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Functional Properties of Flours from Five Nigerian Rice Cultivars

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ABSTRACT

In this study, the functional properties of five Nigerian rice cultivars (*Bisalachi, Ebagichi, Lamiyatu, Majalisa* and *Walue*) were determined. Functional properties such as hydration, pasting and thermal parameters, and vibrational spectroscopy of the flours were determined using standard methods. Bulk density, water binding capacity, water holding capacity, water absorption index, water solubility index, oil absorption capacity and swelling power ranged from 0.32 to 0.41 g/cm^3, 1.21 to 1.40 g/g, 1.33 to 1.92 g/g, 5.81 to 7.53 g/g, 1.49 to 1.74 g/g, 1.26 to 1.35 g/g, and 10.35 g/g to 12.80 g/g, respectively. Peak viscosity, trough viscosity, breakdown viscosity, final viscosity, pasting temperature and peak time ranged from 158.04 to 187.30 RVU, 107.59 to 124.76 RVU, 50.45 to 62.54 RVU, 222.86 to 275.27 RVU, 115.27 to 151.89 RVU, 87.65 to 88.53 °C and 5.29 to 5.96 min, respectively. Onset, peak and conclusion temperatures, and enthalpy of gelatinization ranged from 65.02 to 68.41 °C, 68.73 to 72.05 °C, 74.59 to 79.26 °C, and 11.62 to 14.88 J/g, respectively. Raman spectroscopy revealed that the bands in the spectra of the rice flours originated mainly from the vibrational modes of amylose and amylopectin. The results obtained are useful in determining the application of the rice flours in food systems.

Keywords: Rice cultivars, flour, functional properties.

1.0 Introduction

Rice is the most important cereal crop in the developing world and the most staple food of over half the world's population (Liu, 2018). The world rice production in 2017/ 2018 was estimated at 481.0 million metric tons (MMT) (Anon, 2017). Rice is an important staple food that provides energy in the form of carbohydrates, protein of higher biological value, and trace elements (Bhattacharya, 2011). Rice flour (obtained from rice grain) is widely used as an ingredient in many food products, including beverages, meat products, puddings, salad dressings, and gluten-free diets (Falade and Christopher, 2015).

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There is an increasing demand for rice varieties with excellent quality characteristics throughout the world (Bhat and Riar, 2017). Traditional rice cultivars are preferred by consumers over hybrid varieties in terms of higher palatability, nutritional significance, health benefits and price (Bhat and Riar, 2017). Chinma *et al.* (2015) reported a renewed interest in the consumption of local varieties of Nigerian rice cultivars due to low starch content and higher bioactive properties of the flours. Many hybrid and traditional rice varieties are cultivated in Nigeria (Odejobi *et al.*, 2015).

Functional properties of rice flour govern the behaviour of nutrients in foods during processing, storage and preparation as they affect food quality and acceptability (Falade and Christopher, 2014). Functional properties of cereal grains are the fundamental physico-chemical properties that reflect the complex interaction between the structure, molecular components and physico-chemical properties of food components (Ramashia *et al.*, 2017). The characteristics and use of flours to produce acceptable sensory characteristics products depend on the functional properties of the flours (Oladale and Aina, 2007). Presently, data on the functional properties of flours from many Nigerian rice cultivars are either insufficient or non-existent. The objective of this study was to determine the functional properties of flours from five Nigerian rice cultivars in order to enhance their utilization beyond traditional usage.

2.0 Materials and Methods

2.1 Materials

Five Nigerian rice cultivars (*Bisalachi, Ebagichi, Lamiyatu, Majalisa* and *Waluea*) were procured from the rice breeding Laboratory of National Cereal Research Institute Badeggi, Bida, Niger State, Nigeria during 2014 and 2015 harvest season. The rice cultivars were cultivated under lowland ecology with recommended agronomic practices for rice production in Nigeria.

2.2 Sample preparation

Substantial quantities of paddy of each rice cultivar (about 11.00% moisture content) samples were dehusked in a Satake rice husker (THU-35B, Satake Corporation, Japan). The brown rice obtained was polished in Satake grain testing mill (Model No. 553504, Satake Engineering Co., Japan) to obtain 8% degree of milling. Milled rice samples from each cultivar were separated from broken rice samples and ground into fine flour using hammer mill (Globe P 44, Diamond Tools Co. Ltd. Henan, China). The samples were sieved through 100 μm sieve size and stored in airtight plastic containers covered with lids.

