

Experimental investigation of the effect of cassava starch as a natural retarding admixture on the setting time of cement paste

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Abstract

The increasing demand for sustainable and environmentally friendly construction materials has encouraged research into the use of locally available agricultural products as alternatives to conventional chemical admixtures. This study investigated the effect of cassava starch as a natural retarding admixture on the setting time of cement paste. Cassava starch was incorporated into cement paste at dosage levels of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% by weight of cement and water cement ratio of 0.5 was adopted. Two commercially available cement brands, Dangote Cement and Ashaka Cement, were used to evaluate the influence of cement type on the performance of cassava starch. The initial and final setting times of the cement pastes were determined using the Vicat apparatus. The results showed that the incorporation of cassava starch generally delayed both the initial and final setting times of the cement paste. For Dangote Cement, the control paste recorded initial and final setting times of 160 and 250 minutes, respectively, while the 2% cassava starch paste recorded 300 and 410 minutes. For Ashaka Cement, the corresponding values increased from 202 and 253 minutes for the control to 313 and 423 minutes at 2% cassava starch. A slight reduction in setting time was observed at 2.5% dosage in both cement brands. The results demonstrate that cassava starch has significant potential as a locally available natural retarding admixture. The study recommends controlled dosage levels, particularly around 1–2%, depending on the cement type and the required delay in setting. Cassava starch may provide a low-cost and renewable alternative to some conventional chemical retarders, especially in regions where cassava is abundantly produced.

Keywords: *Cassava starch; cement paste; final setting time; initial setting time: natural admixture; retarding admixture; Vicat apparatus.*

1. INTRODUCTION

Cement is one of the most important materials used in the construction industry. When cement is mixed with water, a series of chemical reactions known as hydration begins (Beaudoin & Odler, 2019). These reactions cause the cement paste to gradually lose its plasticity and eventually harden. The time required for this transition is referred to as the setting time of cement. The initial and final setting times are important parameters because they influence the time available for mixing, transporting, placing, compacting and finishing cement-based materials (Ghoddousi *et.al.*, 2016).

According to Rodrigues & Joekes (2011) in construction practice, the setting of cement paste may occur too rapidly under certain environmental and material conditions. High temperatures, low water–cement ratios, cement composition and the presence of certain chemical compounds may accelerate the hydration process. Rapid setting can create difficulties during transportation and placement, particularly in large construction projects, hot climates and locations where construction activities are affected by long transportation distances. Retarding admixtures are therefore used to delay the setting of cement paste and concrete,

According to Khudhair, El Hilal & Elharfi, (2018) Conventional chemical retarders such as lignosulphonates, hydroxycarboxylic acids and certain synthetic compounds are widely used in concrete production. However, the availability, cost, environmental impact and sustainability of some chemical admixtures have encouraged the search for alternative natural materials. Agricultural products and plant-based polymers have attracted considerable attention because they are renewable and may be locally available (Drishya *et.al.*, 2025).

As reported by Okafor (2008) Cassava (*Manihot esculenta Crantz*) is an important agricultural crop in Nigeria and many tropical countries. Cassava contains a significant quantity of starch, a natural polysaccharide with the ability to absorb and retain water. Its polymeric structure may influence the movement of water and the hydration process of cement particles. Previous studies have reported that cassava-derived materials can improve workability and delay the setting of cement-based materials. For instance, cassava flour has been reported to delay cement setting by several hours and improve the workability of concrete (Arimanwa *et.al.*, 2021).

Previous research has also specifically investigated cassava starch in cement paste and concrete. A study on cassava starch reported increases in initial and final setting times with increasing starch concentration (Fransiska *et.al.*, 2025). More recent work has similarly reported that cassava starch can prolong cement setting and influence the fresh and hardened properties of concrete.

Despite these findings, the performance of natural starch-based admixtures may vary according to the cement type, dosage, chemical composition of the starch and water–cement ratio. Therefore, there is need for further experimental investigation into the effectiveness of cassava starch as a natural retarding admixture, particularly using commercially available cement brands used in Nigeria. This study aimed at investigating the effect of different dosages of cassava starch on the initial and final setting times of cement paste produced with two cement brands with a view to explore its suitability in concrete production.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for this research include the following: cassava starch, cement, and water.

2.1.1 Cement

Limestone-blended cement manufactured by Dangote and Ashaka Cement Companies, and conforming to the requirements of BS EN 196, was used for this study.

2.1.2 Water

Clean, potable water, free from impurities and organic contaminants, was used throughout the study in accordance with the requirements of ASTM C1602/C1602M-22.

