Impact of Heating Duration on Viscosity Characteristics in Cassava and Millet Flour Mixtures

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ABSTRACT

Background and Objective: Viscosity is a key rheological parameter that significantly influences the quality and sensory characteristics of flour-based products. This study examines how heating time affects the viscosity profiles of cassava (CS) and millet (ML) flour blends. **Materials and Methods:** The investigation included blends with varying ratios of cassava and millet flours, ranging from 100% cassava flour to 100% millet flour, as well as intermediate ratios (90:10, 80:20, 70:30, 50:50 and 30:70 cassava to millet flour). Each sample's viscosity was measured under different heating times to understand the impact of heating on the rheological behavior of the blends. Statistical analysis was conducted using the BMDP statistical software, with the BMDP 2R program utilized for stepwise multiple regression. Results were presented as the average of three independent analyses. The results of the blends were obtained at a significance level of $p < 0.05$. **Results:** The results showed distinct viscosity profiles for each blend, with notable variations based on the cassava and millet flour proportions and the heating duration. Blends with higher cassava flour content generally exhibited higher viscosities, while prolonged heating led to changes in viscosity levels. **Conclusion:** This analysis offers valuable insights into the rheological properties of cassava and millet flour blends, aiding in optimizing processing parameters to produce flour-based food products with desired textures and quality attributes.

INTRODUCTION

The rheological properties of flour-based products are essential factors that determine their quality, texture and sensory characteristics. Understanding how various factors, including heating time, affect the viscosity profiles of flour blends is crucial for optimizing processing conditions and achieving desired product characteristics[1-6]. This study examines the impact of heating time on the viscosity profiles of cassava and millet flour blends.

Cassava (*Manihot esculenta*) and millet (*Panicum miliaceum*) are essential staple crops extensively consumed in regions where they are cultivated. These grains are prized for their nutritional benefits, cost-effectiveness and versatility in different culinary uses[7-14]. Combining cassava and millet flours can yield products with enhanced nutritional value, texture and functional properties[15-17].

The purpose of this study is to clarify the effect of heating time on the viscosity of blends made from cassava and millet flours. Viscosity, which measures a fluid's resistance to flow, is critical in food processing because it influences mixing, pumping and spreading. By methodically altering heating times and observing the resulting changes in viscosity, this study seeks to understand the rheological characteristics of these flour blends and fine-tune their processing conditions[18-20].

This investigation examines the viscosity profiles of different cassava and millet flour blends subjected to various heating conditions. By assessing the rheological properties of these blends, we aim to determine the ideal heating time to achieve specific viscosity levels and texture characteristics in flour-based products[21,22]. This study investigates how heating time affects the viscosity profiles of cassava (CS) and millet (ML) flour blends.

MATERIALS AND METHODS
Study area and sites: Benin City is a significant urban hub located in Edo State, Nigeria. It is positioned approximately at 6.34°N Latitude and 5.63°E Longitude, with an elevation of about 88 m above sea level. The city boasts a population estimated at around 1,125,058 residents, making it the most densely populated city in Edo State[23,24].

Sample collection and analysis
Cassava flour: Mature cassava roots, weighing 25 kg and aged over twelve months, were harvested from a farm located within the Department of Agricultural Science Education at the College of Education, Ekiadolor-Benin, Edo State, Nigeria. This study was conducted from February, 2021 to July, 2021. The cassava roots were carefully cleaned to remove sand and soil, peeled using stainless knives and washed thoroughly to remove any remaining dirt. The tubers were then sliced into smaller pieces and spread out on a clean, flat surface for air and sun drying. This drying process facilitated fermentation and reduced the moisture content. Once the cassava chips were adequately dried, they were processed through dry milling. The milled dried cassava chips, now cassava flour, were sieved to reduce the fiber content. The sieved cassava flour was carefully packed in air-tight containers in powdered form for use as samples in the research, characterized by its white color. Additionally, millet grains were sourced from Uselu market, Benin City, Edo State, Nigeria. These grains underwent thorough physical examination, sorting, cleaning and drying processes before being ground into powdered form at the mill, resulting in whole millet flour. This whole millet flour was then packed in air-tight containers and used as samples in the research. The whole millet flour exhibited a pale green color[25,26].

