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Application of Vibration Technique for the Control of Physical Properties of Yam (Dioscorea Spp.) Sprouts During Storage in Funaab, Nigeria Environment

APPLICATION OF VIBRATION TECHNIQUE FOR THE CONTROL OF PHYSICAL PROPERTIES OF YAM (*Dioscorea spp.)* SPROUTS DURING STORAGE IN FUNAAB, NIGERIA ENVIRONMENT

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ABSTRACT

Early sprouting of yam tuber is a typical problem during storage resulting into weight losses, deterioration, shrinkage and reduction in quality. This research work therefore carried out investigation on the application of vibration technique for the control of physical properties of yam (*Dioscorea spp.)* sprouts during storage in FUNAAB, Nigeria environment. The physical properties (length, number and weight of sprout, number of leaves and weight of roots) of the yam sprouts were determined for 140 white yam tubers. The yam tubers were divided into 108 experiment and 32 as control. The factors of the experimental design examined were frequency, amplitude and time of vibration of low (1 – 5 Hz, 5 mm and 3 minutes), medium (60 – 100 Hz, 10 mm and 10 minutes) and high (150 – 200 Hz, 20 mm and 15 minutes) respectively; weight of yam tuber of two levels of small (0.1 – 2.9 kg) and big (3.0 – 5.0 kg) were also considered. The tubers were stored for ten weeks after vibration, the physical properties of the yam sprouts were observed and records were taken every week. All the physical properties of yam sprouts examined followed the same trend. It was discovered that as the frequency, amplitude and time of vibration were increasing, the physical properties of the yam sprouts studied were decreasing significantly at $p < 0.05$ for both weight of yams between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The results revealed that mechanical vibration significantly help in slowing down sprouting in yam tubers.

Keywords: Yam sprout, vibration technique, FUNAAB, *Dioscorea spp*, physical properties.

INTRODUCTION

Yam belongs to the members of the Dioscorea genus of the *Dioscoreaceae* family within the order Dioscoreales (Obidiegwu et al., 2020). It comprises of over 600 species which is distributed across the world; out of which only six species are edible and of great significance (Ojinnaka et al., 2017). The edible species of the *Dioscorea* are *D. rotundata* (white Guinea yam), *D. alata* (water or greater yam), *D. cayenensis* (yellow yam), *D. dumetorum* (bitter or trifoliate yam), *D. esculenta* (Chinese yam) and *D. bulbifera* (aerial yam). Among the edible species, *D. rotundata* (white yam) is the most planted and consumed which took large proportion of the yam production in West Africa (Gbadamosi et al., 2018).

In tropical countries; yam is the second most important root and tuber crop apart from cassava (Kiunjuri et al., 2019). It provides protein three times more superior than the one of cassava and sweet potato (Ezeocha and Ojimelukwe, 2012). The economic importance of tuber yam lies in their utility as a source of carbohydrate, minerals and B – complex group of vitamins (pyridoxine, thiamine, riboflavin, folates, pantothenic, niacin, ascorbic acid and carotenes) in human diet, its health benefits, nutritional value, foreign exchange earnings for the country, industrial potential as a source of starch, potential as a source of animal feed, cosmetics purposes and a source of steroids for pharmaceutical products (Morse, 2021).

The yam tubers are well known and integrated into the social, cultural and religious lifestyle of the people in Africa (Mulualem et al., 2018). It is the only crop that is usually celebrated during and after harvest with traditional festivals in the West Africa (Aighewi et al., 2021). In Nigeria, among Igbo and Yoruba ethnic groups, yam serves as a major vital food crop for many social, cultural and religious functions such as marriage, burials, rituals, religious festivals and other traditional ceremonies which give it a unique value among all crops (Epping and Laibach, 2020). No other crop has taboo and festivity as yam (Ike and Inoni, 2006).

Postharvest losses of yam tuber due to sprouting constitute problem of food shortage and security in Africa and not making the crop to be available all year round. Quality of the tuber for production of yam – based food products is a major criterion for acceptance of yam varieties by stakeholder: farmers, processors and consumers. Yams are usually harvested in August or September which are used for planting again in October. Such plantings invariably fail to emerge until about February, a period of about 4 months (Acedo and Arradaza, 2013). This unnecessarily adds to the total duration of field occupancy (period from planting to harvesting of the yam crop).

Around February, sprouting of yam begins and effort to prolong the dormancy of yam tuber had not yielded any success. Early sprouting of yam tuber is a typical problem during storage resulting into weight losses, deterioration, shrinkage and reduction in quality (Onwueme, 2012). Attempt to find a simple methods to prolong the dormancy period of tubers and to break this dormancy when require constitute major problem especially in yam tuber (Bazabakana et al., 1999). A range of sprout inhibitors are being used for yam such as treatment with chemicals (called plant growth regulator like Gibberellins, cytokinin), plant extracts (from cocoa pod, potash, neem seed, neem leaves, sweet potato leaves), palm wine, electromagnetic radiation (gamma irradiation from cobalt – 60 or cesium – 137), electric field of high voltage for long storage but these appear not to yield significant results (Okagami and Tanno, 1993; Tortoe et al., 2015).

If even if there were positive results, the increase in awareness to their health hazard requires need to find alternative ways for good yam storage and for good quality supply (Eze et al., 2015). Some of these chemicals use in treating the yam tuber have high mammalian toxicity and are considered not safe on the environment. The used of gamma irradiation and low temperature to prolong the dormancy of yam tuber as reported by many researchers are not cost effective for subsistent yam farmers (Tortue et al., 2015). The utilization of sprout suppressant chemicals (plant growth regulators) which were widely used for the control of dormancy in sweet potatoes was unsuccessful for yam tuber. Sprouting of yam tuber occur beneath the periderm (cell layer below the epidermis), thus protected it from the effects of such treatment.

