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Analysis of Thermal and Physical (Mechanical) Properties of Local Fruits and Vegetables in Wukari, Taraba State, Nigeria

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ABSTRACT

I*n this research,physical methods have been used to analyzed fruits: black berry (Vitex Doriana), Shea butter (Vitellaria Paradixa), Bush Fig (Ficus sur), Wild Custard Apple (Annona Senegalensis); Vegetables: Drumstick tree (Moringa oleifera), Zobo drink or Roselle (Hibiscus Sabdariffa) and Beans leave (Phaseolus vulgaris). The pH, density (ρ) , thermal conductivity (K), specific heat capacity (c), latent heat capacity (L_f), thermal diffusivity (Td), moisture content(MC), and the total solid (Ts) were determined. The average mechanical properties of the samples are: pH (5.48), density (435.06Kg/m^3), K (0.53JS m^3), c (3.60 J/kgK), L_{hf}(2585.61J/Kg), Td (3.89m^2s^{-1}), MC (76.77 %) and Ts is (23.25%). The following samples have the highest properties among others: Shea butter has pH (6.81), Wild Custard Apple has ρ (600Kg/M^3), beans leave has K (0.5642 JS M^3), beans leave has c (3.79J/kg K), beans leave has L_f (282840.00.J/kg), black berry Td (5.8802m^2s^{-1}), beans leave has Mc (84.43 %) and bush Fig has Ts (34.00%). The beans leave has the 50% highest property while other samples have the other 50% of the properties. The pH were acidic, K were lower than that of water, Td were higher than that of water, c and L_f were very high, the TS were high and MC were very high which make the sample perishable. To preserve these samples, their moisture contents have to be reduced. A lot of heat will be required to heat or cool these samples, because they are poor conductors of heat.*

Keywords: *Thermal Property, Physical Property, Fruits, Vegetables*

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1. INTRODUCTION

Fruits and vegetables are essential in every day dietary. It is recommended that individual should include fruits and vegetable in every meal. This is because of their importance: protection medicinal and healing power etc.

The process of pH balancing the body starts with diet and nutrition, including adequate hydration and eating a higher percentage of alkaline foods. As a general rule, your diet should consist of 60 percent alkaline-forming foods and 40 percent acid-forming foods, Core One Health, (2011)[1]Acid foods are foods that contain enough acid that have a pH of 4.6 or lower. They include fruits, pickles, sauerkraut, jams, jellies, marmalades, apple, canned guava, honey, pineapple, banana, grapes, and fruit butters etc.

Low-acid foods have pH values higher than 4.6 up to 6.9. Non-acidic or alkaline foods have pH values of 7.0 or greater. They include red meats, seafood, soya beans, poultry, milk, and all fresh vegetables. Most mixtures of low-acid and acid foods also have pH values above 4.6 unless their recipes include enough lemon juice, citric acid, or vinegar to make them acid foods,PickYourOwn.org, (2016)[2].

Body emotions greatly influence the body's pH. Joyous, happy, love-filled emotions tend to create alkaline-forming chemical reactions in the body. Conversely, negative emotions such as anger, fear, jealousy, and hate create acid-forming chemical reactions in the body (Core One Health (2011) [1].

These fruits are not commonly consumed in the northern Nigeria, like Taraba state, Plateau state etc.
pH is a numeric scale used to specify the acidity or basicity of an aqueous solution, Bates R. G (1973)[3].
pH is defined as the `logarithm to base ten of the reciprocal of hydronium concentration (2012)
Mathematically,
pH = – log [H_3O^+] -------------------------------- (1)
[4].
According to mass action law, the product of the Concentrations of H+ and OH- ions are always constant. That is,
(H+)(OH-) =10^{-14}.. (2a)
By taking the negative logarithms of both sides, equation (2a) becomes
pH + pOH = 14.. (2b)
[5]
pH is measured in units of moles per liter (mol/Lt).

