Journal of Advances in Biology & Biotechnology
6(3): 1-17, 2016; Article no.JABB.23189
ISSN: 2394-1081

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Assessment of Phenological Variability and Nutritional Value of the Underutilize Tropical Jackfruit *Artocarpus heterophyllus*' Frost. in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author GMU designed the study and performed the statistical analysis. Authors GMU, JOJ and MNE wrote the protocol and wrote the first draft of the manuscript. Authors GMU, UW and ISE managed the analyses of the study. Authors JOJ and MNE managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2016/23189
Editor(s):
(1) Rafael A. Cañas, Department of Molecular Biology and Biochemistry, Málaga University, Spain.
(2) Joana Chiang, Department of medical laboratory Science and Biotechnology, China Medical University, Taiwan.
Reviewers:
(1) Anonymous, University of Agriculture, Faisalabad, Pakistan.
(2) Edward Missanjo, Malawi College of Forestry and Wildlife, Dedza, Malawi.
(3) Chen-Chin Chang, University of Kang Ning, Taiwan.
Complete Peer review History: http://sciencedomain.org/review-history/14701

Original Research Article

Received 18th November 2015
Accepted 3rd February 2016
Published 20th May 2016

ABSTRACT

Aims: To assess the phenological variability that can help farmers identify Jackfruits and create awareness on the nutritional values of the underutilized tropical Jackfruit *Artocarpus heterophyllus* in Nigeria.
Study Design: The study was a survey and assessment of Jackfruits growing in situ in forest and home gardens where jackfruits ecotypes were identified growing wild under farmers' field conditions.

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Place and Duration of Study: The study was carried out in Cross River State, Nigeria for two seasons of 2013-2014. Collected fruit samples were analysed for mineral and nutritional compositions in the National Root Crop Research Institute laboratory Umudike, Abia State, Nigeria.
Methodology: Mature Jackfruit from Yala ecotype was carefully harvested from farmers field and taken to the National Root Crops Research Institute laboratory, Umudike Abia State for proximate (mineral and nutrient) composition analysis adopting the modified A.O.A.C methods of 2006. Data for phenological variability was obtained through measurements of leaf area (cm^2), leaf length (cm), seed length (cm), 100 seed weight (kg), seed chamber length (cm), seed chamber width (cm), number of seeds per pod, stem diameter (cm), fruit width (cm), fruit weight (kg) and fruit chamber length (cm). Ecotypes location coordinates were read using GPS Etrex model. Qualitative data were taken through observations, photographs, interview of local farmers. Qualitative attributes, like unripe fruit colour, mature fruit colour, seed shape, seed colour, seed size, pulp colour, fruit shape and fruit skin texture were compared with the Royal horticultural colour chart. Generated data were collated and analysed using appropriate statistical tools.
Results: The bread of the tropics fruit was found to be rich in B-complex vitamins and contains very good amounts of vitamin B – 6 (pyridoxine), niacin, riboflavin and folic acid. The result also shows that the fruit contains high starch, protein, minerals and nutrients especially, vitamins: C, E, K, potassium and sodium. Jackfruit is a good source of antioxidants vitamin C, provides about 13.7mg vitamin C which helps the body to develop resistance against infectious agents and scavenge harmful free radicals. Results of phenological variability obtained from analysis of quantitative attributes revealed some significance ($p<0.05$) differences among the ecotypes studied for traits such as Fruit chamber length, Fruit weight, Fruit diameter, Seed per fruit and leaf length, while phenotypic traits such as 100 seed weight, seed length, seed diameter, Leaf area and Seed chamber length did not differ ($p>0.05$) among the ecotypes. The fruit pod weighs between 3 – 40 kg, fruits may be oblong or globular in shape, reaching 25 – 75 cm in diameter, containing between 50 – 500 edible seeds measuring 2 – 4 cm in length and 1 – 3 cm in diameter.
Conclusion: The fruit can be used for the supplementation of food nutrients in human nutrition. In this agro-ecology, the fruit lacks market value because of ignorance and its unpopularity. Hence, this paper provides an insight into the phenological variations among the local ecotypes for which it can be easily identified, revealed the ecological relevance of Jackfruit trees and creates awareness on the nutritional values of this underutilized Jackfruit.

Keywords: Phenological variability; nutritional values; underutilize; jackfruit; Artocarpus heterophyllus.

1. INTRODUCTION

The tropical Jackfruit *Artocarpus heterophyllus* Frost, is commonly called "Bread of the Tropics''. It is a dicotyledonous tree crop belonging to the Moraceae family. Jackfruit is the largest edible fruit known on earth weighing up to 40 kg [1].

The fruit is very rich in starch, protein, calcium, phosphorus, Zinc, fibre, vitamins c and E. The tree grows wild, but mostly cultivated in the Carribean islands. It is of South East Asia origin. Specifically, the fruit is indigenous to the rain forests zone of the Western Ghats of India. It is a perennial fruit tree crop, growing vigorously in mostly evergreen and deciduous forest of tropical Africa. The plant can grow up to 30 m in height and 2 m in girth with numerous leaves and branching patterns [2].

Botanically, the fruit is a large pod with several seeds varying in sizes, numbers and colour which largely depend on cultivar. The pulp is very sweet and made up of fibre and remains the major edible portion of the fruit. The seeds may be eaten raw or cooked, roasted or fried [3].

Medicinally, the leaves of *Artocarpus heterophyllus* have been used in some communities in Nigeria for the treatment of diarrhoea amongst children. Jackfruit is a wonderful fruit with wonderful health benefits [4].

The wood of Jackfruit is used in making musical instruments, furniture and even in house construction. The distinct color of Monks' robes in South East Asia comes from the dye of this wood. The size of jackfruit trees has a very significant ecological relevance by serving as wind brake. Hence, wind erosion and destructive storms actions are greatly reduced [5].

Our interest in *Artocarpus heterophyllus* was borne out of the high level of ignorance of the inhabitants of the study area on this important

fruit tree which has led to the potentials of this fruits to be relatively underutilized and underexploited. Some inhabitants have exploited the timber of this important fruit tree for fuel due to the high level of ignorance on the nutritional values in addition to its ecological relevance. In some areas, the overripe mature fruits fall off, decompose and litter the surrounding environment posing a potential sanitary and health challenge through increase in pathogenic microbial population.

This study therefore seeks to assess the phenological variability that can enable people in this area identify jackfruit trees and fruits using phenotypic attributes and unveil the untapped nutritional potentials of Jackfruit "Bread of the tropics" which can provide the people with income, nutritional benefits and the baseline information needed for the exploration and exploitation of the fruit in Nigeria and the tropics in general.

This information could also be used as a guide for further characterization and documentation of available jackfruit ecotypes towards initiating a breeding and conservation programme for this unknown and underutilized crop species.

2. MATERIALS AND METHODS

2.1 Source of Plant Material and Study Location

Ten (10) local ecotypes of the jackfruits growing wild and in situ in compound garden and homes were investigated for variants in the following locations in Cross River State, Nigeria (Table 1).

