INVESTIGATION OF VIBRATION TECHNIQUE FOR THE CONTROL OF PHYSICAL PROPERTIES OF YAM TUBERS (*Dioscorea spp.)* DURING STORAGE IN SOUTH WEST NIGERIA WEATHER CONDITIONS

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ABSTRACT

Yam tubers loss weight during storage and affect its quality and quantity. This study investigated the application of vibration technique for the control of physical properties of yam tubers during storage in South West Nigeria Weather Conditions. The physical properties (weight loss, swollen value of the middle diameter and shrinkage of the length, top and bottom diameter) of the yam tubers were determined 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 factors of the experimental design examined were three levels of frequencies (low (1 – 5 Hz), medium (60 – 100) Hz and high (150 – 200 Hz)), amplitudes of low (5 mm), medium (10 mm) and high (20 mm) and times of low (5 minutes), medium (10 minutes) and high (15 minutes) with weight of yam tuber of two levels of small (0.1 – 2.9 kg) and big (3.0 – 5.0 kg). The tubers were stored for ten weeks after vibration and the physical properties of the yam tubers were monitored and the records were taken every week during the storage period. It was discovered that; as the main effect of the frequency, amplitude and time of vibration were increasing; the physical properties of yam tubers inspected were decreasing significantly at $p < 0.05$ for both weight of yams 0.1 – 2.9 kg and 3.0 – 5.0 kg. The study shows that mechanical vibration helps in slowing down change in the physical properties of yam tuber during storage.

Keywords: Yam Tuber, Mechanical vibration, Control, Length, Top diameter, Middle Diameter, Bottom Diameter.

INTRODUCTION

Plant, crop and seed response to environmental (physical) abiotic stresses such as water, salt, drought, temperature, heavy metal stress, humidity, heat, cold, sound vibration (music or ultrasound), wind, ultraviolet radiation and pressure, mechanical stimulus (such as touch, rub, brush, bend, press, stretch, some multiplex effects induced by sound, electric or magnetic field) and biotic stresses which are mainly arises from bacteria, fungi, viruses, nematodes and insects (Ganfwar *et al.*, 2014; Thao *et al*, 2015; Vivek *et al.*, 2016).

Control of dormancy is attributed to three groups of plant growth regulators namely abscisic acid (ABA), gibberellins (GA) and cytokinins (Arteca, 1996). The phytohormones (plant growth regulators) are naturally occurring synthesis chemical within the root and tuber crop which play critical roles in helping and regulating growth in root and tuber crop for its to adapt to adverse environmental conditions. They regulate or influence a range of cellular or physiological processes including growth, development and movement (cell division, cell enlargement, cell differentiation and movement (tropisms)). During the harvest period of yam tuber which occur at the period of dry season there is secretion of absicsic acid at low concentration (Davies, 2010) which make the yam to go to dormant (Awologbi and Hamadina, 2015), the tuber cells are metabolically quiescent (all metabolic activities stopped) (Sorth, 2015), cease in physiological, respiration, biochemical change and these are maintained through to the month of February. The action of the hormone is to prevent the yam tuber to survive through the period of the water stress. Abscisic acid (ABA) is the only hormones known to induce and maintain yam dormancy (Cheema, 2010).

At the month of February during the raining season gibberellin is secreted to break yam tuber dormancy and simulate sprouting of the yam tuber (Cheema, 2010). The hormone is secreted in small quantity. Once the dormancy is broken, sprouting begins which constitute rapid carbohydrate metabolism and utilization, senescence and pathogenic invasion (Adeyemi, 2009). Planting of the yam tuber begins February in the humid forest and April in the Guinea savanna in West Africa (Ile *et al.*, 2016) and harvested in August – November depending on the variety in Nigeria (Tortoe *et al.,* 2015). Suttle (2004) are of the opinion that

ABA is important in maintaining dormancy. ABA has been found to play a central role in dormancy regulation. Yam tubers have developed a dormant phase vital in surviving extreme cold winter conditions (Cheema, 2010).

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.

This indicates that an isolated living thing which does not have collision and constructive inference with it environment or surrounding (living and non-living thing) cannot emerge a new organism.

Yam is a living species organism which emerge new species by having interference with the biotic and abiotic factor of the surrounding (Abewoy, 2021). 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. This study investigated the application of vibration technique for the control of physical properties of yam tubers (*Dioscorea spp.)* during storage in South West Nigeria Weather Conditions.

MATERIALS AND METHODS

Evaluation of the Physical Properties of the Yam Tuber and Sprouts

The physical properties (weight loss, swollen value of the middle diameter and shrinkage of the length, top and bottom diameter) of the yam tubers were determined for one hundred and forty white yam tubers.

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 of the yam tuber, diameter of the yam tuber 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. The weight of the yam tuber has two levels which was small weight 0.1 kg – 2.9 kg and large weight 3.0 kg – 5.0 kg.