Emergence of new organism mostly results from collision and constructive interference between living and non-living. The constructive inference between the two parts results into cell division and multiplication which eventually results into new organisms. This cut across micro – organisms and multi – cellular organisms. No new species would even emerge without the collision and constructive inference of the parent objects, where at least one of the species must be living thing. Human, poultry, reptile, amphibian, plant kingdom existence, obey this ideology.

Yam is a living species organism which emerge new species by having interference with the biotic and abiotic factor of the surrounding (Abewoy, 2021; Osanyinpeju et al., 2022a). At some point, during its life time when the environment is not favourable for growth that is when there is destructive interference of the yam with the surrounding (Cheema, 2010). During this period there is no enough water in the soil for the survival of the yam. This condition is referred to as water stress. The yam tuber goes to dormant or inhibits in order to survive during this period (Kevers et al., 2010). During favorable environmental condition that is when there is constructive interference of the yam with the surrounding; growth is promoted and sprouting of the yam tuber begins (Wickham, 2019). Modification on when sprouting emerges and inhibition occurs during the life cycle of yam can be carried out by manipulating on how the environment (living and non – living factors) interacts with the yam species.

There is need to looking for a method which would retain the sensory and quality of the product, be cost effective and would still able to prolong the dormancy of the yam tuber after harvest. The use of mechanical vibration for the control of the dormancy and sprouting is a non-thermal and non-chemical technology which retains the nutritional and sensory properties of yam tuber and preserves better quality attributes than conventional processes. The effect of mechanical vibration on the inhibition and promotion of the sprouting of the yam and also to investigate the physiological changes following the treatment would go a long way in the agricultural sector. It is important to develop a mechanism and create models for use of this potential innovation.

Other non – thermal technology which had been explored for other root crop such as sweet potatoes are ultra-high pressure, ionizing radiation including pulsed X-ray and Gamma ray, ultrasound, pulsed light and pulsed electric fields (PEF), high-voltage arc discharge, magnetic fields, ultra violet light, dense phase carbon dioxide, electron irradiation (soft – electron or low – electron beam) and hurdle technologies (Sarkar and Kumar, 2020).

The advantage of using solid vibration technology does not leave undesirable residues in the foods after application. Mechanical vibration is an external factor that has a great interaction and impact on the physiology, behavior, molecular and biological index of plant, crop, tuber, micro-organism and macro-organism like other mechanical stimuli such as wind, rain, touch and sound (Osanyinpeju et al., 2022b). Proper application of this technology will alleviate post – harvest loses from infestation in food and agricultural products.

The power to control the dormancy of yam tubers after harvest and during storage would makes the yam tubers to be available for consumption all year round. However, making it available all year round would go a long way in improving the health status and standard of living of the rural community and every household. This work therefore applied vibration technique for the control of physical properties of yam sprouts (*Dioscorea spp.)* during storage in Federal University of Agriculture, Abeokuta, Ogun State, Nigeria Environment.

MATERIALS AND METHODS

Experimental Study Location

The experimental study was carried out at Federal University of Agriculture, Alabata, Abeokuta, Ogun State, South West, Nigeria on the latitude 70° N and longitude 30° E.

Materials used for the Experimental Study

The materials used for the experimental study were:

i. A Developed Rigid Mechanical Vibrator of Adjustable Frequency and Amplitude

The developed mechanical yam vibrator of adjustable frequency and amplitude was used to vibrate the yam tubers at different combination of frequencies, amplitudes and time of vibration; afterward the vibrated tubers and control were stored in the laboratory to examine the effect of the treatment on the physical properties of the yam sprouts.

ii. Three Sets of Developed Cycloid Cam

Three sets of developed cycloid cams were used for the developed mechanical yam vibrator used to vibrate the yam tubers to achieve three set of amplitude of vibrations. The mechanical yam vibrator can only house one cam at a time.

iii. ***Yam Tubers***

One hundred and forty white yam tubers were used for the research work. The variety of the yam tubers used for the experimental study was white yam (*Dioscorea rotundata*). The white yam tubers were cultivated on the same farmland and harvested together on the 25^{th} of November, 2019.

iv. ***Tachometer***

The tachometer was used to measure and set the frequency of the developed mechanical yam vibrator during the vibration of the yam tubers to have the required frequency for each yam tuber.

v. ***Digital Weighting Scale***

The digital weighing machine was used to measure the weight of the yam sprout and root after storage period.

vi. ***Flexible Tape Rule***

The flexible tape rule was used to measure the length of the sprout and root of the yam tuber.

Experimental Designs, Analysis and Procedures

Vibration parameters examined were frequency, amplitude and time of duration of vibration and the input parameters of the yam tubers considered were weight, diameter and length of the yam tuber. The yam tubers were selected such that a small weight yam tuber as short length and small diameter while large weight were selected to have long size and big diameter so that the weight, length and diameter of the yam tuber were taken as one main factor. The yam tuber parameter that was looked into was weight of the yam tuber.