2.2 Data Collection Procedures

2.2.1 Collection of quantitative data

Data for quantitative attributes were collected from mature Jackfruits ecotypes *in situ* on the following quantitative traits, leaf area (LA), leaf length (LL), seed length (SL), 100 seed weight (SW), seed chamber length (SCL), seed chamber width (SCW) number of seeds per pod (NS), stem diameter (SD), fruit width (FB), fruit weight (FW) and Fruit chamber length (FCL).

Table 1. Details of study locations

S/N	Location code	Longitude (E)	Latitude (N)	Elevation (m)
1	Yala	06° 40. 260'	008°45.006'	70.5
2	Obubra	05° 52. 279'	008°07.178'	81.6
3	Ikom	06° 03. 062'	008°41.012'	93.9
4	Ugep	05° 58. 200'	008°63.520'	181
5	Calabar	04°56.743'	008°18.513'	19
6	Akpabuyo	04°52.959'	008°24.933'	42.3
7	Akamkpa	05°15.546'	008°20.908'	12.6
8	Biase	05°42.188'	008°03.233'	56
9	Obudu	06° 34. 500'	009°07.718'	216.6
10	Boki	06° 29. 515'	008°48.579'	129.6

A

B

C

D

E

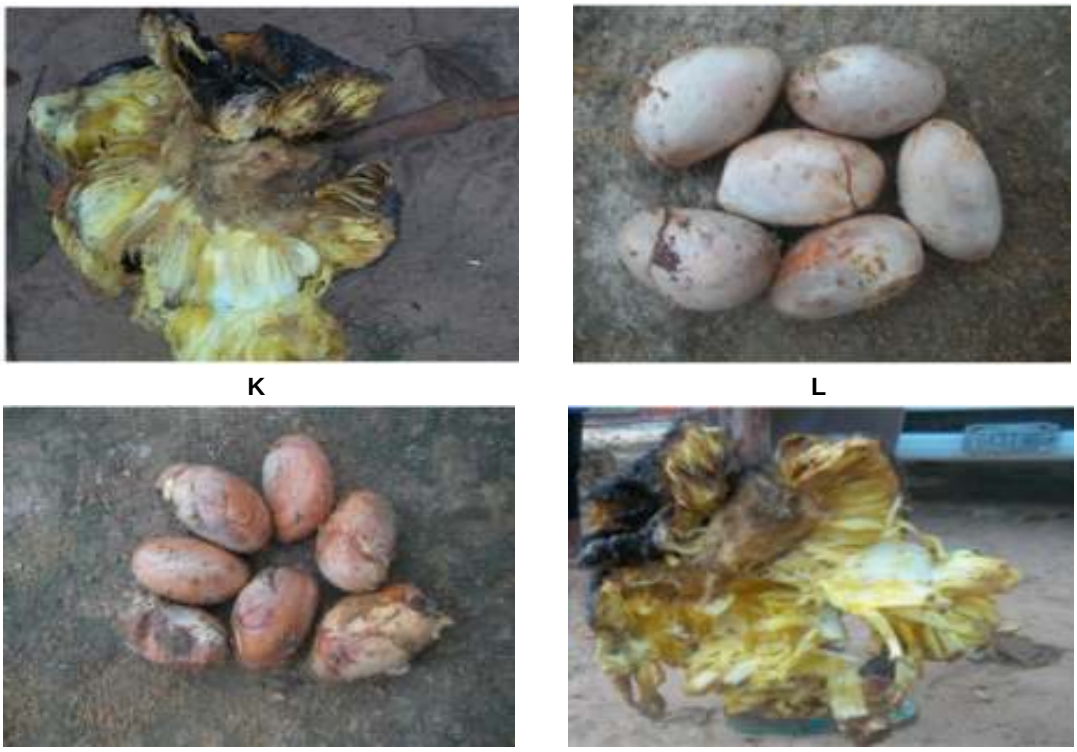
F

G

H

I

J



K **L**

M **N**

Pictures of Jackfruits growing wild insitu in compound gardens and backyards in the study locations

Key: A - D = Mature Jackfruits of different ecotypes; E= Over ripe Jackfruits showing explosive mechanism due to non-utilization; F= Fleshy juicy mesocarp with lot of vitamin C; G= Leaves of Jackfruit (Artocarpus heterophyllus) L= Milky white coloured seeds; M=Brown coloured seeds; K - N=Exposed fleshy mesocarp decomposing due to ignorance on its usage

2.2.1.1 Leaf area (cm^2)

Leaf area for Jackfruit was obtained using the graphical method. Three (3) leaves from each sample were carefully harvested and each placed in a graph sheet of paper. The number of centimetres boxes occupied by each leaf on both the horizontal and vertical axis was counted. The area of the leaf is calculated as number of centimetre boxes on horizontal axis (breath) multiplied by the number of centimetre boxes on the vertical axis (length). Area of leaf = length x breath (cm^2).

2.2.1.2 Leaf length (cm)

The leaf length was calculated by simply using a meter rule to measure vertically across the freshly plucked leaves, the measurement was repeated for three separate leaves per plant.

2.2.1.3 Seed length (cm)

This was measured as the perpendicular distance of the seed measured in centimetres using a meter rule. This was repeated thrice per ecotype.

2.2.1.4 100 seed weight (g)

This was estimated as the weight in grams of 100 seeds of Jackfruit using a sensitive weighing balance. This was replicated thrice per ecotype.

2.2.1.5 Seed chamber length (cm)

This was estimated as the vertical distance of the seed chamber measured in cm with a meter rule after breaking of fruit. Three readings were taken for each.

2.2.1.6 Seed chamber width (cm)

This was estimated and measured as the perpendicular distance of the seed chamber measured in cm with a meter rule. Three readings were taken for three different seeds per ecotype.

2.2.1.7 Stem diameter (cm)

This was estimated as the perpendicular distance measured round the stem using a measuring tape in meter.

2.2.1.8 Fruit width (cm)

This was estimated as the perpendicular distance measured round the fruit using a measuring tape in centimetre. Three replicates were taken per ecotype.

2.2.1.9 Fruit weight (g)

This was estimated as the weight of the mature fruits in kilograms measured using a weighing beam. Three replicates were taken per ecotype.

2.2.1.10 Fruit chamber length (cm)

This was estimated and measured as the perpendicular distance of the fruit chamber measured in cm with a meter rule. Three readings were taken for three different fruits per ecotype.

Data for qualitative data were taken through observation, interview of local farmer and comparison with the Royal horticultural colour chart for the under listed qualitative attributes unripe fruit colour, mature fruit colour, seed shape, seed colour, seed size, pulp colour, fruit shape and fruit skin texture.

2.3 Determination of Mineral and Nutrient Composition of Jackfruit *Artocarpus heterophyllus*

The determination of mineral and nutrient contents of Jackfruit was carried out in the Research laboratory of the National Root Crops Research Institute (NRCRI) Umudike, Abia State, Nigeria, following all prescribed and modified AOAC protocols of 2006. One of the methods for determining nutrient content in jackfruit is described below.

2.4 Determination of Vitamin C Content in Jackfruit

2.4.1 Method

Matured ripe Jackfruit fleshy mesocarp sample was carefully harvested, washed, air dried and ground in the blender. The liquid extract was carefully decanted and filtered to obtain a concentrated plant extract for the Jackfruit.