pH measurements are important in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering, chemical engineering, nutrition, water treatment & water purification, and many other applications, Aishwarya Jha B.A. (2015)[6]. pH is also very important in the field of Physics and other sciences.
The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode. It usually has a glass electrode plus a calomel reference electrode, or a combination electrode, Richard C., et al (2006) [7]. Frequent calibration with solutions of known pH, perhaps before each use, ensures the best accuracy result.
Fruits and vegetable are very essential in our daily dietary. They are needed because, of their high components such as vitamins, their healing power, protection (immunity), digesting ability, energy, and fiber contents in living things. Though fruits and vegetables are mostly used as food, they are also use as medicine in curing many diseases.
Fruits and vegetables are universally promoted as healthy. The Dietary Guidelines for Americans 2010 recommend that one to make one-half of your plate fruits and vegetables. Myplate.gov also supports that one-half the plate should be fruits and vegetables. Fruits and vegetables include a diverse group of plant foods that vary greatly in content of energy and nutrients, Joanne L., et al (2012) [8].
Daily intake of fresh fruit and vegetable might be beneficial for the prevention and as therapeutic regime for cardiovascular complications, Adebawo, O.O., et al (2007) [9].
Moisture content is one of the most commonly measured properties of food materials. It is important to food scientists for a number of different reasons: Legal and Labeling, Economic, Microbial Stability, Food Quality and Food Processing Operations. D. Julian Mc Clements, (2003) [10].It is therefore important for food scientists to be able to reliably measure moisture contents. A number of analytical techniques have been developed for this purpose, which vary in their accuracy, cost, speed, sensitivity, specificity, ease of operation, *etc*. The choice of an analytical procedure for a particular application depends on the nature of the food being analyzed and the reason the information is needed.
Density as an engineering property is used for quality assessment especially during seperation of intact quality fruits and vegetables (damage and rotten ones), Nwanekezi and Ukagu (1999)[11]. Kato (1996) [12] reported that the quality of water melon is related to its relative and solid density.
The solid content of food products are related to their food values. The greater the solid content (lower moisture content) of the fruits, the greater is it nutritious value, Ikegwu O.J. and Ekwu F.C., (2009) [13].

2. SAMPLE COLLECTION

2.1 Sample Collection/Source

The matured and ripped fruits were plucked from the trees of the samples fruits and vegetables for: (white custard apple (SFI), bush fig (SF2), shear Butter (SF3), black berry (SF4), and drum stick (SV5), zobo drink or Roselle (SV6) and bean leave (SV7), in Wukari local government, Taraba State.

3. LABORATORY WORK

3.1 Sample Preparation

The fruits and vegetable samples were washed with water. About 15g of the manually pilled fruits and vegetables with clean knife were weighed using a digital balance. The weighed samples were poured into amortar and grinded manually with a pestle into a fine paste.

3.2 Physical properties

3.2.1 For pH

The pH of the samples were determined using the pH meter of model no (HI 2214, HANNA), in Department of microbiology, Federal University Wukari. Frequent calibration with solutions (buffer solution) of known pH, were done before each measurement of pH, this is to ensure the best accurate reading. The electrodes of the pH meter were dipped into each of the solution of the samples in 500ml glass beaker, about 100 ml of water was added to both fruits and vegetables samples. The readings were taking every ten minutes. Each sample was taken two times. The average values of the samples were calculated for each fruits and vegetables.

3.2.2 For Density

The densities of the samples were determined using the simple method determination of density of irregular objects. 15g of each of the samples were weighed with spring balance as mass, m. The weighed samples were carefully placed/submerge into the Displacement Can (Eureka can). The volume of water displaced was read from the graduated cylinder. The densities of the object were calculated using the equation.

$Density\ (\rho) = \frac{Mass}{\text{Volume}} = \frac{M}{\text{V}}$ …………………………….. (3)

3.2.3 Moisture Content

The moistures content were determined by placing the samples in laboratory oven Kerro BL of model number NL9023A,at 105 ^{0}C for two hours tree times (trios), until constant mass were achieved. This was conducted in Department of Food Science and Technology, federal University Wukari. The moisture content was calculated using the formula:

Moisture content (M C) = $\frac{W1-W2}{W1-W}$ ………………………. (4)

Where

W1 = the weight of sample in kg of dish before it dried

W2 = the weight of sample in kg of dish when dried to constant mass

W3 = the weight of sample in kg of the empty dish

3.2.4 Total Solid (TS)

Total solids are the total dissolved solids (TDS) and total suspended solids (TSS) in water. It is generally measured in mg/L. That is a measure of material/sample remaining after all the water have been removed or evaporated. Mathematically, it is given by:

Total Solid (TD) = 100 – %moisture content (Mc) ………………………… (5)

It was calculated using equation (5)

3.3 THERMAL PROPERTIES

3.3.1 Thermal conductivity (K)

It is a measure of the ability of a substance to conduct heat. It is defined as time rate of flow normally through a unit cross-sectional area per unit temperature gradient. It is measured in watts per meter per Kelvin. The symbol for conductivity is λ or k, mathematically, thermal conductivity is giving by: K = $\frac{Q/A}{(\theta 2-\theta 1)/L}$ ………………………………………. (6)

Where K = constant for a given material known as the thermal conductivity of the material

Q = Heat flowing through per seconds ($JM^{-2}S^{-1}$)

A = Cross sectional area (m^2)

$\frac{(\theta 2-\theta 1)}{L}$ = Temperature gradient (KM^{-1})

The equation of Sweat, (1974) [14] was used for the calculation of thermal conductivity of the samples, as shown below.

