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FUNCTIONAL AND PASTING PROPERTIES OF FLOUR PRODUCED FROM POTATO (SOLANUM TUBEROSUM) TUBER STORED UNDER DIFFERENT CONDITIONS

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ABSTRACT
Potato is a starchy tuber, consumed as staple in most parts of the world. Potato storage is essential in preserving tuber quality to ensure its suitability for culinary purposes. This study aimed to evaluate the impact of four storage methods consisting of pit storage (PS), room storage (RS), metal-in-block evaporative cooling system (EC), and charcoal cooling chamber (CC) on the physicochemical properties of potato flour. The objectives were to assess the functional and pasting properties of flour produced from stored potato. The study employed a randomized complete block design involving these storage methods. Samples from the various storage methods each containing 4.8-5.0 kg of potato were analyzed fortnightly for eight weeks. The physicochemical properties of the flour were assessed, data obtained were subjected to analysis of variance, and means were separated using Duncan multiple range test. The findings of this study were that: The functional properties of potato flour were significantly affected ($p<0.05$) by storage methods as parameter varied in their bulk density (0.76-0.87 g/ml), water absorption capacity (2.29-2.68ml/g), and swelling capacity (2.60-3.88 ml/g). The pasting properties showed variations in paste viscosity as values ranged from 2486.50-4531.00 cP, while pasting time and temperature were 4.30-5.77 minutes and 71.70-74.63 °C, respectively. The study concluded that the physicochemical properties of potato flour were significantly influenced by the different storage methods, and the EC and CC were the most effective methods for potato storage. The study, therefore recommended CC for adoption based on its affordability.

Keywords: Absorption-capacity, Physicochemical, Potato, Storage, Density, Viscosity

INTRODUCTION
Potato (Solanum tuberosum L.) is a starchy, tuberous crop that belongs to the Solanaceae family (Van et al., 2017). It is the most cultivated tuber crop in the world, and it ranks fourth after rice, wheat, and corn in terms of cultivation (Liu et al., 2020). Globally, 375 million metric tonnes of potato is produced on average each year (FAOSTAT, 2024). More than 1.3 billion people eat them as a staple, and they are grown in more than 80% of the world's countries (Devaux et al., 2021). Almost two-third of the harvested potato is in China and India alone, and China is the world's leading producer with 95.5 million metric tonnes (FAOSTAT, 2024). Potato is stored using various methods globally due to its seasonality and perishability, these methods include; controlled atmosphere storage, cold storage (2–6 °C), evaporative cooling systems, use of chemicals sprout inhibitors, clamps, and pit storage (Wasukira et al., 2017). Several researchers such as Okunade & Ibrahim (2011), Yoldere (2019), and Neeraj et al. (2020) have attempted to use the available and low-cost technologies to palliate potato storage problems, however, limited information or inconsistent results have made potato storage a recurrent issue.
Potato starch generally showed a lower pasting temperature when stored at higher temperatures, as its starch content decreases with storage because starch is converted to sugar and used for respiration (Devaux et al., 2020). Due to changes in enzyme activities, the rate of starch depletion and sugar accumulation varies depending on the cultivar and storage temperature (Ezekiel et al., 2020). According to Devaux et al. (2020), the ratio of amylose to amylopectin increased in the starch granules during tuber storage, however, Ezekiel et al. (2020) reported that when tubers are stored for a certain amount of time, the amount of amylose in the starch decreases significantly.
Furthermore, functional characteristics are needed to potentially help predict and precisely evaluate how new proteins, fats, carbohydrates (starch and sugars), and fibre may behave in particular food systems (Suresh & Samsher, 2013). The functional characteristics of flour dictate its suitability for use in bakery goods where hydration is sought to enhance handling, as well as in goods like pancakes, doughnuts, and biscuits where the oil absorption property is crucial (Mepba et al., 2007). Carbohydrates are the primary hydrophilic component of potato, and potato flour contains both hydrophobic and hydrophilic chemicals that contributed to its interaction with lipids and water (Ndungutse et al., 2019a).
These studies have looked at the physical, chemical, and sensory properties of fresh and stored potato, which may pose a challenge or problem for industries as critical issues such as the physicochemical qualities (functional and pasting properties) of flour produced from stored potato and the viability of the storage methods have not been either sufficiently studied or properly documented. As a result, the existing data from previous research are inadequate for domestic and industrial utilization. Individuals and industries, therefore, find themselves uninformed about the potential or successes of these storage methods in the potato value chain and the proper utilization of flour and products from stored potato. This study therefore aimed to design and construct a Charcoal Cooling Chamber (CC) and comparing it with existing storage methods such as Pit (PS), Room (RS), and

Metal-in-block Evaporative Cooling System (EC) in potato preservation performances using the physicochemical properties of their produced flour.

MATERIALS AND METHODS

Materials

Freshly harvested Nicola variety of potato (Solanum tuberosom) without any form of mechanical damage, at 14 weeks after planting, was used for this study. It was sourced from Zingak's farm in Bokkos, Jos, identified and authenticated at the Department of Crop Production and Protection Department of Ahmadu Bello University Zaria, Kaduna State, Nigeria.

The experimental design

A randomized complete block design (RCBD) was used for the research; this involved four storage methods consisting pit; well-ventilated room; metal-in-block evaporative cooling system; and charcoal cooling chamber. Potato (4.5-5.0 kg) from each of these storage methods were collected without replacement, observed, and analyzed for its tuber and flour properties fortnightly for 56 days. A storage method was discontinued when over 50% spoilage was recorded. Freshly harvested potato without storage was analyzed and processed immediately after curing and used as the control.

Preparation of Potato and Production of Potato Flour for Analysis

The freshly harvested potato (control) and those from the storage methods were prepared into flour using the method of Okaka (2005) with slight modifications by washing the potato thoroughly using portable water to remove dirt, hand-peeled using a stainless-steel knife, and slicing to 2 mm thickness. The potato slices were then steeped in water to remove any adhering dirt. The cleaned slices of potato was then drained and dehydrated at 42-54 °C in a parabolic solar dryer for 36-38 hours to reduce the moisture content of the slices to between 9-10%. The dehydrated slices were then ground using a laboratory attrition mill (Siemens-Schurkt, Germany) into flour. The flour was sieved through a 200 µm Tyler screen and flour with uniform particle size was obtained and then separately packaged in a transparent polypropylene (100 µm) Ziploc bag and kept in a cool dry place for further analysis.

Methods

Functional Properties of Flour produced from Stored Potato

The functional properties of the flour produced from stored potato from the various storage methods were assessed using following methods for bulk density Adeleke and Odedeji (2010), water and oil absorption capacities AACC (2009) method no. 56-40.01, swelling capacity AACC (2009) technique no. 56-30.01, wettability Onwuka (2005) and dispersibility Awoyale (2015).

Pasting Properties of Flour produced from Stored Potato

The pasting qualities of the flour was measured using a Rapid Visco Analyzer (Model RVA-4; Newport Scientific Pty. Ltd, Warriewood, Australia) AACC (2009) no. 76-21.02. for pasting temperature (PT), Peak time (Pt), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown viscosity (BDV), and setback viscosity (SBV).