Five (5 ml) aliquot of the liquid extract was diluted with 50 ml of water. This was transferred into a 1ml burette and allowed to run drop wise into a flask containing a redox dye, 2, 6 – dicholorophenol indophenol mixed with a drop of dilute acetic acid. The dye was just completely decolourized. The volume of the liquid extract required for complete decolourization of the dye was recorded. The titration was repeated using standard ascorbic acid solution (1 mg of ascorbic acid for 100 ml of solution) in place of liquid jackfruit extract. The extract of vitamin C per 100 ml of diluted jackfruit liquid extract was determined thus,

X / Y (mg)/100 ml where X = titre value obtained with liquid jackfruit extract and Y = titre value obtained with standard ascorbic acid and multiplied the results by 10 since 100 ml = 1/10 litre.

All analyses were done in duplicate for the various nutrients using various protocols and procedures.

2.5 Data Analysis

Data generated for quantitative parameters were collated and subjected to analysis of variance using the generalized linear programming model procedure in GENSTAT. Frequency, percentage distribution and charts were used to analyse qualitative data obtained from Jackfruit ecotypes. Treatment means were compared at 5% probability level. Mean separation was done using the Fisher's Least Significant Difference (LSD) test option available in the GENSTAT statistical software. Data generated from mineral and nutritional composition of Jackfruits were averaged and mean results recorded.

3. RESULTS AND DISCUSSION

3.1 Results of Phenological Variability among Jackfruit Ecotypes for Quantitative Attributes

3.1.1 Fruit chamber length (cm)

The results of analysis of fruit chamber length (cm) for the ecotypes showed that significant ($p<0.05$) differences were detected among the ecotypes. Table 2 showed that the ecotype in Yala had the longest fruit chamber measuring 31.40 cm while the ecotype from Ugep showed the shortest fruit chamber of 19.86 cm.

3.1.2 Fruit width (cm)

A wider fruit width of 14.67 cm was measured from the Yala ecotype compared to the smallest fruit width of 7.63 cm measured from the ecotype in Biase. This results differed ($p<0.05$) significantly among the ecotypes as shown in Table 2.

3.1.3 Fruit diameter (cm)

Diameter of fruits was higher 42.98 cm in the Yala ecotype compared to a smaller 29.99 cm fruit diameter measured from Boki ecotype as revealed in Table 2.

3.1.4 Seed per fruit

The results as presented in Table 2 showed that seeds per fruit varied ($p<0.05$) significantly among the ecotypes studied. The results showed that the ecotype from Yala produced the highest number of 102 seeds per fruit while the least number of 58 seeds per fruit was produced from the ecotype from Boki.

3.1.5 100 seed weight (kg)

The weight of a hundred seeds obtained per fruit did not differed ($p>0.05$) significantly among the ecotype evaluated. However, the results in Table 2 showed that the weight of a 100 seeds of 5.88 kg was obtained from the Yala ecotype while the least 100 seeds weight of 3.97 kg was weighed from the Calabar ecotype.

3.1.6 Seed length (cm)

The results of seed length for the ecotypes showed that no significant ($p>0.05$) differences were detected among the cultivars as shown in Table 2. However, the longest seed of 2.10 cm was obtained from was obtained from the Yala ecotype while the shortest seed length of 1.03 cm was measured from the Calabar ecotype.

3.1.7 Seed diameter (cm)

Seed diameters for the ecotypes evaluated did not differ ($P>0.05$) significantly among the cultivars. As presented in the Table 2 above, a wider seed diameter of 1.40 cm was obtained from Yala ecotype while a small seed diameter of 0.73 cm was obtained from the Calabar ecotype.

3.1.8 Leaf length (cm)

Results in Table 2 show that leaf length evaluated among the ecotypes varied ($p<0.05$) significantly at 5 percent level of probability. Longest leaves of 10.20 cm on the average were measured from Yala ecotype while the shortest leaves of 6.34 cm on the average were measured from the ecotype in Biase.

3.1.9 Leaf area (cm²)

The results of leaf area obtained from the ecotypes did not differ ($p>0.05$) significantly among them as shown as Table 2. However, a larger leaf area of 12.88 cm² was obtained from the Yala ecotype while small leaf area of 11.65 cm² was obtained from Calabar ecotype.

3.1.10 Seed chamber length (cm)

Seed chamber length did not show any significant ($p>0.05$) differences among the ecotypes evaluated. A bigger seed chamber length of 2.10 cm was measured from the Yala ecotype while a smaller seed chamber length of 0.78 cm was obtained from the Calabar ecotype as shown in Table 2.

The dendrogram in Fig. 1 above shows the relationship among the Jackfruit ecotypes. The ecotypes are in two major clusters groups but with the Yala ecotype distinct from other ecotypes in terms of much of the phenological attributes evaluated. As shown in Table 3 and captured in the dendrogram, the Yala ecotype is an outstanding Jackfruit ecotype and shows more closeness with the Obubra ecotype and most distant from the Boki ecotype. The Obubra ecotype is a close relative of the Calabar ecotype and a distant relative of the Boki ecotype as shown in Table 3 and the dendrogram above. The close and far relatives among the ecotypes are presented in Table 3 and the dendrogram above. Variation is the basis for selection and the variability observed in the ecotypes can thus be exploited and used as a basis for identifying good ecotypes for planned improvement and conservation program.

3.2 Results of Phenological Variability among Jackfruit Ecotypes for Qualitative Attributes

The qualitative traits for Jackfruit ecotypes were ascertained after comparison with the IBPGR descriptor list for Moraceae of (1988) and Royal Horticultural Standard colour chart. A total of 26 Jackfruit trees growing wild in compounds and back yard gardens in the study area were evaluated for qualitative traits.

Table 2. Results of quantitative phenological attributes of wild ecotypes of tropical jackfruit (*Artocarpus heterophyllus* frost). (Bread of the tropics) in Nigeria

s/n	Ecotypes	FCL(cm)	FW(cm)	FD(cm)	SPF	100SW(kg)	SL(cm)	SD(cm)	LL(cm)	LA(cm²)	SCL(cm)
1.	Yala	31.40±0.05a	14.67±0.43a	42.98±2.31a	102±2.1 1a	5.88±0.04	2.10±0.01	1.40±0.01	10.2±0.17a	12.88±0.29	2.10±0.02
2.	Obubra	29.55±1.10ab	12.22±0.67c	37.99±0.65b	97±3 .65ab	5.34±0.01	1.98±0.01	1.21±0.01	6.34±0.03d	11.9 8±0.02	1.21±0.01
3.	Boki	21.72±0.34de	9.06±1.09de	29.18±0.98d	58±0. 66f	4.94±0.01	1.99±0.02	1.23±0.02	7.94±0.02c	11.99± 0.02	1.23±0.01
4.	Ikom	26.34±2.13c	12.66±0.45bc	37.22±0.08b	90±1.7 4c	5.08±0.12	1.78±0.01	1.19±0.01	8.08±0.13b	11.78±0 .03	1.19±0.04
5.	Ugep	19.86±0.99e	10.95±1.50d	26.79±1.09d	72±0.44 e	4.67±0.09	1.65±0.02	1.08±0.01	8.67±0.11b	11.65±0. 03	1.08±0.01
6.	Calabar	28.21±0.07bc	11.74±0.88cd	37.02±0.02bc	9 4±1.03b	3.97±0.10	1.03±0.01	0.78±0.03	8.97±0.08b	11 .03±0.12	0.78±0.02
7.	Akamkpa	26.98±1.22c	13.44±1.54b	31.90±2.90	67±0. 21ef	4.66± 0.02	2.02±0.04	1.19±0.02	9.66±0.15ab	12. 02±0.13	1.19±0.01
8.	Akpabuyo	23.78±0.30d	12.09±0.97c	34.44±1.78c	88± 0.87cd	5.33±0.20	2.00±0.03	1.16±0.01	7.33±0.05cd	12 .00±0.01	1.16±0.01
9.	Biase	20.11±2.01e	7.63±0.12f	28.90±0.05d	80±0.50 d	5.01±0.03	1.79±0.01	1.20±0.03	8.01±0.07bc	11.79±0 .03	1.20±0.04
10.	Abi	24.09±1.22cd	10.03±1.11d	33.19±0.23cd	91±1 .45bc	4.98±0.02	1.99±0.02	1.21±0.02	7.98± 0.01c	11. 99±0.02	1.21±0.01
LSD (0.05)		**2.43****	**1.05****	**3.76****	**5.54****	**NS**	**NS**	**NS**	**1.02****	**NS**	**NS**

