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DETERMINATION OF THE RHEOLOGICAL CHARACTERISTICS OF SOME VARIETIES OF NEW RICE FOR AFRICA (NERICA) RELEVANT TO ITS PROCESSING
ODREĐIVANJE REOLOŠKIH OSOBINA POJEDINIH VARIJATITETA NOVE SORTE PIRINČA (NERICA) RELEVANTNIH ZA PRERADU

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ABSTRACT

The pasting properties of some NERICA (New Rice for Africa) varieties were determined using the rapid visco-analytical machine (RVA). The studied varieties include FARO 44, FARO 52, FARO 57, FARO 60, and FARO 61. The parameters assessed include the pasting temperature, peak time, peak or maximum viscosity, hot paste viscosity or trough, cold paste or final viscosity, breakdown, and setback. Results obtained indicated that the pasting characteristics of NERICA varieties studied exhibited good pasting behavior. Results showed that peak viscosity, final viscosity, hot paste viscosity, breakdown, and setback ranged from 30.83 to 85.17 RVU; 62.21 to 167.13 RVU; 25.83 to 76.88 RVU; and 5.01 to 8.29 RVU; and 31.38 to 81.96 RVU, respectively. There were significant effects of moisture content and temperature ($p < 0.05$) on all parameters studied. These generated results of the pasting characteristics of NERICA will be extremely useful in determining their suitability in food and other relevant industries.
Keywords: *NERICA, rheological properties, viscosity, pasting properties, rice.*

REZIME

U radu su određena lepljiva svojstva pojedinih varijateta sorte NERICA (novi sorta pirinča za Afriku) upotrebom viskoanalizatora (RVA). Analizirani su varijateti FARO 44, FARO 52, FARO 57, FARO 60 i FARO 61. Ocenjeni su parametri: temperature lepljenja, vreme maksimuma, vršna odnosno maksimalna viskoznost, viskoznost zagrejane paste, viskoznost hladne paste ili kranja viskoznost, slom i nazadovanje. Dobijeni rezultati ukazuju na dobra lepljiva svojstava varijateta NERICA, vršna viskoznost, finalna viskoznost, viskoznost zagrejane paste, slom i nazadovanje se nalazi u opsegu izmerenih vrednosti od 30,83 do 85,17 RVU;od 62,21 do 167,13 RVU; od 25,83 do 76,88 RVU; od 5,01 do 8,29 RVU; od 31,38 do 81,96 RVU, respektabilno. Potvrđen je signifikantni uticaj temperature i vlažnosti ($p < 0.05$) za sve istraživane parametre. Dobijeni rezultati lepljivih karakteristika za pirinač soret NERICA su korisni u određivanju pogodnosti korišćenja u industriji hrane i drugim relevantnim prerađivačkim kapacitetima.
Keywords: *NERICA, reološke osobine, viskoznost, lepljive osobine, pirinač.*

INTRODUCTION

Rice is quite a common foodstuff in Nigeria, and indeed, the world. It is scientifically known as “Oryza,” and it is one of the most popular grains consumed by human beings. Apart from eating rice as a normal meal, it is regarded as one of the best foods for ceremonies in the sub-Saharan part of Africa. Naturally, rice cultivated in this part of Africa is called “Oryza Glaberrima Steud” before the introduction of NERICA. The name, NERICA, is referred to as “New Rice for Africa,” (*WARDA, 2008*). This represents the offspring products developed from the successful hybridization of two rice cultivars, namely, the African rice, Oryza Glaberrima S., and the Asian rice, Oryza Sativa L., to get species that bring together the high-class qualities of the two parentages, (*WARDA, 2008; Eze et al., 2020*). These involve the high-level qualities of the Asian specie, and the African specie’s capability to vigorously grow in harsh and difficult conditions in the African environment. NERICA was normally developed by crossbreeding, and based on this, they were not hereditarily improved rice (*WARDA, 2008*). NERICA species are a new set of varieties of highland rice that perfectly adapts to the highland rain-fed environment in sub-Sahara Africa (SSA), where poor and wretched farmers do not have access to fertilizers (both chemical and solid), irrigation, and/or pesticides. WARDA (2008) reported that NERICA varieties have reacted more positively than the locally cultivated varieties of rice to maximum inputs. However, the high demand for rice consumption, both in quality and quantity, has outweighed local production. Thus, the very need for an increase in rice production and improvement of the locally produced rice to make it more competitive with foreign rice has led to the invention of NERICA (*Udemezue, 2018*).