Statistical Analysis

Statistical analysis was done using Statistical Package for Social Science (SPSS) version 16.0 (IBM SPSS, Inc., Chicago, IL, USA). Data obtained from this research were analyzed using analysis of variance (ANOVA) and Duncan multiple range tests was used to test significant differences between means ($p<0.05$). All determinations were done in triplicates, and all values were expressed as means ± standard deviations.

RESULTS AND DISCUSSION

Functional Properties of Potato Flour

The functional property determines the applications and uses of food materials for various food products. Table 1 displays the results of functional properties of potato flour produced from potato stored using different storage methods.

The bulk density of the control flour was 0.81 g/ml, and after two weeks of storage in the different storage methods, the bulk density of the flour produced from them varied from 0.81 to 0.84 g/ml. The flour produced from potato stored in the pit and room had the lowest bulk densities, and was not significantly different from that in the control, while the flour produced from potato stored in the metal-in-block evaporative cooling system and charcoal cooling chamber were the highest. After four weeks of storage, the flour produced from the stored potato varied in bulk density, and this ranged from 0.82 g/ml in the pit and room storage, to 0.87 g/ml in the metal-in-block evaporative cooling system. By week six, the bulk density ranged from 0.77 g/ml in the flour produced from potato stored in pit to 0.82 g/ml in flour produced from potato stored in the metal-in-block evaporative cooling system.

Table 1: Functional Properties of Potato Flour produced from Stored Potato

Sample	Bulk Density (g/ml)	Water Absorption Capacity (ml/g)	Oil Absorption Capacity (ml/g)	Swelling Capacity (ml/g)	Wettability (sec)	Dispersibility (%)
Control	0.81d±0.02	2.41f±0.01	1.79i±0.00	3.35d±0.08	15.73ij±0.27	17.30h±0.10
After two weeks of storage						
PS2	0.81d±0.04	2.37g±0.01	2.14c±0.00	3.61c±0.00	24.33e±0.34	17.13i±0.06
RS2	0.81d±0.04	2.31l±0.01	2.05ef±0.00	2.82hi±0.04	15.35j±0.23	17.10i±0.10
EC2	0.84bc±0.00	2.57c±0.03	1.63j±0.00	2.87h±0.04	17.77h±0.23	18.23cd±0.06
CC2	0.84bc±0.00	2.39f±0.01	1.89gh±0.07	3.14±0.03f	21.11f±.01	17.87f±0.06
After four weeks of storage						
PS4	0.82d±0.01	2.37g±0.01	2.38a±0.01	3.82a±0.07	33.15b±0.78	16.67k±0.15
RS4	0.82d±0.01	2.29j±0.00	2.15c±0.00	2.60j±0.02	16.23i±0.28	16.77jk±0.06
EC4	0.87a±0.01	2.68a±0.01	1.56k±0.00	2.77i±0.01	19.28g±0.49	19.17a±0.06
CC4	0.85b±0.00	2.33h±0.00	2.09d±0.00	2.96g±0.04	25.47d±0.81	18.37bc±0.06

After six weeks of storage						
PS6	0.77f±0.01	2.42ef±0.04	2.33b±0.03	3.88a±0.02	34.02a±0.24	16.90j±0.10
RS6	0.81d±0.02	2.37g±0.05	2.03f±0.02	2.64j±0.03	19.28g±0.31	17.30h±0.10
EC6	0.82d±0.01	2.61b±0.01	1.51l±0.01	3.11f±0.02	18.55g±0.40	18.47b±0.06
CC6	0.81d±0.01	2.40f±0.01	2.07de±0.03	3.17ef±0.04	24.39e±0.55	18.10de±0.10
After eight weeks of storage						
RS8	0.79e±0.00	2.43e±0.01	1.87h±0.00	2.67 j±0.02	31.12c±0.76	18.07e±0.06
EC8	0.76g±0.01	2.54d±0.00	1.49l±0.01	3.68b±0.06	17.51h±0.44	17.50g±0.10
CC8	0.77f±0.01	2.56c±0.01	1.92g±0.04	3.23e±0.02	21.44f±0.19	17.90f±0.10

Values are expressed as means ±SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($p < 0.05$)
Keys:
Control: Flour produced from potato without storage
PS2, PS4, and PS6: Flour made from potato stored in pit for 2, 4, and 6 weeks respectively
RS2, RS4, RS6, and RS8: Flour prepared from potato stored in a room for 2, 4, 6, and 8 weeks respectively
EC2, EC4, EC6, and EC8: Flour from potato stored in metal-in-block evaporative cooling system for 2, 4, 6, and 8 weeks respectively
CC2, CC4, CC6, and CC8: Flour from potato stored in the charcoal cooling chamber for 2, 4, 6, and 8 weeks respectively

The flour from the pit-stored potato was significantly different from all the other flour (p<0.05). After eight weeks of storage, the bulk density of the flour ranged from 0.76 g/ml in the flour produced from potato stored in the metal-in-block evaporative cooling system, to 0.79 g/ml in flour produced from potato stored in the room. The bulk density of flour in all the storage methods were significantly different (p<0.05).
The bulk densities of potato flour in this research were in consonance with the 0.84 - 0.89 g/cm3 range reported by Ndungutse et al. (2019b) for potato flours derived from different cultivars. Bulk density refers to the relationship between the weight and volume of the product. It is influenced by various factors such as the forces of attraction between particles, particle size, and preparation methods (Onimawo & Akubor, 2012). The structure of starch polymers also plays a role, with loose polymer structures being associated with lower bulk density (Iwe et al., 2016).
Higher bulk densities indicates that the particles are closely packed and this is important for easy dispersibility of flour in water (Amandikwaa et al., 2015), making it suitable for food products that require thorough mixing and as a thickening agent. Bulk density also reveals details on the packing requirements (quality and quantity of material for construction) and characteristics of flours. Higher packed bulk densities suggests greater flour expandability, mixing qualities, and more efficient packaging, therefore, requiring less material for construction (Iwe et al., 2016; Akhila et al., 2022). Conversely, bulk density also influences the aerodynamic properties of flour and as such flour with low bulk density will require less amount of energy in pneumatic transport systems to move the flour through fluidization process.
The ability of flour to absorb and retain water is referred to as its water absorption capacity. When estimating the amount of water needed to make dough, custards, and sausages, it is an essential functional feature (Mohd-Hanim et al., 2014; Akhila et al., 2022). The water absorption capacity of the control was 1.79 ml/g. This varied after two weeks when potato was stored using the different storage methods, from 2.31 ml/g in flour produced from potato stored in the room to 2.57 ml/g in flour produced from potato stored in the metal-in-block evaporative cooling system. By week four, the water absorption capacity of the flour differed significantly (p<0.05) as the water absorption capacity ranged from 2.29 ml/g in the flour produced from the room-stored potato to 2.68 ml/g in the flour produced from potato stored in the metal-in-block evaporative cooling system. By week six of storage, the water absorption capacity of the flour from these storage methods ranged from 2.37 ml/g in the room storage and 2.61 ml/g in the metal-in-block evaporative cooling system. After eight weeks of storage the water absorption capacity ranged from 2.43 to 2.56 ml/g, the flour produced from the room-stored potato had the lowest water absorption capacity, while that produced from potato stored in the charcoal cooling chamber was the highest.
Water absorption capacity of 2.65 to 3.03 ml/g was reported by Ndungutse et al. (2019b) for potato flour, while Akhila et al. (2022) reported 2.42 ml/g for Hausa potato flour. The value of water absorption capacity of potato flour in this study is low when compared to the ones reported by Ndungutse et al. (2019b), but was within the range of values reported by Akhila et al. (2022) for Hausa potato flour. The variations in the water absorption capacity of the flours from this study may be attributed to the differences in their physical and chemical composition. Particle size and shape, chemical characteristics of the food, such as the amount of amylose (Oyeyinka et al., 2015), fibres, protein, and carbohydrates like starch (Falade & Oyeyinka, 2015), all affect water absorption. It also has to do with the ability of molecules to form gels and the existence of hydrophilic groups that bind water molecules (Mohd-Hanim et al., 2014; Brou et al., 2018). Water absorption capacity is decreased by high-fat content (Brou et al., 2018). High water absorption capacity is a characteristic of fibres (Onimawo & Akubor, 2012). Because they have greater exposed surface area for response, fine particles tend to absorb more water than coarse ones (Onimawo & Akubor, 2012; Navaf et al., 2020). Oil absorption capacity is the ability of flour to absorb and retain oil. The oil absorption capacity of the control flour was 1.79 ml/g, and after two weeks of storage in the different storage methods, the oil absorption capacity of the flour produced from potato stored in these storage methods varied significantly (p<0.05) as oil absorption capacity ranged from 1.63 ml/g in the flour from the metal-in-block evaporative cooling system to 2.14 ml/g in the flour produced from potato stored in the pit. By week four of storage, the oil absorption capacity ranged from 1.56 to 2.38 ml/g, the flour produced from potato stored in the metal-in-block evaporative cooling system had the lowest oil absorption capacity, while that produced from potato stored in pit storage was the highest. By week six, a similar trend observed in week four was recorded and the values of oil absorption capacity ranged from 1.51 to 2.33 ml/g. After eight weeks of storage, the oil absorption capacity of the flour produced from potato stored in the metal-in-block evaporative cooling system was lowest (1.49 ml/g), while that produced from potato stored in the charcoal cooling chamber was

