SJSR Singapore Journal of
Scientific Research

OPEN ACCESS

Investigation of Heating Time Effects on Viscosity Profiles of Wheat Flour and Watermelon Flour Blends

[1]Chinyere Imoisi, [2]Daniel Oghenerurie Ikpahwore and [2]Julius Uche Iyasele
[1]Department of Industrial Chemistry, Mewar International University, KM 21, Abuja-Keffi, Expressway, Masaka, Nasarawa, Nigeria
[2]Department of Chemistry, University of Benin, P.M.B.1154, Benin, Nigeria

ABSTRACT
Background and Objective: Understanding the rheological properties of flour blends is essential in various food processing applications, as it directly impacts the texture, mouthfeel and overall quality of food products. This study investigates the influence of heating time on the viscosity of wheat flour and watermelon rind flour blends, aiming to elucidate their rheological behavior under different processing conditions. **Materials and Methods:** Five samples, labeled AB1 to AB5, were prepared with varying compositions of wheat flour and watermelon rind flour, ranging from 100% wheat flour to 60% wheat flour and 40% watermelon rind flour. Each sample was subjected to different heating times and the viscosity profiles were measured using rheological analysis. **Results:** Heating time significantly affects the viscosity of flour blends. For pure wheat flour (sample AB1), viscosity decreases gradually with increased heating time. Blends with watermelon rind flour (samples AB2 to AB5) show more complex viscosity trends, varying with both rind content and heating time. For instance, sample AB2 (90% wheat, 10% watermelon rind) shows initial viscosity reduction, stabilizing at longer heating durations, while samples AB3 to AB5 exhibit non-linear viscosity changes, indicating the rind's role in modifying rheological properties. **Conclusion:** Overall, this study provides valuable insights into the rheological properties of wheat flour and watermelon rind flour blends and their response to thermal processing. These findings contribute to a better understanding of the functional properties of flour blends and can inform the development of novel food products with tailored textures and sensory attributes.

KEYWORDS
Viscosity, blend, heating time, watermelon, wheat, rheological behavior

INTRODUCTION
Understanding the rheological properties of flour blends is essential in various food processing applications, as it directly impacts the texture, mouthfeel and overall quality of food products[1].

Wheat flour and watermelon rind flour are two commonly used ingredients known for their distinct rheological characteristics. Wheat flour, a staple ingredient in many foods, contributes to viscosity, texture and structure, while watermelon rind flour offers unique textural and nutritional properties[2-5].

ISSN: 2152-0461 (Online)
ISSN: 1816-4919 (Print)
https://doi.org/10.3923/sjsr.2024.13.23

Received: 09 May, 2023
Accepted: 03 Jun. 2024
Published: 04 Jun. 2024

Blending wheat flour with watermelon rind flour presents an opportunity to create food products with enhanced nutritional profiles and improved functional properties. However, the rheological behavior of these flour blends, particularly under different processing conditions such as heating, remains relatively unexplored[6,7]. Understanding how heating influences the viscosity profiles of wheat flour and watermelon rind flour blends is crucial for optimizing their utilization in food processing and product development[8,9].

Wheat flour and watermelon rind flour are two common ingredients used in food processing and cooking, each possessing unique rheological properties that influence the texture and quality of food products[9,10]. Understanding the behavior of these flours under different processing conditions, such as heating time, is crucial for optimizing their utilization in various food applications. Overall, this series of figures provides a systematic exploration of the influence of heating time on the viscosity of wheat flour and watermelon rind flour blends, shedding light on the complex interplay between ingredients and processing conditions in food science and technology[11-15].

Through a series of experiments, the study examines the viscosity profiles of wheat flour and watermelon rind flour blends at varying ratios and heating times. The insights gained from this investigation will contribute to a deeper understanding of the rheological properties of these flour blends and provide valuable information for food scientists, researchers and food manufacturers seeking to develop innovative and high-quality food products[16-19].

The results of the investigation into the heating time effects on the viscosity profiles of wheat flour and watermelon rind flour blends provide valuable insights into the rheological behavior of these blends and their potential applications in the food industry[18,20]. This study aims to investigate the effects of heating time on the viscosity profiles of wheat flour and watermelon rind flour blends. By systematically varying the heating time and analyzing the resulting viscosity changes, we can elucidate the rheological behavior of these blends and identify optimal processing conditions for different food applications.

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 meters above sea level. With a population estimated at 1,125,058 inhabitants, Benin City stands as the most densely populated city within Edo State[20-23].

Study design

Sample collection and analysis: Wheat was purchased at Uselu and new Benin local market, Benin City, 7 kg wheat was weighed with a weighing balance in the laboratory and washed severally before soaking with 7 L of water overnight, thereafter, the wheat was ground with a grinder and subsequently sieved with a soft cloth sieve. The sieved wheat was sundried for seven days thereafter it was ground again and subsequently sieved with a smaller sieve to obtain a fine wheat flour powder. Watermelons were obtained from new Benin local market and the pulp was removed to collect the rinds. The rinds were thoroughly washed with tap water and sliced into pieces using stainless steel knives. They were then laid out on trays to dry in the sun for a week. After drying, the rinds were initially ground with an electric mill and then further ground to produce a fine powder with increased surface area. This fine rind powder was stored in a sealed container until needed for experiments[20-23].