K = 0.148 + 0.00493W ……………………………………………………… (7)

Where K = thermal conductivity ($JSM^{-1}\ ^0C$)

W = the moisture content (%) e

3.3.2 Specific Heat Capacity (c)

It is the quantity of heat required to raise the temperature of unit mass of substance by 1k. It S I unit is J/KgK. It related to mass and thermal heat capacity by:

c = Cm ……………………………………………………………… (8)

where,

c = specific heat capacity

C = thermal heat capacity
M = mass of the samples
The equation of Dickerson (1969) [15] was used to calculate the specific heat capacity (c) of the samples.
c = 1.675 + 0.025W ……………………………………………………… (9)
Where
c = specific heat capacity
W = moisture content
It increases as the temperature increases.

3.3.3 Thermal Diffusivity (α)

It is the measure of the ability of a substance to conduct or transfer heat. That is amount of heat passing normally per seconds through a material.

Mathematically it is the time rate of heat flow normally through a parallel –sided material per unit area per unit temperature gradient.

$\frac{dQ}{dt} = KA\frac{(\theta 2-\theta 10)}{L}$ ……………………………………………………… (10)

$\frac{\theta 2-\theta 1}{L}$ = temperature gradient
KA = constant

The equation of Lamb (1976) [16] and Lewis (1987)[17] were used in calculating the thermal diffusivity of the samples it is given by

$\alpha = \frac{k}{[\rho][c]}$ ………………………………………………………………… (11)

Where,
α = thermal diffusivity
k = thermal conductivity
c = specific heat capacity
p == density
It also increases as the temperature increases.

3.3.4 Latent heat (L)

It is the quantity of heat required to change a unit mass (1kg) of a substance from one state to another at a constant temperature. It S I unit is J/Kg. Mathematically it is given by

Q = mL ………………………………………………………………….. (12)

The equation of Lamb (1976) [15] and Lewis (1987)[16] were also used in calculating the latent heat of the samples. It is given by:

L = 3325W ……………………………………………………………… (13)

Where
L = latent heat (J/Kg)
W = moisture content (%)

4. RESULTS AND DISCUSSIONS

4.1 For Physical Properties of the Samples

4.1.1 Moisture Content

From table 4.1 below the moisture contents of the samples are greater than 60%. This makes the mathematical relations connecting the mechanical (physical and thermal properties) properties with moisture of fruits and vegetables content valid.

The fruits and vegetables have high moisture content value, this will make the fruits and vegetables suitable for spoilage by organism and agent to grow and multiply. Hence the fruits and veg tables are classified as highly perishable and cannot be preserved or store in an ambient temperature/conditions. These fruits and samples can be preserved by refrigerating and freezing, which required transfer of heat to achieve them.

For these fruits and vegetable to be preserved, their moisture content have to be reduce to the level that will make moisture unavailable for microbial growths. Themoisture content increases the total solid decreases.

4.1.2 For Density

From table 4.1, Bush Fig has the least density (250.00kg) while Wild Custard Applehas the highest density (600.00kg). This means that mass per unit volume (density) is least in figures and greatest in Wild Custard Apple.

This implies that for each of the fruits of equal mass white pawpaw will be enough to satisfy one, when one eats the same/equal mass per unit volume of Bush Fig and Wild Custard Apple.

4.1.3 pH

From table 4.1 (SV6), Zobo drink or Roselle has the least pH of 2.00 while the Shea butter(SF3) has the highest pH of 6.81. All the samples were acidic except sample number SF3 (Shea butter) which falls within neutral pH: of (6.81). SV5 (Drumstick tree) is strong acid (5.45), SV6 (Zobo drink) 2.00, is extremely acidic, SV7 (beans leave) 5.86, have moderate acidic, SF1 (Wild Custard Apple) 6.01 and 6.43 SF2 (Bush Fig) 6.43 are slightly acidic and SF3 (Shear butt) 6.81 has neutral pH.