highest (1.92 ml/g). There were significant differences (p<0.05) in the oil absorption capacity of the flour produced from these storage methods throughout the period of determination.

Ndungutse et al. (2019a) reported 0.99 and 1.23 ml/g in flours produced from potato cultivars, while Chandra & Samsher (2013) reported the oil absorption capacity of potato flour to be 1.68 ml/g and Akhila et al. (2022) reported 1.15 g/g oil absorption capacity for Hausa potato flour. Additionally, the oil absorption capacity of wheat flour ranged from 1.70 to 2.10 ml/g, and it increased as the size of the flour particles decreased (Bolade et al., 2009). According to reports, the oil absorption capacity of wheat flour is 2.15 ml/g, that of sweet potato flour is 0.65 ml/g (Adeleke & Odedeji, 2010), and that of plantain flour is 1.59 ml/g (Olumurewa et al., 2019). The results from this study were similar to those of Chandra & Samsher (2013) and Akhila et al. (2022). Since oil absorption capacity is known to depend on the nature of the protein, including its amino acids, protein formation, and the proportion of hydrophobic groups compared to hydrophilic groups on the surface of protein molecules, the variation in the oil absorption capacity of the flours from this study may be explained by the differences in their physical and chemical composition (Chandra & Samsher, 2013). High hydrophobic amino acid flour has a high potential to absorb oil (Wang et al., 2020). Products like whipped toppings, sausages, chiffon desserts, and angel and sponge cakes might benefit from the ability of flour with a high oil absorption capacity to bind and retain flavours, improving mouthfeel (Chandra & Samsher, 2013; Iwe et al., 2016; Akhila et al., 2022).

The swelling capacity in the control was found to be 3.35 ml/g. The swelling capacity varied significantly (p<0.05) when the flour was produced from two weeks stored potato in the different storage. The swelling capacity ranged from 2.82 ml/g in the flour produced from potato stored in the room, to 3.61 ml/g in flour produced from potato stored in pit. By week four of storage, the swelling capacity of the flour varied from 2.60 ml/g in the potato stored in the room, to 3.82 ml/g in that produced from potato stored in pit. By week six, the swelling capacity of the flour ranged from 2.64 to 3.88 ml/g, flour produced from potato stored in the room had the lowest swelling capacity, while that produced from potato stored in pit was the highest. After eight weeks of storage, the flour derived from these storage methods varied in their swelling capacities from 2.67 ml/g in the room storage to 3.68 ml/g in that produced from potato stored in the metal-in-block evaporative cooling system.

A swelling power of 1.93 to 5.15 g/g was recorded in Hausa potato flour (Akhila et al., 2022) and results from this study were within the range of these values. Swelling capacity measures how much a flour sample increases in volume after being soaked in water (Olumurewa et al., 2019). The variability in the swelling behaviour of the flour samples from the different storage methods may be because the swelling ability of starchy flours is dependent on some factors, such as the starch content, the ratio of amylose to amylopectin, and the particle size distribution, as similar findings were reported by Eke-Ejiofor (2015). This is plausible because fat can bind starch granules and make them hydrophobic and prevent water absorption. According to Krystyjan et al. (2022), low fat and high phosphorus content in potato starch influences their ability to swell, while Bharti et al. (2019) found that a specific percentage of protein on the surface of starch granules can also prevent starch granules from swelling.

The wettability in the control was within 15.73 seconds, and this varied in the flour produced from potato after storage for two weeks, in the different storage methods, from 15.35 seconds in the room storage to 24.33 seconds in the flour produced from pit stored potato. By week four of storage, the wettability followed a similar pattern observed in week two and the wettability ranged from 16.23 to 33.15 seconds. By week six, the wettability was lowest in the metal-in-block evaporative cooling system (18.55 seconds) and highest (34.02 seconds) in the pit storage. There were, however, no significant differences in the wettability between the flour produced from potato stored in the metal-in-block evaporative cooling system and that produced from potato stored in the room. After eight weeks of storage, the wettability was lowest in flour produced from potato stored in the metal-in-block evaporative cooling system (17.51 seconds), and highest in flour produced from potato stored in the room (31.12 seconds), the wettability was significantly different (p<0.05) among the different methods.

Wettability measures the ability of flour to reduce the surface tension of water in contact with it such that it spreads over the surface and wets it. Potato flour from the pit stored potato, consistently had the least moisture content during each period of determination, this could be why it has a strong affinity for water and an increased propensity to getting wet when compared to flours produced from potato stored in other storage methods.