Therefore, the four factors considered for the experimental design were frequency, amplitude and time duration of the vibration and weight of the yam tuber. The selection of the frequency and amplitude ranges for the yam vibration was based on the possible and achievable frequency and amplitude ranges reported for mechanical vibrator. Nitinkumar et al. (2014) reported that the frequency range of mechanical vibrator falls between 0 – 200 Hz while maximum displacement achievable is 25 mm. Based on this the yam tuber was designed to operate at frequency range of 1 – 200 Hz and amplitude range of 0 to 20 mm. Also, a low, medium and very high frequency were considered. The maximum amplitude was staged at 20 mm and was divided in three categories (low, medium and high levels). The levels of the amplitude was selected using a quadratic progression in order to cover the range of the achievable amplitude reported; where the low, medium and high amplitudes were 5 mm, 10 mm and 20 mm.

A full 3 × 3 × 3 × 2 factorial experimental design based on complete randomized block design (CRBD) with fifty – four treatments and two replicates was used to investigate the effect of frequency, amplitude and time of vibration on the physical properties of yam sprouts. The factors of the experimental design examined for frequency, amplitude and time of vibration were low (1 – 5 Hz, 5 mm and 3 minutes), medium (60 – 100 Hz, 10 mm and 10 minutes) and high (150 – 200 Hz, 20 mm and 15 minutes) respectively; weight of yam tuber of two levels of small (0.1 – 2.9 kg) and big (3.0 – 5.0 kg) were also considered.

The physical properties (length, number and weight of sprout, number of leaves and weight of roots) of the yam tubers were obtained for one hundred and forty white yam tubers. One hundred and eight tubers were subjected to vibration and remaining thirty – two tubers were taken as control. The vibration was carried out from 20th to 24th of January, 2020. The tubers were stored after vibration for ten weeks from 25th of January, 2020 to 29th of March, 2020 in the Agricultural and Bio – Resources Engineering processing laboratory of College of Engineering at Federal University of Agriculture, Abeokuta, Nigeria and the physical properties of the yam tubers were observed and records were taken every week.

The storage of the vibrated and untreated yam tubers was executed in a natural environment place; where plank of woods were placed on the laboratory tables then the yams tuber were positioned on the plank of woods under prevailing ambient conditions with temperature ranging from 24.2 to 32.6 ℃. The effect of each of the main factors was investigated on the response variable as well as the effects of interactions between factors on the responses variable. Plate 1 (A) shows the view of the yam tubers for the experimental study. Plate 1 (B) indicates the view showing the alignment of the yam tubers (weight between 0.1 kg and 2.9 kg and weight between 3.0 kg and 5.0 kg) during the vibration while Plate 1 (C) presents the view of the yam tubers in the first week of storage.

Evaluation and Measurement of the Yam Sprout Response

i. Length of the Longest Length of Sprout of the Yam Tuber

The length of the longest length of sprout on the yam tubers for the treatment and the control were measured and recorded for each week of the storage period using a flexible tape rule.

ii. Number of Sprouts per Tuber

A tuber was considered sprouted when it had at least one visible sprout of at least 3 mm length (Gachango et al., 2008). For each of the treatment and replicate of the control the number of sprouts were counted and recorded.

iii. Number of Leaves on the Stem of the Sprout of the Yam Tuber

The number of leaves on the stem of the longest sprout of the yam tuber were counted and recorded for each week of the storage period.

(A) (B) (C)

Plate 1: (A) The view of the yam tubers for the experimental study (B) The view showing the alignment of the yam tubers (weight between 0.1 kg and 2.9 kg and weight between 3.0 kg and 5.0 kg) during the vibration (C) the view of the yam tubers in the first week of storage.

iv. Weight of the Root of the Yam Tuber

The weight of root of the yam tuber for the treatment and the control were measured using a digital weighing scale which was executed at the end of the storage period and records were taken.

v. Weight of Sprout of the Yam Tuber

The measurement of the weight of the sprout on each tuber was done at the end of the storage period using a digital weighing scale and records were taken.

RESULTS

In the first two weeks of storage none of the yam tuber sprouted. The first rain of that year started to fall on 28th of Feburary, 2020 at 4:52 am although sprouting was spotted on some of the yam tuber on the 08th of February, 2020 which was the 3rd week of storage. However, the emergence of sprouting of yam tuber usually occurs around February either the yam tuber is planted, stored or laid down on the floor as reported by Onwueme (2012).

i. Length of the Longest Length of the Sprout of the Yam Tubers

The maximum mean values of the length of the longest length of the sprout of the yam tuber obtained at the end of the storage period for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg were 319.16 cm and 324.25 cm respectively with both were obtained from the control. Table 1 shows result of the effect of the frequency, amplitude and time of vibration on the mean length of the longest length of the sprout for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg at the end of storage period. For the effect of frequency on the mean of the length of the longest length of the sprout of the yam tuber at the end of the storage period; the Table 1 indicates that the highest length of the longest length of sprout occurs at control (319.16 cm) follow by low frequency (135.34 cm) then medium frequency (15.43 cm) and lastly high frequency (9.77 cm) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest length of the longest length of sprout also occurs at control (324.25 cm) follow by low frequency (121.41 cm) then medium frequency (10.51 cm) and lastly high frequency (6.81 cm). This revealed that as the frequency of vibration was increasing the mean length of the longest length of sprout of the yam tuber was decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The results show that frequency of vibration significantly slow down sprouting length of yam tuber.

For the effect of amplitude on the mean of the length of the longest length of the sprout of the yam tuber at end of the storage period; the Table 1 indicates that the highest length of the longest length of sprout occurred at control (319.16 cm) follow by low amplitude (78.09 cm) then medium amplitude (46.66 cm) and lastly high amplitude (35.79 cm) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest length of the longest length of sprout also occurred at control (324.25 cm) follow by low amplitude (59.37 cm) then medium amplitude (43.64 cm) and lastly high amplitude (35.72 cm). The result indicates that as the amplitude of vibration was increasing the mean length of the longest length of sprout of the yam tuber was decreasing for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This proved that amplitude of vibration significantly helps to decline sprouting length of yam tuber.