The over-emphasized cost-effective essentiality of agricultural food products, coupled with the complexity of the coexisting technology, for the postharvest operations which involve processing, storage, high-end assessment and distribution, handling, and consumption of food, involves comprehensive knowledge of the engineering properties of these agricultural products suitable to their processing, handling, and storage (*Eze et al., 2020*).

In food engineering, rheology is regarded as that part of food processing that investigates the deformation and flow of agricultural products. Information obtained from the rheological analysis of food materials is required in the quality evaluation, engineering data computation, and design process of agricultural products (*Rao et al., 2005*). The knowledge of deformation-flow behavior and characteristics are very essential in deciding or establishing the substantial ranges of the pump and size of pipes and the energy required during food processing (*Sahin and Sumnu, 2006*). Also, models derived from rheological calculations of determined experiments from food materials could be exceptionally significant in the food design process

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when applied incidentally through energy, force and load proportions (*Rao et al., 2005*). The knowledge of rheological properties will help in designing and determination of essential parameters for agro-industries as regards to flow, viscometric and mechanical properties necessary to enhance the quality of NERICA and its products. This study to determine the rheological properties of NERICA is important, more so now that NERICA is being evaluated for adoption in the continent since it is a new rice in Africa. The impacts of processing on rheological parameters need to be recognized for optimum control processes. Several reports from researchers like Tabilo-Munizaga and Barbosa-Ca'novas (2005), Sahin and Sumnu (2006), and Rao *et al,* (2005), proclaimed that there are multiple tests regarding the rheological characterization of agricultural food products. Regardless, it is positively absorbed that no test could suitably supply all the necessary information to acquire a rheological description completely. Thus, a cautious selection through multiple tests is constantly recommended. The recommendation of suchlike tests depends on the types of food materials, the applications, and the availability of capable instrumentation (Tabilo-Munizaga and Barbosa-Ca'novas, 2005). Unique rheological properties of various food products have been reported and summarized in many publications, (*Steffe, 1996; Odejobi et al., 2014; Rather et al., 2016; Iwe et al., 2016; Shafie et al., 2016; Mlakar et al., 2009*). However, this research work is aimed at determining the rheological characteristics of NERICA varieties relevant to its processing.

MATERIALS AND METHOD.

Research materials and sample preparation

The material samples used in this research work were collected from the Ebonyi State Agricultural Development Programme (EBADEP), Abakaliki, Southeastern Nigeria, at a storage moisture content of 12.5% (d.b), and these include FARO 44, FARO 52, FARO 57, FARO 60, and FARO 61. These sample paddy from each variety were then parboiled and dehulled using a rice dehulling machine to obtain milled samples of NERICA. These methods used in the parboiling and dehulling of the NERICA sample varieties, were in line with the rice parboiling and dehulling standard as reported by Ituen and Ukpakha (2011), and these processes include, cleaning, soaking, steaming, drying, and milling. The sample flour was prepared by grinding the sample grains into powder using a hammer mill. The sample powders were passed through a mesh sieve of 250 µm, then vacuum packed in polyethylene bags for further analysis.

The pasting characteristics of the NERICA samples were conducted with the Rapid Visco Analyser equipment of model RVA 4500, Australia. During the experiment, 3.0 g of the NERICA sample was weighed into an earlier desiccated cylinder and 25 ml of purified water was meted out into the cylinder that contains the NERICA varieties. The samples were mixed carefully, and the cylinder well fixed back inside the viscosity machine as proposed. The samples were heated up to 96^o C. Afterwards, they were held at 50^o C for 1 min with a hold time of 2 min. This was followed by cooling of the particles to 50^o C with a hold time of 2 min. The heating and cooling extent of the particles was at a level rate of 11.87 ^{o}C/min. A viscogram was derived from the computer reporting the following viscosity parameters, breakdown, trough, peak viscosity, final viscosity, viscosity time, temperature, and setback. Throughout the analysis, the starch is gelatinized with a subsequent increase in viscosity, dependent on high-level temperature and regulated shear through which its constancy is exposed, then cooled off to deliver a sign of setback during gelatinization.

