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Influence of Blanching on the Mechanical Properties of Solar Dried Aerial Yam and Water Yam

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Abstract
This work focuses on the influence of hot water blanching on the mechanical properties of solar dried aerial yam and water yam. This was done by solar drying some blanched and unblanched water yam and aerial yam at the same condition. The shear stress, hardness, modulus of elasticity, compressive strength, deformation at break, bio-yield, rupture energy, gumminess of the blanched water yam (BWY), unblanched water yam (UWY), blanched aerial yam (UAY) and blanched aerial yam (BAY) were determined using standard methods. The results show that blanching increased the shear strength of water yam from 3.094 to 3.536 N/mm^2 and from 4.739 to 4.86 N/mm^2 for aerial yam. Blanching decreased the hardness, rupture energy, modulus of elasticity and compressive strength of water yam and aerial yam. Bio-yield force increased on blanching from 262.5 to 304.5 N for water yam and decreased from443.5 to 231.5 N for aerial yam. The deformation at break increased for water yam on blanching but decreased for aerial yam on blanching. Gumminess also showed increase in value for both yams on blanching. The research result provides a theoretical basis and generated data for design of dryers and the material processing and handling.
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Keywords: Aerial yam, water yam, mechanical properties, blanching, solar drying

1. Introduction

Yams are monocotyledonous species and belong to the genus *Dioscorea*of the family *Dioscoreaceae*; which constitute a multi-species of crops that are essential for food, socio-cultural activities and income. Yams are essential food crops in West Africa, and other tropical countries including East Africa, Central Africa, the Caribbean, South America, South East Asia and India (Coursey 1967).

The economical part of yam is the tuber and is consumed roasted, fried, boiled, pounded or as flour used for baking and steaming for swallowing with soup. Aside from its nutritional value, yam has significant social and cultural significance, especially among the people of South-Eastern Nigeria (Sangoyomi, 2004). They are of very high nutritional value where it is a major source of carbohydrate, minerals, phosphorus, calcium, iron and vitamins such as thiamine, riboflavin and vitamins B and C (Okigbo & Ogbonnaya 2006)). Various species of yam have been employed in the treatment of some disease like*Diabetes Mellitus*, while some increase coronary flow and prevent high hypercholesteremia (Undie & Akubue 1986).

Yam has been extensively researched in the following areas; air drying characteristics (Sanful, et al 2015), effects of pre-treatment and drying on the functional properties (Sanful et al, 2013), physicochemical properties of processed aerial yam and sensory properties of paste (Kayode et al 2017), physicochemical properties and anti-nutritional factors of aerial yam flour (Jacques et al, 2016), the proximate, functional properties and phytochemical composition of pre-treated aerial yam flour (Ayo et al, 2018), Nutritive and anti-Nutritive Composition of the Wild (Inedible) Species of aerial yam (Ogbuagu 2008), kinetics and the drying conditions of two yam varieties (*Dioscoreaalata*

9506-021 and *Dioscoreaalata* 9506-027) (Ramiro et al 2012), nutritional properties of fourteen water yam cultivars. (Ogidi et al, 2017), measurement and modeling of the thin layer drying properties of water yam and white yam assisted by hot-water blanching (Uyigue & Achadu 2018), quality attributes of yam flour (Adejumo et al. 2013), developing a yam flour processing system (Okafor 2014) and changes in the carbohydrate constituent of yam tubers during growth (Fetuga et al. 1973. However, no work has been done on the mechanical properties of solar dried aerial yam and water yam. The poor knowledge of mechanical properties and effects of pre-treatments (blanching) on these yams, could have resulted into its misuse, mishandling and wastage of these food crops.

The use of traditional methods of drying such as sun drying to preserve food crops such as grains, fish, yam, potato, wood and other agricultural products has been in practice from the earliest time. It uses sun which is a free and renewable source of energy. The use of sun drying for large-scale industrial production, is limited due to damage to the crops by animals, birds and rodents, degradation in quality due to direct exposure to solar radiation, dew or rain, contamination by dirt, dust or debris(Tiwari 2016). This technique is also laborious and time consuming, so that crops have to be covered at night and during bad weather, and have to be protected from domestic animals' interference (Tiwari, 2016). The chance of infestation and growth of microorganism by insects due to non-uniform drying is also high. To eliminate this defects by sun drying methods, solar drying systems are employed. In this, the materials to be dried is protected in a closed system. .Numerous attempts have been made in recent years to harness solar energy for drying mostly to preserve agricultural produce and harness the benefit from the energy provided by the sun. It needs no energy during day time and is mostly beneficial to the small scale farmers who cannot afford the electricity or other fuel for drying and for remote areas that have limited power supply.