The four factors considered for the experimental design were frequency, amplitude and time duration of the vibration and weight of the yam tuber. The range of frequencies of vibration design for the yam vibration was from 1 to 200 Hz. The selection of the frequency range for the yam vibration was based on the possible and achievable frequency range reported for mechanical vibrator. Nitinkumar *et al.* (2014) reported that the frequency range of mechanical vibrator (using eccentric and connecting link, scotch yoke, cam and follower or rotating unbalance mass mechanism) 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. Thirty two replications of yam tuber were taken as control experiments which were not set into vibration. One hundred and eight tubers were subjected to vibration and remaining thirty – two tubers were taken as control. The vibration was carried out from 20/01/2020 to 24/01/2020. For each treatment, the timing of vibration was continuous till the time of vibration lapse.

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 tubers and sprouts. The factors of the experimental design examined were three levels of frequencies (low (1 – 5 Hz), medium (60 – 100) Hz and high (150 – 200 Hz)), amplitudes of low (5 mm), medium (10 mm) and high (20 mm) and times of low (5 minutes), medium (10 minutes) and high (15 minutes) with weight of yam tuber of two levels of small (0.1 – 2.9 kg) and big (3.0 – 5.0 kg). The tubers were stored after vibration in the Agricultural and Bio-Resources Engineering processing laboratory of Agricultural Engineering department at Federal University of Agriculture, Abeokuta for ten weeks (25/01/2020 to 29/03/2020) and the physical properties of the yam tubers and sprouts were monitored and the records were taken every week during the storage period.

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. The variety of yam tube used for the experiment was white yam (*Dioscorea rotundata*). The yam tubers were selected based on easy accessibility. The storage of the vibrated yam tubers were carried in a natural environment place where plank of woods were placed on the laboratory table then the yams tuber were placed on the plank of woods under prevailing ambient conditions with temperature ranging from 24.2 to 32.6 ℃.

Evaluation and Measurement of the Yam Tuber Response

Measurement of weight loss

The weight of each of the 108 treatments and 32 yam tubers of the control were measured and recorded for each week over the duration of study. Digital weighing balance was used for the measuring of the yam tuber.

Weight loss = Weight of the yam tuber in the first day of storage – Weight of the yam tuber in the 10^{th} day of storage (1)

Shrinkage – length of the yam tuber

The length of the yam tubers was measured and recorded every week throughout the storage period. The shrinkage length for each yam tuber for the whole period of storage was determined by subtracting the measured length of yam tuber at the first week of storage from the 10^{th} week of storage period. The length the tuber was measured using flexible tape rule.

Shrinkage-length of the yam tuber = Length of the yam tuber in the first day of storage – Length of the yam tuber in the 10^{th} day of storage (2)

Shrinkage of the top diameter of the yam tuber

The top diameter of each yam tuber was measured and recorded every week throughout of the storage period. The shrinkage diameter of the top part of the yam tuber was determined by removing the measured top diameter at the first week of storage from the 10^{th} week of storage period. The top diameter was measured using micrometer screw gauge.

Shrinkage of the top diameter of the yam tuber = Top diameter of the yam tuber in the first day of storage – Top diameter of the yam tuber in the 10^{th} day of storage (3)

Swollen value of the middle diameter of the yam tuber

The middle diameter of each yam tuber was measured and recorded every week throughout of the storage period. The swollen value diameter of the middle part of the yam tuber was determined by removing the measured middle diameter at the first week of storage from the 10^{th} week of storage period. The top diameter were measured using micrometer screw gauge

Swollen value of the middle diameter of the yam tuber = Middle diameter of the yam tuber in the 10^{th} day of storage – Middle diamter of the yam tuber in the 1^{st} day of storage

Shrinkage of the bottom diameter of the yam tuber

The bottom diameter of each yam tuber was measured and recorded every week throughout of the storage period. The shrinkage diameter of the bottom part of the yam tuber was determined by removing the measured bottom diameter at the first week of storage from the 10^{th} week of storage period. The bottom diameter were measured using micrometer screw gauge

Shrinkage of the bottom diameter of the yam tuber = Shrinkage of the top diameter of the yam tuber = Bottom diameter of the yam tuber in the first day of storage – Bottom diameter of the yam tuber in the 10^{th} day of storage (3)

RESULTS AND DISCUSSIONS

Weight Loss of the Yam Tubers

It was observed during the experimental studied that there were weight loss of some of the yam tubers. The maximum weight loss recorded at the end of storage period was 1000 g which was obtained from the control. The results indicate that without treatment the yam loss weight during the whole storage period while at some levels of interaction of frequency, amplitude and time there was no weight loss throughout out the storage period. Ravi and Balogopalan (1996), Bibah (2014) indicated that sprouting, respiration and transportation are the factors that contribute to weight loss in yam tuber.

Table 1 reveals result of the effect of the frequency, amplitude and time of vibration on the mean of the weight loss 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 storage period. For the effect of frequency on the mean of the weight loss of the yam tuber at end of the end of storage period the Table 1 shows that the highest weight loss of the yam tuber occurs at control (600.00 g) follow by low frequency (305.56 g) then medium frequency (88.88 g) and lastly high frequency (50.00 g) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest weight loss of the yam tuber also occurs at control (660.71 g) follow by low frequency (277.78 g) then medium frequency (116.67 g) and lastly high frequency (61.10 g). This reveled that as the frequency of vibration is increasing the weight loss is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency has effect on the weight loss of yam tuber.

