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Characterization Of Carbohydrates-based Root and Tuber Flour Using Fourier Transform Infrared Radiation (FTIR)

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Abstract: Roots and tubers are starchy foods that give energy to human beings and therefore play an important role in diets particularly in developing countries. The information regarding the production and even the contents in these foods are not enough. The research is aimed to identify the functional groups in the produce of these crops using Fourier transform infrared spectroscopy. This method is used extensively in industry, where it is possible to find that the same compound is marketed by a number of manufacturers but the infrared spectra of the products are slightly different. The results depict that all the samples (cocoyam, yam, cassava and potato) have contents of amides, carboxylic acids, carbohydrates with only cocoyam and yam having alkylhalide contents. Further studies are recommended to determine the nutritional value of the foods.

Keywords: Cocoyam, Yam, Cassava, Potato, FTIR

I. INTRODUCTION

Roots and tuber crops are important cultivated crops and remains among the staple energy sources second to cereals generally in tropical regions in the world (Anoma & Kumar, 2016). On a general note, plants producing starchy roots, tubers and others provide good nutrition to humans. These plants play an essential role in the diets in developing countries in addition to usage as animal feeds and also in starch, alcohol, fermented foods and beverages production in manufacturing companies [Food and Agricultural Organisation (FAO), 1990]. These tubers which could be yam, potatoes sweet potatoes and so on are used as raw materials for different variety of foods in households and in industrial applications. The contribution of crops in energy supply in different populations varies from one country to another. This relative importance is evident through a country's annual global production. Regionally, Asia is the main producer followed by Africa, Europe and America. Asia and Africa produced 43 and 33% respectively out 836 million tonnes while other regions produced 24% (Anoma & Kumar, 2016). The crop's agronomical advantages such as ease and flexibility of cultivation, high productivity, tolerance to drought and its ability to grow well on relatively poor soil has made it rapidly and extensively adaptable. With this researchers are devoted on researches to provide ways of preventing and controlling these pests and diseases, modern system of production, products that could be obtained from the crops and even the systematic ways of identifying the contents from the products. Fourier transform infrared spectroscopy is a reliable means of detecting the functional groups in organic and inorganic materials. This research is therefore designed to study the functional groups of flour of these produce using Fourier transform infrared spectroscopy.

Infrared spectroscopy is a technic that can be used to detect the functional groups present in a materials, and the information can be obtained on the proximity of one group to another. In some cases it is also possible to give data on the amount of sample present. The atoms in molecules are not static, but vibrate about their equilibrium positions, even in the solid state. Each atom vibrates with a frequency which depends on its mass and the length and strength of its bond. Molecular vibrations are stimulated by bonds absorbing radiation of the same frequency as the natural frequency of vibration of the bond (ie in the range $1.20 \times 10^{13} - 1.20 \times 10^{14}$ Hz) which is in the infrared region of the electromagnetic spectrum. Absorption is usually quoted in wavenumbers (cm^{-1}) which is the reciprocal of wavelength in cm (Arun, & Bahl, 2014).

II. LITERATURE REVIEW

Infrared radiation is another name for heat. Infrared radiation (IR), or Infrared light, is a type of radiant energy that is invisible to human eyes but that we can feel as heat. All objects in the universe emit infrared radiation above absolute zero (Adelekan, 2010). When infrared radiation interacts with the molecules of the matter, it can be reflected, transmitted

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or absorbed. If absorbed, it cause the chemical bonds in the material to vibrate. The absorbance of the infrared occurs due to the presence of chemical bonds in that material. The functional groups within the molecules tend to absorb infrared radiation in the same wavenumber range, regardless of the structure of the rest of the molecule the functional group is in. As such, relationship between the wavenumbers at which a molecule absorbs infrared radiation and its structure exists (Gunjan, 1998). This relation allows the structure of unknown molecules in a particular matter to be identified from the infrared spectrum of the molecule. Therefore Infrared spectroscopy can be used to detect the functional groups present in a sample, and information can sometimes be obtained about the proximity of one group to another. In some cases it is also possible to give data on the amount of sample present (Szymanki, 1964). In addition to the chemical structures, infrared spectra can provide quantitative information as well, such as the concentration of a molecule in a sample.