There is, therefore, the need to research on the use of solar dryer to study the influence of pre-treatment (blanching) on the mechanical properties of thisyam cultivar; aerial yam and water yam. It is imperative to determine mechanical properties of these food crops in order to improve the operation involved in processing of these products. Information on mechanical properties of agricultural produce is required in designing and fabrication of machines used for processing of agricultural materials. The properties which are useful during design must be known and determined at laboratory conditions (Frazer et al. 1976).

2.0 Materials and methods

2.1 Collection and preparation of aerial yam and water yam sample

The aerial yam sample was sourced from Afor Opi market in Nsukka local government area of Enugu state. The water yam was bought from Eke Awka market, Awka south local government area, Anambra state. The two yam species were identified in the department of crop science NnamdiAzikiwe University, Awka. The yam species were washed with clean water and spread in open to dry to avoid spoiling.

2.2 Blanching of the Samples

The two samples were cut into 2.0 mm size thickness with a mold designed for it. 100g each of the samples were weighed into a bowel containing boiled water at 80^{o}C. The samples were left in the hot water for 10 minutes. The water was removed and the new weight of the sample taken.

2.3 Solar Drying

Following Fauziah et al. (2013) methods, the experiments were conducted at airspeed of 2.5m/s. The raw water yam and aerial yam samples were cut into 30 X 20 X 4mm with a mold designed for the purpose and put in the drying chamber of the solar dryer with air speed set at 2.5m/s and allowed to dry to constant weight. The samples were allowed to dry to a constant weight with the weight taken at interval 10 minutues. The solar relative humidity and solar radiation was taken daily. The whole procedures were repeated for the blanched water yam and aerial yam. The resulting dried sample was put in an air tight container for further use.

2.4 Mechanical properties

2.4.1 Shear strength

The universal testing machine (UTM) was used to determine the shear strength. The methods involved fixing the shear spindle of the machine to the shear accessory of the UTM. The sample to be tested was fixed into the shear chamber of the UTM while attaching the revolving graph to the graph drum of the UTM. Mercury was used as the working fluid. The working fluid was zeroed and gradual and continuous load was applied to the sample until the mercury returns back to zero. The corresponding load shown on the graph was recorded. Using the area of the shear spindle and the shear force recorded, the shear strength was then determined.

2.4.2 Brinnel hardness test.

The brinnel hardness bulb tester (indenter bulb) of 5 mm diameter was used to replace the testing chamber. A constant load was chosen (for which all the samples must be subjected). The depth of indentation produced on the sample was recorded by the machine graph. The brinnel hardness number (HBN) formulae in Eq. (1) was applied to calculate the hardness strength.

$$\text{HBN} = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)} \quad (1)$$

Where; P is the constant axial load, d is the impression diameter (2mm), D is the depth of indentation (5mm), HBN is Brinnelhardnessstrength

2.4.3 Bio-yield and energy.

The sample to be tested was put on the compressive chamber of the testing machine with the graph fixed on the graph drum. Appropriate load spring was selected and applied gradually while the movement of the working fluid carefully monitored for the point of first failure. The bio yield force (force on the graph drum) was recorded. The rupture energy is a function of the maximum force the material (sample) can withstand prior to failure and its average deformation at the same point. This was also recorded on the fixed machine graph.

2.4.4 Compressive test: (Elasticity, deformation at brake, compressive strength).

The sample to be tested was placed in the compressive chamber of 40*40mm. It was fixed into the appropriate chamber with the working fluid returned to zero load/deformation. Gradual but continuous load was applied to the sample. The movement of the working fluid was monitored with the aid of an attached microscope. The pin button was pushed down to the slider to make the load/deformation graph of the material at a chosen interval. On the point of failure, the working fluid automatically returned to zero. The elasticity, deformation at break and compressive strength were then calculated from the plotted graph.

2.4.5 Gumminess

Gumminess which is also referred to as the separating force was determined by preparing the sample into colloidal form and pasting into the separating wooden buds. The joined wooden buds were placed into the tensile chamber for bio materials on the UTM. Gradual Loads was applied to the test sample and the loads that separate the pastes on the wooden buds was taken. The value of the corresponding force on the machine graph was recorded.