Preparation of composite cassava flour and incorporation with millet flour: Composite cassava flour was prepared using the straight dough method outlined by Imoisi and Iyasele[26,27]. Weighing of cassava, wheat and millet flour was conducted using a laboratory scale. The dough was mixed to achieve optimal consistency in a mixer operating at low speed (85 rpm) for 1 min. Substitutions of cassava flour with millet flour ranged from 0 to 100% in the following proportions: CS/ML (100/0%), CS/ML (90/10%), CS/ML (80/20%), CS/ML (70/30%), CS/ML (50/50%), CS/ML (30/70%) and CS/ML (0/100%) as detailed in Table 1.

Rheological determination of composite cassava flour and millet flour
Tools and equipment manufacturers: The equipment utilized in this study, including the viscometer, rheometer and various other tools, were sourced from manufacturers such as Hanna Instruments (Woonsocket, Rhode Island, USA), Thermo Fisher Scientific (Waltham, Massachusetts, USA) and Mettler Toledo (Columbus, Ohio, USA), among other reputable suppliers.

Table 1: Incorporation of cassava flour with millet

Sample code	Classification
CS/ML (100/0%)	Control (100 g cassava flour)
CS/ML (90/10%)	90% cassava flour+10% millet flour
CS/ML (80/20%)	80% cassava flour+20% millet flour
CS/ML (70/30%)	70% cassava flour+30% millet flour
CS/ML (50/50%)	50% cassava flour+50% millet flour
CS/ML (30/70%)	30% cassava flour+70% millet flour
CS/ML (0/100%)	100% millet flour

Viscometer or rheometer: A viscometer or rheometer was utilized to determine the viscosity of the flour blends. The choice of instrument was based on the anticipated viscosity range of the samples and the necessary precision of the measurements. Prior to use, the instrument was calibrated according to the manufacturer's instructions.

Temperature control: The viscometer or rheometer was set up in a temperature-controlled environment to maintain consistent temperature conditions throughout the analysis. Depending on the instrument's design, this setup included a water bath, temperature-controlled chamber or an integrated heating/cooling system.

Experimental procedure: A small amount of the prepared flour blend sample was placed onto the instrument's measuring platform or spindle. The instrument settings were adjusted to the required parameters, such as shear rate (if applicable) and measurement duration. The measurement process began with the instrument applying a controlled shear force to the sample and recording the resulting viscosity.

Data collection: The viscosity of the samples was measured at regular intervals or specific time points during the heating process. The instrument was configured to allow for real-time or continuous data collection, ensuring the acquisition of accurate viscosity profiles.

Heating time variation: Each sample was subjected to different heating durations as per the experimental design. Viscosity measurements were taken at each designated heating time interval to track changes in viscosity throughout the experiment.

Data analysis: The collected viscosity data was analyzed using software provided by the instrument manufacturer or other compatible data analysis tools. Viscosity profiles were plotted to show the changes over time for each flour blend sample as a function of heating duration. Additionally, relevant rheological parameters, such as shear stress, shear rate and apparent viscosity, were calculated for further analysis.

Interpretation and reporting: The viscosity profiles were analyzed for the study's goals and hypotheses. Trends, variations, or commonalities between the different blends of wheat flour and watermelon rind flour at various heating times were thoroughly examined. The results were presented with detailed statistical analyses and visual representations to support the findings.

Quality control and validation: The instrument performance was consistently verified through periodic calibration and the use of reference standards. Stringent quality control procedures were applied to guarantee the accuracy and consistency of the viscosity measurements.