4.1.4 Total Solid

The values of total solids of the samples were lower than other values of the physical properties, but greater than only the pH values, this means that the amount fruits and vegetable remaining after the removal of water in the samples were small. This is because the sample contains low dissolved particles in the fruits samples.

4.2 For the Chemical Properties of the Samples

4.2.1 Specific Heat Capacity

From table 4.2, the specific heat capacity was very high. This means that very large amount of heat will be required to heat or cool these fruits or vegetables, when heated and cool. This is because of large moistures content of these samples. Among the samples, beans leave will retain it temperature for a long time than other samples since it has the highest specific heat capacity

4.2.2 Thermal conductivity

From table 4.2, the values of thermal conductivity ranges from 0.4734 -0.5642 jM^{-1} C were low compare with that of water. This shows that they are poor conductors of heat. The low value was due to total dissolved solids in the samples. Furthermore, during refrigeration, evaporation and drying, the heat transfer (diffusion) of these fruits may be very low. This corresponds with the results of Ikegwu and Ekwu, 2009 [12].

4.2.3 Thermal Diffusivity

From table 4.2, the values of the thermal conductivity and diffusivity were low compare with other fruits and vegetables. It has a range of (2.4272-5.8802, M^2S^{-1}).The thermal diffusivity of the fruits and vegetables were higher than that of their thermal conductivity. This means that the samples will diffuse more than it can conduct. Therefore the diffusion of heat energy of these samples from one point to another is during thermal conditions, O. J Ikegwu and F.C. Ekwu [13].

4.2.4 Latent heat of fusion L_f

From the table 4.2, the values of latent heat of fusion has ranges from 22110.00 – 28284.05 (J/ Kg). The latent heat of fusion of the samples was very high, like that of specific heat capacity.

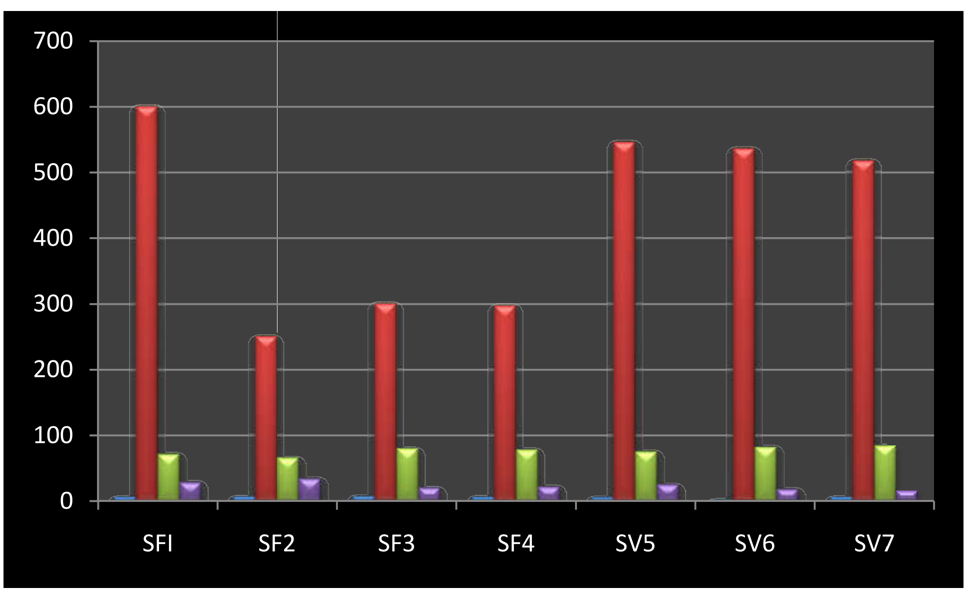

Figure 4.1 Bar chart shows the Physical Properties of the samples

Series1-Ph, Series 2-ρ, Series 3- Mc and Series 4-Ts
This shows that the quantity of heat energy required for these fruits and vegetables sample to change from one state to another will be very high. Wild custard pawpaw has the least L_f of 22110.00 J/kg while beans leave has highest the L_f of 28284.05J/kg.

From fig. 4.1, the bar chart, the increasing other of the physical properties: pH → Total solid (Ts) → moisture content (Mc) → density (ρ). That is the density is the highest among other physical properties while the pH has the least.