2.3 Determination of functional properties

Bulk density was determined according to the method of Falade and Christopher (2015). Water holding capacity, water binding capacity, water absorption index and water solubility index of samples were determined as reported by Cornejo and Rosell (2015). Oil absorption capacity was determined as described by AACC 56-20 method (AACC, 2000). Swelling power was determined according to the method reported by Osundahunsi *et al.* (2003). Pasting properties of rice flours were determined using rapid visco analyser (RVA) (Newport Scientific Pty Ltd., Warriewood, Australia) according to the AACC method (2000).

2.4 Determination of thermal properties

Thermal properties of flour samples were determined using a differential scanning calorimeter (DSC model 204, Nietzsche, Germany) according to the method of Escamilla-Silva *et al.* (2003).

2.5 Raman spectroscopy

Raman spectra of flour samples were recorded using a Raman spectrometer (ProRaman – L – 785, Renishaw, Gloucestershire, UK) working in confocal mode according to the method of Mir and Bosco (2014). The spectra were taken from the same spot size for each flour sample in the range of 100 to 4000 cm^{-1}.

2.6 Statistical analysis

Data obtained from analysis of functional parameters were subjected to analysis of variance, and differences among mean values were compared by Tukey tests at 5% probability level. All computations were done using statistical software (SPSS version 11).

3.0 Results and Discussion

3.1 Functional properties

The functional properties of rice flours are presented in Table 1. The bulk density of the flour samples ranged from 0.32g/cm^3 (*Walue*) to 0.41gcm^3 (*Ebagichi*). The values of bulk density of rice flours were lower than the values (0.57 to 0.73g/cm^3) reported by Kraithong *et al.* (2018) for Thai organic rice flours. The low bulk density of the rice flours would be an advantage in the preparation of weaning food formulation.

The water binding capacity (WBC) is the amount of water retained by the sample under low-speed centrifugation (Cornejo and Rosell, 2015). Water

Table 1: Functional properties of rice flour

Parameter	*Bisalachi*	*Ebagichi*	*Lamiyatu*	*Majalisa*	*Walue*
Bulk density (g/cm^3)	0.40 ± 0.01^a	0.41 ± 0.00^a	0.37 ± 0.04^a	0.35 ± 0.00^a	0.32 ± 0.00^a
Water binding capacity (g/g)	1.27 ± 0.00^b	1.31 ± 0.03^{ab}	1.37 ± 0.01^a	1.40 ± 0.02^a	1.21 ± 0.07^b
Water holding capacity(g/g)	1.81 ± 0.05^a	1.50 ± 0.01^b	1.38 ± 0.02^c	1.33 ± 0.01^c	1.92 ± 0.03^a
Water absorption index (g/g)	7.03 ± 0.11^b	6.75 ± 0.08^c	6.20 ± 0.12^d	5.81 ± 0.17^e	7.53 ± 0.11^a
Water solubility index (g/g)	1.60 ± 0.05^a	1.49 ± 0.02^a	1.65 ± 0.08^a	1.52 ± 0.10^a	1.74 ± 0.06^a
Oil absorption capacity (g/g)	1.26 ± 0.01^a	1.28 ± 0.00^a	1.32 ± 0.02^a	1.35 ± 0.01^a	1.26 ± 0.03^a
Swelling power (g/g)	12.33 ± 0.17^b	11.60 ± 0.10^c	11.02 ± 0.05^d	12.80 ± 0.03^a	10.35 ± 0.08^e

*Mean and standard deviation of triplicates.
Mean value with different superscript in a row are significantly ($p \leq 0.05$) different from each other.

binding capacity of rice flours ranged from 1.21g/g (*Walue*) to 1.40 g/g (*Majalisa*). The WBC values are in agreement with values (1.23 to 1.38 g/g) reported by Cornejo and Rosell (2015) for different long-grain rice varieties. Low water binding capacity of rice flours is beneficial in gluten-free bread formulations (Han *et al.*, 2012). The low WBC values of the rice flours suggest that the flours have potential application in gluten-free bread making.

Water holding capacity (WHC) is the amount of water retained by the sample without being subjected to any stress (Cornejo and Rosell, 2015). The WHC of rice flours ranged from 1.33g/g (*Majalisa*) to 1.92 g/g (*Walue*). Rice flour with high WHC value could retard staling when used in gluten-free bread (Cornejo and Rosell, 2015).

