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Investigation of Heating Time Effects on Viscosity Profiles of Cassava Flour and Citrus Flour Blends

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ABSTRACT

Background and Objective: Blending cassava flour with citrus flour presents an opportunity to create food products with enhanced nutritional profiles and improved functional properties. This study investigates the influence of heating time on the viscosity profiles of various flour blends, focusing on cassava and citrus flour combinations. **Materials and Methods:** Four samples, labeled AB_1 to AB_4, were prepared with varying compositions of cassava flour and citrus flour, ranging from 100% cassava flour to 25% cassava flour and 75% citrus flour. Each sample was subjected to different heating times and the viscosity profiles were measured using rheological analysis. **Results:** The results demonstrate significant findings regarding the impact of heating time on the viscosity of cassava and citrus flour blends. For pure cassava flour (sample AB_1), viscosity decreases with prolonged heating, establishing a baseline for comparison. In sample AB_2 (25% cassava, 75% citrus), the blend exhibits altered rheological behavior, suggesting interactions between the flours. Sample AB_3 (50-50 ratio) shows further changes in viscosity, influenced by the equal presence of both flours. Finally, sample AB_4 (75% cassava, 25% citrus) provides insights into how a higher cassava content affects viscosity under heating. These findings highlight the dynamic interplay between cassava and citrus flours during thermal processing, essential for optimizing food product formulations. **Conclusion:** By varying the proportion of citrus flour, the study assesses the impact on viscosity, contributing to a comprehensive understanding of the rheological behavior of mixed flours. These findings offer valuable information for food scientists and technologists seeking to optimize processing parameters and develop high-quality food products using cassava and citrus flour blends.

KEYWORDS

Viscosity, flour blend, heating time, citrus, cassava, rheological analysis

INTRODUCTION

In the realm of food science and technology, the manipulation of ingredients and processing parameters plays a crucial role in determining the quality and functionality of food products[1,2]. One essential aspect of food processing is the investigation of how different factors, such as heating time, influence the physical properties of food blends[3-6]. This study delves into the effects of heating time on the viscosity profiles of cassava flour and citrus flour blends, aiming to elucidate how variations in heating time impact the rheological behavior of the blends[7-10].

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Cassava flour, derived from the cassava root and citrus flour, typically obtained from citrus fruits, are both important ingredients in various food formulations due to their unique nutritional composition and functional properties[11,12]. Understanding how the viscosity of blends containing these flours changes under different heating conditions is pertinent for optimizing processing techniques and ultimately enhancing the quality of food products[13-16].

Viscosity, a measure of a fluid's resistance to flow, is a critical parameter in food processing as it affects various aspects such as mixing, pumping and coating. Changes in viscosity can significantly impact the texture, mouthfeel and overall sensory attributes of food products[17]. Therefore, investigating the effects of heating time on the viscosity profiles of cassava flour and citrus flour blends can provide valuable insights into the rheological behavior of these blends during processing and storage[18-21].

By systematically varying the heating time and analyzing the resulting changes in viscosity, this study aims to elucidate the underlying mechanisms governing the rheological properties of cassava flour and citrus flour blends[22]. The findings of this investigation can contribute to the development of optimized processing protocols for food manufacturers, leading to the production of high-quality products with desirable rheological characteristics[23]. Additionally, gaining insights into the effects of heating time on viscosity profiles can inform future research endeavors aimed at further enhancing the functional properties of cassava flour and citrus flour blends for diverse food applications[24].

Understanding the rheological behavior of flour blends is essential in food science and technology, particularly in optimizing processing conditions and enhancing the quality of food products. The investigation of pasting properties, a crucial aspect of flour functionality, provides valuable insights into the behavior of flour blends under different heating conditions[25-28]. This study focuses on elucidating the pasting properties profiles of various cassava-citrus flour blends, aiming to uncover how the composition and heating time influence the rheological characteristics of the blends.

MATERIALS AND METHODS

Study area and sites: Benin City is a prominent urban center situated in Edo State, Nigeria. Positioned at approximately 6.34°N Latitude and 5.63°E Longitude, it rests at an elevation of 88 m above sea level. With a population estimated at 1,125,058 inhabitants, Benin City stands as the most densely populated city within Edo State[29-32].