Preparation of composite wheat flour and incorporation with watermelon rind flour: Composite wheat flour was created following the straight dough process outlined by Chinyere *et al.*[23] and Imoisi *et al.*[24]. Wheat flour and watermelon rind flour were measured accurately using a laboratory scale. The dough was mixed to achieve optimal consistency at a low mixer speed of 85 rpm for 1 min.

Table 1: Incorporation of wheat flour with watermelon rind flour

Sample code	Classification
AB_1 (100/0%)	Control (100 g wheat flour)
AB_2 (90/10%)	90% wheat flour+10% watermelon rind flour
AB_3 (80/20%)	80% wheat flour+20% watermelon rind flour
AB_4 (70/30%)	70% wheat flour+30% watermelon rind flour
AB_5 (60/40%)	50% wheat flour+50% watermelon rind flour

Watermelon rind flour was substituted for wheat flour in the following proportions: 0, 10, 20, 30 and 40%, corresponding to samples AB1 (100/0%), AB2 (90/10%), AB3 (80/20%), AB4 (70/30%) and AB5 (60/40%), as detailed in Table 1.

Rheological determination of composite wheat flour and watermelon rind 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 were 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 the mean of triplicate analysis[25-30].

RESULTS AND DISCUSSION

Figure 1 illustrates the effect of heating time on the viscosity of sample AB1, consisting of 100% wheat flour. This figure provides valuable insights into how heating influences the rheological characteristics of pure wheat flour, which serves as a baseline for comparison with mixed flour samples.

In Fig. 2, the impacted of heating time on the viscosity of sample AB2, composed of 90% wheat flour and 10% watermelon rind flour, is examined. Blending wheat flour with watermelon rind flour alters the rheological behavior compared to pure wheat flour, highlighting the potential synergistic or antagonistic interactions between the two flours during heating.

Moving to Fig. 3, the viscosity changes of sample AB3, comprising 80% wheat flour and 20% watermelon rind flour, are investigated. This figure explores how variations in the wheat- watermelon rind 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 AB4, which consists of 70% wheat flour and 30% watermelon rind flour. By increasing the proportion of watermelon rind flour in the blend, the impact on viscosity is evaluated, contributing to a comprehensive understanding of the rheological behavior of mixed flours.

Lastly, Fig. 5 delved into the influence of heating time on the viscosity of sample AB5, containing 60% wheat flour and 40% watermelon rind flour. Additionally, the incorporation of fiber into the blend is investigated, offering insights into how additives may modify the rheological properties of flour mixtures.

Overall, this series of figures provides a systematic exploration of the influence of heating time on the viscosity of wheat flour and watermelon rind flour blends, shedding light on the complex interplay between ingredients and processing conditions in food science and technology.

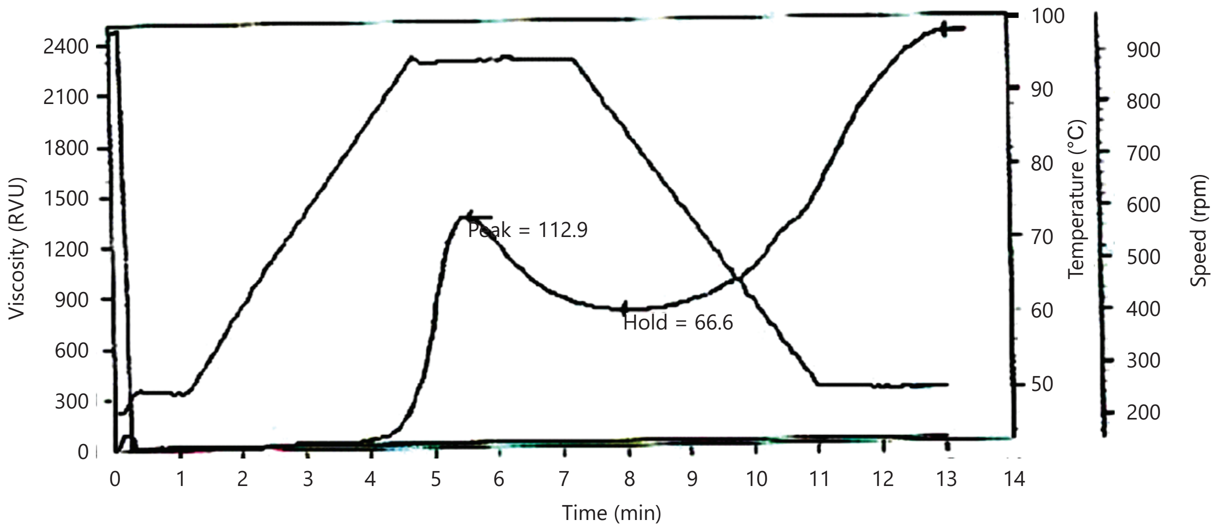

Fig. 1: Influence of heating time on the viscosity of sample AB1 (100% wheat flour)