*NS = Not statistically significant (p>0.05). ** Statistically significant (p<0.05). Same letter subscript in same column indicates no statistical significant differences among ecotypes for the given trait.*
FCL=Fruit chamber length; FW=Fruit weight; FD = Fruit diameter; SPF=Seed per fruit; 100SW = 100 seed weight
SL= seed length; SD=seed diameter; LL=leaf length; LA = Leaf area; SCL = Seed chamber length

Table 3. Proximity matrix showing closeness and farthest relatives among the jackfruit ecotypes in Nigeria

Case	Squared Euclidean distance									
	1:yala	**2:Obub**	**3:boki**	**4:ikom**	**5:ugep**	**6:cala**	**7:akam**	**8:akpa**	**9:bias**	**10:abi**
1:yala	.000	76.169	2259.196	214.140	1315.789	130.021	1372.214	343.917	866.959	299.181
2:Obub	76.169	.000	1672.632	63.267	852.078	22.917	956.670	127.898	484.780	96.467
3:boki	2259.196	1672.632	.000	1123.077	209.626	1411.126	138.292	941.626	488.807	1111.642
4:ikom	214.140	63.267	1123.077	.000	478.274	23.832	561.108	19.331	233.346	29.329
5:ugep	1315.789	852.078	209.626	478.274	.000	660.560	109.285	333.677	80.156	421.536
6:cala	130.021	22.917	1411.126	23.832	660.560	.000	762.798	69.100	348.113	47.849
7:akam	1372.214	956.670	138.292	561.108	109.285	762.798	.000	465.395	261.904	600.572
8:akpa	343.917	127.898	941.626	19.331	333.677	69.100	465.395	.000	128.708	15.452
9:bias	866.959	484.780	488.807	233.346	80.156	348.113	261.904	128.708	.000	161.087
10:abi	299.181	96.467	1111.642	29.329	421.536	47.849	600.572	15.452	161.087	.000

This is a dissimilarity matrix
Red figures = closest relative
Blue figures = Most distant relative

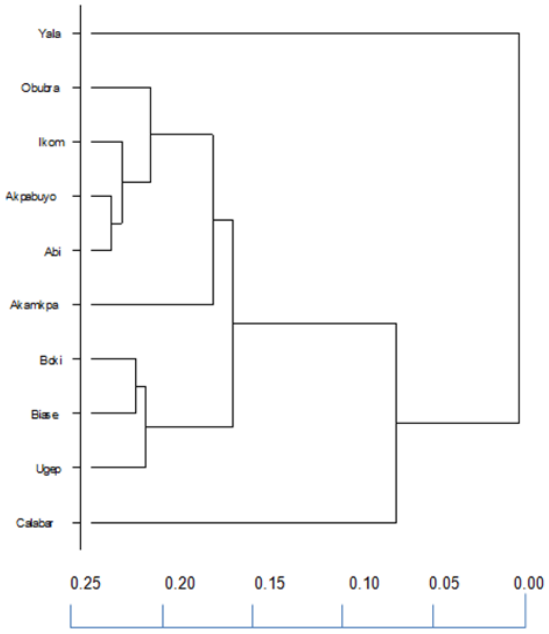


Fig. 1. Dendrogram showing relationship and variability among the Jackfruit ecotypes

The result shows that 54 percent of unripe Jackfruit ecotypes had dark fruit colour, 6 percent ecotypes had olive green fruit colour while 10 percent had brownish fruit colour as presented in Fig. 2.

Results of mature fruit colour of Jackfruit ectypes as shown in Fig. 3 revealed that a higher proportion (54 percent) of the ecotypes had dark dirty green mature fruit colour while only 6 percent of ecotypes showed olive green mature fruit colour.

About 60 percent of the jackfruit ecotypes had milky white matured seed colour, 30 percent had brownish mature seed colour while only 10 percent had tan red coloured seeds and 2 percent had Greyish mature seed colour as shown in the Fig. 4.

All the 26 Jackfruit trees sampled in the 10 ecotypes, had fruits with rough texture and none showed smooth fruit texture as shown in the Fig. 5.

Results of mature fruit shape of Jackfruits showed that 48 percent were oblong, 12 percent were club shaped, 30 percent were globular in shape while the remaining 10 percent of Jackfruits were pear shaped as presented in Fig. 6.

Fig. 7 show results of size of mature seeds of *Artocarpus heterophyllus* after comparison with the IBPGR qualitative descriptor for Moraceae. A high proportion (73 percent) of the ecotypes had big sized seeds, 23 percent had medium sized seeds while 4 percent ecotypes had small size seeds.

Fig. 8 shows results of shape of mature seeds of *Artocarpus heterophyllus.* A higher proportion (94 percent) of the Jackfruit ecotypes showed globular mature seeds shape, while 6 percent ecotypes showed oblong mature seeds shape. None of the ecotypes had club shaped and pear shaped seeds.