Infrared spectrum is a plot of infrared radiation intensity versus wavenumber (Stewart, 1970). Traditionally, infrared spectrum is plotted with high wavenumber on the left and low wavenumber on the right. Looking from left to right in an infrared spectrum connotes looking from high energy to low energy. Infrared spectroscopy is the study of the interaction of infrared light with the matter (Garcia-Alvarez *et al.*, 2000). Light like other electromagnetic waves is made of electric and magnetic waves and the two waves are perpendicular to each other. The electric part of the light is the electric vector, which interacts with molecules in matter. The wavenumber is the reciprocal of the wavelength, also the measure of the number of waves and is mostly reported in centimetres (Stewart, 1970). FTIR is remained the main tool to identify the functional compounds present in foods.

Reginold (2015), in his research reported that the peaks at 2931 cm−1 are always attributed to with asymmetric and symmetric stretching modes of alkane C-H. While in the fingerprint region of 860–1080 cm−1 shows the alkane C-C and anhydrides C = O. He went further to state that 1539.20 cm-1 in his result corresponds to aromatic C=C bending. Monika *et al.* (2018) observed the characteristic differences in the FTIR spectral analysis for natural honeys and related the differences to the content of carboxylic acids in different types of honey resulting from the floral origin, geographic location and possible environmental pollution. Similarly as for alcohols, the O–H stretching vibration band in carboxylic acids is very broad and occurs in the range of 3300-2500 cm^{-1} with the maximum at 3000 cm^{-1}. This lies in the same area as the stretching vibration region for carbon and aromatic C–H groups. Therefore, carboxylic acids are characterized by an irregular character of absorption in 3300-2500 cm^{-1} with a wide range of the O-H stretching vibration band for C-H. Furthermore, the strong hydrogen bonds present in dimeric carboxylic acids are the reason for the significant extension of the band stretching vibration of the OH group.

According to Reginold (2019), when comparing the germinated pearl millets, 18 functional compounds in a tray drier were identified. The asymmetric stretching frequencies for aqueous carboxylates are normally between 1540 to 1650 cm−1 while the stretching vibration of amines (K-N) substituents is in the region from 1080.14 and the carboxylic acids (C-O) groups falls between 1155 to 1244.

Muhamad *et al.* (2019), emphasized that their method successfully classified the honey as authentic or fraudulent based on the FTIR spectra. To authenticate the honey, they formed two classes: Real honey and fake honey. The wavelengths that can best differentiate between these two classes correspond to four regions: 1600-1700 cm^{-1}; 1175-1540 cm^{-1}; 940-1175 cm^{-1}; and 700-940 cm^{-1}. Similarly, for classification purpose, they formed two classes: *Apis* spp. and *Tetragonula* spp and concluded that the wavelength region that can best classify the samples as belonging to the *Apis* spp. or *Tetragonula* spp. class is explicitly within the range of 1600-1700 cm^{-1}.

III. MATERIALS AND METHOD

In this work, Cocoyam, yam cassava and potato are obtained from local farmers. They is peeled, cut in to pieces, washed and dried under the sun. They were grinded by using mortar and pestle to fine powder. The powders were taken to laboratory for FTIR. FTIR spectroscopy with wavelengths ranging between 500 and 4000 cm^{-1} as an analysis method, which is relatively less expensive was used. The spectra of of all the samples were obtained. The FTIR machine used for this research is FTIR-8400S at the Central Research Laboratory of Kebbi State University of Science and Technology Aliero.

IV. RESULTS AND DISCUSSION

FTIR remained another reliable means of assessing food products. It reveals the presence of functional groups in them. FTIR analysis of samples were successfully carried out and the result discussed. The equation used for calculation was that illustrated by Arul and Bahl (2014), the wavenumber of a light is proportional to its energy as follows:

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E = hcL [1]

Where

E = Light energy
c = The speed of light (3 x 10^8 meters/second)
h = Planck's constant (6.63 x 10^{-34} Joule- second)
L = Avogadro constant (6.02 x 10^{23} mol^{-1}).