Statistical analysis: Statistical analysis was conducted using the BMDP statistical software, with the BMDP 2R program utilized for stepwise multiple regression. Results were presented as the average of three independent analyses[28,29].

RESULTS

The study depicted the impact of heating duration on the viscosity of a sample comprising 100% cassava flour (CS/ML). It offered insights into the viscosity behavior of pure cassava flour across different heating conditions as shown in Fig. 1.

Figure 2, investigated the impact of heating duration on viscosity using a sample containing 100% millet flour (CS/ML). It highlights the viscosity properties of pure millet flour across various heating periods.

Figure 3, examination of the impact of heating duration on the viscosity of a blend comprising 90% cassava flour and 10% millet flour (CS/ML). This figure analyzes the changes in viscosity due to the inclusion of millet flour in the blend, contrasting with the viscosity profile of pure cassava flour.

Figure 4, exploration of heating time effects on viscosity in a blend comprising 80% cassava flour and 20% millet flour (CS/ML). This figure examines how adjusting the cassava-to-millet flour ratio influences the rheological properties of the blend during heating.
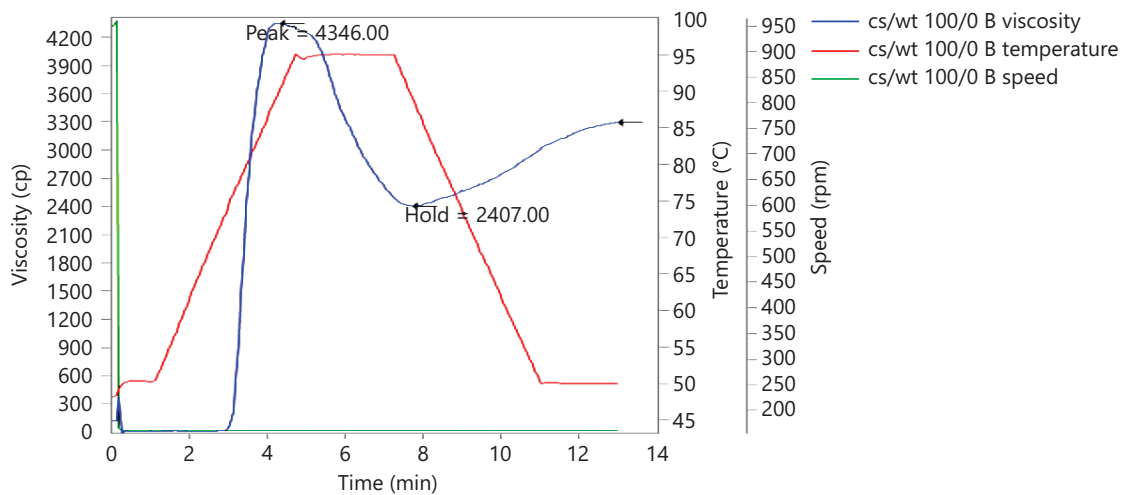