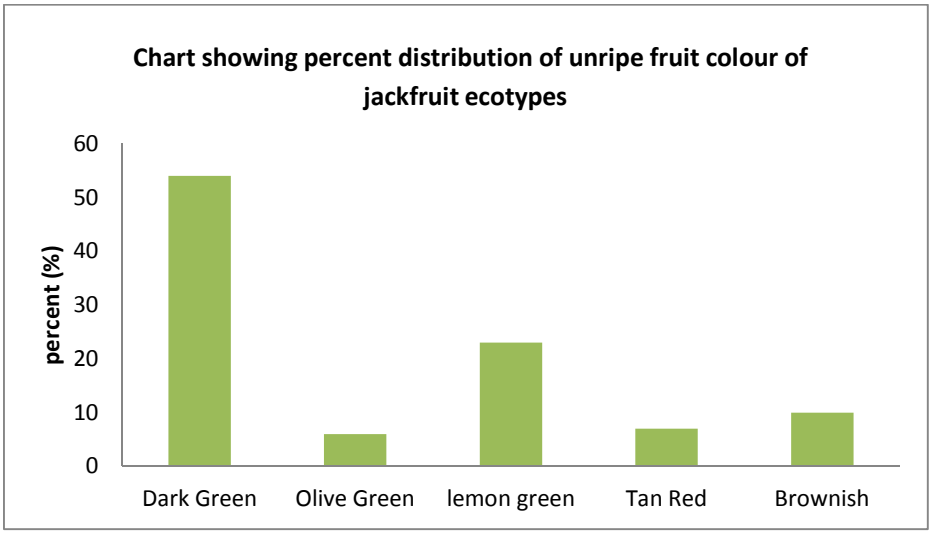


Fig. 2. Unripe fruit colour

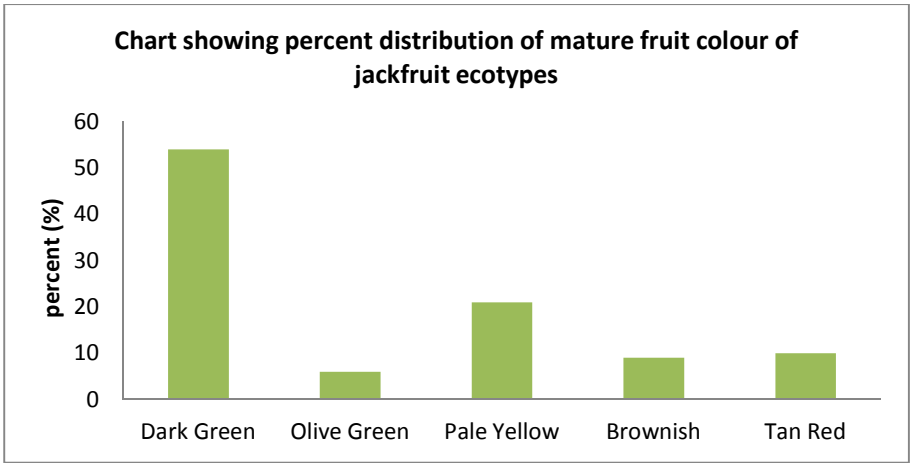


Fig. 3. Mature fruit colour

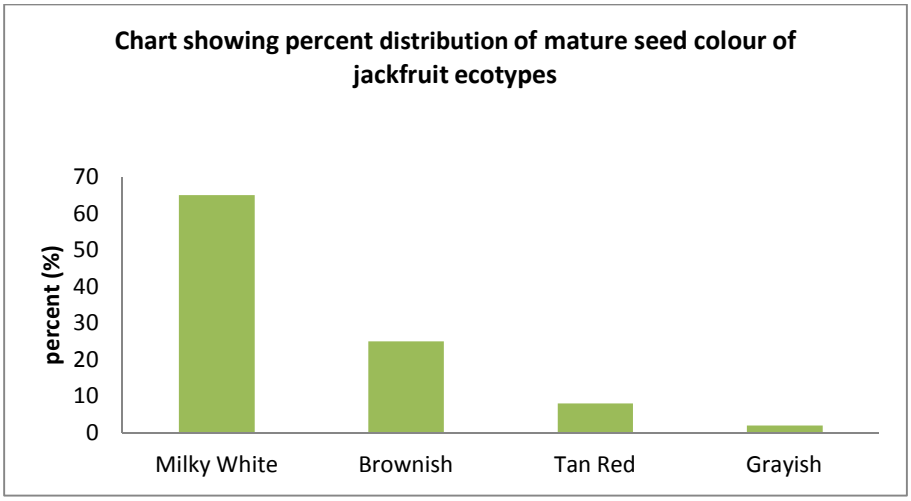


Fig. 4. Mature seed colour

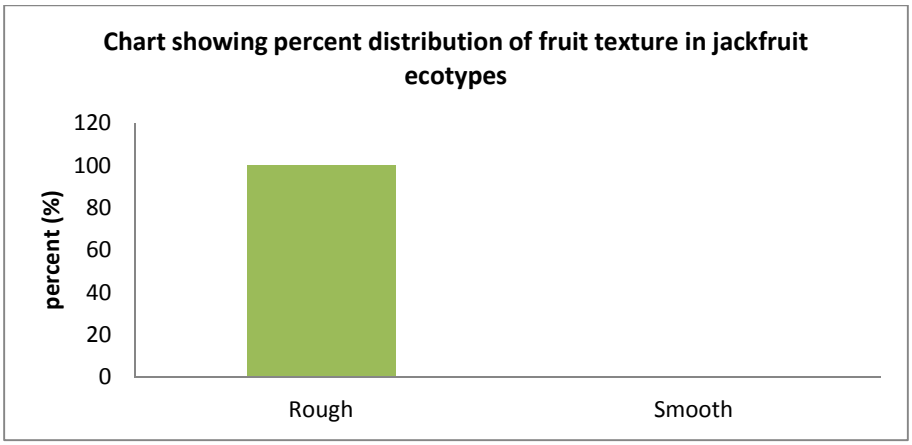


Fig. 5. Fruit texture

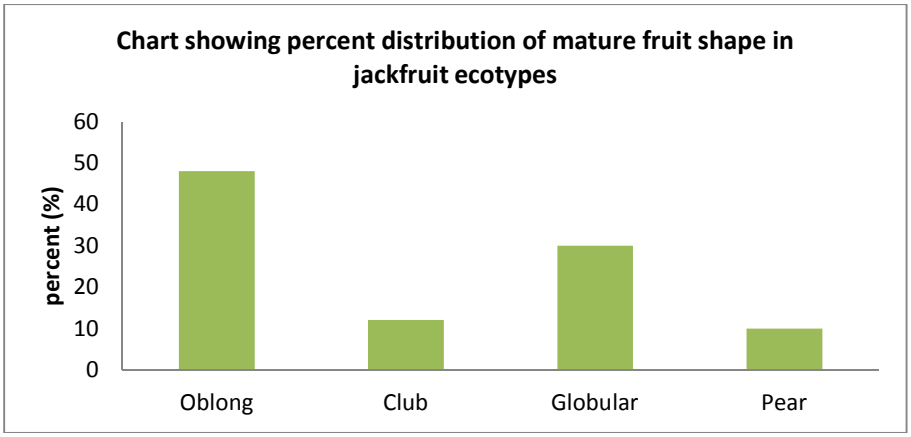


Fig. 6. Mature fruit shape

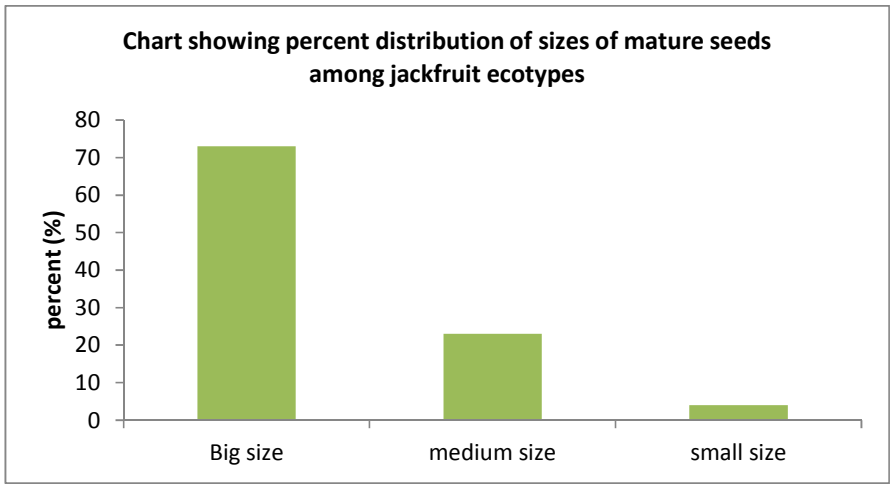


Fig. 7. Mature seed size

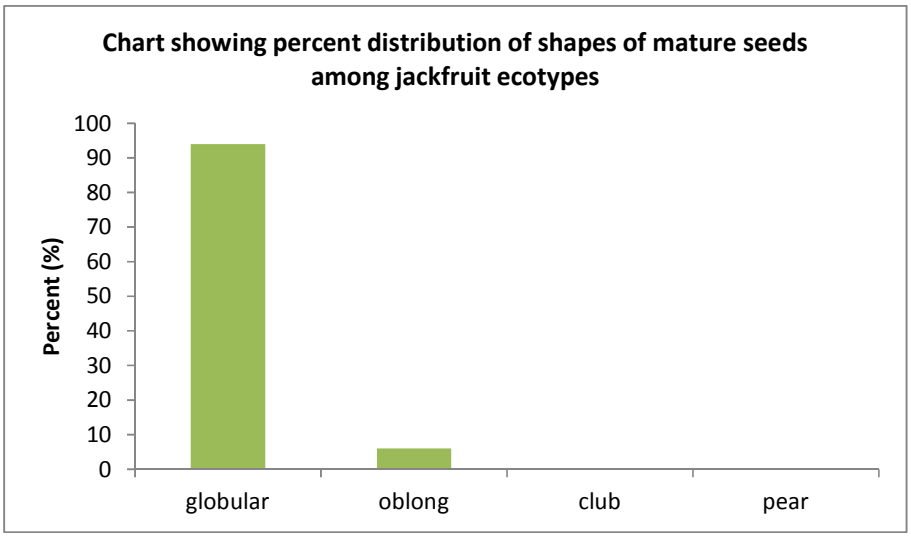


Fig. 8. Mature seed shape

Fig. 9 present the results of colour of mature jackfruit pulp among the ecotypes. The results showed that 83 percent of the ecotypes have yellowish pulp colour, 15 percent have milky white coloured pulp while only 2 percent of the ecotypes had reddish coloured pulp. The pulp is the major edible portion of the fruit and reported to contain a lot of minerals and nutrients [6,7].

Table 4. Results of qualitative phenological traits observed from variants of ecotypes of tropical jackfruit (*Artocarpus heterophyllus* frost) bread of the tropics in Nigeria

S/N	Qualitative traits	Variants / Description	Percentage distribution
1.	Unripe fruit colour	Dark Green	54%
		Olive Green	6%
		Lemon Green	23%
		Tan Red	7%
		Brownish	10%
2.	Mature fruit colour	Dark Green	54%
		Olive Green	6%
		Pale yellow	21%
		Brownish	9%
		Tan Red	10%
3.	Seed colour	Milky White	65%
		Brownish	25%
		Tan Red	8%
		Grayish	2%
4.	Fruit texture	Smooth	0%
		Rough	100%
5.	Fruit shape	Oblong	48%
		Club	12%
		Globular	30%
		Pear	10%
6.	Mature pulp colour	Yellowish	83%
		Milky White	15%
		Reddish	2%
7.	Seed size	Big	73%
		Medium	23%
		Small	4%
8.	Seed shape	Pear	0%
		Globular	94%
		Club	0%
		Oblong	6%

3.3 Nutritional Values of the Tropical Jackfruit *Artocarpus heterophyllus*

The results of the nutritional and mineral contents of the tropical jackfruit (*Artocarpus heterophyllus)* are presented in Table 5.

Table 5. Results of proximate composition of the jackfruit *Artocarpus heterophyllus* (Bread of the tropics) as analysed in the laboratory showing mineral and nutritional values