A. Cocoyam

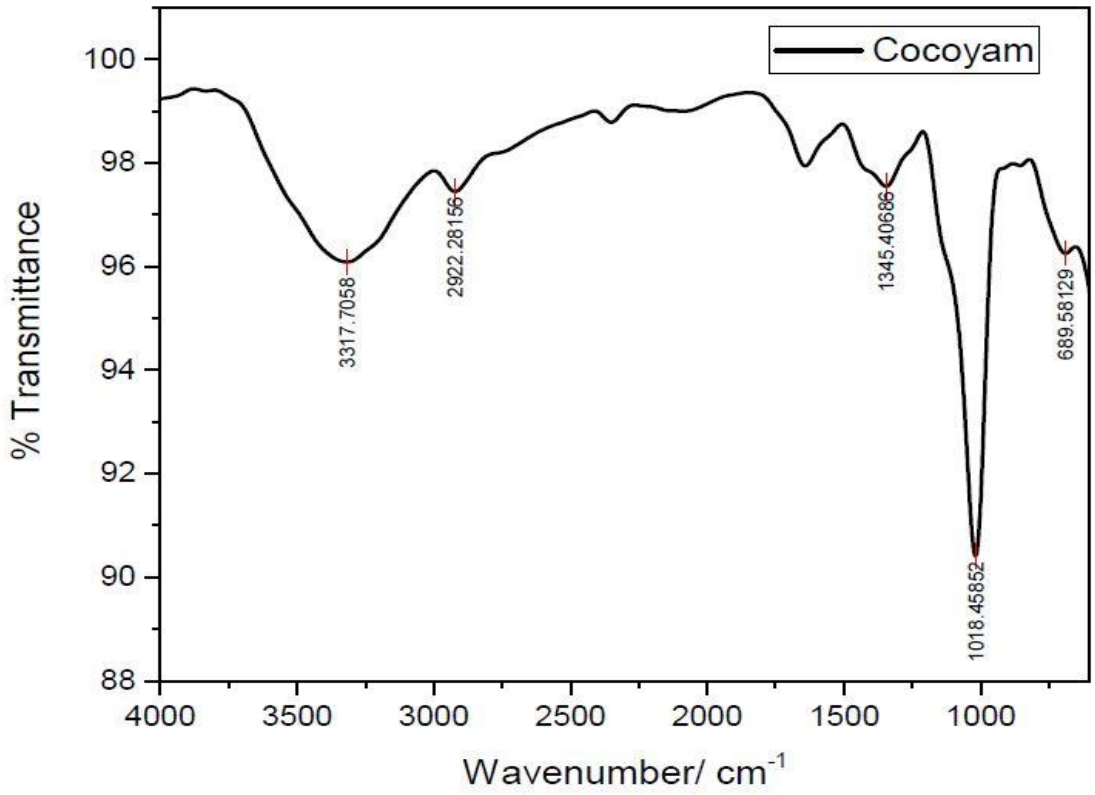

Fig. 1 FTIR Spectrum for Cocoyam Flour

Figure 1 depicts the spectrum for Cocoyam. Transmittance in percentage against wavenumber per centimeter. It has about seven peaks indicating different functional groups. The transmittance in other hand is indicating the level of infrared light transmission at a particular wavenumber. The bands obtained are 3317.71 (broad shape and weak intensity), 2922.28, 1345.41 (broad shape and weak intensity), 1018.46 (sharp shape and strong intensity) and 689.58 (broad shape and weak intensity). The highest transmittance is 99.1 % and the lowest transmittance is 90 %.

TABLE 1 INFRARED ENERGY ABSORPTION AND FUNCTIONAL GROUPS IN COCOYAM FLOUR

S/N	Wave number (1/cm)	Wavelength (m)	Frequency (GHz)	Energy (J/mol)	Functional group
1	3317.71	0.0301	9.9	3.98	Amides (N-H)
2	2922.28	00342	8.7	3.50	Carboxylic Acids (O-H)
3	1345.41	0.0743	4.0	1.61	Nitro (N=O)
4	1018.46	0.0982	3.0	1.24	Amine (C-N)
5	689.58	0.1450	2.0	0.83	Alkyl Halide (C-Cl)

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From table 1, each wavenumber has its corresponding wavelength, frequency and functional groups. The functional groups are determined based on the wavenumbers. Each wavenumber corresponds to a particular frequency that is absorbed by a molecule. The absorption band 3317.71 corresponds to bending vibration of Amides (N-H). 2922.28 corresponds to stretching vibration of Carboxylic Acids (O-H). The band at 1345.41 corresponds to Nitro (N=O) group and 1018.46 corresponds to Amine (C-N) bending vibration referring to carbohydrates contents. Similarly the band at 689.58 corresponds to stretching vibration of Alkylhalide (C-CL). The results agrees with that of Reginol *et al*. (2015) who studied the functional group of *Jamun* Pulp dried in Cross flow drier and reported similar result. Amides and carboxylic acids indicates the presence of proteins.