For the effect of time on the mean of the length of the longest length of the sprout of the yam tuber at end of the storage period; the Table 1 shows that the highest length of the longest length of sprout occurred at control (319.16 cm) follow by low time (91.63 cm) then medium time (45.39 cm) and lastly high time (23.52 cm) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest length of the longest length of sprout also occurred at control (324.25 cm) follow by low time (82.33 cm) then medium time (33.41 cm) and lastly high time (22.99 cm). The result indicates that as the time of vibration was increasing the mean length of the longest length of sprout of the yam tuber was decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The result revealed that time of vibration would significantly reduce the sprout length of yam tuber during storage thereby preserve the quality of yam tuber.

The results show that mechanical vibration as the power of significantly retarding sprouting length of yam tuber which was in accordance to the report of Al – Salihy et al. (2006); Wang et al. (2007); Asare and Akama (2014) and Pristijono et al. (2018). Al – Salihy et al. (2006); Wang et al. (2007); Asare and Akama (2014) findings indicate that at higher dosage of gamma irradiation (another form of vibration), there was delay in the sprouting of sweet potato vine. Pristijono et al. (2018) conducted an experiment on effect of UV – C irradiation on sprouting of potatoes in storage which was carried out in Australia. They indicated that ultra violet irradiation alter the postharvest quality of some horticulture crops. They also concluded that ultra violet irradiation as a potential postharvest treatment to reduce the incidence of sprouting in potato tubers stored in air at 20 ℃. In their studied they observed that UV – C irradiation affected and shorten the sprout length of the treated potatoes.

The analysis of variance (ANOVA) shows that there was significant different between the low, medium and high levels of frequency of vibration on the mean length of the longest length of sprout of yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg at $p < 0.05$. Also, based on the statistical analysis, there was significant difference between the low, medium and high levels of amplitude of vibration on the mean length of the longest length of sprout of yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg at $p < 0.05$. More so, there was significant difference among the low, medium and high time for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg at $p < 0.05$. The result from analysis of variance revealed that for frequency, amplitude and time; there was no significant difference between the levels of weight of yam tuber (weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for the mean length of the longest length of the sprout of the yam tuber at $p > 0.05$.

Table 1: The effect of the frequency, amplitude and time of vibration on the length of the longest length of the sprout for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Length of longest length of sprout, cm	
	Tuber weight (0.1 – 2.9 kg)	**Tuber weight (3.0 – 5.0 kg)**
Control	319.16 ± 6.63a	324.25 ± 8.34a
Low frequency (1 – 5 Hz)	135.34 ± 9.03b	121.41 ± 8.98b
Medium frequency (60 – 100 Hz)	15.43 ± 3.09c	10.51 ± 1.89c
High frequency (150 – 200 Hz)	9.77 ± 2.42c	6.81 ± 0.80c
Control	319.16 ± 6.63d	324.25 ± 8.34d
Low amplitude (5 mm)	78.09 ± 9.12e	59.37 ± 8.99e
Medium amplitude (10 mm)	46.66 ± 8.54e,f	43.64 ± 7.99f
High amplitude (20 mm)	35.79 ± 6.08f	35.72 ± 7.47g
Control	319.16 ± 6.63h	324.25 ± 8.34h
Low time (3 minutes)	91.63 ± 10.8j	82.33 ± 11.58j
Medium time (10 minutes)	45.39 ± 7.70k	33.41 ± 4.90k
High time (15 minutes)	23.52 ± 4.39k	22.99 ± 3.55m

Note: All data represent means ± standard deviation (S.D.); Means followed by the same letter within a column were not significantly different at $p > 0.05$ according to LSD test at $\alpha = 5$ %.

ii. Number of Sprouts on the Yam Tuber

The results show that the number of sprouts on the yam tuber was increasing with time throughout the storage period for the control and some of the treated yam. At high frequency, high amplitude and high time interaction there were no sprout throughout the period of storage for both yam tubers whose weight were between 0.1 – 2.9 kg and between 3.0 – 5 kg. This reveals that mechanical vibration can prevent yam tubers from sprouting at some levels of interaction of frequency, time and amplitude of vibration of the yam tuber. The maximum mean values of the number of sprouts of the yam tubers obtained at the end of the storage period for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg were 4.40 and 4.29 respectively with both were obtained from the control.

Table 2 presents result of the effect of the frequency, amplitude and time of vibration on the mean of the number of the sprouts on the yam tuber for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg at the end of storage period. For the effect of frequency on the mean of number of sprouts of the yam tuber at the end of the storage period; the Table 2 shows that the highest number of sprouts of the yam tuber occurred at control (4.40) follow by low frequency (3.00) then medium frequency (1.23) and lastly high frequency (0.83) for yam tubers whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5 kg, the highest number of sprout of the yam tuber also occurred at control (4.29) follow by low frequency (3.12) then medium frequency (0.94) and lastly high frequency (0.72). This revealed that as the frequency of vibration was increasing the number of sprouts of the yam tuber was decreasing for both the weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency of vibration can significantly decrease the number of sprouts of yam tuber during storage.