Mineral and nutrient (proximate) composition of jackfruit per 100 g of raw edible portion of fruit		
Energy	-	93.7 Kcal
Protein	-	1.45 g
Carbohydrate (C)	-	22.2 g
Dietary Fibre	-	1.5 g
Vit. C	-	12.9 mg
Vit. A	-	40 µg
Vit. B1	-	0.03 mg
Vit. B2	-	0.12 mg
Niacin	-	0.4 mg
Vit. B6	-	0.107
Folates	-	13.6 µg
Vit. E	-	0.16 mg
Calcium	-	36.8 mg
Phosphorus	-	35.4 mg
Magnesium	–	36.6 mg
Iron (Fe)	-	0.61 mg
Potassium	-	303 mg
Zinc	-	0.43 mg
Total Fat	-	0.33 g
Saturated Fat	–	0.066 g
Cholesterol	-	0.00
Sodium	-	3.1 mg

3.4 Energy (kcal) Supply Potentials of Jackfruit

The results of proximate analysis (Table 5) of jackfruit showed that the fruit contains a high energy 93.7 kcal which is needed for the physiological and biochemical functioning of the body. This source of energy is very important coming from a natural source like jackfruit. As reported by [6], an energy content of 93.7 kCal found per 100 g fruit is very comparable to synthetic energy found in glucose. This makes jackfruit a very important nutritional component of food and the need to enlighten the people on its usefulness to reduce the level of ignorance and underutilization.

3.5 Vitamin C in Jackfruit

Daily average optimal intake requirement of 100 – 600 mg per adult can be sourced and easily obtained from jackfruit which contains approximately 13.9 mg per 100 g of raw edible portion accounting for a greater proportion of nutrient in the fruit as shown in the results of nutrient analysis in Table 5.

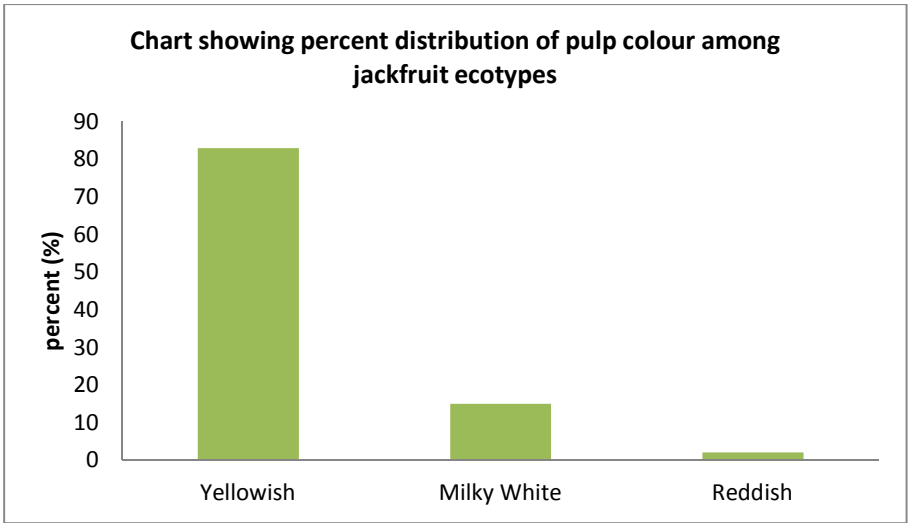


Fig. 9. Mature jackfruit pulp colour

Jackfruit is an excellent source of vitamin c with a high content of 13.9 mg per 100 grams. Several studies have shown that vitamin c is a better anti-oxidant than compounds like Methanol and Ethanol [6]. This makes vitamin c very effective against the free radicals in the body. The purification of our body by ridding it of free radicals increases immune system function. It increases immunity to protect against common diseases like cough, cold and flu. It has also been found to form a strong resistance against infections [8].