3.0 Results and discussion

3.1 Shear Strength

In engineering, shear strength of a food crop is the strength of the material against structural failure where the material or component fails in shear. It is the load that a material is able to withstand in a direction parallel to the face of the material, as opposed to perpendicular to the material surface.Tables 1 and 2show the mechanical properties of solar dried water yam and aerial yam, and solar radiation data during the experiment, respectively.

Fig. 1 shows the shear strength of the blanched aerial yam (BAY) and blanched water yam (BWY) were higher than the unblanched aerial yam (UAY) and unblanched water yam (UWY) with values of 4.86, 3.536, 4.739 and 3.094 N/mm^2, respectively. This differences could be attributed to the change in structural orientation of the samples during hot water blanching. It was observed that during drying, that blanched samples dried faster than the unblanched sample at the same condition. Some components of the yam samples were lost on blanching while there was some structural rearrangement of the internal structures of the samples that helped loosen the constituent moisture so that the water gets evaporated faster than the unblanched samples. The final weight of unblanched samples dried at the same condition was observed to be higher than that of the blanched sample.Similar result was reported by Shi et al. (2017)for *Artemisia selengensis*stalk, and Soliman et al. (2009) for wheat grain.

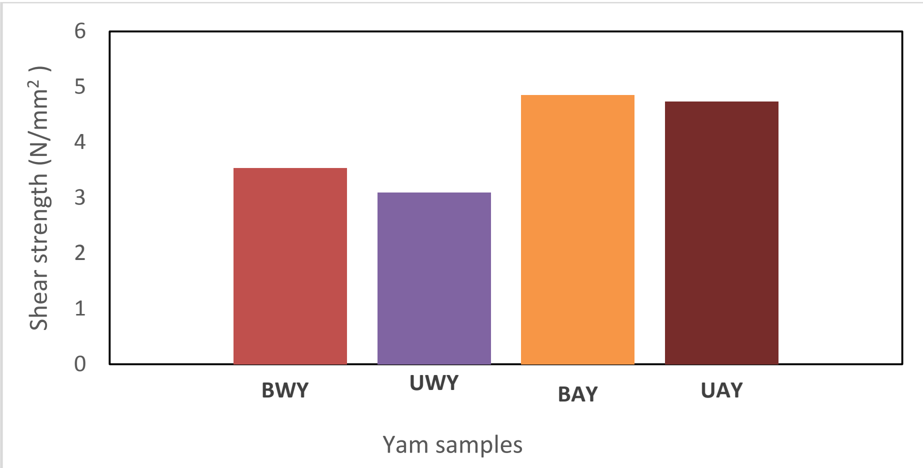


Figure 1. Shear strength of samples

3.2 Hardness

This is a term used to describe a measure of materials ability to resist localized plastic deformation and is estimated using an indentation test. This property is needed for the design of agricultural processing equipment to minimize breakage and wastage (Ryder 1996). The food crop's hardness is an important milling quality descriptor, according to which they are divided into soft or hard Fig. 2 shows BWY, UWY, BAY and UAY with corresponding values of 29.374, 30.064, 24.729 and 30.064 N, respectively showing that the unblanched products have a slightly higher value that the blanched products. The closeness in the values of hardness for all the samples (blanched and unblanched) show that water yam and aerial yam had tolerable properties appropriate for efficient industrial and food processing application .Ogbonnaya and Musliu (2010), Hruškova and Švecreported similar results for cowpea and wheat respectively.

