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Optimizing Acetylation Reaction Time to Enhance Jackfruit Seed Starch Properties

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A B S T R A C T

Jackfruit seed starch is a potential bioresource with numerous industrial applications. However, its native properties limit its utility. Acetylation, a chemical modification, can enhance these properties, making it more suitable for various uses. This study aims to optimize the acetylation reaction time to improve the physicochemical properties of jackfruit seed starch, focusing on the degree of substitution (DS) and viscosity. To achieve this, jackfruit seed starch was subjected to acetylation over varying reaction times. The acetyl content of the modified starch was measured, and the DS was calculated to assess the extent of acetylation. Additionally, a viscometer was employed to determine the viscosity of the acetylated starch, correlating these measurements with reaction times.

The results demonstrate that the reaction time significantly impacts the DS and viscosity of the jackfruit seed starch. Specifically, the DS increased with longer reaction times, peaking at 0.142 after 60 minutes of acetylation. This indicates a higher degree of acetylation, enhancing the starch's properties. Correspondingly, the viscosity also increased, reaching a maximum value of 675.257 cP at the 60-minute mark. These findings suggest that the optimal reaction time for acetylation, balancing both DS and viscosity, is around 60 minutes.

The implications of these results are substantial for industrial applications. Enhanced viscosity and optimized DS improve the functionality of jackfruit seed starch in food products, pharmaceuticals, and biodegradable materials. Future research should explore the scalability of this process and its economic feasibility. Additionally, investigating other reaction conditions, such as temperature and catalyst concentration, could further refine the acetylation process. Understanding the structural changes at a molecular level through advanced characterization techniques will also provide deeper insights into the modification mechanisms and their effects on starch properties.

In conclusion, optimizing the acetylation reaction time is crucial for enhancing the properties of jackfruit seed starch. This study provides a foundational understanding that can be applied to improve the performance and application range of this bioresource, promoting its use in various industrial sectors.

Keywords : jackfruit seed starch, acetylation reaction time, degree of substitution, starch viscosity, starch modification

INTRODUCTION

The modification of starch is a significant area of research due to its potential to enhance the functional properties of this ubiquitous biopolymer, making it highly valuable for a wide range of industrial applications. One common modification technique is acetylation, a process that introduces acetyl groups into the starch molecule, thereby altering its physicochemical characteristics. Studies have shown that acetylation can improve various properties of starch, including its swelling power, water solubility, retrogradation stability, and morphological characteristics. For instance, research on sweet potato starch has demonstrated significant enhancements in these properties post-acetylation, making it more suitable for use in food products that require specific textural qualities (Edy et al., 2023; Triana et al., 2023). Similarly, cassava starch has shown improved performance in terms of stability and solubility, which are critical for its application in pharmaceuticals and food industries (Maite et al., 2023).

In addition to these improvements, acetylated starches exhibit increased water and oil absorption capacities, better paste stability, and higher clarity. These attributes make them ideal for various applications, including use as encapsulants, adhesives, and fat replacers (Chunglan et al., 2023). Furthermore, acetylation enhances the thermal stability of starch, broadening its application potential in sectors such as textiles, where thermal resistance is crucial. This modification has also been shown to affect the granular structure and digestibility of starch, adding to its versatility in food science, particularly in developing low digestible and resistant starch products (Carla et al., 2018). Despite the recognized benefits of starch acetylation, the specific conditions required to optimize these modifications, particularly the reaction time and choice of acetylating agents, remain underexplored. This study addresses this gap by investigating the optimal acetylation reaction time for enhancing the properties of jackfruit seed starch, an underutilized byproduct with significant industrial potential.

The influence of acetylation reaction time on starch properties has been extensively studied in various starches, but limited research has been conducted on jackfruit seed starch. Previous studies have indicated that the degree of substitution (DS) achieved through acetylation significantly affects the physicochemical properties of starch. For instance, in starches from Chinese yam and rice, increasing DS has been associated with enhanced thermal stability, reduced glass transition temperature, and modified pasting properties (Wang et al., 2008; Makarov et al., 2009). These changes are attributed to the structural alterations induced by the substitution of hydroxyl groups with acetyl groups, which affect the starch's interaction with water and other molecules.