Fig. 1: Influence of heating time on the viscosity of sample CS/ML (100% cassava flour)
Horizontal axis depicts "heating time" (independent variable), whereas the vertical axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds
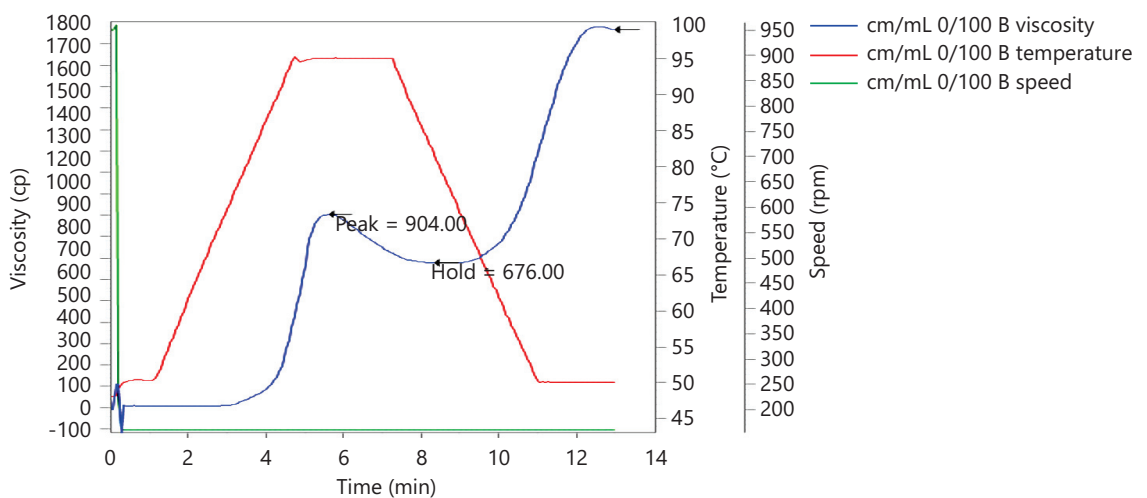

Fig. 2: Impact of heating duration on the viscosity of sample CS/ML (100% millet flour)
Horizontal axis depicts "heating time" (independent variable), whereas the vertical axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds
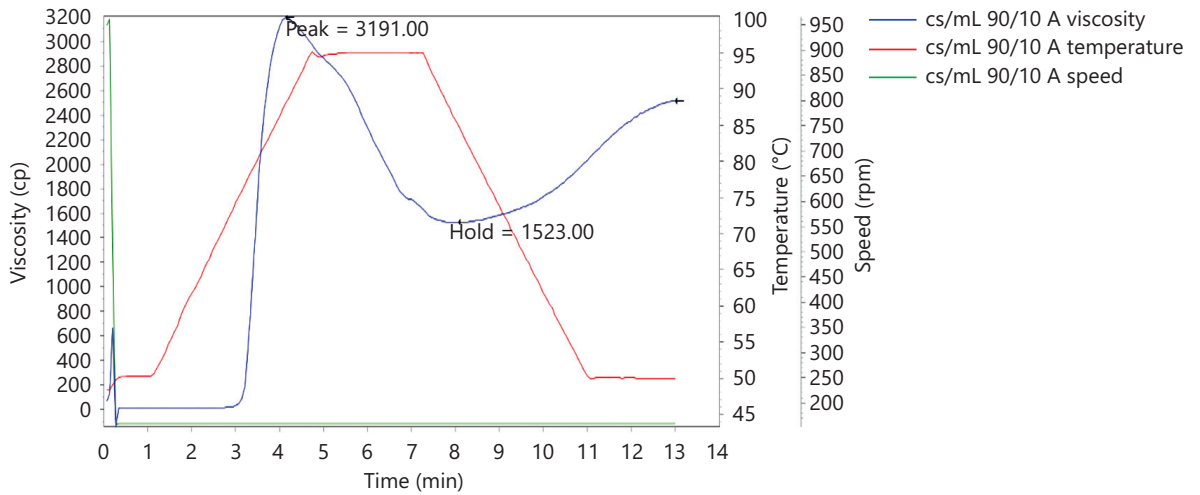
Fig. 3: Effect of heating duration on the viscosity of sample CS/ML (90% cassava flour and 10% millet flour)