Water absorption index (WAI) of the rice flours ranged significantly ($p\leq 0.05$) from 5.81g/g (*Majalisa*) to 7.53 g/g (*Walue*). The WAI of the flours obtained in this study was in line with the values (5.44 to 7.53g/g) reported by Kraithong *et al.* (2018) for Thai organic rice flours. The WAI of flour is important for determining if the flour can be incorporated into aqueous food formulations, especially those involving dough handling (Ramashia *et al.*, 2017). Flour with high WAI would provide softness, smoothness and viscosity in food systems (Aprianita *et al.*, 2014). High absorption of water during baking can enhance initial softness and decrease firming of bread (Arendt *et al.*, 2008). This suggests that the rice flour samples could be desirable as composite in bread making.

Water solubility index ranged from 1.49 to 1.74 g/g, and showed no significant ($p \geq 0.05$) difference among samples. The WSI results obtained in this study are lower than the values (1. 74 to 3.00 g/g) reported by Cornejo and Rosell (2015) for long grain rice flours. A high water solubility index in rice flour is an indication of high value of adhesiveness and stickiness in food products and a low ability to preserve food structure (Kraithong *et al.*, 2018). This implies that the low water solubility index of the flour samples suggests high ability to maintain food structure during thermal processing.

Oil absorption capacity (OAC) ranged from 1.26 to 1.35 g/g. The OAC of flour samples were consistent with Kraithong *et al.* (2018) who reported that OAC of Thai rice flours ranged from 1.11 to 1.34 g/g. The presence of large amount of hydrophobic groups in a starch molecule contributes to high value of oil absorption capacity (Tharise *et al.*, 2014). Oil absorption capacity is a desirable characteristic in products where emulsifying capacity is of great importance (Alimi *et al.*, 2016).

Swelling power of rice flours varied between 10.35 g/g (*Walue*) and 12.80 g/g (*Majalisa*). *Walue* with the highest amylose content had the lowest swelling power. This is in line with the report of Singh *et al.* (2006) that high amylose content inhibits swelling power of cereal starch. Swelling power of flour depends on the packing of starch granules with proteins and lipids. The difference in swelling power of the rice flours may be attributed to variation in the contents of amylose, lipid, protein, and bonding forces between the amylose and amylopectin molecules (Sodhi and Singh, 2003). Swelling power (SP) of the rice flours were in agreement with Cornejo and Rosell (2015) who reported SP values that ranged from 5.16 to 13.58g/g.

3.2. Pasting properties

Pasting properties are important quality indices in predicting the functional behavior of flour and their applicability to food systems (Alimi *et al.*, 2016). Peak viscosity, breakdown viscosity, final viscosity, setback viscosity, pasting temperature and peak time of the rice flours differed significantly ($p \leq 0.05$) among cultivars (Table 2). Peak viscosity is an indication of water absorption capacity or the extent of starch granule swelling. The highest peak viscosity (187.30 RVU) was observed in *Walue* while *Majalisa* the lowest value (158.04 RVU). High peak viscosity value recorded in *Walue* may be attributed to high water holding capacity of the flour. This is in line with the report of Ye *et al.* (2016) that high peak viscosity is associated with high water holding capacity. *Walue* also had high trough viscosity (124.76 RVU), breakdown viscosity (62.54 RVU), final viscosity (275.27 RVU) and pasting temperature (88.53 °C). This may be attributed to high amylose and fat content of the flour (Chinma *et al.*, in press). According to Ye *et al.* (2016), amylose content and other components such as lipid and protein affect pasting properties of rice flour. Consequently, the amylose-lipid or amylose-protein complex formations can promote high values of setback and final viscosities, while these complexes reduce peak and breakdown viscosities (Alcázar-Alay and Meireles 2015).

Setback viscosity, a measure of the tendency of starch paste to retrograde, ranged from 115.27 RVU (*Majalisa*) to 151.89 RVU (*Bisalachi*). High setback value is useful if the flour is to be used in food product such as stiff porridge preparation, which requires high viscosity and paste stability at low