For the effect of amplitude on the mean of number of the sprouts of the yam tuber at the end of the storage period; the Table 2 indicates that the highest magnitude of number of sprouts of the yam tuber occurred at control (4.40) follow by low amplitude (2.33) then medium amplitude (1.56) and lastly high amplitude (1.17) for yam tubers whose weight were between 0.1 – 2.9 kg while for yam tubers whose weight were between 3.0 – 5.0 kg the maximum value of the number of sprouts of the yam tuber also occurred at control (4.29) follow by low amplitude (2.11) then medium amplitude (1.56) and lastly high amplitude (1.11). The result revealed that as the amplitude of vibration was increasing the number of sprouts of the yam tuber was decreasing both for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that amplitude of vibration can help to considerable reduce the number of sprouts of yam tubers during storage.

Table 2: The effect of the frequency, amplitude and time of vibration on the mean of the number of sprouts for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the number of sprouts	
	Tuber weight (0.1 – 2.9 kg)	**Tuber weight (3.0 – 5.0 kg)**
Control	4.40 ± 0.37a	4.29 ± 0.35a
Low frequency (1 – 5 Hz)	3.00 ± 0.10b	3.12 ± 0.10b
Medium frequency (60 – 100 Hz)	1.23 ± 0.15c	0.94 ± 0.10c
High frequency (150 – 200 Hz)	0.83 ± 0.12c	0.72 ± 0.11c
Control	4.40 ± 0.37d	4.29 ± 0.35d
Low amplitude (5 mm)	2.33 ± 0.16e	2.11 ± 0.12e
Medium amplitude (10 mm)	1.56 ± 0.16f	1.56 ± 0.15f
High amplitude (20 mm)	1.17 ± 0.13f	1.11 ± 0.15g
Control	4.40 ± 0.37h	4.29 ± 0.35h
Low time (3 minutes)	2.89 ± 0.15j	2.28 ± 0.11j
Medium time (10 minutes)	1.17 ± 0.13k	1.39 ± 0.13k
High time (15 minutes)	1.00 ± 0.12k	1.11 ± 0.13k

Note: All data represent means ± standard deviation (S.D.); Means followed by the same letter within a column were not significantly different at p > 0.05 according to LSD test at α = 5%.

For the effect of time on the mean of number of sprouts of yam tuber at the end of storage period; the Table 2 shows that the highest number of sprouts of the yam tuber occurred at control (4.40) follow by low time (2.89) then medium time (1.17) and lastly high time (1.00) for yam tubers whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest number of sprouts of the yam tuber also occurs at control (4.29) follow by low time (2.28) then medium time (1.39) and lastly high time (1.11).

The result indicates that as the time of vibration was increasing the number of sprouts of the yam tuber was decreasing for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The result revealed that time of vibration can significantly decline the number of sprouts of yam tubers during storage period.

The result from ANOVA revealed that there was significant different (at $p < 0.05$) between the low, medium and high levels of frequency of vibration on the number of sprouts of the yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg. Also, there was significant difference (at $p < 0.05$) between the low, medium and high levels of amplitude of vibration on the number of sprouts of the yam tuber for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. More so, there was significant difference (at $p < 0.05$) among the low, medium and high time of vibration on the number of sprouts of the yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg. The analysis of variance also, revealed that for frequency, amplitude and time there was no significant difference between the levels of weight of the yam tuber (weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for the mean number of the sprouts of the yam tuber at $p > 0.05$.

iii. Weight of Sprouts of the Yam Tuber

The maximum mean values of the weight of the sprouts of the yam tuber obtained at the end of the storage period for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg were 302.53 g and 283.49 g respectively with both were obtained from the control. It was observed that at a high frequency, high amplitude and high time there were no sprouting throughout the storage period indicating that mechanical vibrations have great influence and potential to significantly decline sprouting weight of yam tuber.

Table 3 indicates result of the effect of the frequency, amplitude and time of vibration on the mean of the weight of the sprouts of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg at the end of the storage period. For the effect of frequency on the mean of weight of the sprouts of the yam tuber at the end of the storage period; the Table 3 shows that the highest weight of sprouts of the yam tuber occurs at control (302.53 g) follow by low frequency (155.35 g) then medium frequency (29.02 g) and lastly high frequency (25.66 g) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest weight of sprouts of the yam tuber also occurred at control (283.49 g) follow by low frequency (150.39 g) then medium frequency (33.05 g) and lastly high frequency (27.86 g). This revealed that as the frequency of vibration was increasing the weight of the sprouts of the yam tuber was decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency of vibration can significantly help to retard the weight of sprouts of yam tuber during storage period.

Table 3: The effect of the frequency, amplitude and time of vibration on the mean weight of the sprout for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the weight of sprouts, g	
	Tuber weight (0.1 – 2.9 kg)	**Tuber weight (3.0 – 5.0 kg)**
Control	302.53 ± 11.01a	283.49 ± 8.48a
Low frequency (1 – 5 Hz)	155.35 ± 7.13b	150.39 ± 7.47b
Medium frequency (60 – 100 Hz)	29.02 ± 3.34c	33.05 ± 3.36c
High frequency (150 – 200 Hz)	25.66 ± 2.89c	27.86 ± 3.13c
Control	302.53 ± 11.01d	283.49 ± 8.48d
Low amplitude (5 mm)	88.16 ± 8.38e	89.32 ± 7.90e
Medium amplitude (10 mm)	71.24 ± 8.75e,f	68.69 ± 8.76f
High amplitude (20 mm)	50.63 ± 5.64f	53.29 g ± 5.71g
Control	302.53 ± 11.01h	283.49 ± 8.48h
Low time (3 minutes)	116.25 ± 7.93j	125.88 ± 8.72j
Medium time (10 minutes)	56.50 ± 8.10k	48.52 ± 5.87k
High time (15 minutes)	37.28 ± 4.92k	36.90 ± 4.30m

Note: All data represent means ± standard deviation (S.D.); Means followed by the same letter within a column were not significantly different at $p > 0.05$ according to LSD test at $\alpha = 5\%$.