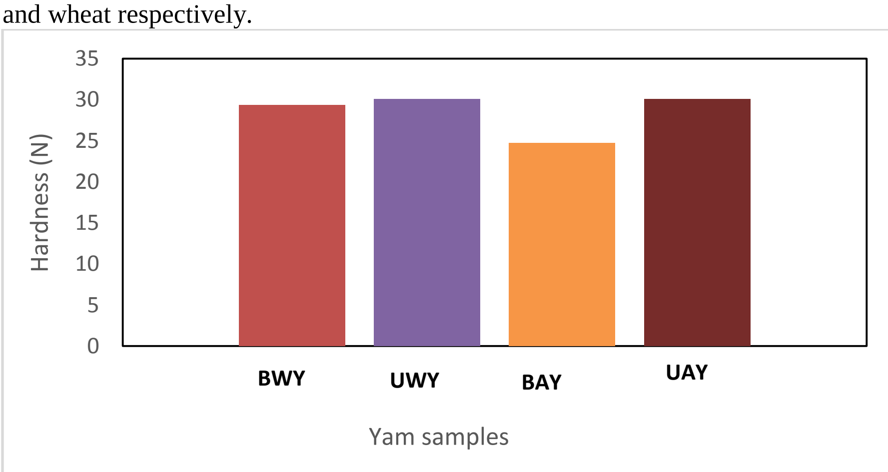


Figure 2. HBN of samples

3.3 Bio-yield point

Fig. 3 represents the bio-yield force of the blanched and unblanched samples. It could be observed that the bio-yield force of water yam increased with blanching from 262.5 N (UWY) to 304.5 N (BWY). However, the bio-yield force of aerial yam decreased with blanching from 443.5 N (UAY) to 231.5 N (BAY). The bio-yield force for aerial yam

(UAY) is higher than that of water yam (BWY, UWY) showing that it needs the highest stress to fail in its internal cellular structure. Aviara et al (2013) reported bio-yield point within the range obtained in this report.

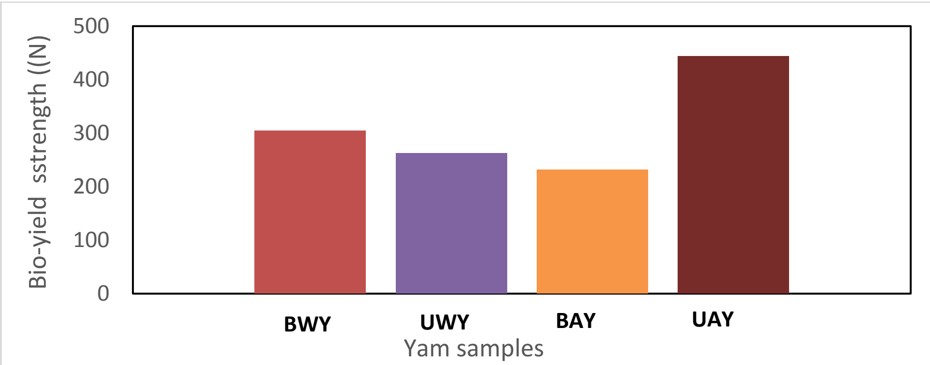


Figure 3. Bio-Yield of samples

3.4 The rupture energy

The rupture energy is the maximum energy absorbed by a material before initiating a rupture. Fig 4 shows that UAY needs 6.419 J of energy to initiate a rupture. This value represented the highest amount of energy amongst the samples to initiate a rupture. It shows that BWY, UWY and BAY need 1.250, 1.727 and 1.204 J of energy to initiate a rupture. It also shows that unblanched samples (UWY and UAY) had higher rupture energy than the blanched sample (BWY and BAY). This result shows that water yam and aerial yam had tolerable properties appropriate for efficient industrial and food processing application.

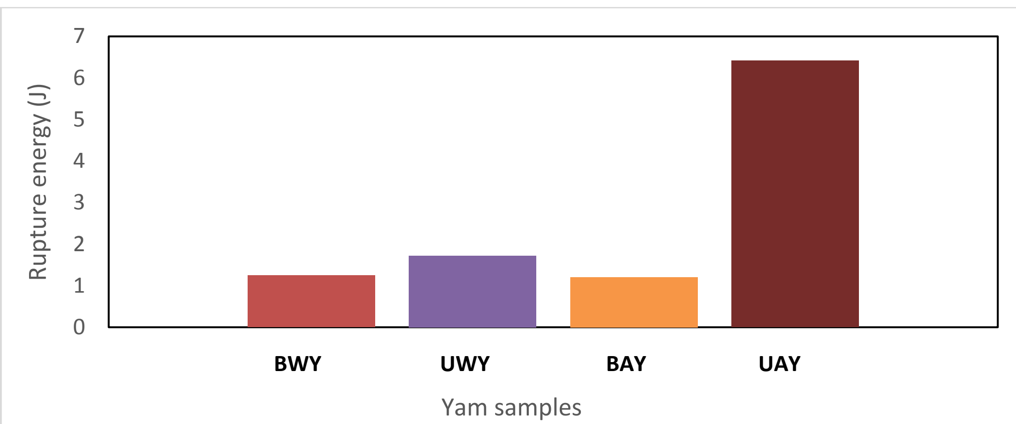
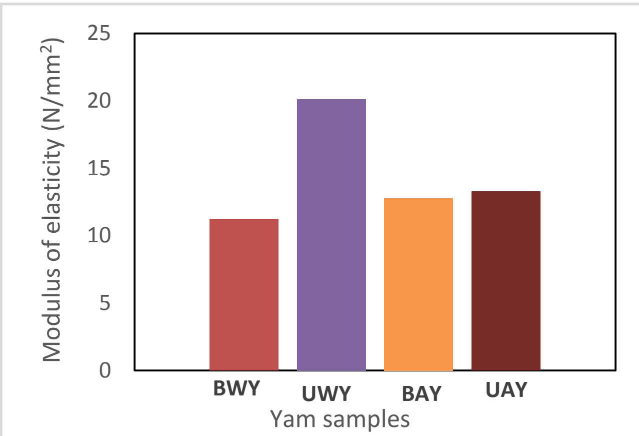