X-axis denotes "heating time" (independent variable), whereas the Y-axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds
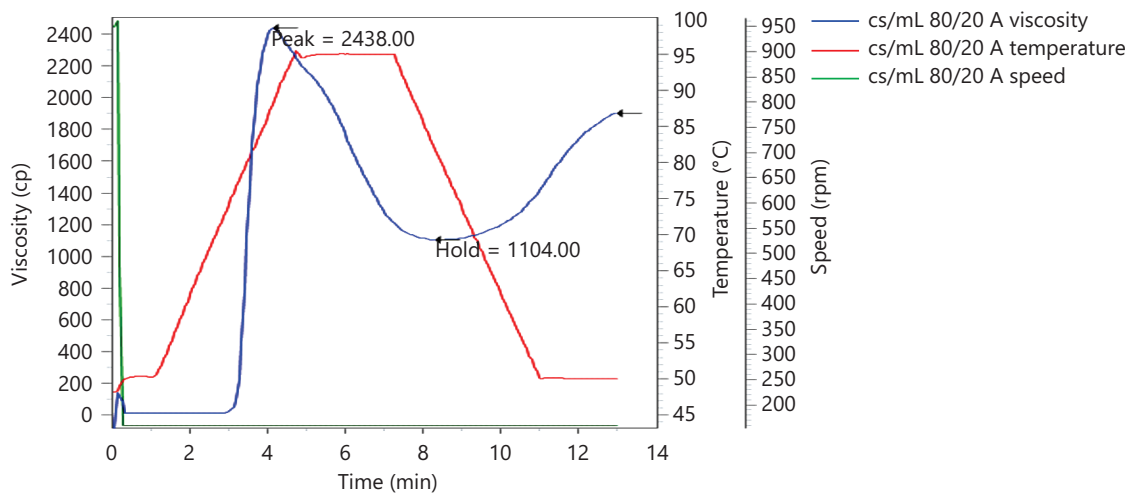

Fig. 4: Effect of heating time on viscosity in sample CS/ML (80% cassava flour and 20% millet flour)

X-axis represents "heating time" (independent variable), whereas the Y-axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds

Figure 5, influence of heating time on viscosity in sample CS/ML (70% cassava flour and 30% millet flour). This figure examines how heating time affects viscosity, illustrating changes in viscosity based on different ratios of cassava to millet flour in the blend.

Figure 6, influence of heating time on the viscosity of sample CS/ML (50% cassava flour and 50% millet flour). The X-axis represents "heating time" (independent variable), while the Y-axis denotes "viscosity" (dependent variable), measured in units appropriate for viscosity (e.g., centipoise or pascal-seconds).