Citrus flour preparation: Oranges weighing 12 kg were purchased from Oba Market, Benin City. They were washed with water to remove the contaminants, peeled with a knife and the juice was extracted with a juice extractor. The pectinaceous and cellulosic material called citrus vesicle was blended and washed with hot water. This was done repeatedly five times to remove the odour, taste, color and acids present in the pulp. It was filtered and sundried for three days at 30-37°C. The coarse pulp was milled to a very fine powder and preserved in the refrigerator at 4°C[29,30]. The study was carried out from March, 2014 to November, 2015.

Cassava flour preparation: The 20 kg cassava roots were purchased from Oba Market, Benin City. They were washed with water, peeled and re-washed to remove contaminants. The cassava roots were soaked with warm water for 3 days at 30-37°C. It was filtered and sundried at 30-37°C for 7 days. The coarse flour was milled to smooth cassava flour and preserved in the refrigerator at 4°C[29,30].

Experimental design: Preparation of bread and incorporation with citrus flour: Bread was prepared using the straight dough process described by Imoisi *et al.*[31]. Baking was carried out under laboratory conditions to optimize baking conditions. On a laboratory scale, cassava flour and citrus vesicle flour were weighed.

Table 1: Incorporation of cassava flour with citrus flour

Sample code (%)	Classification
AB_1 (100/0)	Control (100 g cassava flour)
AB_2 (25/75)	25% cassava flour+75% citrus flour
AB_3 (50/50)	50% cassava flour+50% citrus flour
AB_4 (75/25)	75% cassava flour+25% citrus flour

The dough was mixed to optimum consistency in a mixer with a low speed of 85 rpm for 1 min. For AB_1, AB_2, AB_3 and AB_4, citrus vesicle flour was substituted for cassava flour at 0, 75, 50 and 25%, respectively (Table 1). Fiber, sugar, yeast and other ingredients for bread were accurately added. The mixed cream was then put into medium size round calibrated pan. The bread was oven-baked for 1 hr 25 min at 100°C[32].

Rheological determination of composite cassava flour and citrus flour

Tools and equipment manufacturers: The viscometer or rheometer and other tools/equipment utilized in this study were sourced from manufacturers such as Hanna Instruments (based in Woonsocket, Rhode Island, USA), Thermo Fisher Scientific (headquartered in Waltham, Massachusetts, USA) and Mettler Toledo (located in Columbus, Ohio, USA), among others.

Viscometer or rheometer: A viscometer or rheometer to measure the viscosity of the flour blends. An appropriate instrument based on the viscosity range expected for the samples and the desired measurement accuracy. The instrument is properly calibrated according to the manufacturer's instructions before use.

Temperature control: The viscometer or rheometer was set up in a temperature-controlled environment to maintain a constant temperature throughout the analysis. A water bath, temperature-controlled chamber or built-in heating/cooling system depending on the instrument design.

Experimental procedure: A small amount of the prepared flour blend sample onto the measuring platform or spindle of the instrument. The measurement settings were adjusted on the instrument to the desired parameters, including shear rate (if applicable) and measurement time. Start the measurement, allowing the instrument to apply a controlled shear force to the sample and measure the resulting viscosity.

Data collection: The viscosity measurements at regular intervals or specific time points during the heating process were recorded. Ensure that the instrument provides real-time or continuous data acquisition for accurate viscosity profiling.

Heating time variation: Each sample was subjected to different heating times as per the experimental design. Record viscosity measurements at each heating time interval to capture changes in viscosity over time.

Data analysis: The collected viscosity data was analyzed using software provided by the instrument manufacturer or compatible data analysis tools. Plot viscosity profiles as a function of heating time for each flour blend sample to visualize changes over time. Relevant rheological parameters, such as shear stress, shear rate and apparent viscosity, if applicable are calculated.

Interpretation and reporting: Viscosity profiles in relation to the experimental objectives and hypotheses were interpreted and any observed trends, differences or similarities between the wheat flour and watermelon rind flour blends under varying heating times were discussed. The results with appropriate statistical analyses and graphical representations to support the findings were reported.

Quality control and validation: The instrument performance was validated periodically by running calibration checks and using reference standards. Implement quality control measures to ensure reproducibility and reliability of viscosity measurements.