Table 2: Pasting properties of rice flour

Parameter	*Bisalachi*	*Ebagichi*	*Lamiyatu*	*Majalisa*	*Walue*
Peak viscosity (RVU)	175.84±0.17b	168.50±0.36c	165.47±0.48d	158.04±0.53e	187.30±0.65a
Trough (RVU)	117.56±0.39b	110.90±0.42c	110.29±0.29d	107.59±0.25e	124.76±0.47a
Breakdown (RVU)	58.28±0.23b	57.60±0.15c	55.18±0.26d	50.45±0.19e	62.54±0.24a
Final viscosity(RVU)	269.45±0.58b	255.67±0.27c	248.20±0.42d	222.86±0.35e	275.27±0.40a
Setback (RVU)	151.89±0.41a	144.77±0.35c	137.91±0.48d	115.27±0.29e	150.51±0.31b
Pasting temperature (°C)	88.22±0.16b	88.01±0.10c	87.80±0.16d	87.65±0.11e	88.53±0.25a
Peak time (Min)	5.73±0.01b	5.51±0.06c	5.29±0.03d	5.42±0.08c	5.96±0.10a

*Mean and standard deviation of triplicates.

Mean value with different superscript in a row are significantly ($p \leq 0.05$) different from each other.

temperature (Oduro *et al.*, 2000). Pasting temperature (the temperature at the onset of viscosity increase) was lowest (87.65 °C) in *Majalisa*, while the highest value (88.53 °C) was recorded in *Walue*. The order of pasting temperature is consistent with that of amylose and protein content (except *Ebagichi*), which probably suggests that amylose and protein content influenced pasting temperature. Peak time, a measure of the cooking time, ranged from 5.29 min (*Lamiyatu*) to 5.96 min (*Walue*). The peak time value obtained in this study was lower than the values (6.10 to 6.53 min) reported by Falade and Christopher (2015) for some improved Nigerian rice cultivars. The variations in pasting properties of flours may be attributed to variation in protein, amylose and amylopectin, fine structure, genotype, agronomic conditions and other factors such as the presence of starch granule-associated proteins

(Zhang *et al.*, 2016). The pasting characteristics of the rice flours are in agreement with Gayin *et al.* (2017) for African and Asian rice flours.

3.3 Thermal properties

Thermal properties are important to understand rice processing, structure and energy consumption (Ye *et al.*, 2016). The onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and enthalpy of gelatinization (ΔH) varied significantly ($p \leq 0.05$) among cultivars (Table 3). Higher values of T_o (68.41 °C), T_p (72.05 °C), T_c (79.26 °C) and ΔH (14.88 J/g) were recorded in *Majalisa*, while lower values of T_o (65.02 °C), T_p (68.73 °C), T_c (74.59 °C) and ΔH (11.62 J/g) were observed in *Walue*. Higher values of DSC parameters (T_o, T_p and T_c) are promoted by large amylopectin branches (presence of crystallinity) (Kraithong *et al.*, 2018). Consequently, high energy is required for disrupting the large crystalline regions of high amylopectin rice flour (Alcázar-Alay and Meireles, 2015). The rice flours displayed high range of gelatinization temperatures and enthalpy. A high range of gelatinization temperatures indicates heterogeneity of ordered structures inside starch granules and/or heterogeneity in their population (Palavecino *et al.*, 2016). The T_o, T_p, T_c and ΔH results obtained in this study were in agreement with Singh *et al.* (2006) who reported T_o, T_p, T_c and ΔH that ranged from 61.10 to 75.76 °C, 66.91 to 79.21 °C, 71.93 to 84.59 °C, and 8.09 to 13.81 J/g, respectively, for rice cultivars harvested in India.

Table 3: Thermal properties of rice flour

Parameter	*Bisalachi*	*Ebagichi*	*Lamiyatu*	*Majalisa*	*Walue*
Onset temperature (°C)	65.58 ± 0.42^d	66.29 ± 0.13^c	67.73 ± 0.34^b	68.41 ± 0.29^a	65.02 ± 0.55^e
Peak-temperature (°C)	69.40 ± 0.75^d	70.64 ± 0.60^c	71.80 ± 0.57^b	72.05 ± 0.93^a	68.73 ± 0.42^e
Conclusion temperature (°C)	76.29 ± 0.82^d	77.52 ± 0.54^c	78.14 ± 0.43^b	79.26 ± 0.51^a	74.59 ± 0.67^e
Enthalpy of gelatinization (J/g)	12.33 ± 0.40^d	12.75 ± 0.62^c	13.94 ± 0.38^b	14.88 ± 0.45^a	11.62 ± 0.27^e