The dispersibility in the control flour was 17.30%, the flour produced after storing potato in the different stores for two weeks varied significantly in its dispersibilities, and this ranged from 17.10% in flour produced from potato stored in the room, to 18.23% in flour produced from potato stored in the metal-in-block evaporative cooling system. After four weeks of storage, the dispersibility in the flour ranged from 16.67% in flour produced from potato stored in pit, to 19.17% in flour produced from potato stored in the metal-in-block evaporative cooling system. By week six, the dispersibility ranged from 16.90% in flour produced from potato stored in pit, to 18.47% in flour produced from potato stored in the metal-in-block evaporative cooling system, and after eight weeks of storage, the dispersibility ranged from 17.50% in flour produced from potato stored in the metal-in-block evaporative cooling system, to 18.07% in flour produced from potato stored in the room. The dispersibility of potato flour from this study were significantly different (p<0.05) among the storage methods in each period of determination.

The dispersibility of flour refers to its ability to reconstitute in water, indicating its hydrophobic interaction with water molecules (Baranwal & Sankhla, 2019). Studies have shown that particle size distribution and bulk density play crucial roles in determining the rate of dispersibility (Oyeyinka et al., 2023). Similarly, Baranwal & Sankhla (2019) have also highlighted the importance of flour density in influencing the mixing quality of food materials. Findings from this study also observed that flours with higher bulk density exhibited greater dispersibility.

Pasting Properties of Potato Flour

Table 2 depicts the pasting properties of flour produced from potato stored in the pit, room, metal-in-block evaporative cooling system, and charcoal cooling chamber.

The peak viscosity of the control was 2486.50 cP, and the flour produced from two weeks stored potato using the different storage methods had peak viscosity that ranged from 2521.50 cP in flour produced from potato stored in pit, to 3395.50 cP in flour produced from potato stored in the charcoal cooling chamber. After four weeks of storage, the peak viscosity varied from 2555.00 cP in flour produced from potato stored in pit, to 3801.50 cP in flour produced from potato stored in the metal-in-block evaporative cooling system. By week six of storage, the peak viscosity ranged from 2797.50 cP in flour produced from potato stored in pit, to 3706.00 cP in flour produced from potato stored in the charcoal cooling chamber, and after eight weeks of storage, the peak viscosity ranged from 3575.00 cP in flour produced from potato stored in the metal-in-block evaporative cooling system, to 4531.00 cP in flour produced from potato stored in the room. There were, however, significant differences ($p<0.05$) in peak viscosity among the flour produced from potato stored in the different storage methods throughout the period of analysis.

Peak viscosity measures the ability of starch to swell freely before it physically breaks down or dissolves (Aido *et al*., 2022). However, the results from this study indicate that the aging of potato in storage had more influence on the peak viscosity than the storage methods used. The findings of Buzera *et al*. (2023) revealed that the peak viscosity of potato flour varied from 1921.33 to 7098.33 cP, while Ajayi *et al*. (2018) and Obomeghei *et al*. (2020), respectively reported 2302 to 7160 cP, and 562.8 to 1032 cP in sweet potato varieties. Similarly, Akhila *et al*. (2022) recorded 3005 cP for peak viscosity in Hausa potato flour. The results from this study are in the range of peak viscosity reported by these authors. This increase in peak viscosity with an increase in storage time could be due to increased carbohydrate content with storage. High peak viscosity is influenced by high starch content and it connotes a higher water-binding capacity of the starch granules of flour (Olumurewa *et al*., 2019). Avula & Singh (2009) reported that a high thickening capability is related to flour with a high peak viscosity. Additionally, weaning and supplemental diets are best from flours with low peak viscosity (Iwe *et al*., 2016).

The trough viscosity (minimum viscosity) which indicates starch stability to heating showed that the trough viscosity in the control was 2060.00 cP, trough viscosity varied after two weeks of storage in flour produced from potato in the different storage methods, from 2005.50 cP in flour produced from potato stored in pit, to 2893.00 cP in flour produced from potato stored in the metal-in-block evaporative cooling system. The trough viscosity in the metal-in-block evaporative cooling system was however, not significantly different from that in the charcoal cooling chamber. By week four, the trough viscosity of the flour ranged from 1929.00 to 3501.50 cP, and the flour produced from the pit-stored potato had the lowest trough viscosity, while that from the metal-in-block evaporative cooling system was the highest. By week six, a similar pattern recorded in week four was observed and the trough viscosity ranged from 1695.00 to 3245.00 cP. After eight weeks of storage, the trough viscosity of the flour was found to be lowest in flour produced from potato stored in the charcoal cooling chamber (2841.00 cP) and highest in flour produced from potato stored in the room (3744.00 cP). There were significant differences ($p<0.05$) in the trough viscosity of the flour produced from potato stored in the different storage methods throughout the period of evaluation.

These results showed that the trough viscosity of potato flour from all the methods except pit storage increased with an increase in the storage time of potato and may have reduced their stability to heat. Kiinto *et al*. (2015) indicated that the lower the trough viscosity of the flour, the higher its stability to heat. Trough viscosity of 1095.00 to 4426.33 cP was reported by Buzera *et al*. (2023) for potato flour, Obomeghei *et al*. (2020) and Ajayi *et al*. (2018) reported 114 to 735.6 cP and 1796.5 to 4173.5 cP, respectively, for flours of sweet potato varieties, and Akhila *et al*. (2022) recorded 1259 cP for Hausa potato flour. The trough viscosity from this research agrees with the results of previous researchers. The low trough values (high holding strength) exhibited by flour produced from pit-stored potato could be due to the high temperature in the ground that has enhanced the starch in the potato and made them more stable to heat. High holding strength typically indicates less cooking loss and improved eating quality, according to Bhattacharya *et al*. (1999). This further suggested that an increase in the storage time of potato in the pit will improve the resistance of its flour to cooking loss and may enhance its utilization.

The breakdown viscosity of the control was 426.50 cP, breakdown viscosity in the flour produced from two weeks stored potato varied from 402.50 cP in flour produced from potato stored in the metal-in-block evaporative cooling system to 571.50 cP in flour produced from potato stored in the charcoal cooling chamber. There was however no significant difference in breakdown viscosity in the flour produced from the pit and room-stored potato. By week four, the breakdown viscosity of the flour ranged from 300.00 cP in flour produced from potato stored in the metal-in-block evaporative cooling system, to 648.50 cP in flour produced from potato stored in pit. There was no significant difference ($p<0.05$) in the breakdown viscosity of the flour produced from the pit and room stored potato. By week six, the breakdown viscosity varied from 326.50 cP in flour produced from potato stored in the metal-in-block evaporative cooling system, to 1102.50 cP in flour produced from potato stored in pit. After eight weeks of storage, the breakdown viscosity did not vary significantly among the flour produced from the different storage methods and the breakdown viscosity ranged from 734.00 cP in flour produced from potato stored in the metal-in-block evaporative cooling system to 787.00 cP in flour produced from potato stored in the room.