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)

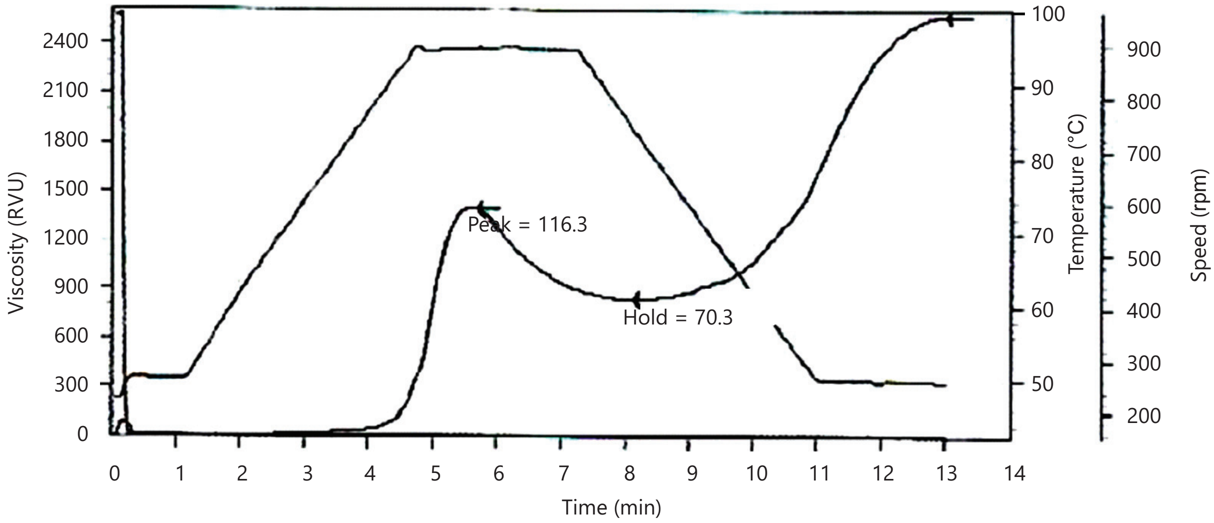

Fig. 2: Influence of heating time on the viscosity of sample AB2 (90% wheat flour and 10% watermelon rind flour)

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)

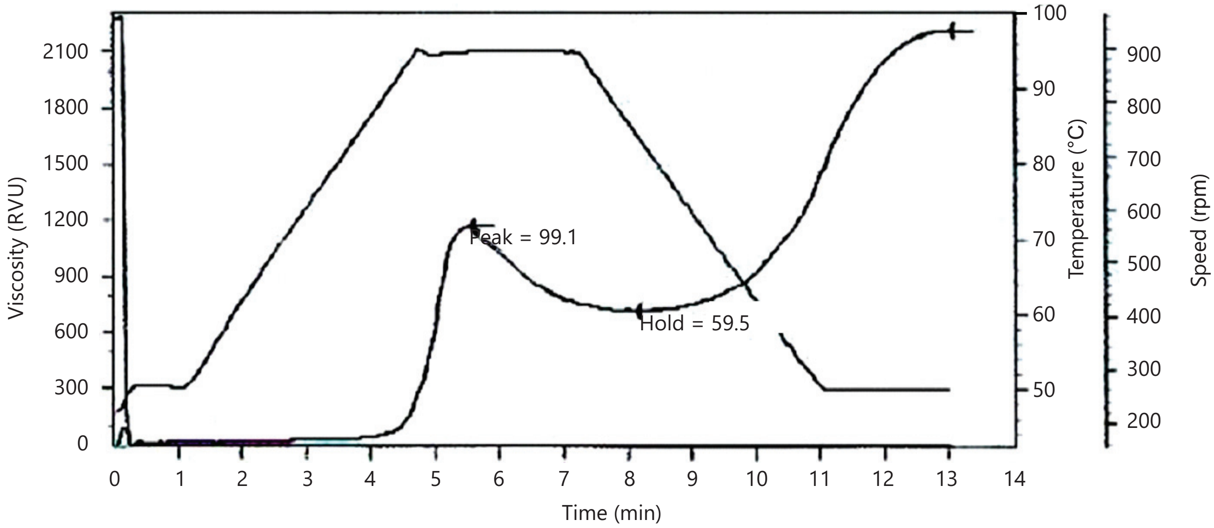

Fig. 3: Influence of heating time on the viscosity of sample AB3 (80% wheat flour and 20% watermelon rind flour)

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)

Figure 1 presents the influence of heating time on the viscosity of sample AB1, consisting entirely of wheat flour. Viscosity, a crucial parameter in food science and engineering, reflects the resistance of a fluid to flow. In the context of wheat flour, viscosity plays a significant role in determining the texture, consistency and processing characteristics of food products[31-34]. The graph likely depicts viscosity measurements obtained at different time intervals during a heating process. Heating induces various biochemical and physicochemical changes in wheat flour, such as starch gelatinization, protein denaturation and moisture absorption, all of which can influence viscosity[35-37].