B. Yam

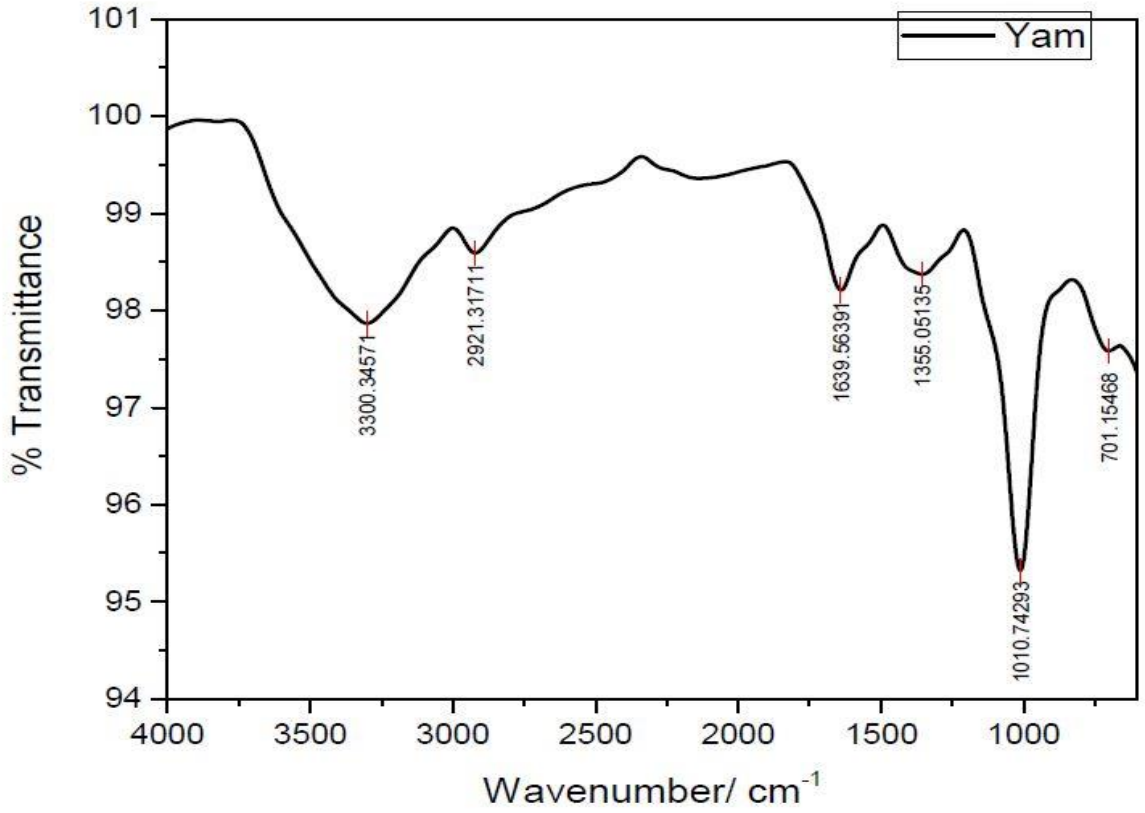

Fig. 2 FTIR spectrum for Yam

Figure 2 depicts the spectrum for Yam flour. Transmittance in percentage against wavenumber per centimeter. It has about six peaks indicating different functional groups. The transmittance in the other hand is indicating the level of infrared light transmission at a particular wavenumber. The bands obtained are 3300.35 (broad shape and weak intensity), 2921.32 (broad shape and weak intensity), 1639.56 (broad shape and weak intensity), 1355.05 (broad shape and weak intensity), 1010.74 (sharp shape and strong intensity) and 701.15 (broad shape and weak intensity). The highest and lowest transmittances are 99.8 and 95.2 % respectively.