Statistical analysis: Statistical analysis was carried out with the statistical package BMDP, using the BMDP 2R program (stepwise multiple regression). Results were expressed as mean of triplicate analysis[33,34].

RESULTS AND DISCUSSION

Figure 1 illustrated the effect of heating time on the viscosity of sample AB_1, consisting of 100% cassava flour. This figure provides valuable insights into how heating influences the rheological characteristics of pure cassava flour, which serves as a baseline for comparison with mixed flour samples[35].

In Fig. 2, the impact of heating time on the viscosity of sample AB_2, composed of 25% cassava flour and 75% citrus flour, is examined. Blending cassava flour with citrus flour alters the rheological behavior compared to pure cassava flour, highlighting the potential synergistic or antagonistic interactions between the two flours during heating.

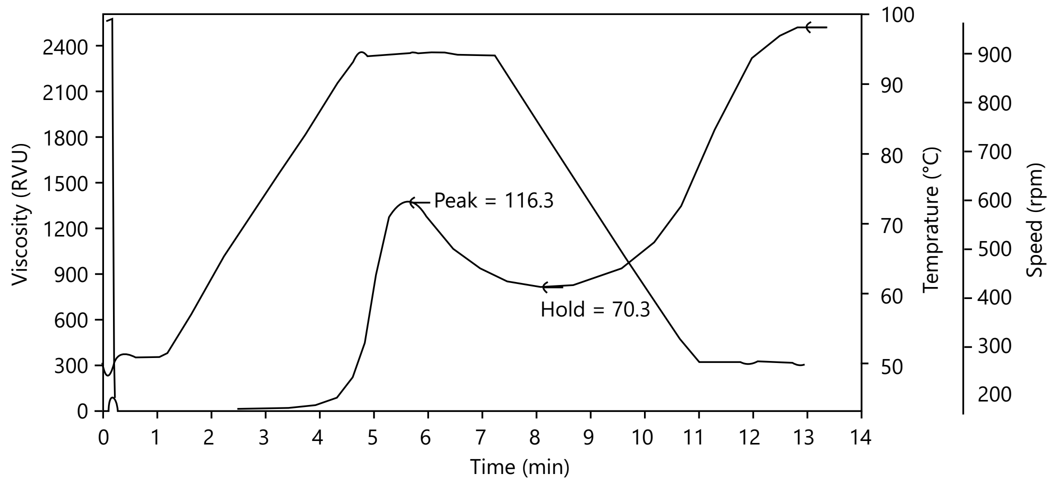

Fig. 1: Influence of heating time on the viscosity of sample AB_1 (100% cassava flour)
X-axis represents "Heating Time" (independent variable), while the Y-axis represents "Viscosity" (dependent variable), measured in units appropriate for viscosity (e.g., centipoise or pascal-seconds)

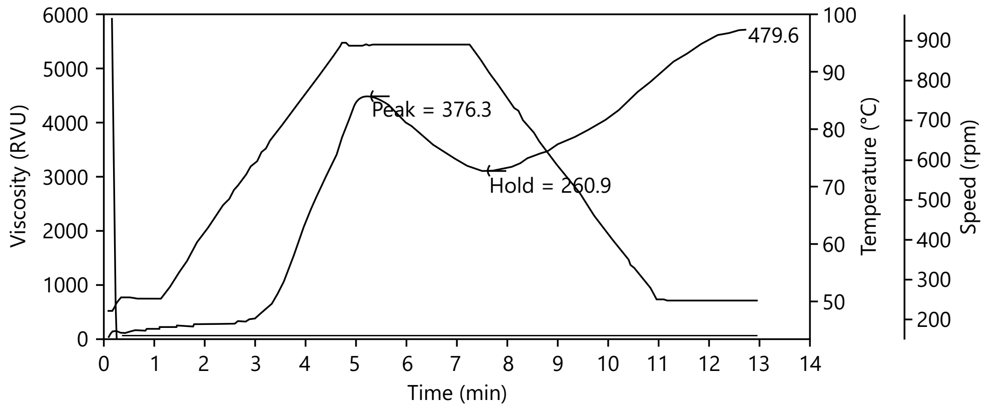

Fig. 2: Influence of heating time on the viscosity of sample AB_2 (25% cassava flour and 75% citrus flour)
X-axis represents "Heating Time" (independent variable), while the Y-axis represents "Viscosity" (dependent variable), measured in units appropriate for viscosity (e.g., centipoise or pascal-seconds)