The results obtained were statistically analyzed using analysis of (ANOVA), with the averages evaluated by Duncan's test at a 5% significance confidence level ($P < 0.05$). All calculated results were stated as the average values standard error (SE) of triplicate observations.

RESULTS AND DISCUSSION

The results of the pasting characteristics of NERICA varieties are shown in Table 1. There were significant differences ($p<0.05$) in the pasting profile of the flour of NERICA varieties. The result shows that FARO 61, FARO 44 and FARO 60 have significantly lower pasting characteristic values than FAROs 52 and 57. Pasting occurs after or simultaneously with gelatinization. Gelatinization transforms food starch into a solid form that is beneficial in various food systems. As an endothermic process, gelatinization results in the derangement of molecular order within the starch granules (*Wani et al., 2012*). The pasting properties of food starch are very essential indicators of how starch behaves while processing, and starch, generally, is regarded as the utmost significance of rice in terms of cooking quality, and functionality (*Wani et al., 2012*). The pasting properties of food starch are generally used as indicators to determine the suitability of starch in various food materials and other allied food products, but the most essential pasting property of granular starch dissipation is its viscosity. High pasting viscosity of food material suggests suitability as a thickening agent in foods, and as a finishing agent in the textile and paper industries. Generally, a graph showing the pasting characteristics of NERICA flour is shown in Figure 1, and the generated rheogram of viscous characteristics of NERICA varieties is shown in Figure 2.

Table 1. Rheological Characteristics (RVA) of NERICA varieties (in BU)

Varieties	Pasting Temp, P_{temp}(°c)	Peak Time, $P_{time(min)}$	Peak Viscosity (PV) or Max Viscosity	Hot Paste Viscosity (HPV) or Trough.	Cold Paste Viscosity (CPV) or Final Viscosity	Breakdown (PV-HPV)	Setback (CPV-PV)
FARO 44	50.25	7.00	35.96 (2.32)	29.51 (1.76)	68.17 (2.54)	6.46 (0.45)	32.21 (2.11)
FARO 52	50.33	7.00	69.25 (3.09)	61.71 (2.77)	128.34 (3.32)	7.54 (0.56)	59.09 (1.42)
FARO 57	50.55	7.00	85.17 (2.88)	76.88 (3.12)	167.13 (2.76)	8.29 (1.33)	81.96 (2.46)
FARO 60	50.25	7.00	49.21 (2.11)	42.17 (2.43)	86.71 (2.43)	7.04 (0.54)	37.50 (1.72)
FARO 61	50.58	7.00	30.83 (1.67)	25.83 (1.08)	62.21(1.99)	5.01 (0,89)	31.38 (1.54)
Average	5039	7.00	54.08 (2.41)	47.22 (2.23)	102.51 (2.61)	6.87 (0.75)	48.43 (1.85)

*N.B: Numbers in parentheses represent the standard deviation.

From Table 1, peak paste viscosity, PV (or maximum viscosity) of NERICA varieties were recorded. FARO 61 recorded the lowest peak viscosity of 30.83 RVU, while FARO 57 recorded the highest viscosity of 85.17 RVU. According to Adegunwa *et al.,* (2012), Peak viscosity is the maximum viscosity developed during or soon after the heating portion of the test. It is used as an indicator of the strength of the paste formed during cooking and determines the ease of swelling of starch molecules during heating. Increased viscosity markedly after gelatinization, causes further disintegration of the granules at high temperatures. Thus, a drop in viscosity is highly influenced by the peak in the viscosity-temperature curve. Products that have high peak viscosity do not swell easily. Such product requires a lot of energy to initiate swelling and gelatinization, and, they have high pasting temperatures.