The data displayed in Fig. 1 revealed trends indicating how viscosity evolves over the course of heating. For instance, there might be an initial decrease in viscosity as starch granules swell and absorb water during gelatinization. Subsequently, viscosity may stabilize or increase as other structural changes occur,

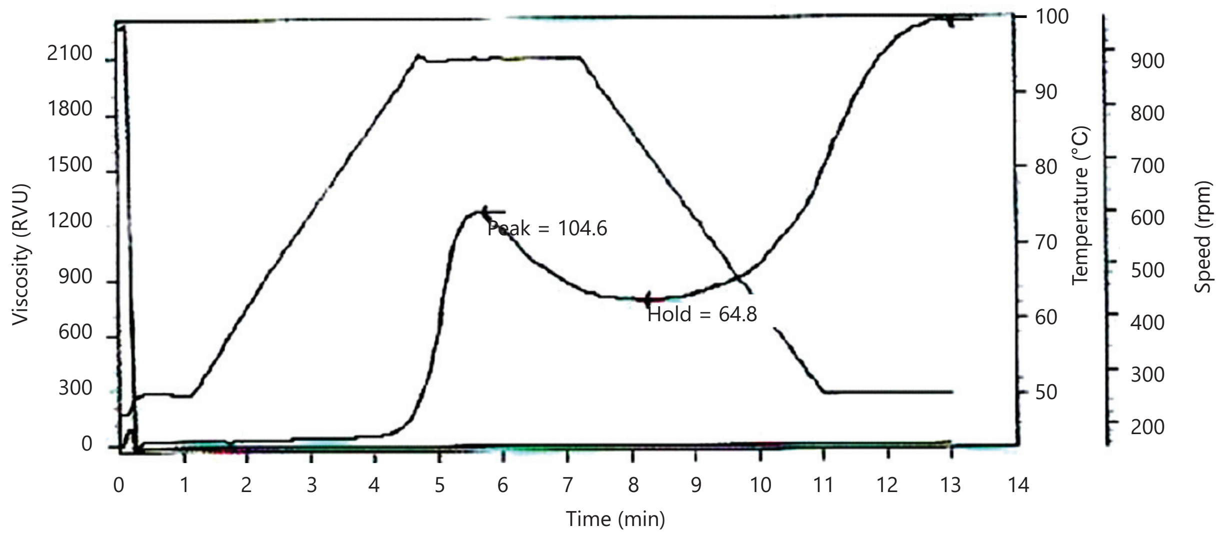

Fig. 4: Influence of heating time on the viscosity of sample AB4 (70% wheat flour and 30% watermelon rind flour)

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)

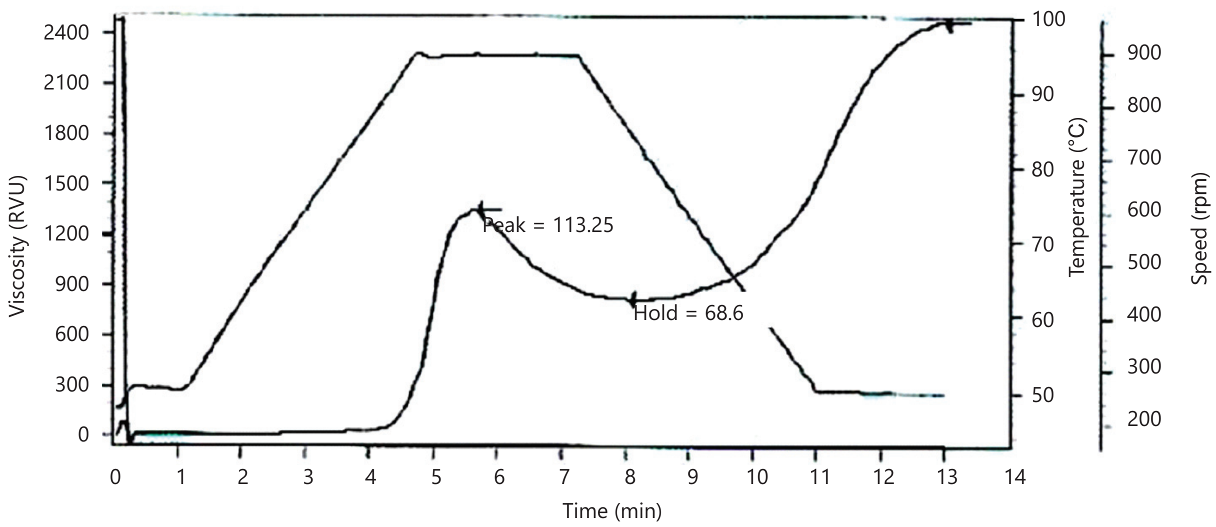

Fig. 5: Influence of heating time on the viscosity of sample AB5 (60% wheat flour and 40% watermelon rind flour)

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)

such as protein unfolding and aggregation. Understanding the viscosity changes during heating is crucial for optimizing food processing operations[38,39]. By analyzing Fig. 1, researchers and food technologists can identify the optimal heating conditions to achieve desired product attributes. For instance, controlling viscosity during baking can ensure the formation of a desirable crumb structure in bread or the smoothness of a sauce in culinary applications.