Breakdown viscosity is the difference between the peak viscosity and the trough viscosity. It measures the susceptibility of the starch granule to disintegrate during heating, and it is also regarded as a measure of paste breakdown or stability during cooking (Kiinto *et al*., 2015; Oyeyinka *et al*., 2019; Syukriani *et al*., 2021). Findings from Buzera *et al*. (2023) revealed that the breakdown viscosity of potato flour ranged from 360.33 to 2672.00 cP, Ajayi *et al*. (2018) and Obomeghei *et al*. (2020) reported 505.5 to 3460.5 cP and 295.2 to 748.8 cP, respectively, for sweet potato varieties, while a breakdown viscosity of 1218 cP was reported by Akhila *et al*. (2022). High breakdown viscosity indicates that the starch granules of the flour have low stability and are less resistant to hydrothermal disruption during gelatinization (Alam *et al*., 2009). The results from this study showed that potato flour produced from potato stored using the Metal-in-block evaporative cooling system for four weeks with a lower breakdown viscosity may tolerate shear stress and high heat treatment. As stated by Aido *et al*. (2020), this will make it more appropriate for use in products that require high-temperature processing.

Table 2: Pasting Properties of Potato Flour produced from Stored Potato

Sample	Peak Viscosity (cP)	Trough Viscosity (cP)	Breakdown Viscosity (cP)	Final viscosity Viscosity (cP)	Setback Viscosity (cP)	Peak Time (min)	Pasting Temperature (°C)
Control	2486.50h±30.41	2060.00h±29.70	426.50def±0.71	2770.50i±33.23	710.50gh±62.93	4.60bc±0.09	72.18de±0.53
After two weeks of storage							
PS2	2521.50h±16.26	2005.50hi±20.51	516.00cde±4.24	2973.50h±27.58	968.00bcde±7.07	4.49bc±0.09	72.30cde±0.21
RS2	2798.00g±8.49	2302.50g±24.75	495.50cde±33.23	3198.00g±11.31	895.50de±36.06	4.56bc±0.08	71.90e±0.14
EC2	3295.50e±20.51	2893.00e±12.73	402.50ef±7.78	3500.00f±16.97	602.50h±2.12	4.97abc±0.16	73.40bc±0.14
CC2	3395.50e±9.19	2824.00e±65.05	571.50cd±74.25	3516.00f±5.66	692.00gh±59.40	5.24abc±0.30	72.55cde±0.35
After four weeks of storage							
PS4	2555.00h±72.12	1929.00i±45.25	648.50bc±85.56	2654.00i±12.73	747.50fg±0.70	4.30c±0.04	73.35bc±1.13
RS4	3105.50f±98.29	2462.50f±77.07	643.00bc±21.21	3486.50f±34.65	1024.00abcd±111.72	4.60bc±0.00	71.78e±0.04
EC4	3801.50bc±133.64	3501.50b±150.61	300.00f±16.97	4491.50b±159.09	990.00bcde±8.49	5.44ab±1.18	74.63a±0.60
CC4	3740.50cd±161.93	3329.50c±23.33	411.00def±185.26	4308.50c±133.64	979.00bcde±110.31	5.77a±0.99	73.40bc±1.27
After six weeks of storage							
PS6	2797.50g±120.20	1695.00j±9.90	1102.50a±111.02	3767.00e±39.60	571.50h±58.69	4.63bc±0.27	73.48bc±0.32
RS6	3575.50c±36.06	3198.50d±3.54	387.00ef±46.67	4350.50bc±43.13	1152.00a±39.60	4.90abc±0.14	72.35cde±0.07
EC6	3571.50c±41.72	3245.00cd±48.08	326.50f±6.36	4213.00c±16.97	1058.00abc±62.23	5.28abc±0.11	74.25ab±0.21
CC6	3706.00cd±115.97	3199.50d±34.65	506.50cde±81.32	4304.00c±11.31	1104.50ab±23.33	5.26abc±0.23	73.45bc±0.14
After eight weeks of storage							
RS8	4531.00a±57.98	3744.00a±72.12	787.00b±14.14	4695.50a±24.75	951.50de±47.38	4.64bc±0.05	74.25ab±0.07
EC8	3575.00c±36.77	2841.00e±2.83	734.00b±39.60	3800.50e±115.26	959.50bcde±112.43	4.44bc±0.05	71.70e±0.07
CC8	3947.50b±26.16	3195.50d±19.09	752.00b±45.25	4056.50d±82.73	861.00ef±63.64	4.52bc±0.03	73.13bcd±0.11

Values are expressed as means ±SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($p< 0.05$)

Keys:

Control: Flour prepared from potato without storage

PS2, PS4, and PS6: Flour made from potato stored in pit for 2, 4, and 6 weeks respectively

RS2, RS4, RS6, and RS8: Flour produced from potato stored in a room for 2, 4, 6, and 8 weeks respectively

EC2, EC4, EC6, and EC8: Flour from potato stored in metal-in-block evaporative cooling system for 2, 4, 6, and 8 weeks respectively

CC2, CC4, CC6, and CC8: Flour from potato stored in the charcoal cooling chamber for 2, 4, 6, and 8 weeks respectively

The final viscosity of the control was 2770.50 cP, and after two weeks of storage in the various methods, final viscosity ranged from 2973.50 cP in flour produced from potato stored in pit, to 3516.00 cP in flour produced from potato stored in the charcoal cooling chamber. The flour from the charcoal cooling chamber was not significantly different ($p<0.05$) from that in the metal-in-block evaporative cooling system. After four weeks of storage, the final viscosity of the flour varied significantly ($p<0.05$) among flour samples from the different storage methods, and ranged from 2654.00 cP in flour produced from potato stored in pit, to 4491.50 cP in the flour produced from potato stored in the metal-in-block evaporative cooling system. By week six, the final viscosity ranged from 3767.00 cP in flour produced from potato stored in pit, to 4350.50 cP in flour produced from potato stored in room. There were, however, no significant differences between the flour produced from the metal-in-block evaporative cooling system and that produced from the charcoal cooling chamber in final viscosity. After eight weeks of storage, the final viscosity of the flour produced from the various methods varied significantly among methods and the final viscosity ranged from 3800.50 cP in flour produced from potato stored in the metal-in-block evaporative cooling system to 4695.50 cP in flour produced from potato stored in the room.

Buzera *et al*. (2023) reported that the final viscosity of potato flour ranged from 1596.33 to 7989.00 cP, Akhila *et al*. (2022) reported 2026 cP for Hausa potato flour, while Ajayi *et al*. (2018) and Obomeghei *et al*. (2020) recorded 2249.5 to 5444.5 cP and 159.6 to 986.4 cP, respectively, for sweet potato flour. The results from this study corroborated the results from all these authors. The ability of starch to form a viscous paste or gel after cooking and cooling due to the re-association of starch molecules is indicated by final viscosity (Olumurewa *et al*., 2019). A lower final viscosity indicated that the flour would be less likely to form a more solid paste upon cooling and less likely to withstand shear stress during stirring. This means that flours made from room-stored potato will resist shear stress better and produce a more solid paste than those made from pit storage.

