, the resistance to heat and paste stability was lowest in TSCG produced after the second week of storage. In general, starch products (TSCS, TBCS, SDSCS, and SDBCS) show an increase in heat resistance and paste stability as the storage period extends.

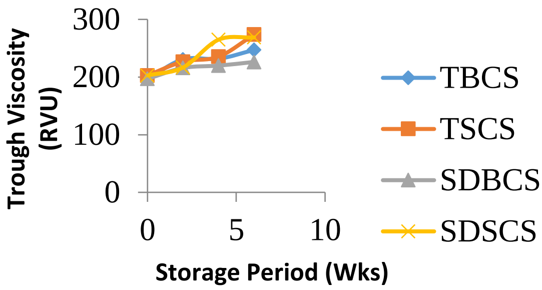

Figure 8: Effect of storage methods and period of storage on the trough viscosity value of different cassava products processed after storage
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Figure 9: shows the effect of storage on the breakdown viscosity of cassava starch processed after being stored. The viscosity curves for starch show fluctuations in breakdown viscosity values throughout the storage duration. Notably, TBCS recorded the highest breakdown viscosity at the second week of storage. According to Beta *et al.,* (2000), breakdown viscosity measures how susceptible cooked starch granules are to disintegration, which plays a crucial role in the sample's stability. The lower breakdown viscosity observed in some of the cassava root products indicates that these products are more stable at elevated temperatures. The trough and breakdown viscosity values suggest that the sample has the greatest capacity among all blends to remain undisturbed during prolonged exposure to high temperatures and to resist breakdown during cooking.

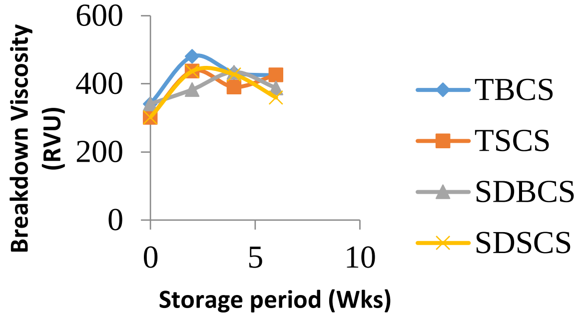

Figure 9: Effect of storage methods and storage period on the breakdown viscosity value of starch processed after storage
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Final viscosity curves of the starch processed after storage are presented in Figure 10: The final viscosity is the most frequently utilized parameter to characterize the quality of a specific sample or product, as it reflects the material's capacity to create a viscous paste or gel during cooking and cooling. The starch products display a sequence of increases and decreases in their final viscosity values. Flores-Farias *et al*., (2000) reveals that the rise in final viscosity results from the alignment of amylase chains within the starch products.

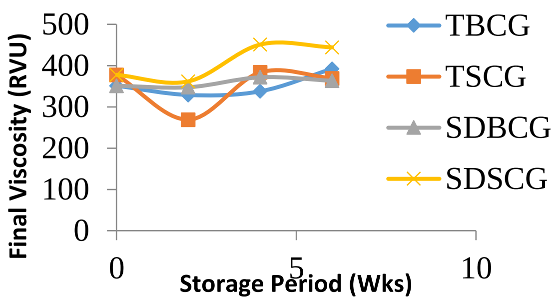

Figure 10: Effect of storage methods and storage period on the final viscosity value of starch processed after storage
TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Figure 11: shows how storage impacts the setback viscosity of starch processed after storage in trench and moist sawdust. The curves for TBCS and SDBCS show an increase in setback viscosity from the 0 to the 4th week of storage, followed by a decrease at the 6th week. The TSCS curve demonstrates a consistent rise in value from the 0 to the 6th week of storage, while the SDSCS curve exhibits fluctuations of increase and decrease in setback viscosity. Setback viscosity is related to the retrogradation or

reorganization of starch molecules and has been linked to the texture of different products (Gaisford, 2015) Setback refers to the speed at which the gel loses its water. As noted by El-Gindy (2018), a higher setback value indicates lower retrogradation during cooling and a slower staling rate for products made from the starch.