Figure 4. Rupture energy of samples

3.5 Modulus of elasticity and deformation at break

The modulus of elasticity is the property of a material that describes its stiffness and is, therefore, one of the most important properties of solid materials. The modulus of elasticity for BWY, UWY, BAY and UAY were given as 11.232, 20.125, 12.784 and 13.294 N/mm^2, respectively (Fig.5). The result showed that the unblanched samples (UWY, UAY) had a higher modulus of elasticity than the blanched samples (BWY, BAY).Fig. 6 represents the plot of deformation at break. It showed that BWY (3.125 N/mm^2) had a higher value than the UWY (2.75N/mm^2). However, UAY (6.5 N/mm^2) had a higher value than BAY (2.875 N/mm^2). Alteration of the internal structure of a material leads to alteration of the internal stresses and strains of the material. Increase inthe porosity of a material reduces the stiffness of the material structure and result in a lower elastic modulus. When the samples are exposed to heat treatment (blanching), the constituent moisture goes off leaving pore spaces in the internal cavity of the samples, this results to lower values of elastic modulus as evidenced in this report. Soliman et al. (2009) reported elasticity value of wheat grain between 19.002 to 46.602 N/mm^2 which is within the range obtained in this report.

Similar elastic modulus results were reported by Shi et al. (2017) for *Artemisia selengensis*stalk. Kayode et al (2018) reported similar result on deformation at break on aerial yam.



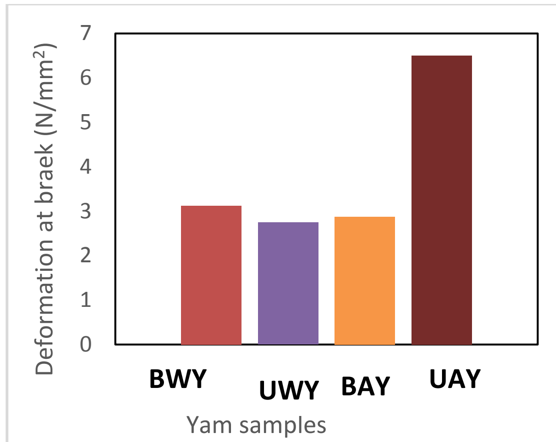


Figure 5. Modulus of elasticity of samplesFigure 6. Deformation at break of samples

3.6 Compressive strength

This is the maximum compressive stress which under a gradually applied load, a given solid sample can withstand without fracture. It is the resistance of a solid material to breaking under compression. Figure 7 represent the variation of compressive strength of BWY, UWY, BAY and UAY when applied to compressive loading. It shows UAY (2.469 N/mm^2) requires the highest amount of compressive stress to withstand fracture or deformation. It also showed that unblanched samples require more compressive stress to initiate a fracture. UWY needed 1.232 N/mm^2 as against 0.938 N/mm^2 for BWY, while UAY requires 2.469 N/mm^2 as against 1.048 N/mm^2 for BAY.