The setback viscosity of the control flour was 710.50 cP, setback viscosity varied significantly ($p<0.05$) among the flour from the different storage methods as the flour produced from two weeks stored potato recorded the lowest setback viscosity (602.50 cP) in the metal-in-block evaporative cooling system and highest (968.00 cP) in the pit storage. By week four, the setback viscosity ranged from 747.50 cP in flour produced from potato stored in pit, to 1024.00 cP in flour produced from potato stored in the room, and the setback viscosity were significantly different ($p<0.05$) among methods. By week six, the setback viscosity of the flour ranged from 571.50 to 1152.00 cP, the flour produced from the pit-stored potato had the lowest setback viscosity, while that produced from the room stored potato was the highest. After eight weeks of storage, the setback viscosity of the flour varied from 861.00 cP in flour produced from potato stored in the charcoal cooling chamber, to 959.50 cP in flour produced from potato stored in the metal-in-block evaporative cooling system.

A setback viscosity of 501.33 to 3780.67 cP was reported by Buzera *et al*. (2023) for potato flour, Ajayi *et al*. (2018) and Obomeghei *et al*. (2020) reported 453.0 to 1565 cP and 45.8 to 264 cP, respectively, while Akhila *et al*. (2022) recorded 808 cP for Hausa potato flour. The setback viscosities in this study, fell within the same range as those found by earlier investigations. The difference between the final and trough viscosities is known as the setback viscosity, and it measures the propensity of the cooked flour paste to retrograde after cooling. High setback viscosity flours have been reported to have a higher propensity for retrogradation (Balet *et al*., 2019; Navaf *et al*., 2020; Neeraj *et al*., 2021). In addition to having a higher potential for retrogradation and lower storage stability at low temperatures, the higher setback viscosity of flour made from potato kept in a room for six weeks suggested that the flour will form a more cohesive paste and a firm gel (Kiinto *et al*., 2015; Olumurewa *et al*., 2019; Sudheesh *et al*., 2019). Conversely, the low setback viscosity achieved in flour processed from potato stored in a pit for six weeks will be particularly beneficial in soup and sauce formulations, which experience viscosity loss due to retrogradation, as suggested by Kaur *et al*. (2014).

The peak time of the control flour was 4.60 minutes, and after two weeks of storage, the peak time of the flour produced from potato in the various storage methods ranged from 4.49 minutes in flour from the pit storage, to 5.24 minutes in flour produced from potato stored in the charcoal cooling chamber. However, the peak time of the flour produced from the pit-stored potato was not significantly different ($p<0.05$) from that in the control and flour from the room-stored potato, and the peak time of the flour in the charcoal cooling chamber was not different from that produced from potato stored in the metal-in-block evaporative cooling system. By week four, the peak time varied significantly among storage methods and ranged from 4.30 minutes in flour produced from the pit-stored potato, to 5.77 minutes in flour produced from potato stored in the charcoal cooling chamber. By week six, the peak time ranged from 4.63 minutes in flour produced from potato stored in pit, to 5.28 minutes in flour produced from potato stored in the metal-in-block evaporative cooling system. The peak time of the flour produced from pit-stored potato was significantly different ($p<0.05$) from that in all the other storage methods. After eight weeks of storage, the peak time ranged from 4.44 minutes in flour produced from the potato stored in the metal-in-block evaporative cooling system, to 4.64 minutes in flour produced from potato stored in the room. There was, however, no significant differences ($p<0.05$) among flours produced from the different storage methods.

Peak time of 4.78 to 6.13 minutes and 5.76 to 6.13 minutes were respectively, reported by Buzera *et al*. (2023) and Tao *et al*. (2020) for potato flour, while Obomeghei *et al*. (2020) and Ajayi *et al*. (2018) reported 4 to 5 minutes and 4.47 to 4.63 minutes, respectively, for sweet potato flour. The results of peak time from this research are in agreement with the findings of the previous studies. According to Adebowale *et al*. (2005), peak time is a measure of cooking time, and according to McWatters (1985), it is the amount of time it takes for a paste to cook and the point at which the highest viscosity occurs during or shortly after cooking. Generally, when every other property is comparable, starches and flours with reduced pasting times and temperatures may be selected for technical and cost advantages (Baah *et al*., 2009). However, hence they were not significantly different during each period of determination and the times were relatively short, which showed that cooking these flours will be economical as it will not consume time and energy.

The pasting temperature of the control was 72.18 °C, and after two weeks of storage, the pasting temperature of the flour from the various storage methods ranged from 71.90 °C in the flour produced from the room stored potato to 72.55 °C in that produced from potato stored in the charcoal cooling chamber. The pasting temperature of the flour in the charcoal cooling chamber was not significantly different from that in the pit storage. By week four, the pasting temperature ranged from 71.78 °C in flour produced from potato stored in the room, to 74.63 °C in flour produced from potato stored in the metal-in-block evaporative cooling system, there was however, no significant difference ($p<0.05$) in the pasting temperature of the flour produced from the pit and charcoal cooling chamber. By week six, the pasting temperature varied from 72.35 °C in flour produced from potato stored in the room, to 74.25 °C in flour produced from potato stored in the metal-in-block evaporative cooling system, however, the pasting temperature of the flour produced from potato stored in the pit and charcoal cooling chamber were not significantly different ($p<0.05$). After eight weeks of storage the pasting temperature of the flour produced from the potato stored in the room, metal-in-block evaporative cooling system, and charcoal cooling chamber were 74.25, 71.70, and 73.13 °C, respectively, and were significantly different ($p<0.05$).

The results from the research of Tao *et al*. (2020) and Buzera *et al*. (2023) showed that pasting temperature in potato flour was 77.1 to 78.2 °C and 68.78 to 78.98 °C, respectively, while Obomeghei *et al*. (2020) and Ajayi *et al*. (2018) showed that the pasting temperatures of sweet potato flour ranged from 78 to 83 °C and 80.68 to 81.58 °C, respectively, and Akhila *et al*. (2022) revealed 78.5 °C as the pasting temperature of Hausa potato flour. The results from this study were similar to those of Tao *et al*. (2020) and Buzera *et al*. (2023) for potato flour and were quite lower than the values reported for sweet and Hausa potato. These differences could be due to the difference in the genetics of the root and tuber.

According to Shimelis *et al*. (2006), pasting temperature determines the lowest temperature required to cook any food sample, the energy costs involved, and the retention of components in the food sample. Because of the high energy expenses, flour with a high pasting temperature might not be advisable for some products. The slight distinction in the pasting temperatures among the potato flour from the different storage methods from this research confirmed that the required energy for preparing the cooked dough will not vary significantly. Additionally, the low pasting temperature in all the flour samples indicates that the pasting temperature of the potato flour was lower than the boiling temperature of water; hence, the flour can paste in hot water below the boiling point of water, suggesting that there would be significant energy saving at a commercial scale.

CONCLUSION

The results from the functional properties have shown significant variations in the potato flour among the different storage methods. These variations can be attributed to differences in starch composition, moisture content, and other changes during storage. The metal-in-block evaporative cooling system exhibited the highest values for bulk density, water absorption capacity, and dispersibility compared to other storage methods. In contrast, flour from potato stored in the pit displayed higher oil absorption capacity, swelling capacity, and wettability. These differences highlight how storage conditions can influence the functional properties of potato flour, impacting its suitability for various culinary and industrial applications. The peak, trough, breakdown, final, and setback viscosities of the potato flour from the different storage methods increased significantly as the storage progressed in all the storage methods. The peak time and pasting temperature had no definite pattern, there were no significant differences in their peak time, and all the flour paste at temperatures below the boiling point of water.