2.1.3 Cassava

Cassava starch was sourced from Bali Local Government Area of Taraba State. The material was subsequently sieved through a BS No. 85 sieve to remove any chaff and other unwanted particles and was found to comply with the relevant standard specifications.

2.2 Methods (procedure)

2.2.1 Method of Processing Cassava Starch

Granular cassava starch powder was purchased from Bali Local Government Area of Taraba State, Nigeria. The material was thoroughly sieved to remove unwanted substances and impurities prior to activation.

Cassava Starch Paste Consistency

2.2.2 Production of slurry before paste

a. *The production of slurry before paste*

Cold water or starch powder, one was introduced into the other to produce slurry devoid of granules or balls. The slurry was stirred enough to remove air bubbles and to dissolve the powder completely. Hot water near or at boiling point was then added to the slurry, which reacted by swelling and transforming into paste.

A test to determine the amount of water for producing starch paste was necessary in order to obtain consistent paste throughout the experiment. The quantities of cold/hot water was varied while the quantity of powder was kept constant in order to achieve consistent paste by using the formulae, adopted from Khalil (2005):

$$L_s = S_p + C_w \dots \dots \dots (2.2)$$

$$U_{CP} = L_s + H_w \dots \dots \dots (2.3)$$

Where L_s = light slurry, U_{CP} = uniform clear paste, S_p = starch powder, C_w = cold water and H_w = hot water.

After several efforts and calculations, the process of producing clear, thick and uniform paste with standard viscosity was achieved with a mix ratio of 1: 2.5: 10.1; dry starch powder to cold water to hot water at boiling point. Through this test the quantity, each of cold and hot water required to produce paste of standard consistency with paste clarity and uniform viscosity were determined.

This procedure enabled the quantities of cold and hot water required to produce a paste with standard consistency, clarity and uniform viscosity to be determined. The results of the trial test are presented in the table below.

Table: 1 cassava Paste Consistency Test

Test No.	1	2	3	4
Wp (g)	150	150	100	100
Wc (g)	100	120	150	250
Cm	TS	LS	LS	LS
Wh (g)	600	800	1000	1100
Ps (g)	UT N	UT U	CT U	CW U

Source: Laboratory work, (2026)

Note:

WP: weight of powder starch measured in gramme

Wc: weight of cold water measured in gramm

UTU: unclear thick and uniform paste,

TS: Thick slurry,

UTN: unclear thick and non- uniform paste

CTU: Clear, thick and uniform,

Wh: weight of hot water measured in gram

CWU: Clear, watery and uniform,

LS: Light slurry

2.3 Experimental Dosage

Cassava starch was added at the following dosage levels:

- 0% — control;
- 0.5%;
- 1%;
- 1.5%;
- 2%; and
- 2.5%.

The dosage was calculated as a percentage of the mass of cement.

The general dosage relationship is Cassava starch dosage (%) = $\frac{\text{ratio of Mass of cassava starch to Mass of cement}}{100}$

2.4 Determination of Setting Time

According to Okafor (2008), setting time of the cement paste was determined using the Vicat apparatus. Cement paste was prepared by mixing cement, water and the required quantity of cassava starch. The paste was placed into the Vicat mould and tested at regular time intervals.

The **initial setting time** was determined as the time elapsed between the addition of water and

the point at which the penetration of the Vicat needle reached the specified criterion for initial setting.

The **final setting time** was determined as the time elapsed between the addition of water and the point at which the cement paste had sufficiently hardened according to the relevant testing procedure.

The test procedure was carried out consistently for the control and cassava-starch-modified cement pastes.

3.0 RESULTS AND DISCUSSION

3.1 Effect of Cassava Starch on the Setting Time of Dangote Cement

The results obtained for Dangote Cement demonstrate that cassava starch has a significant retarding effect on both the initial and final setting times of cement paste. The control sample recorded an initial setting time of 160 minutes and a final setting time of 250 minutes. With the addition of 0.5% cassava starch, the initial setting time increased to 182 minutes, while the final setting time increased to 292 minutes. At 1% dosage, the initial and final setting times further increased to 224 and 324 minutes, respectively. At 1.5% dosage, the initial setting time remained at 224 minutes, whereas the final setting time increased substantially to 394 minutes. The maximum retardation was obtained at 2% cassava starch, with initial and final setting times of 300 and 410 minutes, respectively. This represents increases of 140 minutes (87.5%) and 160 minutes (64.0%) in the initial and final setting times, respectively, compared with the control.