For the effect of amplitude on the mean of weight of the sprouts of the yam tuber at the end of the storage period; the Table 3 indicates that the highest weight of sprouts of the yam tuber occurred at control (302.53 g) follow by low amplitude (88.16 g) then medium amplitude (71.24 g) and lastly high amplitude (50.63 g) for yam tuber whose weight were between 0.1 kg and 2.9 kg while for yam tuber whose weight were between 3.0 kg and 5.0 kg the weight of sprout the yam tuber also occurred at control (283.49 g) follow by low amplitude (89.32 g) then medium amplitude (68.69 g) and lastly high amplitude (53.29 g). The result revealed that as the amplitude of vibration was increasing the weight of the sprouts of the yam tuber was decreasing both for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This proved that amplitude of vibration can significantly help to decline the weight of sprouts of yam tuber during storage.

For the effect of time on the mean of weight of the sprouts of the yam tuber at the end of the storage period; the Table 3 reveals that the highest weight of sprout of the yam tuber occurred at control (302.53 g) follow by low time (116.25 g) then medium time (56.50 g) and lastly high time (37.28 g) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight was 3.0 – 5.0 kg the highest weight of sprouts of the yam tuber also occurred at control (283.49 g) follow by low time (125.88 g) then medium time (48.52 g) and lastly high time (36.90 g). The result indicates that as the time of vibration was increasing the weight of the sprout of the yam tuber was decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The result revealed that time of vibration significantly declines the weight of the sprouts of the yam tuber during storage.

The result from ANOVA indicated that there was significant difference (at $p < 0.05$) between the low, medium and high levels of frequency of vibration on the weight of sprouts of the yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg. Also, there was significant difference (at $p < 0.05$) between the low, medium and high levels of amplitude of vibration on the weight of sprouts of the yam tuber for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. More so, there was significant difference (at $p < 0.05$) among the low, medium and high time of vibration on the weight of sprouts of the yam tuber for both weight between 0.1 – 2.9 kg and 3.0 – 5.0 kg. The analysis of variance also, revealed that for frequency, amplitude and time there was no significant difference between the levels of weight of the yam tuber (weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for the mean weight of the sprouts of the yam tuber at $p > 0.05$.

iv. Number of Leaves on the Stem of the Sprout of the Yam Tuber

It was observed from the data obtained that the number of leaves on the stem of the sprouts of the yam tuber was increasing with time throughout the storage period for the control and some of the treated yam which is in line with the findings of Asare and Akama (2014). Asare and Akama (2014) indicate that the mean number of leaves of sweet potatoes increases as the plant grows in relation to increase in the number of weeks of storage. At high frequency, high amplitude and high time interaction there were no sprout indicating no leaf production throughout the storage period for both yam tuber whose weight were between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This reveals that mechanical vibration can prevent the production of leaves during storage period. The maximum mean values of the number of leaves on the stem of the sprout of the yam tubers obtained at the end of the storage period for weight between 0.1 – 2.9 kg and between 3.0 –

5.0 kg were 29.60 and 29.39 respectively with both were obtained from the control.

Table 4 presents result of the effect of the frequency, amplitude and time of vibration on the mean of the number of leaves on the stem of the sprout for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg at the end of storage period. For the effect of frequency on the mean of the number of leaves on the stem of the sprout of the yam tuber at the end of storage period; the Table 4 shows that the highest number of number of leaves on the stem of the sprout of the yam tuber occurred at control (29.60) follow by low frequency (14.17) then medium frequency (2.05) and lastly high frequency (0.78) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were 3.0 – 5.0 kg the highest number of leaves on the stem of the sprout of the yam tuber also occurred at control (29.39) follow by low frequency (13.83) then medium frequency (1.28) and lastly high frequency (0.67). This revealed that as the frequency of vibration was increasing the number of leaves on the stem of the sprout of the yam tuber was decreasing for both the weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency of vibration can significantly diminish the number of leaves on the stem of the sprout of yam tuber during storage.

Sharma et al. (2015) indicated from their results that melodious music (form of vibration) applied to plants had higher number of leaves and growth rate compared to the control which were not exposed to music which was similar to the results obtained by Jun – ru (2011), Chatterjee et al. (2013), Gagliano (2013) and Vanol (2014). These results of melodious music on plants contradicted the results obtained from this research using mechanical vibration on yam tubers (another form of vibration) and finding of Sharma et al. (2015) of effect of noise on growth of plant. Using mechanical vibration; the control has the highest value of the number of leaves on the stem of the sprout of yam tuber compare to the treated yam tubers. The different in results may be due to the different in nature of vibration used in the interaction with the matter (plant and tuber).