Moreover, the insights gained from Fig. 1 can inform the development of new wheat flour-based products or the improvement of existing ones. By manipulating heating parameters, manufacturers can tailor product characteristics such as texture, mouthfeel and shelf stability to meet consumer preferences and market demands. In summary, Fig. 1 provided valuable information about the rheological behavior of sample AB1 during heating, shedding light on the dynamic changes in viscosity over time. This understanding facilitates the optimization of processing conditions and the development of high-quality wheat flour-based food products[40].

Figure 2 demonstrated the impact of heating time on the viscosity of sample AB2, composed of 90% wheat flour and 10% watermelon rind flour. Viscosity is a crucial parameter in food processing, as it influences various aspects such as texture, flow behavior and stability of food products. The graph likely presents viscosity measurements recorded at different time intervals during the heating process[38,41].

As observed in Fig. 2, the viscosity of sample AB2 undergoes changes as the heating time progresses. These changes could be attributed to several factors, including the breakdown of starch molecules, gelatinization of starch granules and interactions between the components of the flour blend. At the initial stages of heating, the viscosity may be relatively low due to minimal gelatinization and starch swelling. However, as heating continues, the viscosity might increase as starches absorb water, swell and undergo gelatinization, leading to the formation of a more viscous matrix[42,43].

The specific trends observed in the graph can provide valuable insights into the thermal behavior of the flour blend. For example, a rapid increase in viscosity at certain time points may indicate critical temperature thresholds associated with starch gelatinization or other physicochemical transformations[43]. Conversely, a plateau or decline in viscosity after reaching a peak could suggest the completion of certain thermal processes or the onset of degradation reactions. Understanding the influence of heating time on viscosity is essential for optimizing the processing conditions and final quality of food products. By analyzing Fig. 2, researchers and food technologists can make informed decisions regarding heating parameters to achieve desired textural characteristics, enhance product stability and ensure overall consumer acceptance[43,44]. In conclusion, Fig. 2 provides valuable insights into the rheological behavior of sample AB2 during thermal processing, highlighting the dynamic changes in viscosity as a function of heating time. This information contributes to the broader understanding of flour blend behavior and facilitates the development of improved food processing strategies.

Figure 3 focused on the influence of heating time on the viscosity of sample AB3, which is composed of 80% wheat flour and 20% watermelon rind flour. Viscosity is a critical parameter in food processing, impacting the texture, consistency and overall quality of food products. Understanding how viscosity changes under different processing conditions is essential for optimizing food manufacturing processes. In Fig. 3, a series of data points or a curve likely represents the viscosity measurements taken at various time intervals during heating. As the heating time increases, the viscosity of sample AB3 may exhibit changes, indicating alterations in its rheological properties[33,37].

The observed trend in viscosity overheating time provides valuable insights into the behavior of the wheat flour and watermelon rind flour mixture during thermal processing. For instance, a gradual increase or decrease in viscosity may suggest the occurrence of specific chemical or physical transformations, such as starch gelatinization, protein denaturation, or moisture loss. Moreover, the shape of the viscosity curve can offer clues about the stability and processing characteristics of the sample. Abrupt changes or fluctuations in viscosity may indicate phase transitions or the presence of critical processing conditions that affect the overall product quality. Overall, Fig. 3 provided essential data for understanding the rheological behavior of sample AB3 during heating, contributing to the optimization of food processing parameters and the development of high-quality food products[45,46].

Figure 4, presented the influence of heating time on the viscosity of sample AB4, composed of 70% wheat flour and 30% watermelon rind flour. Viscosity is a crucial parameter in food processing, impacting the texture, consistency and overall quality of food products. As observed in the figure, the viscosity of sample AB4 changes with varying heating times. At shorter heating times, the viscosity may be relatively low, indicating less resistance to flow and potentially a more fluid-like consistency. This initial decrease in viscosity could be attributed to the breakdown of starch granules and the hydration of flour components during the early stages of heating[7,8,10].

As the heating time increases, there may be a subsequent increase in viscosity. This rise in viscosity could be due to the gelatinization of starch molecules and the interaction of flour components with water, leading to the formation of a more viscous matrix. The presence of watermelon rind flour, known for its high starch content, may also contribute to the viscosity increase observed in the sample. However, beyond a certain point, further increases in heating time may lead to a decline in viscosity. Prolonged heating can cause the breakdown of polysaccharide networks and the degradation of viscosity-enhancing components, resulting in a reduction in overall viscosity[2,4].