In the case of jackfruit seed starch, the acetylation process could similarly enhance its functional properties, making it suitable for diverse industrial applications. Research has shown that varying the reaction times and acetylating agents can lead to significant changes in DS, morphological characteristics, retrogradation ability, and pasting properties of the starch (Van et al., 2021; Johnsy et al., 2022). Additionally, innovative techniques such as cold plasma treatment have been explored to modify the functionality of jackfruit seed flour, resulting in changes in physicochemical properties, starch-protein interactions, and hydration properties (Yutong et al., 2021). These findings suggest that optimizing acetylation conditions could significantly enhance the performance of jackfruit seed starch in various applications.

While the benefits of acetylated starches from sources like sweet potatoes, cassava, and chickpeas are well-documented, the specific conditions for optimizing jackfruit seed starch acetylation have not been thoroughly investigated. Studies have shown that starches with high amylose content and unique granule structures, such as jackfruit seed starch, have potential applications as resistant starches, which are beneficial for developing low digestible food products (Carla et al., 2018). However, the impact of different acetylation reaction times on the degree of substitution and the resulting physicochemical properties of jackfruit seed starch remains underexplored. The research gap lies in the detailed understanding of how varying reaction times influence the DS and viscosity of jackfruit seed starch, as well as how these changes affect its industrial applicability. Previous studies have primarily focused on other starch sources, leaving a significant gap in the knowledge regarding the optimal conditions for jackfruit seed starch acetylation. This study aims to fill this gap by systematically investigating the effect of reaction time on the acetylation of jackfruit seed starch, thereby providing insights into optimizing its properties for industrial use.

The objective of this study is to determine the optimal acetylation reaction time that maximizes the degree of substitution and enhances the viscosity of jackfruit seed starch. The novelty of this research lies in its focus on an underutilized agricultural byproduct, jackfruit seed starch, and the systematic investigation of acetylation reaction times, which have not been extensively studied for this particular starch source. This study hypothesizes that specific reaction times will yield higher degrees of substitution, leading to significant improvements in the physicochemical properties of the starch. The scope of this study is the effect of acetylation reaction time of jackfruit seed starch on its degree of substitution and viscosity. The findings will provide valuable insights in optimizing the acetylation process, potentially leading to increased industrial applications of jackfruit seed starch in the food, pharmaceutical, and textile industries. This research will contribute to the sustainable utilization of agricultural by-products, promoting innovation and efficiency in starch modification processes.

MATERIALS AND METHODS

Sample Preparation

The primary material for this study was jackfruit seed starch, sourced from mature jackfruit seeds. The seeds were cleaned, dried, and milled to obtain fine starch powder. Acetylation was performed using acetic anhydride as the acetylating agent, and sodium hydroxide (NaOH) was used as the catalyst. All chemicals used in the study were of analytical grade and procured from reputable suppliers. The starch was pre-treated by dispersing it in distilled water to create a slurry, ensuring consistent reaction conditions during acetylation.

Acetylation Procedure

The acetylation process was conducted by adding a measured amount of acetic anhydride to the starch slurry, maintained at a controlled temperature. The reaction was catalyzed by the addition of NaOH. The reaction times were varied systematically at intervals of 15, 30, 45, and 60 minutes to determine the optimal duration for the highest degree of substitution. After the reaction, the mixture was neutralized, filtered, and washed multiple times with distilled water to remove any unreacted acetic anhydride and by-products. The acetylated starch was then dried in an oven at 50°C until a constant weight was achieved.

Data Analysis and Interpretation

The degree of substitution (DS) was calculated based on the acetyl content in the modified starch, using a standard titration method. The results were analyzed to determine the relationship between reaction time and DS, as well as the corresponding changes in viscosity. The optimal reaction time was identified based on the highest DS and favorable viscosity characteristics, providing a comprehensive understanding of the modification process and its effects on jackfruit seed starch.

Results And Discussion

Degree of Substitution (DS)

The degree of substitution (DS) of jackfruit seed starch was observed to increase with reaction time. DS values were calculated for reaction times of 15, 30, 45, and 60 minutes. At 15 minutes, the DS was relatively low, indicating limited incorporation of acetyl groups. As the reaction time increased, the DS value showed a significant increase, peaking at 0.142 after 60 min. as shown in figure 1.