The present findings are consistent with those of Kone et al. (2022), who investigated cassava starch as a natural admixture in concrete and reported that cassava starch prolonged the setting

Experimental investigation of the effect of cassava starch as a natural retarding admixture on the setting time of cement paste

time of cement. Their experimental programme included cassava starch dosages of 0%, 1%, 1.5% and 2%, and the results confirmed the ability of cassava starch to retard cement setting. Although Kone et al. (2022) also investigated rice husk ash in combination with cassava starch, their observation that cassava starch prolonged setting time supports the trend obtained in the present study. The agreement is particularly evident within the 1–2% dosage range, where the present study also recorded progressive increases in setting time. Kone et al. reported 1% cassava starch combined with 10% rice husk ash as the optimum combination for good strength development, indicating that the optimum dosage may vary depending on whether the objective is setting retardation or strength development.

The findings also agree with Okafor (2008), who investigated cassava flour as a set-retarding admixture in concrete. Okafor reported that cassava flour considerably delayed cement setting, with the retardation reaching approximately six hours, and identified 3% cassava flour as the optimum dosage under the conditions of his study. The present investigation similarly confirms that cassava-derived materials can substantially delay cement hydration and setting. However, the maximum retardation in the present study occurred at 2% cassava starch rather than at 3% as reported by Okafor. This difference may be attributed to differences in the form of cassava material used, since cassava starch and cassava flour may possess different chemical and physical characteristics. Other factors, including cement brand, water-cement ratio, mix proportions, starch preparation, ambient conditions and testing procedures, may also influence the optimum dosage and magnitude of retardation.

A particularly important observation in the present study is the reduction in setting time at

2.5% cassava starch. The initial setting time decreased from 300 minutes at 2% to 255 minutes at 2.5%, while the final setting time decreased from 410 minutes to 345 minutes. This indicates that the relationship between cassava starch dosage and setting time is not strictly linear. Instead, the results suggest the existence of an optimum dosage beyond which additional cassava starch may not produce further retardation. Excessive starch concentration may modify the physical and chemical conditions within the cement paste, including the availability and movement of water, dispersion of cement particles and interaction between starch constituents and cement hydration products. Consequently, the retarding effect may diminish at higher dosages.

Overall, the present results strongly support the findings of Kone et al. (2022) and Okafor (2008) that cassava-based materials have potential as natural set-retarding admixtures. However, the present study indicates that 2% cassava starch was the most effective dosage for delaying both initial and final setting of Dangote Cement under the experimental conditions adopted. The subsequent reduction at 2.5% demonstrates that increasing the dosage beyond the optimum does not necessarily improve the retarding effect. Therefore, cassava starch can be considered a promising locally available natural retarder, but its optimum dosage should be established experimentally for each cement type and concrete mixture.

Experimental investigation of the effect of cassava starch as a natural retarding admixture on the setting time of cement paste

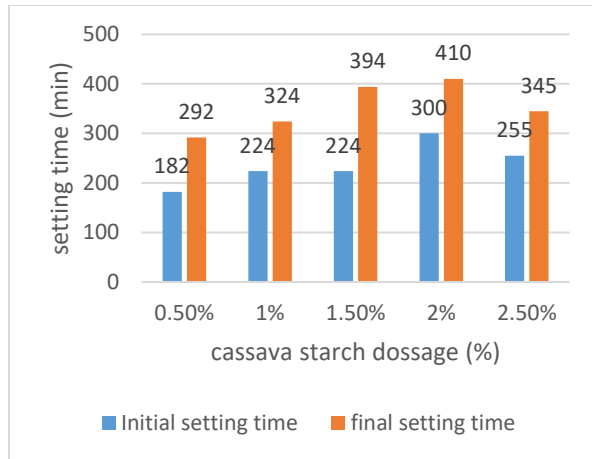


Figure 1: Effect of Cassava Starch on the Setting Time of Dangote Cement

3.2 Effect of Cassava Starch on the Setting Time of Ashaka Cement

The results obtained in this study are in agreement with the findings of Kone, Mwero and Ronoh (2022) and Okafor (2008), who reported that cassava-based materials possess significant set-retarding properties when incorporated into cementitious materials. In the present investigation, the initial setting time increased progressively from 202 minutes in the control sample to 313 minutes at 2% cassava starch, representing an increase of 111 minutes or approximately 55.0%. Similarly, the final setting time increased from 253 minutes to 423 minutes, corresponding to an increase of 170 minutes or approximately 67.2%. These results demonstrate that cassava starch substantially delays both the initial and final setting of the cement paste.