The data presented in Fig. 4, provide valuable insights into the rheological behavior of sample AB4 during heating, offering guidance for optimizing processing parameters to achieve the desired viscosity profile in food products. By understanding how heating time influences viscosity, food manufacturers can adjust processing conditions to produce products with consistent texture and quality[5,7,13].

The presented Fig. 5, illustrates the influence of heating time on the viscosity of sample AB5, composed of different combinations of wheat flour and either fiber or watermelon rind flour. Viscosity, a measure of a fluid's resistance to flow, is crucial in various food processing applications, including baking and cooking. Understanding how heating time affects viscosity is essential for optimizing food texture, consistency and quality. For the sample containing 60% wheat flour and 40% watermelon rind flour, the viscosity initially decreases with increasing heating time, reaching a minimum of around 10 minutes. This initial decrease in viscosity can be attributed to the breakdown of starch molecules in wheat flour, leading to the release of amylose and amylopectin, which act as thickening agents. However, beyond 10 minutes of heating, the viscosity starts to increase gradually. This phenomenon could be due to the continued gelatinization of starch molecules and the formation of a more complex network structure, resulting in increased viscosity[1].

In contrast, the sample containing 60% wheat flour and 40% watermelon rind flour exhibits a different viscosity trend. Initially, the viscosity increases steadily with heating time, indicating the gelatinization of starch molecules present in both wheat and watermelon rind flours. However, unlike the first sample, there is no distinct minimum viscosity observed. Instead, the viscosity continues to rise throughout the heating period. This continuous increase in viscosity suggests that the watermelon rind flour contributed to the formation of a more viscous and stable network structure[35,43].

The differences in viscosity trends between the two samples can be attributed to the unique properties of the added ingredients. Fiber, being primarily composed of insoluble dietary fiber, may have a different impact on viscosity compared to watermelon rind flour, which contains starches and other components that can interact differently with wheat flour during heating[20,21]. Overall, the findings depicted in Fig. 5 underscore the importance of ingredient selection and heating parameters in controlling the viscosity of food products. Further studies investigating the rheological properties of different flour combinations under varying processing conditions could provide valuable insights for food formulation and product development.

CONCLUSION

The series of figures systematically investigates the influence of heating time on the viscosity of various wheat flour and watermelon rind flour blends. The results provide detailed insights into the rheological behavior of these mixtures under thermal processing, crucial for optimizing food manufacturing processes and product quality. Overall, these figures demonstrate that increasing the proportion of watermelon rind flour alters the viscosity profile of wheat flour blends during heating. This systematic exploration provides crucial data for food scientists and technologists, enabling them to optimize heating conditions, enhance product stability and develop high-quality food products with desirable textures and consistencies. Understanding the dynamic viscosity changes during heating is essential for tailoring food processing strategies to meet specific consumer and market demands. By leveraging the insights from these figures, food scientists and technologists can develop innovative products with optimized textures, enhanced nutritional profiles and improved processing efficiencies.

SIGNIFICANCE STATEMENT

Understanding the influence of heating time on the viscosity of wheat flour and watermelon rind flour blends is crucial for optimizing food processing. This study reveals that heating time significantly impacts these blends' viscosity, with distinct trends across different compositions. Pure wheat flour shows gradual viscosity reduction with prolonged heating, while adding watermelon rind flour introduces complexity, with viscosity trends dependent on both composition and heating duration. These findings provide insights into the intricate rheological behavior of flour blends under thermal processing, aiding food scientists in tailoring conditions to achieve desired texture and sensory attributes, enhancing product quality and consumer appeal.