Table 4: The effect of the frequency, amplitude and time of vibration on the mean number of leave on the stem of the sprout for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the number of leave on the stem of the sprouts	
	Tuber weight (0.1 – 2.9 kg)	**Tuber weight (3.0 – 5.0 kg)**
Control	29.60 ± 1.73a	29.39 ± 1.67a
Low frequency (1 – 5 Hz)	14.17 ± 0.72b	13.83 ± 0.86b
Medium frequency (60 – 100 Hz)	2.05 ± 0.52c	1.28 ± 0.17c
High frequency (150 – 200 Hz)	0.78 ± 0.14c	0.67 ± 0.11c
Control	29.60 ± 1.73d	29.39 ± 1.67d
Low amplitude (5 mm)	7.00 ± 0.89e	5.89 ± 0.85e
Medium amplitude (10 mm)	5.56 ± 0.94e,f	5.61 ± 0.93e
High amplitude (20 mm)	4.44 ± 0.70f	4.28 ± 0.68e
Control	29.60 ± 1.73g	29.39 ± 1.67g
Low time (3 minutes)	9.73 ± 1.01h	10.00 ± 1.13h
Medium time (10 minutes)	4.33 ± 0.67j,k	3.06 ± 0.50j,k
High time (15 minutes)	2.94 ± 0.51k	2.72 ± 0.44k

Note: All data represent means ± standard deviation (S.D.); Means followed by the same letter within a column were not significantly different at p > 0.05 according to LSD test at α = 5%.

Furthermore, Sharma et al. (2015) gathered in their results that noise which is a non-rhythmic and unharmonious superposition of various audio frequencies has negative effect on the growth of plant. Also, it was indicated that plant exposed to noise tried to bend away from the direction of the noise was coming from. This was similar to the findings of Chivukula and Ramaswamy (2014) for rock music which is also not a soothing vibration.

For the effect of amplitude on the mean of the number of leaves on the stem of the sprout of the yam tuber at the end of the storage period; the Table 4 indicates that the highest magnitude of number of leaves on the stem of the sprout of the yam tuber occurred at control (29.60) follow by low amplitude (7.00) then medium amplitude (5.56) and lastly high amplitude (4.44) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the value of the number of sprout of the yam tuber also occurred at control (29.39) follow by low amplitude (5.89) then medium amplitude (5.61) and lastly high amplitude (4.28). The result revealed that as the amplitude of vibration was increasing the number of leaves on the stem of the sprout of the yam tuber was decreasing both for weight of yam tubers between 0.1 – 2.9 kg and 3.0 – 5.0 kg. This indicates that amplitude of vibration has the potential of significantly decreasing the number of leaves on the sprout of the yam tuber during storage.

For the effect of time on the mean of the number of leaves on the stem of the sprout of the yam tuber at the end of the storage period; the Table 4 shows that the highest number of leaves on the stem of the sprout of the yam tuber occurred at control (29.60) follow by low time (9.73) then medium time (4.33) and lastly high time (2.94) for yam tubers whose weight were between 0.1 – 2.9 kg while for yam tubers whose weight were between 3.0 – 5.0 kg the highest number of leaves of the sprout of the yam tuber also occurred at control (29.39) follow by low time (10.00) then medium time (3.06) and lastly high time (2.72). The result indicates that as the time of vibration was increasing the number of leaves on the stem of the sprout of the yam tuber was decreasing for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The result revealed that time of vibration can helps to significantly reduce the number of leaves on the stem of sprout of the yam tuber.

From analysis of variance, there were significant difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the number of leaves on the stem of sprout of the yam tubers examined for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. There was no significant difference ($p > 0.05$) between the levels of weight of yam tuber (weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for all the number of leaves on the stem of sprout of the yam tubers studied.

v. Weight of the Root of the Yam Tuber

In the analysis of the data collated at the end of the storage period; at high frequency, high amplitude and high time interaction there were no indication of growth of root throughout the storage period for both yam tubers whose weight were between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This reveals that mechanical vibration can prevent the growth of roots of yam tuber during storage period. The maximum mean values of the weight of the roots of the yam tuber obtained at the end of the storage period for weight between 0.1 – 2.9 kg and between 3.0 – 5.0 kg were 32.74 g and 36.51 g respectively with both were obtained from the control.

Table 5 shows result of the effect of the frequency, amplitude and time of vibration on the mean of the weight of roots of the yam tuber for weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg at the end of storage period. For the effect of frequency on the mean of the weight of roots of the yam tuber at the end of the storage period; the Table 5 indicates that the highest magnitude of the weight of roots of the yam tuber occurred at control (32.74 g) follow by low frequency (18.81 g) then medium frequency (2.24 g) and lastly high frequency (1.60 g) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were 3.0 – 5.0 kg the highest weight of roots of the yam tuber also occurred at control (36.51 g) follow by low frequency (16.41 g) then medium frequency (1.29 g) and lastly high frequency (0.74 g). This reveled that as the frequency of vibration was increasing the weight of roots of the yam tuber was decreasing for both the weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency of vibration has the ability to significantly decline the weight of roots of yam tuber during storage.

For the effect of amplitude on the mean of the weight of roots of the yam tuber at the end of the storage period; the Table 5 indicates that the highest magnitude of the weight of the root of the yam tuber occurred at control (32.74 g) follow by low amplitude (10.33 g) then medium amplitude (7.83 g) and lastly high amplitude (4.49 g) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were 3.0 – 5.0 kg the value of the weight of roots of yam tuber also occurred at control (36.51 g) follow by low amplitude (8.06 g) then medium amplitude (6.28 g) and lastly high amplitude (4.10 g). The result revealed that as the amplitude of vibration was increasing the weight of roots of the yam tuber was decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that amplitude of vibration can considerably decrease the weight of roots of yam tuber during storage.