Generally, peak viscosity is influenced by amylose content and other interfering non-starch components (AOAC, 2005; *Gayin et al.,* 2009). Therefore, the lower the peak viscosity, the more the product swells, and the higher the peak viscosity, the lower the product swells. Thus, FARO 61 which recorded the lowest value of 30.83 RVU for peak paste viscosity is the best variety for this parameter, followed by FARO 44 of value 35.96 RVU.

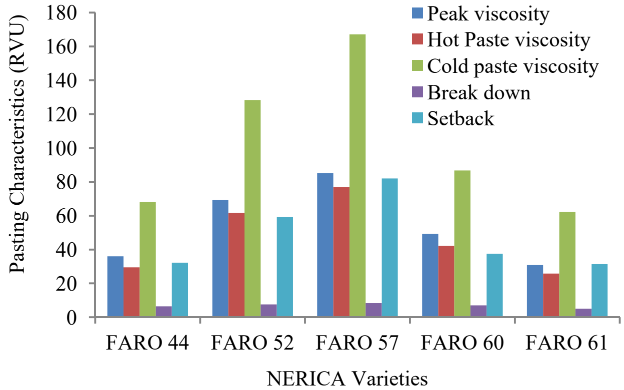

Fig. 1. Chart showing Pasting Characteristics of NERICA flour

Hot paste viscosities, HPV (or trough), were also recorded for all NERICA varieties in Table 1. The hot paste viscosity, HPV (or trough/holding strength) indicates the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of the paste to withstand breakdown during cooling (AOAC, 2005). It is also indicating the holding strength of a particular product during heating. Trough (holding strength) can also be regarded as the minimum viscosity after the peak and normally occurs around the commencement of sample cooling (*Adegunwa et al.,* 2012). It is the ability of the granules to remain undisrupted when the flour paste is subjected to a hold period of constant high temperature and mechanical shear stress. The hot paste viscosity of the NERICA varieties ranged from 25.83 to 76.88 RVU. FARO 57 recorded the highest value of 76.88 RVU, while FARO 61 recorded the lowest value of 25.83 RVU for HPV. The results indicate that the higher the trough, the higher the holding strength capacity of the NERICA varieties.

Cold paste viscosity, CPV (or final viscosity) is the viscosity at the end of the test, and it is important in predicting and defining the final textural quality of the product in terms of springiness (drawability). High cold paste viscosity (or final viscosity) implies firm gel formation after cooking and cooling to 5 ^{0}C rather than a viscous paste. Normally, a loose paste or gel is formed which depends on the concentration of the food starch as gelatinized dispersion of the starch is cooled. It the end, a three-dimensional network is established at concentrations above the critical concentration, where the swollen granules become embedded in a continuous matrix of entangled amylose molecules (*Adegunwa et al.,* 2012). Such a complex polymer matrix is set as a viscoelastic gel in which the molecular associations involving hydrogen bonding between chains, are mainly physical rather than covalent cross-links, (*Applqvist and Debet, 1997; Gayin et al., 2009*). The formation of such gel that is indicated by an increase in viscosity is known as the final viscosity in the paste gel curve. FARO 57 recorded the highest value of final viscosity; 167.13 RVU, followed by FARO 52 of value 128.34 RVU. FARO 61 recorded the lowest value of 62.21 RVU. These results and trends conform with (*Gayin et al., 2009; and Adegunwa et al., 2012*).

The values for breakdown paste viscosities were also recorded in Table 1. Low breakdown values imply that paste stability is low on cooling due to weak cross-linking among the starch granules. This is also related to the setback value. *Adebowale et al.,* (2004), reported that the higher the viscosity breakdown, the lower the ability of the sample to withstand heating and stress during cooking. *Also, Patindol et al.*, (2005) and *Gayin et al.*, (2009), reported that breakdown viscosity estimates the tendency of the swollen starch particles to rupture when held at high continuous shearing and temperature. Therefore, the least breakdown viscosity of the starch granules of FARO 61 rice variety makes it useful for dishes involving boiled rice for grains that do not stick together since it recorded the lowest value of 5.01 RVU, though breakdown paste viscosity values for the reported NERICA varieties ranged from 5.01 to 8.29 RVU with little or no significant difference.