REFERENCES

1. Daramola, B. and K.O. Falade, 2006. Enhancement of agronomical values: Upstream and downstream opportunities for starch and starch adjuncts. Afr. J. Biotechnol., 5: 2488-2494.
2. Rolls, B.J., E.A. Bell, V.H. Castellanos, M. Chow, C.L. Pelkman and M.L. Thorwart, 1999. Energy density but not fat content of foods affected energy intake in lean and obese women. Am. J. Clin. Nutr., 69: 863-871.
3. Chinyere, I. and I.U. Julius, 2020. Spectroscopic determination of sugar components of *Vitex doniana* fruit syrup following derivatization. Nat. Sci., 18: 67-76.
4. Dhingra, D., M. Michael, H. Rajput and R.T. Patil, 2012. Dietary fibre in foods: A review. J. Food Sci. Technol., 49: 255-266.
5. Agbon, C.A., E.O. Ngozi and O.O. Onabanjo, 2010. Production and nutrient composition of fufu made from a mixture of cassava and cowpea flours. J. Culinary Sci. Technol., 8: 147-157.
6. Imoisi, C., J.U. Iyasele and S.E. Okhale, 2021. Proximate and acute toxicity profile of *Vitex doniana* (black plum) fruit. J. Chem. Soc. Nigeria, 46: 276-282.
7. Jitngarmkusol, S., J. Hongsuwankul and K. Tananuwong, 2008. Chemical compositions, functional properties and microstructure of defatted macadamia flours. Food Chem., 110: 23-30.
8. Okhale, S.E., I. Chinyere, M.I. Aboh and U.A. Osunkwo, 2021. Effects of semisynthetic modifications on the antimicrobial activities of ethyl acetate extract of *Mitracarpus villosus* (Sw.) DC aerial part. Nat. Sci., 19: 36-41.
9. Adeleke, R.O. and J.O. Odedeji, 2010. Functional properties of wheat and sweet potato flour blends. Pak. J. Nutr., 9: 535-538.
10. Sozer, N. and A.C. Dalgic, 2007. Modelling of rheological characteristics of various spaghetti types. Eur. Food Res. Technol., 225: 183-190.
11. Okhale, S.E., I. Chinyere, S.A. Fidelis and M.I. Aboh, 2021. Antiproliferative, growth inhibitory and antibacterial activities of thymol isolated from the leaf of *Ocimum gratissimum* L. Life Sci. J., 18: 67-76.
12. Afoakwa, E.O., E.J. Kongor, G.A. Annor and R. Adjonu, 2010. Acidification and starch behaviour during co-fermentation of cassava (*Manihot esculenta* Crantz) and soybean (*Glycine max* Merr) into *gari*, an African fermented food. Int. J. Food Sci. Nutr., 61: 449-462.
13. Delcour, J.A., J. Vansteelandt, M.C. Hythier and J. Abécassis, 2000. Fractionation and reconstitution experiments provide insight into the role of starch gelatinization and pasting properties in pasta quality. J. Agric. Food Chem., 48: 3774-3778.

14. Daramola, B. and S.A. Osanyinlusi, 2006. Production, characterization and application of banana (*Musa* spp) flour in whole maize. Afr. J. Biotechnol., 5: 992-995.
15. Imoisi, C., J.U. Iyasele and S.A. Okhale, 2021. Phytochemical and antioxidant capability of *Vitex doniana* (black plum) fruit. J. Chem. Soc. Nigeria, 46: 191-196.
16. Charles, A.L., Y.H. Chang, W.C. Ko, K. Sriroth and T.C. Huang, 2004. Some physical and chemical properties of starch isolates of cassava genotypes. Starch Starke, 56: 413-418.
17. Egbeneje, V.O., S.E. Okhale, C. Imoisi, I.O. Ogbogo and O. Ojo, 2023. Evaluation of the inhibitive properties of silver nanoparticles in *Senna occidentalis* root extract as corrosion inhibitor of mild steel. Tanzania J. Sci., 49: 655-663.
18. Imoisi, C. and U.C. Michael, 2020. Comparative physicochemical and proximate analyses of different extracts of *Persea americana*. J. Chem. Soc. Niger., 45: 1139-1146.
19. Ajenu, C.O., C. Imoisi, E.E. Imhontu and U.R. Orji, 2021. Comparative evaluation of the proximate and micro-nutritional benefits of pawpaw, carrots, turmeric and coconut. J. Food Technol. Nutr. Sci., Vol. 3. 10.47363/JFTNS/2021(3)124.
20. Imoisi, C., J.U. Iyasele, D.O. Ikpahwore and A.O. Okpebho, 2023. The effects of watermelon rind flour on the proximate properties of wheat cake. Int. J. Nutr. Res. Health, Vol. 2. 10.59657/2871-6021.brs.23.004.
21. Imoisi, C., J.U. Iyasele, E.E. Imhontu, D.O. Ikpahwore and A.O. Okpebho, 2020. Pasting properties of composite of cassava and wheat flours. J. Chem. Soc. Niger., 45: 1157-1163.
22. Imoisi, C., J.U. Iyasele, U.C. Michael and E.E. Imhontu, 2020. The effects of watermelon rind flour on the functional and proximate properties of wheat bread. J. Chem. Soc. Niger., 45: 978-986.
23. Chinyere, I., I.U. Julius and O.E. Samuel, 2021. Determination of the flavoring components in *Vitex doniana* fruit following hydrodistillation extraction. Am. J. Food Nutr., 9: 69-75.
24. Imoisi, C., J.U. Iyasele and A.O. Okpebho, 2023. The effects of citrus vesicle flour on the functional and proximate properties of cassava bread. Pak. J. Nutr., 22: 19-26.
25. Yaich, H., H. Garna, B. Bchir, S. Besbes and M. Paquot *et al*. 2015. Chemical composition and functional properties of dietary fibre extracted by Englyst and Prosky methods from the alga *Ulva lactuca* collected in Tunisia. Algal Res., 9: 65-73.
26. Ozoh, C.A., C. Imoisi and J.U. Iyasele, 2023. Effect of pH and duration of fermentation on the quality characteristics of garri. Pak. J. Nutr., 22: 45-51.
27. Macagnan, F.T., L.P. da Silva and L.H. Hecktheuer, 2016. Dietary fibre: The scientific search for an ideal definition and methodology of analysis, and its physiological importance as a carrier of bioactive compounds. Food Res. Int., 85: 144-154.
28. Edogun, P.I., C. Imoisi and J.U. Iyasele, 2024. Study on the effect of *Ficus exasperata* aqueous leaf extract on the rate of lactic acid formation of fermented milk. Trends Appl. Sci. Res., 19: 72-82.
29. Omenai, F.I., C. Imoisi and J.U. Iyasele, 2024. Physico-chemical and pasting characteristics of cassava, wheat flours and their composite blends. Asian Sci. Bull., 2: 333-344.
30. Blazek, J., E.P. Gilbert and L. Copeland, 2011. Effects of monoglycerides on pasting properties of wheat starch after repeated heating and cooling. J. Cereal Sci., 54: 151-159.
31. Aremu, M.O., O. Olaofe and E.T. Akintayo, 2007. Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. J. Food Technol., 5: 109-115.
32. Adebowale, Y.A., A. Adeyemi and A.A. Oshodi, 2005. Variability in the physicochemical, nutritional and antinutritional attributes of six *Mucuna* species. Food Chem., 89: 37-48.
33. Kurhade, A., S. Patil, S.K. Sonawane, J.S. Waghmare and S.S. Arya, 2016. Effect of banana peel powder on bioactive constituents and microstructural quality of chapatti: Unleavened Indian flat bread. J. Food Meas. Charact., 10: 32-41.
34. Josiah, J.G., J.Y. Adama, Z. Jiya, O.M. Abah and C. Imoisi, 2023. *In vitro* anthelmintic activities of stem and root barks extracts of *Parkia biglobosa* on infective larvae and adult of *Haemonchus contortus*. Afr. J. Biotechnol., 22: 26-38.