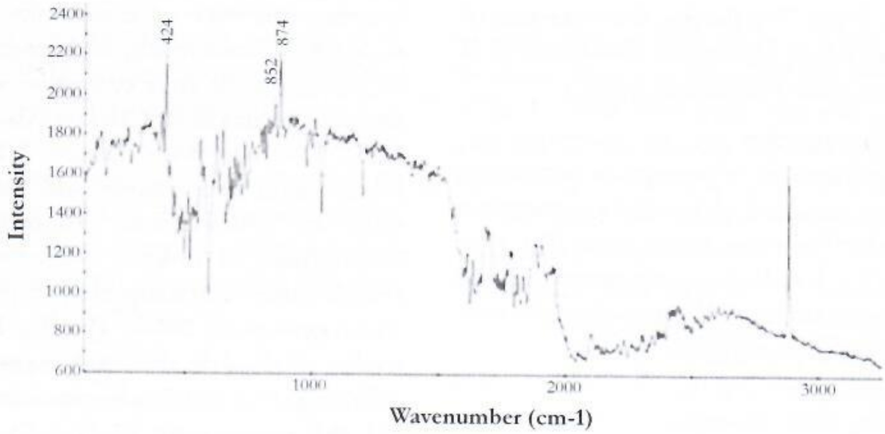
Mean and standard deviation of triplicates.
Mean value with different superscript in a row are significantly ($p \leq 0.05$) different from each other.

3.4 Raman spectroscopy

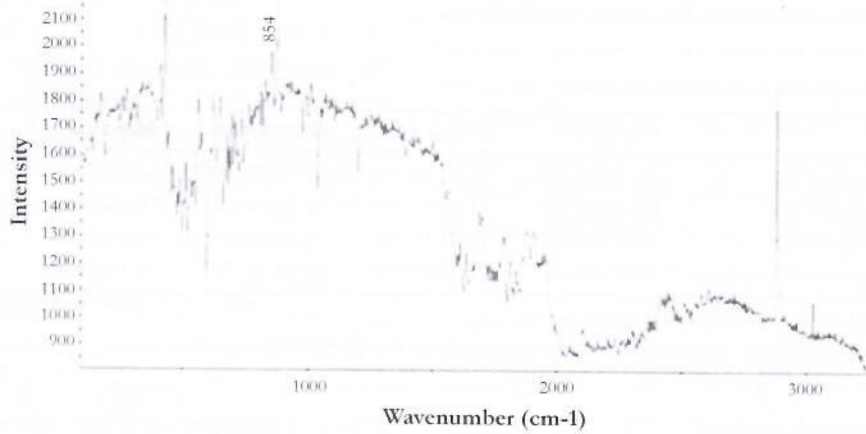
Raman spectroscopy is a rapid and non-destructive method used to identify various materials based on their molecular vibration frequency (Zhou *et al.*, 2016). Different components produce energy levels for molecular vibration and rotation, which can be shown in different Raman shifts (Zhu *et al.*, 2018) and each component in a particular material is characterized by its specific spectrum (Fan *et al.*, 2012). Figure 1 shows that primary characteristic bands for the different groups were present in the spectrum. These main bands included 424, 852, 874, 1012, 1200 and 2800 cm^{-1} observed in *Bisalachi;* 424, 854, 1012, 1200, 2800 and 3048cm^{-1} in *Ebagichi;* 425, 505, 512, 526, 874, 1012 and 1200 and 2800 cm^{-1} in *Lamiyatu;* and 426, 876, 1012, 1200, 2878 and 3180 cm^{-1} in *Majalisa*; and 426, 854, 876, 1104, 1810 and 2803 cm^{-1} in *Walue*. The skeletal vibration band around 400 to 800 cm^{-1} is mainly associated with the cytoskeleton vibration of the glucosamine ring, which can reflect the combined state of different polysaccharides.

The band between 800 and 1500 cm^{-1} is considered to be the fingerprint region for the Raman method and provides the highly overlapping and complex vibration modes for different functional groups. Raman band between 2800 and 3100 indicates the spectral features of the C–H stretch (Fencher *et al.*, 2005). In this study, it was observed that the Raman spectral bands originated mainly from the vibrational modes of amylose and amylopectin. This is in line with the reports of Wang *et al.* (2015) and Amir *et al.* (2013) that spectra band around 3200, 2900, 930, and 477 cm^{-1} are associated with