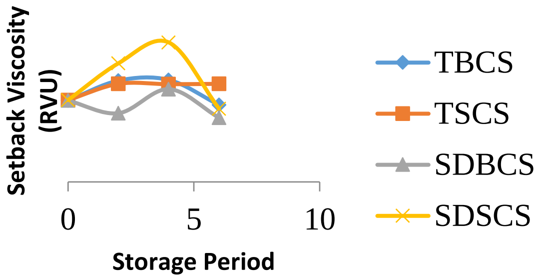

Figure 11: Effect of storage methods and storage period on the setback viscosity value of different cassava products processed after storage

TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SBCS=Sawdust bitter cassava starch, SSCS=Sawdust sweet cassava starch.

The impact of storage duration on the peak time of starch processed immediately after harvest and during storage is illustrated in Figure 12. The curve for TBCS exhibited the lowest value in the second week of storage, while the products SDSCS and TSCS displayed a similar curve pattern. Additionally, TBCS demonstrated a comparable curve pattern; it showed a decline in value from the start to the second week of storage, followed by a steady increase up to the sixth week of storage. The peak time reflects the cooking ease, representing the duration required for the sample to attain pasting temperature during heating as well as the time taken to reach peak viscosity. A shorter cooking time indicates greater convenience in cooking (Agume Ntso *et al*., 2017). TBCS recorded the lowest value at the second week of storage, suggesting that TBCS exhibited the highest gelation properties at this time, which aligns with its low least gelation concentration of 6 and a higher carbohydrate content of 85%.

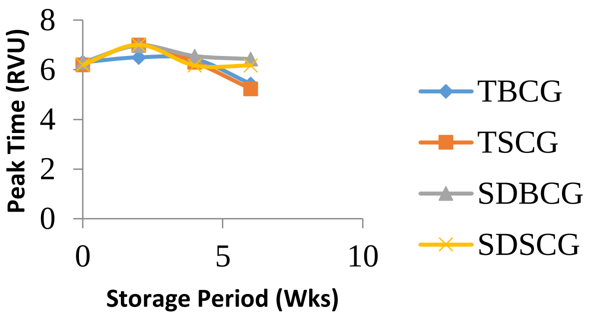

Figure 12: Effect of storage methods and storage period on the peak time value of different cassava products processed after storage

TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

Figure 13. shows how the storage duration influences the pasting temperature of starch processed shortly after harvest and during storage. All starch products, excluding SDSCS, exhibit a similar curve pattern. The pasting temperature rises from the start to the second week of storage, then declines by the fourth week, before rising again by the sixth week of storage. In contrast, the SDSCS curve declines sharply from the start to the second week of storage before experiencing a significant increase by the fourth week. The capacity of starch to absorb water and swell is mainly influenced by the pasting temperature; higher pasting temperatures lead to a quicker formation of paste (Tulyathan *et al*., 2005). Therefore, when exposed to water and heat, starch granules swell and create a paste by absorbing water. This explains why the peak viscosity values of starch products result from starch having a high viscosity. Tulyathan *et al*., (2005) also reported that the pasting temperature is affected by the granule size of starch; smaller granules are more resistant to rupture and loss of molecular structure, which could account for the relatively elevated pasting temperature of starch.

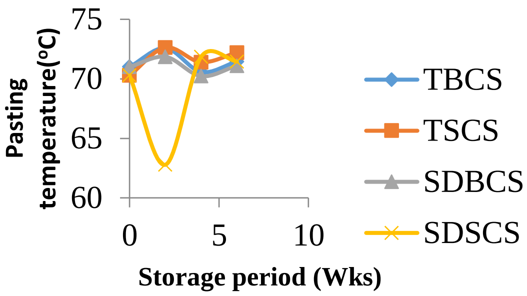

Figure 13: Effect of storage methods and storage period on the pasting temperature value of starch products processed after storage

TBCS=Trench bitter cassava starch, TSCS=Trench sweet cassava starch, SDBCS=Sawdust bitter cassava starch, SDSCS=Sawdust sweet cassava starch.

CONCLUSION

This study demonstrated that postharvest storage significantly modulates the functional properties of cassava starch, with moist sawdust offering superior preservation and enhancement compared to trench storage. Variations in swelling index, gelation capacity, and pasting behavior across storage durations reflect complex starch-water-microbe interactions, influenced by both variety and environment. Moist sawdust storage consistently maintained starch integrity, especially in sweet cassava, suggesting its viability as a scalable, low tech solution for improving starch quality and extending root usability. These findings offer practical value for cassava processors and policymakers seeking to strengthen food systems, reduce losses, and increase the industrial applicability of cassava-derived products.

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