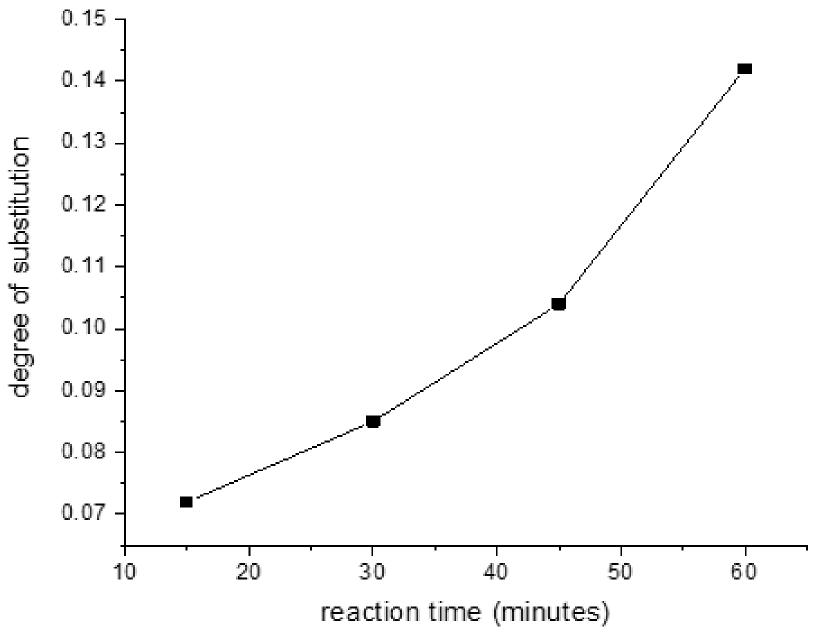

Figure 1. Degree of substitution (DS) value on variation of jackfruit seed starch acetylation reaction duration

These findings show that the DS of jackfruit seed starch increases with reaction time, reaching a maximum value of 0.142 after 60 minutes. This indicates a significant incorporation of acetyl groups, which correlates with improved starch properties. These results are in line with our research objectives, confirming that optimal reaction time is essential to maximize DS and viscosity. Increasing the acetylation reaction time increased the DS of jackfruit seed starch. At the initial reaction time of 15 minutes, the DS was relatively low, indicating limited acetylation. As the reaction time increased to 30 and 45 minutes, there was a marked increase in DS, culminating in the highest value of 0.142 at 60 minutes (Figure 1). This trend suggests that longer reaction times allow for greater interaction between acetyl groups and starch molecules, leading to more significant modification. This improvement in properties offers significant practical benefits. Likewise, the viscosity value observed at 60 minutes (675.257 cP) indicates that acetylated jackfruit seed starch can serve as a better thickening agent in food products compared to its original form. In addition, higher DS can improve the stability and resistance of starch to retrogradation, making it more suitable for pharmaceutical applications and biodegradable materials.

Viscosity Measurements

Viscosity measurements revealed a direct correlation between reaction time and the viscosity of acetylated starch pastes. The native starch exhibited a certain baseline viscosity, which increased significantly upon acetylation. At 60 minutes, the viscosity reached its value of 675.257 cP, indicating optimal modification. Beyond this point, further increases in reaction time did not significantly enhance viscosity, suggesting that 60 minutes is the optimal reaction time for achieving desirable viscosity characteristics in jackfruit seed starch. The increased viscosity can be attributed to the greater interaction between acetylated starch molecules, leading to enhanced thickening properties.

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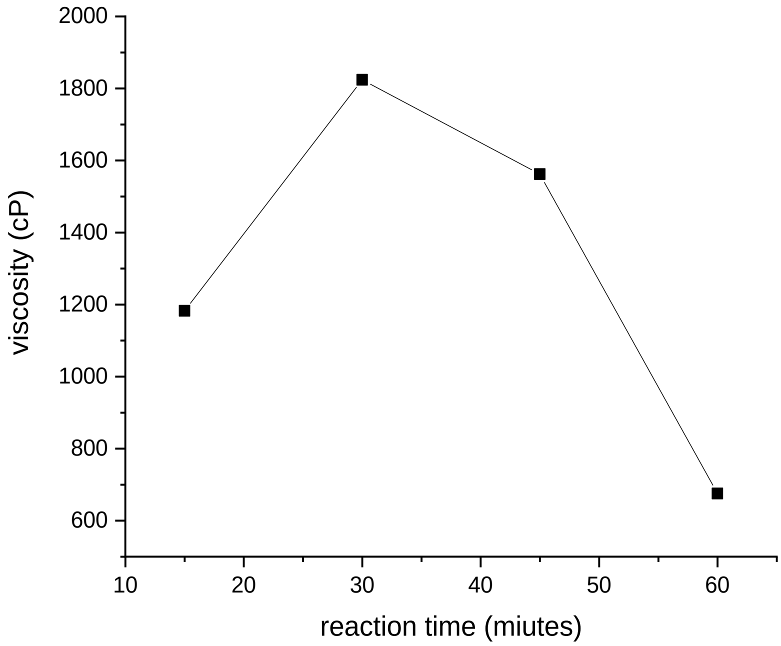