Figure 7, explores the viscosity profile of a blend consisting of 30% cassava flour and 70% millet flour (CS/ML), specifically examining how heating time affects viscosity. This figure provides insights into how the higher proportion of millet flour influences the rheological properties of the blend during heating.
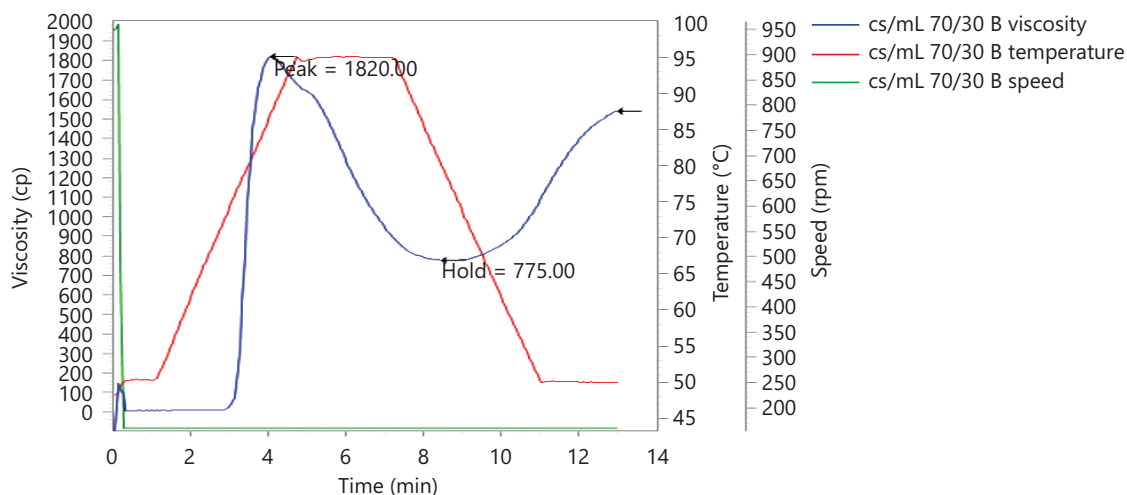
Fig. 5: Impact of heating time on viscosity in sample CS/ML (70% cassava flour and 30% millet flour)
X-axis denotes "heating time" (independent variable), whereas the Y-axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds
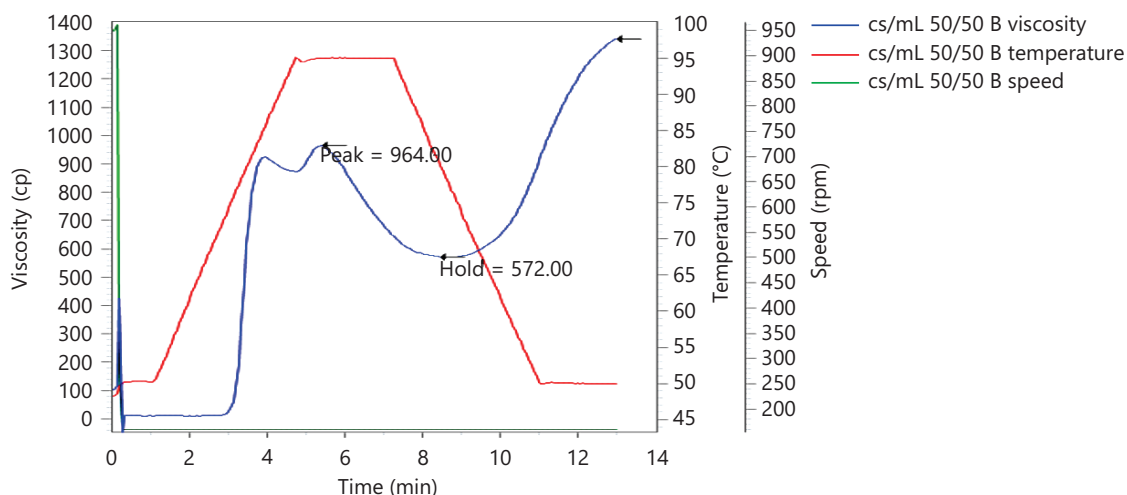

Fig. 6: Effect of heating time on viscosity for CS/ML (50% cassava flour and 50% millet flour)
X-axis represents "heating time" (independent variable), whereas the Y-axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds

DISCUSSION

The rheological behavior of flour blends containing cassava (CS) and millet (ML) flours, observed across different heating durations, provides essential insights into their viscosity profiles. This exploration is pivotal for assessing their applicability in diverse food contexts[30-34].

Beginning with Fig. 1-2, which illustrate the viscosity of 100% cassava and millet flour samples, respectively, distinct rheological properties specific to each flour type are evident. Cassava flour is known for its elevated viscosity attributed to its high starch content and distinctive granular structure. In contrast, millet flour, characterized by finer particle size and lower starch content, typically displays lower viscosity. These distinctions underscore the critical role of flour type in food formulation to achieve desired product attributes[35-37].