REFERENCES

AACC. (2009). Approved methods of the American Association of Cereal Chemist, 11th Edition, St. Paul, Minnesota, USA.

Adebowale, A. A, Sanni, L. O. & Awonorin, S. O. (2005). Effects of texture modifiers on the physicochemical and sensory properties of dried fufu. *International. Journal of Food Science and Technology*. *11*(5), 373- 382.

Adeleke, R. O. & Odedeji, J. O. (2010) Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition, 9*(6), 535–538.

Aidoo, R., Oduro, I. N., Agbenorhevi, J. K., Ellis, W. O. & Pepra-Ameyaw, N. B. (2022). Physicochemical and pasting properties of flour and starch from two new cassava accessions. *International Journal of Food Properties*, *25*(1), 561–569.

Ajayi, O. I., Kosoko, S. B., Awogbemi, B. J., Okedina, T. A., Onyema, C. P. Ehiwuogu-Onyibe, J., Lawal, A. K. & Elemo, G. N. (2018). Colour profile, pasting and sensory properties of processed sweet potato flour. *Biotechnology Journal International, 22*(4), 1-12.

Akhila, P. P., Sunooj, K. V., Aaliya, B., Navaf, M., Sudheesh, C., Yadav, D. N., Khan, M. A. Mir, S. A. & George, J. (2022) Morphological, physicochemical, functional, pasting, thermal properties and digestibility of hausa potato (*Plectranthus rotundifolius*) flour and starch *Applied Food Research 2*(2) 100193: 1-14

Alam, F., Siddiqui, A. & Lutfi Z. (2009) Effect of different hydrocolloids on gelatinization behavior of hard wheat flour. *Trakia Journal of Science*, *7*(1), 1–6.

Amandikwaa, C., Iwe, M. O., Uzomaha, A. & Olawunia, A. I. (2015). Physicochemical properties of wheat-yam flour composite bread. *Nigerian Food Journal, 33*, 12–17.

Avula, R. Y & Singh, R. K (2009). Functional Properties of Potato Flour and its Role in Food Product Development - A Review. *Foods*, *2*(3), 105-112

Awoyale, W., Sanni, L. O., Shittu, T. A., & Adegunwa, M. O. (2015). Effect of varieties on the functional and pasting properties of biofortified cassava root starches. *Journal of Food Measurement and Characterization*, *9,* 225–232.

Baah, F. D., Maziya-Dixon, B., Asiedu, R., Oduro, I. & Ellis, W. O. (2009). Nutritional and biochemical compositeon of *D. alata* (*Dioscorea* spp.) tubers. *Journal of Food Agriculture and Environment*, *7*(2), 373-378.

Balet, S., Guelpa, A., Fox, G. & Manley, M. (2019). Rapid Visco-Analyser (RVA) as a tool for measuring starch-related physiochemical properties in cereals: A review. *Food Analytical Methods*, *12*(10), 2344–2360.

Baranwal, D. & Sankhla, A. (2019). Physical and functional properties of malted composite flour for biscuit production. *Journal of Pharmacognosy and Phytochemistry, 8*(2), 959–965.

Bharti, I., Singh, S. & Saxena, D. C. (2019). Exploring the influence of heat moisture treatment on physicochemical, pasting, structural and morphological properties of mango kernel starches from Indian cultivars. *LWT-Food Science and Technology, 110*, 197–206.

Bhattacharya, M., Zee, S. Y. & Corke, H. (1991). Physicochemical properties related to quality of rice noodles, *Cereal Chemistry, 76*(6), 861–867

Bolade, M. K., Adeyemi, I. A. & Ogunsua, A. O. (2009) Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based non fermented food gel. *International Journal of Food Science, 44*, 646–655.

Brou, R. M., Faulet, B. M., Serge, G., Ekissi, G. S. E., Koné, T. M. F. & Kouamé, P. L. (2018) Assessment of phytochemical and functional properties from heart of oil palm tree (*Elaeis Guineensis* Jacq.) consumed in Côte d'Ivoire. *International Journal of Advanced Research, 6*(2), 934–946.

Buzera, A., Nkirote, E., Abass, A., Orina, I. & Sila, D. (2023) Chemical and pasting properties of potato flour (*Solanum tuberosum L.*) in relation to different processing techniques. *Hindawi Journal of Food Processing and Preservation, 1*, 3414760: 1-12 https://doi.org/10.1155/2023/3414760

Chandra S & Samsher (2013) Assessment of functional properties of different flours. *African Journal of Agricultural Research,* 8(38), 4849–4852.

Devaux, A., Goffart, J. P., Kromann, P., Andrade, P. J., Polar, V. & Hareau, G. (2021). The potato of the future: opportunities and challenges in sustainable agri-food systems. *Potato Research, 64*, 681–720

Devaux, A., Goffart, J. P., Petsakos, A., Kromann, P., Gatto, M., Okello, J., Suarez, V., & Hareau, G. (2020). Global food security, contributions from sustainable potato agri-food systems. In: Campos H, Ortiz O (eds). The potato crop: its agricultural, nutritional and social contribution to humankind. Springer, Dordrecht.

Eke-Ejiofor, J. (2015). Physico-chemical and pasting properties of starches from cassava, sweet potato and three leaf yam and their application in salad cream production. *International Journal of Biotechnology and Food Science, 3*(2), 23–30.

Ezekiel, T. W., Nuhu, N. D. & Nachana'a, T. (2020). Phytochemical, elemental, proximate and anti- nitrients composition of Irish potato (*Solanum tuberosum*) obtained in Kwaja, Mubi Sourth Local Government Area of Adamawa State. *International Journal of Innovative Science, Engineering & Technology*, *7*(7), 258-268.

Falade, K. O., & Oyeyinka, S. A. (2015). Color, chemical and functional properties of plantain cultivars and cooking banana flour as affected by drying method and maturity. *Journal of Food Processing and Preservation, 39*(6), 816–828.

FAOSTAT (2024). Food and Agricultural Organization of the United Nations. FAO Statistical Database. http://www.potatopro.com

Iwe, M. O., Onyeukwu, U. & Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food and Agriculture 3*(1), 1–10.

Kaur, S. Aggarwal, P. & Kaur, A. (2014). Pasting properties and color attributes of potato flour as influenced by pre-cooking. *International Journal of Scientific Research*, *3*(8), 168 - 169

Kiinto, K. D. B., Eketo-Ejiofor, J. & Giami, S. Y. (2015). Functional and pasting properties of wheat/plantain flours enriched with bambara groundnut protein concentrate. *International Journal of Food Science and Nutrition Engineering*, 5(2), 75–81.

Krystyjan, M., Dobosz-Kobędza, A., Sikora, M., & Baranowska, H. M. (2022). Influence of xanthan gum addition on the short-and long-term retrogradation of corn starches of various amylose content. *Polymers, 14*(3), 452.