For the effect of time on the mean of the weight of roots of the yam tuber at the end of the storage period; the Table 5 shows that the highest weight of the roots of the yam tuber occurred at control (32.74 g) follow by low time (13.32 g) then medium time (5.93 g) and lastly high time (3.40 g) for yam tuber whose weight were between 0.1 – 2.9 kg while for yam tuber whose weight were between 3.0 – 5.0 kg the highest weight of roots of the yam tuber also occurred at control (36.51 g) follow by low time (10.60 g) then medium time (5.08 g) and lastly high time (2.76 g). The result indicates that as the time of vibration was increasing the weight of roots of the yam tuber was decreasing for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. The result revealed that time of vibration has the potential of significantly reduce the weight of roots of yam tuber during storage.

From analysis of variance, there were significant difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the weight of roots of the yam tubers examined for both weights of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. There was no significant difference ($p > 0.05$) between the levels of weight of yam tuber (weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for all the weight of roots of the yam tubers studied.

Table 5: The effect of the frequency, amplitude and time of vibration on the mean of the weight of the root for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the weight of the root, g	
	Tuber weight (0.1 – 2.9 kg)	**Tuber weight (3.0 – 5.0 kg)**
Control	32.74 ± 0.40a	36.51 ± 0.71a
Low frequency (1 – 5 Hz)	18.81 ± 1.11b	16.41 ± 0.95b
Medium frequency (60 – 100 Hz)	2.24 ± 0.44c	1.29 ± 0.18c
High frequency (150 – 200 Hz)	1.60 ± 0.46c	0.74 ± 0.10c
Control	32.74 ± 0.40d	36.51 ± 0.71d
Low amplitude (5 mm)	10.33 ± 1.13e	8.06 ± 1.10e
Medium amplitude (10 mm)	7.83 ± 1.24e	6.28 ± 0.96f
High amplitude (20 mm)	4.49 ± 0.82f	4.10 ± 0.63g
Control	32.74 ± 0.40h	36.51 ± 0.71h
Low time (3 minutes)	13.32 ± 1.30j	10.60 ± 1.23j
Medium time (10 minutes)	5.93 ± 1.00k	5.08 ± 0.78k
High time (15 minutes)	3.40 ± 0.64k	2.76 ± 0.39m

Note: All data represent means ± standard deviation (S.D.); Means followed by the same letter within a column were not significantly different at $p > 0.05$ according to LSD test at $\alpha = 5\%$.

(A) (B) (C)

Plate 2. (A) the view of the highly, slightly and unsprouted yam tuber on the 9th week of storage (B) The view of highly sprouted with elongated root of yam tuber (C) The view of the stem and leave of highly sprouted yam tuber

DISCUSSION

The study reveals that as the frequency, amplitude and time of vibration were increasing the length of sprout, number of leaves, weight of roots, weight of sprout, number of sprout on the yam tuber were decreasing which was similar to the report of James et al. (2012) on the effect of irradiation of gamma ray on water yam. Collins (2001) indicates that pleasant music increases the sprouting rate and growth of plant but noise and unpleasant sound decreases sprouting rate, number of leaves produced by plants.

The mechanical vibration of the yam tuber undergone a force vibration with the particles of the yam tuber such that every particle of the yam tuber both interior and exterior parts of the yam tuber had the same frequency with the forcing vibration of the vibrator. This indicates that the frequency of the vibrator would also be the frequency the particles of the yam tuber would vibrate. As the frequency, amplitude and time of vibration of the vibrator increases; this induced more mechanical stress in the yam tuber. The induced mechanical stress at higher level of frequency, amplitude and time can trigger responses of the plant hormones in the yam tuber. It can be suggested that the increase in mechanical stress of the yam tuber increase the secretion of the Abscisic acid (ABA) in the yam tubers. The higher the level of secretion of the Abscisic acid (ABA) in the yam tuber; the delay in sprouting and prolong dormancy of the yam tuber. Plates 2 (A), 2 (B) and 2 (C) present the view of the highly, slightly and unsprouted yam tuber on week 9 of storage, the view of highly sprouted with elongated root of yam tuber and the view of the stem and leave of highly sprouted yam tuber respectively.

The results from a three way analysis of variance (ANOVA) with factorial design using complete randomized block design (CRBD) at (α = 0.05) indicates that there were significance difference (at $p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for each of physical properties of the yam sprout examined for both weight of yam tubers between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. There was no significant difference (at $p > 0.05$) between the levels of weight of yam tuber (weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg) for all the physical properties of yam sprouts studied.

CONCLUSION

This research work applied vibration technique for the control of physical properties of yam (*Dioscorea spp.)* sprouts during storage in FUNAAB, Nigeria Environment. From the result of the research; as the frequency, amplitude and time of vibration were increasing length, number and weight of sprout, number of leaves and weight of roots of the yam tuber were decreasing for both weights of yam between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. There is significant difference at $p < 0.05$ between the low, medium and high levels of frequency, amplitude and time of vibration for each of physical properties of the white yam sprout examined for both weight of yam tuber between 0.1 –2.9 kg and between 3.0 – 5.0 kg. There was no significant difference at $p > 0.05$ of the weight of white yam tubers between the range of 0.1 – 2.9 kg and that of 3.0 – 5.0 kg. The results revealed that mechanical vibration significantly helps in slowing down sprouting in white yam tubers.

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CONFLICT OF INTEREST

All the authors declare that there is no conflict of interests.

AUTHORS' CONTRIBUTIONS

KL and ESA contributed to the conceptualization of the research work. KL carried out the experiment, collection, analysis of the data and interpretation of the results. AA, OU, OR and ESA supervised and directed the project. KL performed the drafting and writing the original manuscript with input from all authors. The thorough reading, editing and corrections of the manuscript were conducted by KL. All the authors carefully read, corrected and approved the original manuscript.

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