Figures 3-7 investigate the viscosity variations in blends containing cassava and millet flours with different compositions and heating durations. As the ratio of cassava flour decreases and millet flour increases in
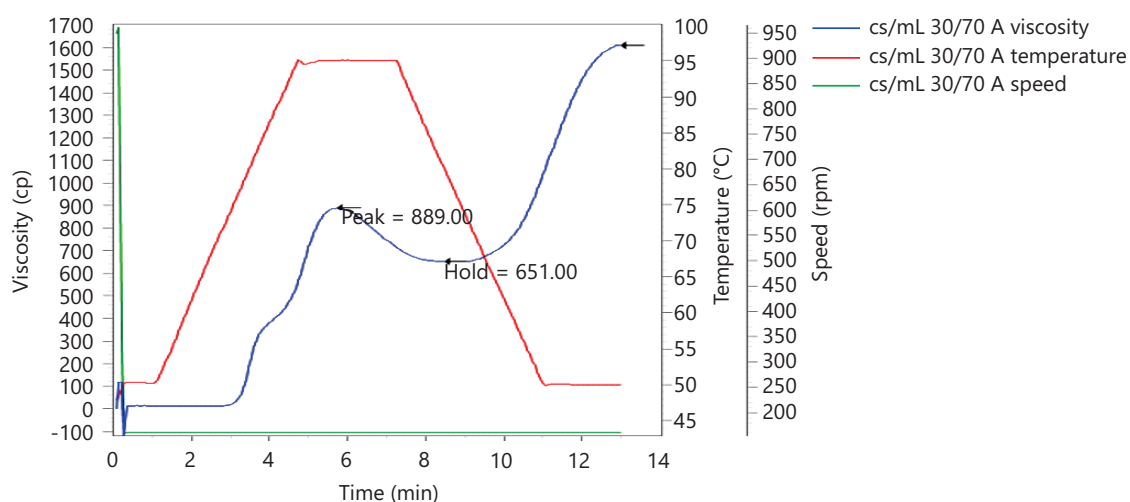
Fig. 7: Impact of heating time on the viscosity of the CS/ML blend composed of 30% cassava flour and 70% millet flour

X-axis denotes "heating time" (independent variable), whereas the Y-axis represents "viscosity" (dependent variable) and measured in viscosity units such as centipoise or pascal-seconds

the blends, a gradual decrease in viscosity is noted. This phenomenon is likely due to the dilution effect caused by the lower viscosity of millet flour blending with the higher viscosity of cassava flour. Additionally, prolonged heating durations could potentially alter the starch structure, influencing viscosity changes[38-43].

Blends where cassava flour predominates (Fig. 3-4) typically show elevated viscosities, aligning with the characteristics of pure cassava flour. Conversely, as the proportion of millet flour rises (Fig. 5-7), viscosity declines due to the dilution effect previously discussed. Importantly, the rate at which viscosity changes can vary based on the exact composition and heating parameters, evident from the distinct slopes observed in the viscosity profiles[44-46].

In conclusion, this thorough examination underscores the complex interactions among flour composition, heating duration and viscosity within CS/ML flour blends. This understanding is crucial for refining processing conditions and developing flour-based products that meet specific criteria for texture, mouthfeel and sensory experience. Moreover, these insights advance the utilization of cassava and millet flours across various food applications, addressing both nutritional and functional requirements[47-50].

CONCLUSION AND RECOMMENDATIONS

In summary, this study explores the effect of heating time on the viscosity of cassava (CS) and millet (ML) flour blends. It reveals that cassava flour generally has higher viscosity compared to millet flour, which decreases viscosity as its proportion increases in the blends. The research also shows that longer heating times typically reduce viscosity, though this effect varies with different flour compositions. These findings highlight the need to optimize heating conditions and flour blend ratios to achieve desired product textures and sensory qualities in food processing. This study recommends and enhances the use of cassava and millet flours in various culinary applications.

SIGNIFICANCE STATEMENT

Investigating how heating time influences the viscosity of cassava and millet flour blends is crucial for enhancing food processing methods and product quality. This study explores the rheological properties of these flour mixtures, demonstrating the effect of heat on their viscosity. By examining various

compositions, ranging from pure cassava flour to different ratios of cassava and millet flour, the study reveals the connection between heating time, flour composition and viscosity. These findings assist in optimizing processing parameters, enabling food scientists to develop innovative products with the desired sensory characteristics. This research contributes to food science and technology by providing valuable insights for creating high-quality products based on cassava and millet flour.

ACKNOWLEDGMENTS

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