Kone et al. (2022) reported that cassava starch prolonged the setting time of cement and concluded that cassava starch has potential as a natural admixture in concrete. Their experimental programme incorporated cassava starch at 0%, 1%, 1.5% and 2%, either independently or in combination with rice husk ash. Their observation of prolonged setting time with

increasing cassava starch content supports the present finding. However, their reported optimum combination for strength development was 1% cassava starch with 10% rice husk ash, indicating that the optimum dosage for setting retardation or strength development may depend on the constituent materials and experimental conditions employed. The difference between the present result and that of Kone et al. may therefore be attributed to variations in cement characteristics, water-cement ratio, mix proportion, starch preparation, rice husk ash content and curing or testing conditions.

The present result also agrees with Okafor (2008), who investigated cassava flour as a set-retarding admixture in concrete and reported that cassava flour could delay cement setting by up to approximately six hours. Okafor identified 3% cassava flour as the optimum dosage in his experimental concrete mixture. In comparison, the present study recorded its maximum setting-time retardation at 2% cassava starch, where the initial and final setting times reached 313 and 423 minutes, respectively. The difference in optimum dosage does not contradict the findings of Okafor; rather, it suggests that the optimum concentration of cassava-based admixture is dependent on the type and form of cassava material, cement composition, water-cement ratio and other mixture characteristics.

An important observation from the present study is the slight reduction in both initial and final setting times at 2.5% cassava starch. This indicates that the relationship between cassava starch concentration and setting time is not strictly linear. The behaviour suggests that cassava starch has an optimum concentration beyond which further addition does not necessarily produce additional retardation. Similar dosage-dependent behaviour is consistent with the general findings of cassava-based

Experimental investigation of the effect of cassava starch as a natural retarding admixture on the setting time of cement paste

admixture studies, where excessive quantities may alter the hydration environment and consequently reduce the effectiveness of the retarding mechanism.

Overall, the present findings confirm the potential of cassava starch as a natural set-retarding admixture. The increase in setting time up to the 2% dosage demonstrates its effectiveness in extending the workable period of concrete, while the subsequent reduction at 2.5% suggests that approximately 2% may represent a critical or optimum dosage under the conditions of the present experiment. This result is particularly significant for construction practice in environments where extended placing and finishing times are required, while also providing evidence that cassava starch can serve as a locally available alternative to conventional chemical retarders.

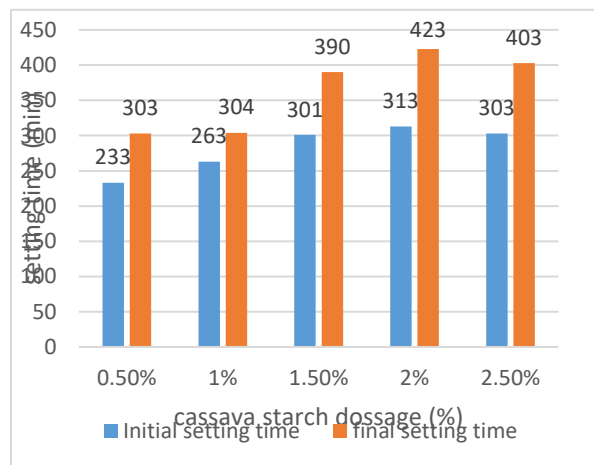


Figure 2. Effect of Cassava Starch on the Setting Time of Ashaka Cement

3.3 Comparison of the Two Cement Brand

The results demonstrate that the two cement brands exhibited different responses to the incorporation of cassava starch, indicating that

the effectiveness of the natural retarding admixture is influenced by the characteristics of the cement used. In general, Ashaka Cement exhibited slightly longer setting times than Dangote Cement at comparable cassava starch dosages. At the optimum dosage of 2%, for example, Ashaka Cement recorded an initial setting time of 313 minutes, compared with 300 minutes for Dangote Cement. Similarly, the final setting time increased to 423 minutes for Ashaka Cement, compared with 410 minutes for Dangote Cement. Although the differences between the two cement brands were relatively small, the results indicate that Ashaka Cement experienced a slightly greater retardation effect at the 2% cassava starch dosage.

The observed behaviour is consistent with the findings of Kone et al. (2022), who reported that cassava starch has the capacity to prolong the setting time of cement and can therefore function as a natural retarding admixture. The present study further demonstrates that the magnitude of this retarding effect can vary between cement brands, even when the same cassava starch dosage is applied. Kone et al. (2022) investigated cassava starch within the 1–2% dosage range and observed a beneficial retarding effect, supporting the progressive increase in setting time obtained in the present investigation.