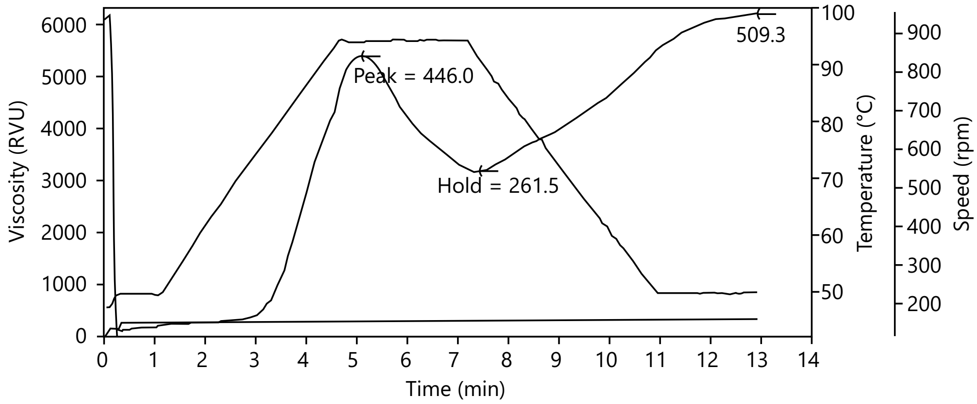

Fig. 3: Influence of Heating time on the viscosity of sample AB_3 (50% cassava flour and 50% citrus flour)
X-axis represents "Heating Time" (independent variable), while the Y-axis represents "Viscosity" (dependent variable), measured in units appropriate for viscosity (e.g., centipoise or pascal-seconds)

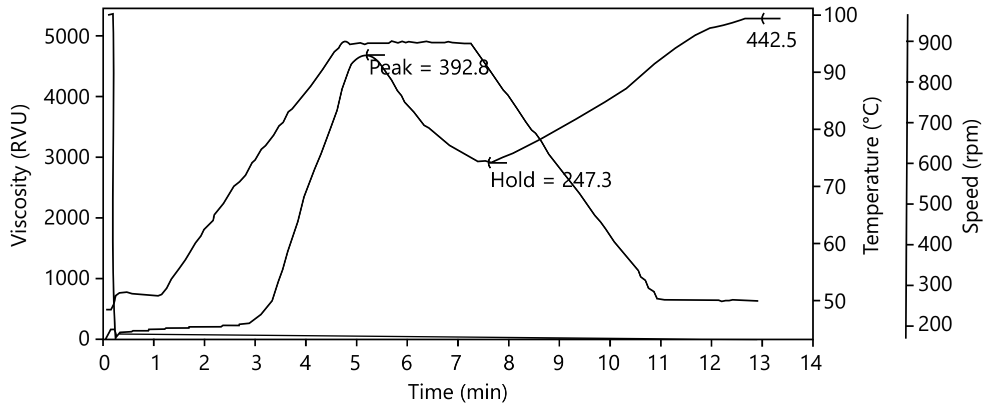

Fig. 4: Influence of heating time on the viscosity of sample AB_4 (75% cassava flour and 25% citrus flour)
X-axis represents "Heating Time" (independent variable), while the Y-axis represents "Viscosity" (dependent variable), measured in units appropriate for viscosity (e.g., centipoise or pascal-seconds)

Moving to Fig. 3, the viscosity changes of sample AB_3, comprising 50% cassava flour and 50% citrus flour, are investigated. This figure explores how variations in the cassava-citrus flour ratio affect viscosity under different heating conditions, providing further insights into the rheological properties of flour blends.

Figure 4 extended the analysis to sample AB_4, which consists of 75% cassava flour and 25% citrus flour. By decreasing the proportion of citrus flour in the blend, the impact on viscosity is evaluated, contributing to a comprehensive understanding of the rheological behavior of mixed flours.

The presented data explores the influence of heating time on the viscosity profiles of different flour blends, particularly focusing on cassava and citrus flour combinations. Understanding the rheological behavior of these blends is crucial for optimizing processing parameters and developing high-quality food products[36].