35. Ağar, B., H. Gençcelep, F.T. Saricaoğlu and S. Turhan, 2016. Effect of sugar beet fiber concentrations on rheological properties of meat emulsions and their correlation with texture profile analysis. Food Bioprod. Process., 100: 118-131.
36. Okhale, S.E., V.O. Egbeneje and C. Imoisi, 2021. GC-MS evaluation of palm oil as benign extraction medium for bioactive constituents of *Ocimum gratissimum* L and *Bryophyllum pinnatum* (Lam.). J. Am. Sci., 17: 46-53.
37. Kaushal, P., V. Kumar and H.K. Sharma, 2012. Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeonpea (*Cajanus cajan*) flour and their blends. LWT-Food Sci. Technol., 48: 59-68.
38. Ajenu, C.O., M.E. Ukhun, C. Imoisi, E.E. Imhontu, L.E. Irede and U.R. Orji, 2021. Characterization and stability studies of egusi melon seed oil (*Citrullus colocynthis* L.). J. Chem. Soc. Nigeria, 46: 238-244.
39. Ikegwu, O.J., P.E. Okechukwu and E.O. Ekumankana, 2010. Physico-chemical and pasting characteristics of flour and starch from Achi *Brachystegia eurycoma* seed. J. Food Technol., 8: 58-66.
40. Josiah, J.G., J.Y. Adama, E.H. Edim, I. Chinyere and J. Zipporah, 2024. Acute toxicity profile of crude methanolic stem bark extract of *Parkia biglobosa* in West African Dwarf (Wad) goats. J. Biosci. Biotechnol. Discovery, 9: 10-22.
41. Okhale, S.E., H.O. Egharevba, C. Imoisi, J.A. Ibrahim and I.A. Jegede, 2022. Gas Chromatography-Mass Spectrometry (GC-MS) analysis of the essential oil from Nigerian *Artemisia annua* L. at different growth stages. Nat. Sci., 20: 49-54.
42. Adebowale, A.A., L.O. Sanni and S.O. Awonorin, 2005. Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Sci. Technol. Int., 11: 373-382.
43. Okhale, S.E., P.O. Oladosu, M.I. Aboh, C. Imoisi and J.J. Gana, 2022. *In-vitro* evaluation of *Eucalyptus citriodora* leaf essential oil and extracts on selected pathogens implicated in respiratory tract infections. Int. J. Pharmacogn., 9: 195-201.
44. Butt, M.S. and R. Batool, 2010. Nutritional and functional properties of some promising legumes protein isolates. Pak. J. Nutr., 9: 373-379.
45. Saikia, S. and C.L. Mahanta, 2016. *In vitro* physicochemical, phytochemical and functional properties of fiber rich fractions derived from by-products of six fruits. J. Food Sci. Technol., 53: 1496-1504.
46. Cummings, J.H. and A.M. Stephen, 2007. Carbohydrate terminology and classification. Eur. J. Clin. Nutr., 61: S5-S18.