The present findings are also in agreement with Okafor (2008), who reported significant retardation of cement setting when cassava flour was incorporated into concrete. Okafor identified 3% cassava flour as the optimum dosage under his experimental conditions, whereas the present investigation identified 2% cassava starch as the dosage producing the greatest retardation for both cement brands. The difference in optimum dosage may be explained by differences in the form of cassava material used, cement composition, water-cement ratio, mixture

proportions and experimental conditions. Nevertheless, both studies confirm the potential of cassava-derived materials to delay cement setting.

The slightly longer setting times recorded for Ashaka Cement compared with Dangote Cement may be attributed to differences in their chemical and physical characteristics, including clinker mineral composition, cement fineness, gypsum content, hydration behaviour and manufacturing processes. Such differences can influence the interaction between cement particles, water and the constituents of cassava starch, thereby affecting the rate of hydration and setting. Consequently, the performance of cassava starch as a natural retarding admixture cannot be assumed to be identical for all cement brands and should be evaluated for the specific cement intended for use.

Despite the observed differences between the two cement brands, all the measured setting times remained within the requirements of BS EN 196-3. The initial setting times were considerably greater than the minimum specified value of 45 minutes, while the final setting times remained below the maximum allowable period of 10 hours. This confirms that the incorporation of cassava starch, particularly at the investigated dosages, did not cause the cement paste to fall outside the specified setting-time requirements. Overall, the results support the findings of Kone et al. (2022) and Okafor (2008) concerning the retarding potential of cassava-based materials, while additionally demonstrating that cement brand and composition can influence the magnitude of the retardation obtained.

3.4 Mechanism of Retardation

The retarding effect of cassava starch may be associated with the behaviour of starch molecules

in the cement–water system. Cassava starch contains polysaccharide chains capable of interacting with water and cement particles. When incorporated into cement paste, the starch may absorb or retain part of the mixing water and form a viscous film around cement particles.

This may reduce the immediate availability of water for cement hydration and slow the dissolution of reactive cement compounds. The resulting reduction in the rate of hydration may delay the formation of hydration products responsible for the loss of plasticity and development of rigidity.

The effect may also involve adsorption of starch molecules on the surface of cement particles. Such adsorption may temporarily hinder the contact between cement particles and water, thereby delaying hydration. The extent of the effect is likely to depend on the starch concentration, cement chemistry, water–cement ratio and temperature.

3.5 Percentage Increase in Setting Time

The percentage increase in setting time can be calculated using:

$$\text{Percentage increase} = \frac{T_a - T_c}{T_c} \times 100$$

Where:

(T_a) = setting time of the admixture-modified paste; and

(T_c) = setting time of the control paste.

For example, the initial setting time of Dangote Cement increased from 160 minutes for the control to 300 minutes at 2% cassava starch:

$$300-160/160 \times 100 = 87.5\%$$

Experimental investigation of the effect of cassava starch as a natural retarding admixture on the setting time of cement paste

Thus, the initial setting time increased by approximately **87.5%**.

For the final setting time: $410-250/\{250\} \times 100 = 64.0\%$

Therefore, the final setting time increased by approximately **64.0%**.

These results demonstrate the considerable retarding potential of cassava starch.

4. CONCLUSION

This study investigated the effect of cassava starch as a natural retarding admixture on the setting time of cement paste. Based on the experimental results, the following conclusions were drawn:

1. Cassava starch significantly affected the setting time of cement paste.
2. The addition of cassava starch generally increased both the initial and final setting times of the two cement brands investigated.
3. Dangote Cement recorded an initial setting time of 160 minutes and a final setting time of 250 minutes for the control paste. These values increased to 300 and 410 minutes, respectively, at 2% cassava starch dosage.
4. Ashaka Cement recorded initial and final setting times of 202 and 253 minutes, respectively, for the control paste. These increased to 313 and 423 minutes at 2% cassava starch dosage.
5. The highest retardation was generally recorded at the 2% dosage level.
6. A slight reduction in setting time was observed at 2.5% dosage, indicating that excessive cassava starch addition may not continuously increase the retarding effect.

5. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Cassava starch may be considered as a natural retarding admixture where a controlled delay in cement setting is required.
2. The dosage of cassava starch should be carefully controlled because excessive addition may reduce the retarding effect.
3. The compatibility of cassava starch should be evaluated separately for different cement brands before large-scale application.
4. Further studies should investigate the effect of cassava starch on the compressive strength, tensile strength, flexural strength, durability and microstructure of concrete.
5. Further research should examine the chemical composition and mechanism of interaction between cassava starches and cement hydration products.

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