Figure 1 illustrates the effect of heating time on the viscosity of sample AB_1, which comprises 100% cassava flour. The observed changes in viscosity provide fundamental insights into how heating affects the rheological properties of pure cassava flour. The data obtained here serves as a baseline for comparison with mixed flour samples[37]. Figure 2 examined the impact of heating time on sample AB_2, composed of 25% cassava flour and 75% citrus flour. Blending cassava flour with citrus flour alters the rheological behavior compared to pure cassava flour. The observed changes indicate potential synergistic or antagonistic interactions between the two flours during heating[38].

Figure 3 extended the analysis to sample AB_3, which consists of an equal ratio of cassava flour and citrus flour (50-50%). This figure investigates how variations in the cassava-citrus flour ratio affect viscosity under different heating conditions. The data obtained here provides valuable insights into the rheological properties of flour blends, aiding in the formulation of food products with specific textural attributes[39-42].

Figure 4 evaluated sample AB_4, containing 75% cassava flour and 25% citrus flour. By decreasing the proportion of citrus flour in the blend, the study assesses the impact on viscosity. The findings contribute to a comprehensive understanding of the rheological behavior of mixed flours, offering valuable information for food product development and optimization[43,44].

In summary, the data presented in these figures elucidate the complex interplay between heating time, flour composition and viscosity profiles. Understanding these relationships is essential for designing food processing protocols that yield products with desirable textural characteristics and overall quality. Further research in this area can lead to the development of innovative flour blends tailored to specific applications in the food industry[45]. The study's findings highlight the significant impact of heating time on the viscosity of both pure cassava flour and its blends with citrus flour. Understanding these effects is crucial for optimizing the processing parameters in food production, particularly for products that rely on specific textural attributes. The rheological behavior insights gained here can guide the formulation of new flour-based products, enhancing their quality and consumer acceptability. These results can be directly applied in the food industry to develop and refine products such as gluten-free baked goods, sauces and thickening agents where texture and viscosity are key attributes. By tailoring the heating time and the proportion of cassava and citrus flours, manufacturers can create products with the desired consistency and stability.

This study provides valuable insights into the rheological behavior of cassava and citrus flour blends under different heating conditions, with significant implications for the food industry. By applying these findings, manufacturers can enhance product quality and innovate new formulations. However, further research and careful consideration of the study's limitations are essential for successful real-world application. Further research should be conducted to explore the effects of other variables such as pH, moisture content and different types of citrus flours on the rheological properties of flour blends. The findings should be used to innovate and improve the formulation of gluten-free and other specialty products. Additionally, insights from this study should be implemented into industrial processes to optimize heating times for achieving the desired viscosity in various food products. The study focuses on cassava and citrus flours, so the results may not be directly applicable to other types of flours. Experiments were conducted under controlled laboratory conditions, which may differ from real-world food processing environments. The transition from laboratory-scale findings to industrial-scale applications may present challenges that need to be addressed through pilot testing and validation.

CONCLUSION

The investigation into the heating time effects on viscosity profiles of cassava and citrus flour blends provides valuable insights into the rheological behavior of these mixtures. Through the analysis of different blend compositions and varying heating durations, several key findings have emerged. In conclusion, the data obtained from these investigations underscore the complex interplay between heating time, flour composition and viscosity profiles. These insights are crucial for designing processing protocols and formulating flour blends tailored to specific food applications, ultimately contributing to the development of high-quality food products with desirable textural attributes. Further research in this area is warranted to explore additional factors influencing rheological properties and to refine processing parameters for optimal product performance.

SIGNIFICANCE STATEMENT

Understanding how heating time affects the viscosity of cassava and citrus flour blends is essential for improving food processing techniques and product quality. This study examines the rheological characteristics of these flour combinations, revealing how heating impacts their viscosity. By analyzing various compositions, from pure cassava flour to different ratios of cassava and citrus flour blends, it highlights the dynamic relationship between heating time, flour composition and viscosity. These insights aid in optimizing processing parameters, allowing food scientists to develop innovative products with desired sensory attributes. This research enhances food science and technology, providing valuable knowledge for creating high-quality cassava and citrus flour-based products.

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