According to [9], vitamin c is a potent antioxidant to protect against cellular damage and degeneration. Vitamin c is highly involved in the formation and maintenance of collagen (the skin's "cement'') which helps in wound healing and burns. It increases the absorption of iron and calcium and activates insulin for the proper functioning of the nervous system. Vitamin c helps the body to produce interferon, which also play a vital role in infertility. It also protect against industrial pollutants for cataract and other eye disorders. Vitamin c prevents many types of viral and bacterial infections as well as many forms of cancer [10]. Vitamin c is a natural anti-oxidant but since it is water soluble and is not found in our bodies, you need to consume it through dietary sources. Thus vitamin c plays a very vital role in human nutrition.

The vitamin c content further enables an effective absorption of iron [8,11] in the body. It is said that all iron that you get from dietary sources can pass right through your body without being absorbed if there is no vitamin c in the body. Other minerals like copper and magnesium in Jackfruit improve the quality of blood. Jackfruit alleviates anemia by adding iron and increasing the iron absorption with vitamin c in the body.

Reports by [9,11], these free radicals have been associated with natural processes like ageing, skin wrinkling, increased vulnerability to infections and diseases.

According to [11], Jackfruit is a high grade anti-oxidant owing to dense concentration of vitamin c which strengthens the immune functions and protects from infections.

3.6 Carbohydrate (CHO) Content of Jackfruits

The result of analysis showed that Jackfruit contains high amount of carbohydrate of 22.2 g/100 g of fruit and calorie that can provide energy. According to [10,12], Jackfruit is a quick energy boost than very many other fruits. Jackfruit contains high amount of carbohydrate and calorie but hardly any companion fat [11,13]. It contains a healthy amount of simple sugar like fructose and sucrose that are easily digested by our bodies. The sugar in Jackfruit is not only easy to digest but also comes from a category called "slowly available glucose" or SAG [12,14]. This releases the glucose in our body in a restrained manner and therefore reduces the glycemic index of Jackfruit. In simple words, diabetic people suffering from high sugar levels and sugar spikes can enjoy this deliciously sweet

fruit without worrying about the glucose levels. Jackfruit is a powerhouse of energy [9,14]. It can lend a quick boost of energy without disturbing the sugar levels in the body significantly.

3.7 Potassium (k) Availability in Jackfruit

Potassium balances fluids with sodium inside the cells for proper muscles and heart contraction. The results of analysis (Table 5) showed that a high amount of 303 mg of potassium was obtained from 100 g portion of raw jackfruit and is a very good source of this important mineral nutrient.

Potassium helps in stimulating water waste through kidneys for proper and for proper carbohydrate metabolism. It is useful for energy storage in the muscles and liver. It reduces high blood pressure, prevent heart attack, help allergies and important for those using diuretics [13,7].

Potassium is one of the most important components that regulate blood pressure. Our body needs about 4700 milligrams of potassium in a day. Optimum balance of potassium is key to controlling the right amount of sodium in our body. Potassium deficiency can make your sodium levels spiral out of control leading to substantial damage to heart and the arteries [14,7]. Apart from this functionality, potassium is responsible for coordinating and maintaining muscle function which includes heart muscles as well. Jackfruit contains good amount of potassium which is about 10% of our daily requirement [14,15].

The ideal level of potassium is required to maintain fluid level that is to balance electrolyte also. All these different functions of potassium helps in maintaining ideal blood pressure and reduces the risk of stroke and heart attack. Potassium controls sodium, maintains the electrolyte balance along with regulating muscle function. All these roles make potassium a very healthy food for arresting high blood pressure and maintaining health [15].

3.8 Dietary Fibre Content of Jackfruit

Jackfruit contains 1.5 g of dietary fiber per 100 g of fruit (Table 5) of serving which is considered excellent. This fiber is actually converted to important and significant amount of roughage. Dietary fiber makes laxative which adds bulk to stools and softens them. Both of these factors make it easy for the body to push them through during defecation, thus improving digestion and preventing constipation [12,15]. The high fiber content in Jackfruit aids healthy digestion and an effective excretion which keeps the gastrointestinal tract clean and healthy [15].

Jackfruit contains both soluble and insoluble fiber with soluble content of 25% of the total fiber [13,16]. Soluble fiber is the one which is digested in our body and provides energy whereas insoluble just passes through the gastrointestinal tract.

3.9 Vitamin A Content of Jackfruit

The result in Table 5 shows that Jackfruit contains Vitamin A of 40 µg. According to [16], this is present in its equivalent in form of beta carotene and lutein zeaxanthin in Jackfruit in which the beta carotene gets synthesized and converts itself into Vitamin A. Vitamin A is an important food nutrient for eye health. It is an anti-oxidant that improves the vision and protects the eye from free radicals. It is also known to protect eyes from bacterial and viral infections by strengthening the mucous membranes that create a film on the cornea.

Reports of [7,15,16], revealed that Lutein zeaxanthin in Jackfruit is also known for its anti-oxidant properties that serve your eye sight effectively. Jackfruit is a rich source Vitamin A and its equivalents that protect eyes from infections, improve eye sight and prevent vision related medical problems. This is of great nutritional significance in humans.

3.10 Jackfruit Calcium Content

Jackfruit contains high amount of calcium 36.8 mg as presented in Table 5 which strengthens and promotes healthy bone health. Other bone related illnesses like Arthritis, osteoporosis can also be managed and prevented with regular seasonal consumption of Jackfruit. Reports by [17] showed that high potassium in fruits can decrease the loss of calcium through kidney thereby increasing calcium density in bone and strengthening it. Jackfruit maintains good bone health with high calcium content and increases its density by reducing the calcium loss owing to healthy potassium content [16,17].

3.11 Protein Content of Jackfruit

Although, the protein content of jackfruit may not be very high (1.45 g per 100 g of fruit) as shown in the Table 5, but compared to other fruits, the

protein content of jackfruit is very high. This can complement the high energy level and CHO content found in the fruit. Proteins as food component according to [18] can build and repair damage tissues and cells in the body. It was also stated by [18,19] that anemia is a condition which is defined by reduction of red blood cells (RBC) or Hemoglobin in blood below the acceptable minimum levels due to low protein uptake. This makes protein very indispensable in human nutrition and jackfruit consumption very important.