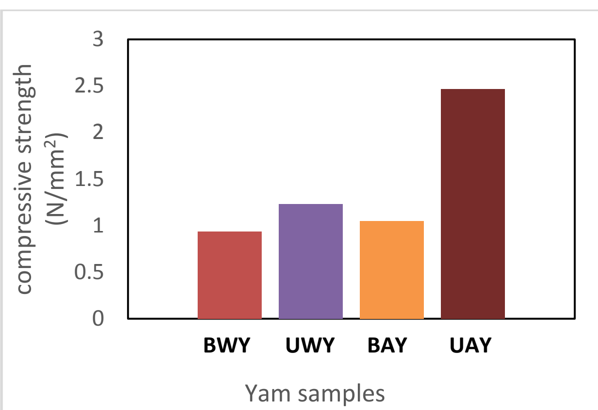


Figure 7. Compressive strength of samples

3.7 **Gumminess**

Gumminess is a characteristic of semisolid foods with a low degree of hardness and a high degree of cohesiveness. Figure 8 represent the plot of gumminess for a solar dried water yam and aerial yam. According to Table 1, blanched water yam and aerial yam presented higher values of gumminess than the unblanched samples. BWY and BAY had values of 9.9 and 13.85 N, as against 8.1 and 12.99 N for UWY and UAY, respectively. This could be as a result of the distortion in water starch bond that occurs during blanching which enhances starch to starch bond. Also during drying, blanched samples lose more moisture than the unblanched samples thus, resulting in higher starch concentration. Özge et al. (2018) reported similar result on onion drying.

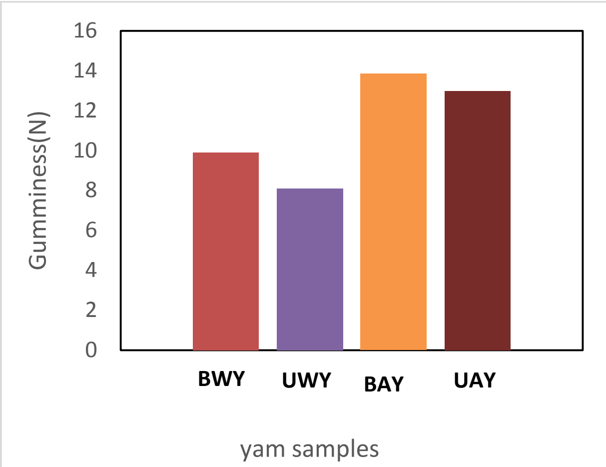


Figure 8. Gumminess of samples

Table 1: Mechanical properties of solar dried water yam and aerial yam

properties	BWY	UWY	BAY	UAY
shear force(N)	100.00	87.50	137.50	134.00
shear strength (N/mm^2)	3.53	3.09	4.86	4.74
HBN (N)	29.37	30.06	24.73	30.06
Bio-yield (N)	304.50	262.50	231.50	443.50
Energy (J)	1.25	1.73	1.20	6.42
Elasticity(N/mm^2)	11.23	20.13	12.78	13.29
Deformation at break (N/mm^2)	3.12	2.75	2.88	6.50
compressive force (N)	400.25	627.50	419	987.50
compressive strength(N/mm^2)	0.94	1.23	1.05	2.47
Gumminess(N)	9.90	8.10	13.85	12.99

Table 2: Solar Radiation data during the experiment

Period	Ave. Min Temp.(^{o}C)	Ave. Max.Temp. (^{o}C)	Ave. Relative humidity (%)	Ave. Solar Radiation(W/m^2)
	33.78	35.90	61.0	160.21
	34.27	36.15	63.0	165.21
May	31.65	32.08	61.5	162.39
	30.03	33.53	63.5	173.42
	31.34	34.59	64.0	161.09
	32.61	36.11	65.0	175.31
	31.64	33.04	67.5	151.32
June	34.01	35.24	65.0	154.23
	32.49	36.23	69.5	149.00
	31.84	35.22	65.0	143.67
	30.22	33.41	63.0	144.23
	31.34	34.61	68.0	147.32
July	32.28	35.50	67.5	137.23
	33.41	35.69	70.0	139.09

	30.31	33.29	65.0	135.62
	30.40	33.88	59.5	130.30
	33.28	35.29	61.0	132.40
August	32.41	36.49	60.0	133.99
	31.23	35.39	61.5	130.01
	34.12	36.01	59.5	129.45

4.0 Conclusion

The influence of blanching on mechanical properties of water yam and aerial yam dried with solar dryer showed that:

i. Shear stress and gumminess of both water yam and aerial yam increased on blanching.
ii. Blanching decreases the hardness, rupture energy, compressive strength and modulus of elasticity of both water yam and aerial yam

Bio-yield and deformation at break increase on blanching of water yam but decrease on blanching of aerial yam.

5.0 Recommendation

It is recommended to replicate the methodology of this work over a wider range of seasons and post-harvest age of yam samples. This is because the properties of the studied yam species are expected to vary over seasons of the year and post-harvest age of the yam species.

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Abbreviations

BAY: Blanched aerial yam
BWY: Blanched water yam
UAY: unblanched aerial yam
BWY: unblanched water yam

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