Figure 2. Effect of acetylation reaction time of jackfruit seed starch on its viscosity

Figure 2 above shows that the viscosity of acetylated starch peaked at 30 minutes reaction time, with a value of 1823.648 cP, and then decreased to 675.257 cP at 60 minutes reaction time. The decrease in viscosity observed with longer reaction times is due to changes in the percent acetyl and degree of substitution, resulting in reduced amylose content. These results are in line with previous studies on acetylation of various starches, which highlighted the importance of optimizing reaction parameters to achieve the desired functional properties.

The viscosity of acetylated jackfruit seed starch exhibited a significant peak at 30 minutes of reaction time, with a value of 1823.648 cP. However, as the reaction time extended to 60 minutes, the viscosity markedly decreased to 675.257 cP. This trend is consistent with the findings of previous studies on acetylated starches from other botanical sources (Lawal, 2004; Olu-Owolabi et al., 2010).

The reduction in viscosity with prolonged reaction time can be attributed to the increased degree of substitution (DS) and acetyl percent, which replace the hydroxyl groups of amylose and amylopectin chains (Singh et al., 2007). Higher DS values lead to the introduction of more acetyl groups, resulting in decreased intermolecular hydrogen bonding and lower gel-forming ability, thereby reducing viscosity (Luo et al., 2015). Furthermore, the acetylation process preferentially targets the linear amylose component, reducing its content and consequently lowering the overall viscosity (Miao et al., 2011).

The optimized acetylation process for jackfruit seed starch holds significant implications for various industrial applications. The increased DS and improved viscosity suggest that acetylated jackfruit seed starch can function effectively as a thickening agent, stabilizer, and emulsifier in food products. Its enhanced thermal stability and water absorption capacity make it suitable for use in processed foods that require prolonged shelf life and stability under varying temperature conditions. Additionally, the improved clarity and paste stability can benefit applications in the pharmaceutical industry, where consistency and performance of excipients are crucial.

When compared to other acetylated starches such as those from sweet potatoes, cassava, and chickpeas, jackfruit seed starch exhibits similar enhancements in functional properties post-acetylation. The DS and viscosity improvements align with findings from studies on these other starch sources, suggesting that the acetylation mechanism and its effects are broadly applicable across different types of starches. However, the unique granule structure and high amylose content of jackfruit seed starch may offer specific advantages, such as the potential for developing low digestible starch products, which are increasingly sought after in health-conscious food markets.

Future research should focus on exploring the effects of other reaction parameters, such as varying acetylating agents, reaction temperatures, and catalyst concentrations, to further optimize the acetylation process for jackfruit seed starch. Additionally, investigating the performance of acetylated jackfruit seed starch in specific industrial applications, such as in the formulation of biodegradable films, adhesives, and as fat replacers, could provide deeper insights into its practical benefits and commercial viability. The potential for integrating cold plasma treatment with acetylation to further enhance starch functionality also warrants exploration. These directions will not only broaden the understanding of starch modification but also promote the sustainable utilization of agricultural byproducts.

Conclusion

This study has demonstrated that the acetylation of jackfruit seed starch significantly enhances its functional properties, with the optimal reaction time identified as 60 minutes. At this duration, the degree of substitution (DS) peaked at 0.142, and the viscosity of the starch paste reached its value of 675.257 centipoise (cp). The findings underscore the potential of acetylated jackfruit seed starch for various industrial applications, including its use as a thickening agent, stabilizer, and emulsifier in the food industry, as well as in pharmaceutical formulations. The enhanced thermal stability, water absorption capacity, and paste clarity further expand its applicability across different sectors.

Future research should explore additional reaction parameters and innovative modification techniques, such as cold plasma treatment, to further optimize and expand the functional properties of jackfruit seed starch. Investigating its performance in specific applications and its commercial viability will provide deeper insights into its potential benefits and contribute to the sustainable utilization of this underutilized agricultural byproduct. Through such advancements, jackfruit seed starch can be effectively transformed into a valuable industrial resource, promoting both economic and environmental sustainability.

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