Setback viscosity values were also reported for NERICA rice varieties in Table 1. Setback viscosity is measured as the difference between the final viscosity and the trough. It is the phase of the pasting curve after cooling the starches to 50°C. This stage involves re-association, retrogradation, or reordering of starch molecules. It shows the tendency of the starch to associate and retrograde, *Adegunwa et al.,* (2012). The setback viscosity of flours has been correlated with the texture of various products (*Adeyemi and Idowu, 1990; Mkhiyo et al., 2004*). The high setback is also associated with syneresis or weeping. High setback viscosities in NERICA samples are indicative of greater tendencies towards low retrogradation of the samples. High setback values were reported to associate with cohesive or mouldable dough. Such products have a greater tendency to retrograde on cooling thereby becoming soft and soggy due to the realignment of amylose and amylopectin molecules. The setback values of FAROs 44, 52, 57, 60, and 61 were recorded as 32.21 RVU, 59.09 RVU, 81.96 RVU, 37.50 RVU and 31.38 RVU, respectively. The higher the setback value, the lower the retrogradation during the cooling of the products made from flour.

The pasting temperatures of NERICA varieties as reported in Table 1 ranged from 50.25 to 50.58 ^{0}C. Pasting temperature gives an indication of the gelatinization temperature, or the minimum temperature required to cook the sample. High pasting temperature indicates that the starch exhibits restriction to swelling. The reported temperature range of the NERICA varieties indicated that they possessed high swelling characteristics with the temperature range.

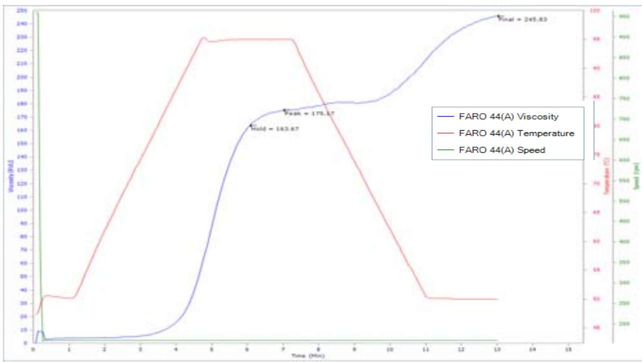

Fig. 2. Sample Rapid Visco Analytical (RVA) rheogram of a NERICA variety.

Pasting time was reported the same in all the NERICA varieties at 7 minutes per run. From Table 1, it was observed that the results obtained agreed with Rather et al., (2016) for varieties of rice from India; Iwe et al., (2016) for FARO 44 rice, African yam bean and brown cowpea composite flour; and Ikegwu et al., (2010). Though there are few differences in pasting time and pasting temperatures. These might be due to some factors like the size and shape of the flour granules, ionic charge on the flour, type, and degree of crystallinity within the granules, presence or absence of fat and protein and perhaps the molecular size of the flour, Ikegwu et al., (2010). There were significant differences ($p<0.05$) in all the pasting profiles of the flour of the NERICA varieties.

CONCLUSION.

The NERICA varieties (FAROs 44, 52, 57, 60, and 61) studied exhibited good pasting characteristics and were all significantly ($p < 0.05$) affected by temperature. The peak viscosity (maximum viscosity), ranged from 30.83 to 85.17 RVU. The trough (hot paste viscosity) which indicates the holding strength of a particular product during heating, ranged from 25.83 to 76.88 RVU, while the cold paste viscosity (final viscosity), ranged from 62.21 to 167.13 RVU. The breakdown viscosity ranged from 5.01 to 8.29 RVU and the setback viscosity, which signifies the tendency of the material to associate and retrograde, ranged from 31.38 to 81.96 RVU. The pasting temperature ranged from 50.25 to 50.58 ^{O}C, while the pasting time or gelatinization time remained constant for all the NERICA varieties at 7 minutes. The results showed that FARO 57 recorded the highest pasting characteristics than FAROs 44, 52, 60, and 61. Pasting properties of starch are important indicators of how the starch will behave during processing and, starch is generally regarded as the most important constituent of rice in terms of cooking quality and functionality, therefore, the results obtained from this study provide basic information that is beneficial to the food industry.

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