Liu, N., Zhao, R., Qiao, L., Zhang, Y., Li, M., Sun, H., Xing, Z., & Wang, X. (2020). Growth stages classification of potato crop based on analysis of spectral response and variables optimization. *Sensors*, *20*(14), 3995: 1-20 https://doi.org/10.3390/s20143995

McWatters, K. H. (1985) Functionality of cowpea meal and flour in selected foods. In Cowpea research production and utilization, S. R. Singh and K. O. Rachie (Eds). Chickester John Willey and Sons. 361-366.

Mepba, H., Eboh, L. & Nwaojigwa, S. U. (2007). Chemical composition, functional and baking properties of wheat-plantain composite flours. *African Journal Food, Agriculture, Nutrition and Development*, *7,* 1–22.

Mohd-Hanim, A. B., Chin, N. L. & Yusof, Y. A. (2014). Physico-chemical and flowability characteristics of a new variety of Malaysian sweet potato, VitAto Flour. *International Food Research Journal 21*(5), 2099-2107

Navaf, M., Sunooj, K. V., Aaliya, B., Sudheesh, C., & George, J. (2020). Physicochemical, functional, morphological, thermal properties and digestibility of Talipot palm (Corypha umbraculifera L.) flour and starch grown in Malabar region of South India. *Journal of Food Measurement and Characterization, 14*(3), 1601–1613.

Ndungutse, V., Ngoda, P. M. N., Vasanthakaalam, H., Shakala, E. K., & Faraj, A. K. (2019a). Morphological and phytochemical composition of selected potato (*Solanum tuberosum L.*) cultivars grown in Rwanda. *Annals of Food Science and Technology*, *20*(1), 393–401

Ndungutse, V., Ngoda, P. M. N., Vasanthakaalam, H., Shakala, E. K., & Faraj, A. K. (2019b) Functional Properties of Flour From Selected Potato (*Solanum tuberosum L.*) Cultivars Grown In Rwanda. *Potato Journal*, *46*(2), 115-123.

Neeraj, N. D, Vinita, B., & Uma, D. (2020). Potato Starch: Novel ingredient for food industry. *International Journal of Current Microbiology and Applied Sciences*, *9*(1), 1718-1724

Neeraj, Siddiqui, S., Dalal, N., Srivastva, A., & Pathera, A. K. (2021). Physicochemical, morphological, functional, and pasting properties of potato starch as a function of extraction methods. *Journal of Food Measurement and Characterization, 15*(3), 2805–2820.

Obomeghei, A. A., Olapade, A. A. & Akinoso, R. (2020). Evaluation of the Chemical Composition, Functional and

Pasting Properties of Four Varieties of Nigerian Sweet Potato [*Ipomoea Batatas* L. (Lam.)] Flour. *African Journal of Food and Agriculture*, *20*(3), 15764 – 15778

Okaka, J. C. (2005). Handling, storage and processing of plant food. OCJANCO Academic Publisher, Enugu, Nigeria.

Okunade, S. O. & Ibrahim, M. H. (2011). Assessment of the evaporative cooling system for storage of Irish potato. *Journal of Production Agriculture and Technology of Nasarawa State University, Keffi, 7*(1), 74-83

Olumurewa, J. A. V., Ibidapo, P. O. & Adebileje, J. F. (2019). Evaluation of functional and pasting properties of instant pounded yam/plantain flour. *Advances in Obesity Weight Management & Control, 9*(1), 1–6.

Onimawo, I. A. & Akubor, P. I. (2012). Food Chemistry: Integrated Approach with Biochemical background. (2nd ed.). Joytal Printing Press, Agbowo, Ibada, Nigeria.

Onwuka, G. I. (2005) Food Analysis and Instrumentation (Theory and Practice) 1st edn, Naphthali Print, Surulere, Lagos, 133-137

Oyeyinka, S. A, Taiwo, O. E., Abdul, H., Rustria, G. A. Oyedeji, A. B., Adebo, O. A., Gerrano, A. S., Amoo, S. O. & Njobeh, P. B. (2023). Enhancement of the functional, pasting and textural properties of *poundo* yam flour through cassava flour supplementation. *Food Chemistry Advances*, *3*(2023), 1-8.

Oyeyinka, S. A., Adeloye, A. A., Smith, S. A., Adesina, B. O. & Akinwande, F. F. (2019). Physicochemical properties of flour and starch from two cassava varieties. *Agrosearch, 19*(1), 28-45.

Oyeyinka, S. A., Singh, S., Adebola, P. O., Gerrano, A. S. & Amonsou, E. O. (2015). Physicochemical properties of starches with variable amylose contents extracted from bambara groundnut genotypes. *Carbohydrate Polymers, 133*, 171–178.

Shimelis, E. A., Meaza, M., Rakshit, S. K., Program, B. T. & Ababa, A. (2006). Physico-chemical properties, pasting behavior and functional characteristics of flours and starches from improved bean (*Phaseolus vulgaris L.*) varieties grown in East Africa. *CIGR Agricultural Engineering Journal*, *8*, 1–19.

Sudheesh, C., Sunooj, K. V., George, J., Kumar, S. & Sajeevkumar, V. A. (2019). Physico-chemical, morphological, pasting and thermal properties of stem flour and starch isolated from kithul palm (Caryota urens) grown in valley of Western Ghats of India. *Journal of Food Measurement and Characterization, 13*(2), 1020–1030.

Suresh, C. & Samsher, S. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*(38), 4849-4852.

Syukriani, L., Yunita, R. & Jamsari, J. (2021). Physicochemical characterization of starch from seven genotypes banana in West Sumatera. In *IOP Conference Series: Earth and Environmental Science 741*(1), 0120007: 1-8 https://doi.org/10.1088/1755-1315/741/1/012007

Tao, C., Wang, K., Liu, X., Shi, W., Liu, Y. & Gou, E. (2020). Effects of potato powder and starch on the pasting, rheological, and thermal properties of dough. *Food Science and Technology Research*, *26*(5), 579-587

Van, H. P, Huong, N. T, Phi, N. T. & Tien, N. N. (2017). Physicochemical characteristics and in vitro digestibility of potato and cassava starches under organic acid and heat-moisture treatments. *International Journal of Biological Macromolecules*, *95*, 299–305.

Wang, H., Yang, Q., Gao, L., Gong, X., Qu, Y. & Feng, B. (2020). Functional and physicochemical properties of flours and starches from different tuber crops. *International journal of biological macromolecules, 148*(1), 324-332.

Wang, S., Li, C., Copeland, L. Niu, Q. & Wang, S. (2015). Starch retrogradation: A comprehensive review. *Comprehensive Reviews in Food Science and Food Safety, 14*(5), 568–585.

Wasukira, A., Walimbwa, K., Wobibi, S., Owere, L., Naziri, D. & Parker, M. (2017). Ware potato harvesting and storage techniques: guidelines for harvesting and storage management of ware potato. Kampala-Uganda. Consultative Group on International Agricultural Research (CGIAR) Reasearch Program on Roots, Tubers and Bananas. 25-26 https://hdl.handle.net/10568/82788

Yoldere, H. M. (2019). Effect of Different Storage Methods on Development of Post-Harvest Rot of Solanum tuberosum L. in Yola, Adamawa State Nigeria. *Journal of Biology, Agriculture and Healthcare, 9*(4), 24-40.