3.12 Jackfruit Vitamin B Content

Jackfruit is one of the rare fruits that is rich in the B-complex group of vitamins. It contains a very high amount of vitamin B 6 also known as pyridoxine, niancin, ribloflavin and folic acid. According to the assertions of [18,19], the B-complex vitamins are very good for the body because they help the body to fight infections and remain a good dietary supplement for consumers.

3.13 Available Zinc (Zn) in Jackfruit

A 0.43 mg of zinc found per 100 g of jackfruit (Table 5) is a good source of meeting the daily requirement of 30-50 mg for adults [19]. Zinc promotes wound healing, helps with acne, affects impotence in men, and aids in increasing sperm count. It helps in infertility and reduce prostrate problems in men. Good uptake of Jackfruit can help supplement the dietary need of zinc in human nutrition.

3.14 Sodium (Na) Availability in Jackfruit

Average daily adult requirement of sodium is between 200 – 600 mg [6,8,19], of which 3.1 mg (Table 5) can be obtained from 100 g portion of jackfruit. Although Jackfruit is low in Sodium content, available concentration can provide a basic need of mineral element. Sodium works with potassium to maintain proper fluid balance between cells, for nerve stimulation and muscles contraction [14,19]. It helps to keep calcium and other minerals in the blood soluble and to strengthen weak muscles while stimulating the adrenal glands.

3.15 Zero Cholesterol in Jackfruit

The fruit has no trace of cholesterol in its mineral and nutrient contents as shown in Table 5 above. This makes the Jackfruit an ideal fruit crop for metabolic engineering for the production of edible vaccine [19,20]. With the high vitamin C content, the fruit can be metabolically engineered using biotechnological tools for the production of edible vaccines for humans. Reports of [20] shows that the fruit is also very good for hypertensive patients who need no trace of cholesterol in their diet or food intake.

Artocarpus heterophyllus commonly called jackfruit, Nagka or 'Bread of the tropics' is the largest edible fruit known (up to 40 kg) and grows wild and rapidly in the tropics and spread across diverse vegetational and climatic belts. In Cross River State, Nigeria, the tree is relatively unknown and thus avoided by many inhabitants. The bread of the tropics is heavily endowed with high starch, protein, minerals and nutritional contents especially, vitamins C, E and K and has been used in the treatment of diarrhoea amongst children. The fruit can be metabolically engineered as an edible vaccine for the correction of malnutrition among humans. For now, it lacks market value because of ignorance and unpopularity in this area.

The vitamin c content further enables an effective absorption of iron in the body. According to [19], It is said that all iron obtained from dietary sources can pass right through your body without being absorbed if there is no vitamin c in the body. This makes Jackfruit with high vitamin c content very indispensable in human nutrition [13,7,20]. Other minerals like Copper and Magnesium in Jackfruit improve the quality of blood. Jackfruit alleviates anemia by adding iron and increasing the iron absorption with vitamin c in the body. This has been possible with the significant high value of protein found and obtainable with consumption of Jackfruits. This was also asserted by [20] in their study findings. Vitamin c is a natural anti-oxidant but since it is water soluble and is not found in our bodies, humans need to consume it through dietary sources like the Jackfruits.

The Jackfruit is very rich in energy, starch, protein, calcium, phosphorus, zinc, fibre, vitamins c and E. Jackfruit is a powerhouse of energy [18,19], which can lend a quick boost of energy without disturbing the sugar levels in the body significantly. According to [15,20], the energy supplied from Jackfruit can supply the body with as much energy as that supplied from synthesized energy sources such as glucose D.

Botanically, [10,12,21] had asserted that the fruit is a large pod with several seeds varying in

sizes, numbers and colour which largely depend on cultivar. The pulp is very sweet and made up of fibre and remains the major edible portion of the fruit. The seeds may be eaten raw or cooked, roasted or fried. These assertions are in line with the findings of this present study.

The results of phenological variability obtained from the study showed that significant ($p<0.05$) variations was observed in fruit chamber length (cm), fruit width (cm), fruit diameter (cm), seeds per fruit and leaf area (cm^2) while 100 seeds weight (kg), leaf length (cm), seed length (cm) and seed chamber length (cm) did not vary significantly ($p>0.05$) among the ecotypes evaluated. Variation remains the basis for selection of species for adaptation and development [20]. *Artocarpus heterophyllus* is relatively unknown by many inhabitants in this part of the tropics, therefore a thorough documentation of the phenotypic characteristics of the fruits, trees and morphology will help in the identification of jackfruit and reduced the destructive attitude of the people towards the fruit due to ignorance. The study has also confirmed that the trees can serve a as wind brakes thereby having a high ecological relevance and benefit. This was earlier reported by [13,21] and is in line with the findings of this present study.

Awareness on the nutritional values of Jackfruits by the inhabitants will in no small measure enlighten inhabitants on the usefulness of the fruit tree as a source of food, nutritional supplements and income to owners and will in addition, create a heighten need for planned cultivation of the fruit tree.

Awareness on the nutritional benefits of the Jackfruit will also ensure food security and reduce malnutrition. In addition, Jackfruit farmers will generate more income through sales of fruits (can produce about 500 fruit per tree per season) [18,20,21].

As stated by [20,21], ageing is caused by free radicals produced in our body due to high oxidative stress caused by pollution. Antioxidant rich diets, including fruits like Jackfruit has proven to destroy these free radicals which slow down the ageing process. The anti-oxidant properties and high water (80%) content of Jackfruit keeps skin healthy, moisturized and reduces the wrinkles and dryness retaining the youthful texture of the skin.

Fruits like Jackfruit that are high on anti-oxidants help to clean toxins from the colon, keeping the colon in a good and healthy shape. Jackfruit prevents constipation due to its high fiber content and can help alleviating the symptoms. Jackfruit contains dietary fiber that reduces the effects of toxin in the colon and protect from colon cancer. It contains high amount of nutrient like vitamin, minerals, electrolytes, phytonutrients, carbohydrate, fiber, fat and protein. Jackfruit is a good source of calorie but contains no cholesterol or saturated fats [20,21].

Jackfruit is rich in vitamins and minerals such as vitamin B5 content which fulfills about 25% of our daily requirement [21]. Apart from Vitamin B5, Jackfruit is also a rich source of vitamin c, Magnesium and Potassium. The fat content of Jackfruit is very low at just about 0.64 grams which helps to keep the body in good shape and form [8,21].

4. CONCLUSION

Jackfruit *Artocarpus heterophyllus* is a very nutritious fruit which is still unknown in this part of the tropics. Many inhabitants view the fruits as waste and prefer cutting down the trees for firewood and timber logs. This paper have been able to bridge the gap between ignorance on the part of the local people and the nutritive value of this neglected fruit tree and create awareness on the nutritional value of this fruit tree, unveil the phenotypic characteristics with which the fruit tree can easily be identified and the need to harness the fruit for the nutritional benefits among the localities where it grows wild and the need to cultivate the fruit for its nutritional and ecological relevance. This tropical fruit tree can be harnessed and metabolically engineered as an edible plant vaccine for the nutritional and health benefit of man.

ACKNOWLEDGEMENTS

The authors wish to extend their gratitude to the Training and Technical Assistance Department of the World Bank Assisted National Fadama Development project in Nigeria (Cross River State Fadama Coordination Office) for the logistics and Financial supports for the accomplishment of this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14701