TABLE 2 INFRARED ENERGY ABSORPTION AND FUNCTIONAL GROUPS IN YAM FLOUR

S/N	Wave number (1/cm)	Wavelength (m)	Frequency (GHz)	Energy (J/mol)	Functional group
1	3300.35	0.0303	9.9	3.95	Amides (N-H)
2	2921.32	0.0342	8.7	3.50	Carboxylic acid (O-H)
3	1639.56	0.0609	4.9	1.96	Alkenes (C=C)
4	1355.05	0.6449	4.6	0.18	Nitro (N=O)
5	1010.74	0.0989	3.0	1.21	Amine (C-N)
6	701.15	0.1426	2.1	0.84	Alkyl Halide (C-Cl)

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Table 2 depicts the functional groups in Yam flour. The functional groups are determined based on their wavenumbers. Each wavenumber corresponds to a particular frequency that is absorbed by a molecule. The absorption band 3300.35 cm^{-1} corresponds to bending vibration of Amides (N-H) indicating the presence of proteins, 2921.32 corresponds to stretching vibration of Carboxylic acid (O-H). The band at 1639.56 and 1010.74 cm^{-1} corresponds to bending vibrations of Alkenes (C=C) and Amines (C-N) respectively indicating the presence of carbohydrates. The bands at 1355.05 and 701.15 cm^{-1}corresponds to Nitro (N=O) and Alkylhalide (C-CL). Similar results were identified in Reginol *et al*. (2019) when he studied functional group analysis of germinated millets and legumes. Amides and carboxylic acids indicates the presence of proteins.

C. Cassava

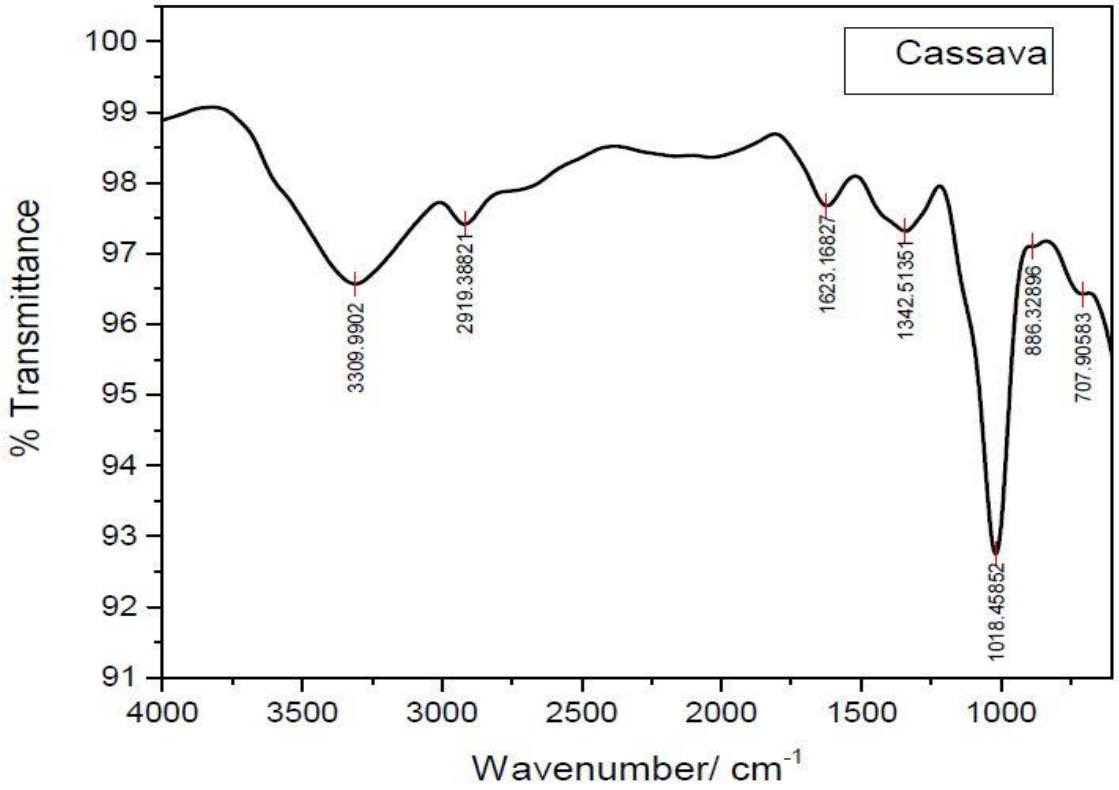

Fig. 3 FTIR spectrum for cassava flour.