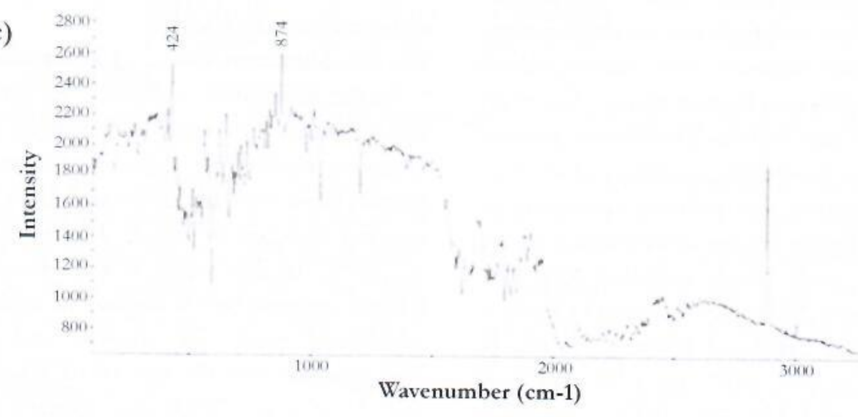
(a)


424
852
874
Intensity
Wavenumber (cm-1)

(b)


854
Intensity
Wavenumber (cm-1)

(c)


424
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Intensity
Wavenumber (cm-1)

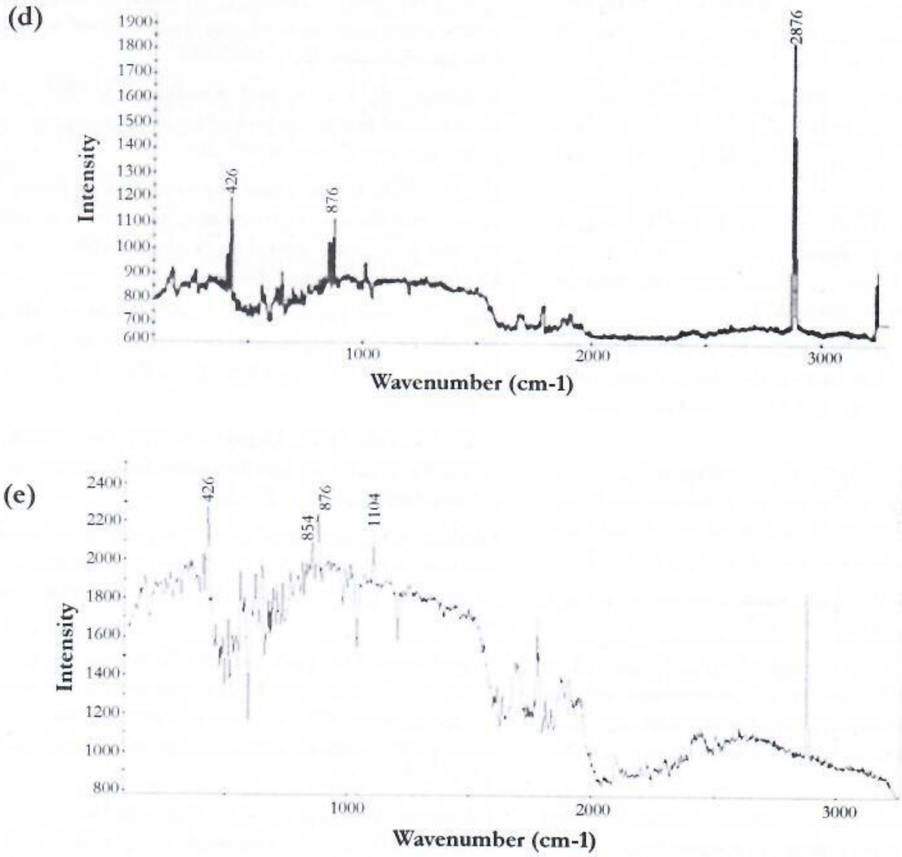

Fig. 1: Raman spectra of rice flours (a) *Bisalachi* (b) *Ebagachi* (c) *Lamiyatu* (d) *Majalisa* (e) *Walue*

amylose and amylopectin because these are the main components of starch.

4.0 Conclusion

Differences in the functional properties of the five Nigerian rice flours were recorded. For example, high water absorption index and swelling power were recorded for *Walue* and *Majalisa*, respectively. Similarly, higher peak viscosity, trough viscosity, breakdown viscosity, final viscosity and pasting temperature was recorded in *Walue*. *Majalisa* had higher onset temperature, peak temperature, conclusion temperature and enthalpy of gelatinization. Raman spectra of bands in the rice flours originated mainly from the vibrational modes of amylose and amylopectin.

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