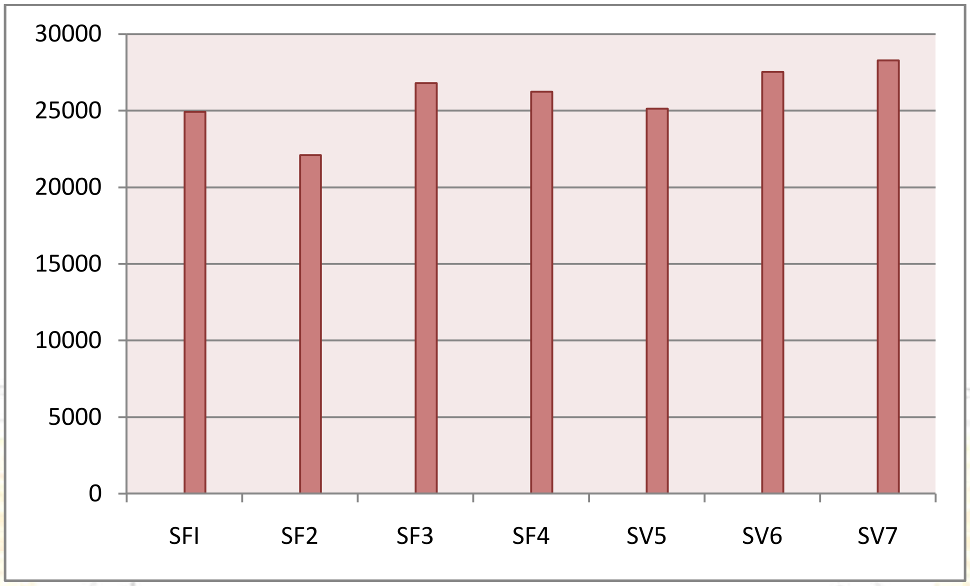

Figure 4.2 Bar chart shows the chemical Properties of the samples
Series1-L_f, Series 2-Td, Series 3- c and Series 4- K
From concerned figures, the increasing other of the chemical properties: thermal conductivity (K) → specific heat capacity (c) → Thermal diffusivity (Td) → latent heat of fusion (L_f). That is the latent heat of fusion is the highest among other chemical properties while thermal conductivity has the least.

Table 4.1 Physical properties of the samples

S/N	Sample No.	Mean values of pH (mol/l)	Density (ρ) [kg/m^3]	Moisture content (Mc) [%]	Total Solid(Ts)[%]
1	SFI	6.01	600.00	71.41	28.59
2	SF2	6.43	250.00	66.00	34.00
3	SF3	6.81	300.00	80.00	20.00
4	SF4	5.83	297.03	78.30	21.70
5	SV5	5.45	545.45	75.01	24.99
6	SV6	2.00	535.71	82.21	17.90
7	SV7	5.86	517.24	84.43	15.57

Table 4.2 Thermal properties of the samples

S/N	Sample No.	Thermal conductivity (K) [JS M^{-10}C]	Specific Heat capacity (c) [KJ/KgK]	Latent Heat of Fusion(L_f) [KJ/ Kg]	Thermal Diffusivity (Td) (x10-^{4}) [M^{2}S^{-1}]
1	SFI	0.5148	3.5350	24924.00	2.4272
2	SF2	0.4734	3.3250	22110.00	5.6950

3	SF3	0.5424	3.6750	26800.00	4.9197
4	SF4	0.5340	3.6325	26230.53	5.8802
5	SV5	0.5178	3.5503	25128.35	2.6739
6	SV6	0.5533	3.7303	27540.36	2.7688
7	SV7	0.5642	3.7858	28284.05	2.8813

KEYS Used:

SFI --------- Wild Custard Apple (AnnonaSenegalensis)
SF2 -------- Bush Fig (Ficus sur),
SF3 --------- Shear butter (Vitellaria Paradixa)
SF4 --------- Black berry (Vitex Doriana)
SV5 -------- Moringa (Moringa oleifera)
SV6 --------- Zobo drink or Roselle (Hibiscus Sabdariffa)
SV7 --------- Beans leave (Phaseolus vulgaris)

5. CONCLUSION

The pH values were acidic. Therefore, people are advice not to take only zobo drink (2.00 pH) (Roselle) often since it is acidic. If they insist, they should balance it with other fruits, vegetable or any food that is alkaline content. The moisture content was above 60%, that is, they are high. Also the total dissolve solid was also high. The samples have a good density. The thermal conductivity and thermal diffusivity were very low. The diffusion of heat energy of these samples from one point to another will be low during thermal conditions. A lot of heat will be required to heat or cool these samples. For these samples to be preserved, the moistures contents have to be reduced to lowers percentage, so that it will not perish. They are poor conductors of heat. The moisture content increases as the total solid decreases.

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