Figure 3 depicts the spectrum for cassava flour. Transmittance in percentage against wavenumber per centimeter. It has about seven peaks indicating different functional groups. The transmittance in the other hand is indicating the level of infrared light transmission at a particular wavenumber. The bands are 3309.99 (broad shape and weak intensity), 2919.39 (broad shape and weak intensity), 1623.17 (broad shape and weak intensity), 1342.51 (broad shape and weak intensity), 1018.46 (sharp shape and strong intensity), 886.33 (broad shape and weak intensity) and 707.91 (broad shape and weak intensity). The highest and lowest transmittance are 98.5% and 92.5% respectively.

TABLE 3 INFRARED ENERGY ABSORPTION AND FUNCTIONAL GROUPS IN CASSAVA FLOUR

S/N	Wavenumber (1/cm)	Wavelength (m)	Frequency (GHz)	Energy (J/mol)	Functional Groups
1	3309.99	0.0302	9.9	3.96	Amides (N-H)
2	2919.39	0.0343	8.7	3.49	Carboxylic acid (O-H)
3	1623.17	0.0616	4.9	1.94	Alkenes (C=C)
4	1342.51	0.0745	4.0	1.61	Nitro(N=O)
5	1018.46	0.0982	3.1	1.22	Amine (C-N)
6	886.33	0.1128	2.7	1.06	Alkane (C-C)
7	707.91	0.1413	2.1	0.84	Alkyl Halide (C-Cl)

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Table 3 depicts the functional groups in cassava flour. The functional groups are determined based on their wavenumbers. Each wavenumber corresponds to a particular frequency that is absorbed by a molecule. The absorption band 3309.99 cm^{-1} corresponds to stretching vibrations of Amides (N-H) confirming proteins contents and 2919.39 corresponds to Carboxylic acid (O-H). The bands at 1623.17, 1342.51, 1018.46, 886.33, 707.91cm^{-1} corresponds to Alkenes (C=C), Nitro (N=O), Amines (C-N) bending vibration referring to carbohydrates contents and Alkane (C-C) and Alkyl Halide (C-Cl) respectively. The results is in agreement with that of Adelekan (2010). Amides and carboxylic acids indicates the presence of proteins.

D. Potato

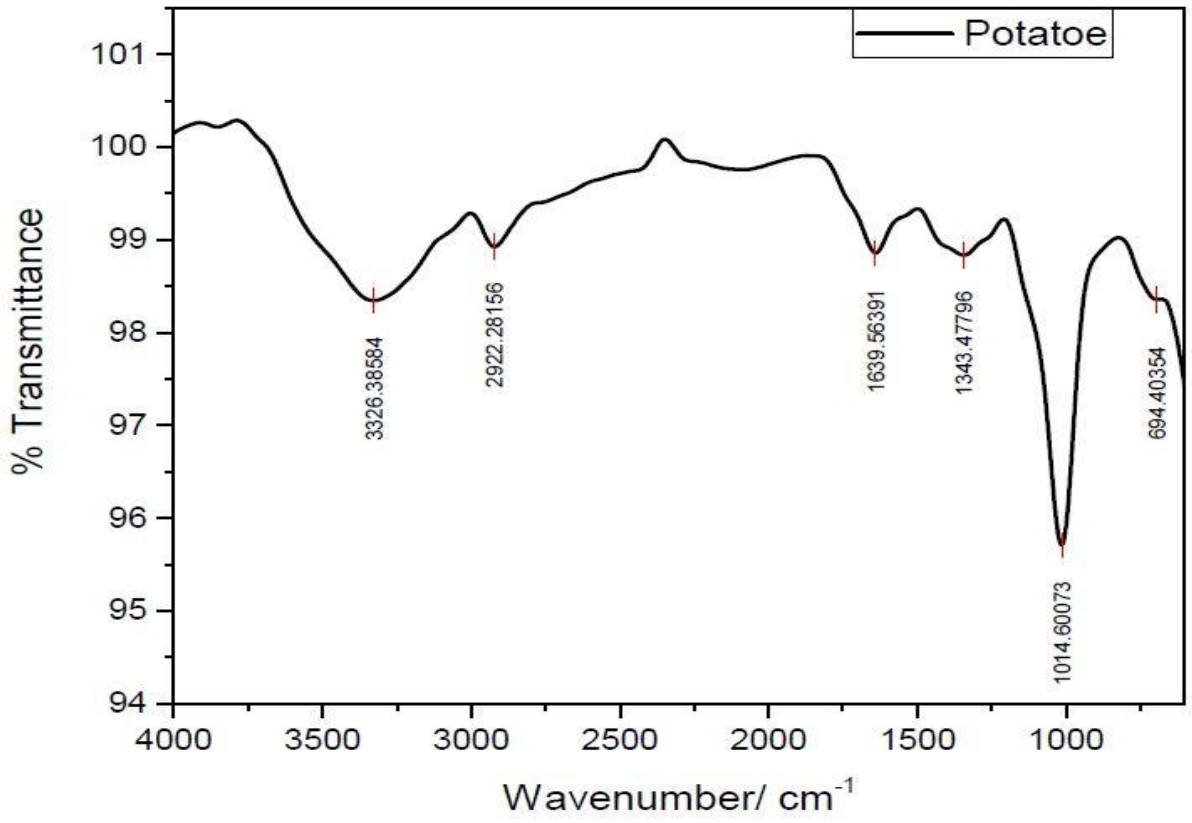

Fig. 4 FTIR spectrum for potato flour

Figure 4 depicts the spectrum for potato flour. Transmittance in percentage against wavenumber per centimeter, it has about six peaks indicating different functional groups. The transmittance in the other hand is indicating the level of infrared light transmission at a particular wavenumber. The bands are 3326.39 (broad shape and weak intensity), 2922.28 (broad shape and weak intensity), 1639.56 (broad shape and weak intensity), 1343.48 (broad shape and weak intensity), 1014.60 (sharp shape and strong intensity) and 694.40 (broad shape and weak intensity). The highest and lowest transmittances are 100.1 % and 96% respectively.

TABLE 4 INFRARED ENERGY ABSORPTION AND FUNCTIONAL GROUPS IN POTATO

S/n	Wavenumber (1/cm)	Wavelength (m)	Frequency (GHz)	Energy (J/mol)	Functional Groups
1	3326.39	0.0300	10.0	3.99	Amide (N-H)
2	2922.28	0.0342	8.7	3.47	Carboxylic acid (O-H)
3	1639.56	0.0609	4.9	1.95	Alkene (C=C)
4	1343.48	0.0744	4.0	1.59	Nitro (N=O)
5	1014.60	0.0985	3.0	1.19	Amine (C-N)
6	694.40	0.1440	2.0	0.79	Alkyl halide (C-Cl)

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From table 4, the functional groups, wavenumber and frequencies of absorption are determined. Each wavenumber corresponds to a particular frequency that is absorbed by the molecule. The absorption band 3326.39 corresponds to Amides (N-H), 2922.28 corresponds to Carboxylic acid (O-H), 1639.56 corresponds to Alkenes (C=C), 1343.48 and 1014.60 corresponds to Nitro (N=O) and Amine (C-N) bending vibration of the medium bond respectively referring to carbohydrates contents, and 694.40 corresponds to Alkyl halide (C-Cl). The results is in agreement with Regional *et al*. (2015). Amides and carboxylic acids indicates the presence of proteins.

V. CONCLUSION

The fact that functional groups give absorptions at particular frequencies can be used to show the purity of a sample. Contamination owing to solvent residues or by-products will show absorptions not observed in the pure compound. This is used extensively in industry, where it is possible to find that the same compound is marketed by a number of manufacturers but the infrared spectra of the products are slightly different. This happens in the pharmaceutical industry, particularly, where the infrared spectrum of a drug or its formulation is often included in its patent. The results depict that all the samples (cocoyam, yam, cassava and potato) have contents of amides, carboxylic acids, carbohydrates with only cocoyam and yam having alkylhalide contents.

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BIOGRAPHY

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