Lawal *et. al.* (2011) carried out effects of gamma irradiation (a form of vibration) on the sprouting of yam tuber at different dose levels with untreated control and put forward that the untreated control (47.16 %) of the yam tuber has the highest weight loss while the weight loss of the yam tuber irradiated at dose of 80-180 Gy were significantly reduced to the range of 5.13 – 12.02 % which was in accordance with the report of Imeh *et. al.* (2012). Imeh *et. al.* (2012) also indicated in their results that has the dose levels of the Gamma irradiation is increasing there is significant decreased in the weight loss of the yam tuber.

For the effect of amplitude on the mean of the weight loss of the yam tuber at end of the end of storage period the Table 1 indicates that the highest weight loss of the yam tuber occurs at control (600.00 g) follow by low amplitude (183.33 g) then medium amplitude (155.55 g) and lastly high amplitude (105.56 g) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the weight loss of the yam tuber also occurs at control (600.71 g) follow by low amplitude (200.00 g) then medium amplitude (144.44 g) and lastly high amplitude (111.11 g). The result revealed that as the amplitude of vibration is increasing the weight of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This proved that amplitude has effect on the weight loss of yam tuber.

For the effect of time on the mean of the weight loss of the yam tuber at end of the end of storage period the Table 1 indicates that the highest weight loss occurs at control (600.00 g) follow by low time (250.00 g) then medium time (111.11 g) and lastly high frequency (83.33 g) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest weight loss of the yam tuber also occurs at control (660.71 g) follow by low time (261.11 g) then medium time (116.67 g) and lastly high time (77.77 g). The result indicates that as the time of vibration is increasing the weight loss of the yam tuber is 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 has effect on the weight loss of yam tuber. Adegoke and Odebade (2017) reported that control tuber has the highest significant weight loss compare to tubers treated with aqueous extracts of Turmeri at different concentrations which agreed with the findings of Ibrahim *et al.* (1987) and Schmutterer *et al.* (1980).

From analysis of variance, there were significance difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the weight loss 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 significance 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 loss of the yam tubers studied.

Table 1: Result of the effect of the frequency, amplitude and time of vibration on the mean of the weight loss of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 kg and 2.9 kg and between 3.0– 5.0 kg.

	Mean of the weight loss of the yam tuber, g	
	For weight of yam tuber between 0.1 kg – 2.9 kg	For weight of yam tuber between 3.0 kg – 5.0 kg
Control	600.00 g ± 36.83	660.71 g ± 31.13
Low frequency (1 – 5 Hz)	305.56 g ± 16.09	277.78 g ± 11.66
Medium frequency (60 – 100 Hz)	88.88 g ± 11.50	116.67 g ± 11.50
High frequency (150 – 200 Hz)	50.00 g ± 10.42	61.10 g ± 9.16
Control	600.00 g ± 36.83	600.71 g ± 31.13
Low amplitude (5 mm)	183.33 g ± 16.18	200.00 g ± 14.95
Medium amplitude (10 mm)	155.55 g ± 17.23	144.44 g ± 15.04
High amplitude (20 mm)	105.56 g ± 12.11	111.11 g ± 11.32
Control	600.00 g ± 36.83	660.71 g ± 31.13
Low time (3 minutes)	250.00 g ± 13.83	261.11 g ± 13.78
Medium time (10 minutes)	111.11 g ± 14.51	116.67 g ± 11.38
High time (15 minutes)	83.33 g ± 12.95	77.77 g ± 10.56

All data represent means ± standard deviation (S.D.)

Shrinkage Length of the Yam Tubers at End of the Storage

It was observed that the length of the yam tuber was decreasing over time throughout the storage period for the control and some of the treated yam. At high frequency, high amplitude and high time interaction the length of the yam tuber did not change throughout the period of storage for both yam tuber whose weight is between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

This indicates that mechanical vibration can prevent the length yam tuber not to change over time during storage. The maximum value of shrinkage length of the yam tuber recorded at the end of the storage period is 10.5 cm which was obtained from the control.

Table 2 displays result of the effect of the frequency, amplitude and time of vibration on the mean of the shrinkage length 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 storage period. For the effect of frequency on the mean of the shrinkage length of the yam tuber at end of the end of storage period the Table 2 reveals that the highest shrinkage of the length of the yam tuber occurs at control (7.42 cm) follow by low frequency (3.90 cm) then medium frequency (1.22 cm) and lastly high frequency (0.81 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest shrinkage length of the yam tuber also occurs at control (6.36 cm) follow by low frequency (4.30 cm) then medium frequency (0.83 cm) and lastly high frequency (0.74 cm). This reveled that as the frequency of vibration is increasing the shrinkage length of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency has effect on the shrinkage length of yam tuber.

For the effect of amplitude on the mean of the shrinkage length of the yam tuber at end of the end of storage period the Table 2 indicates that the highest magnitude of shrinkage length of the yam tuber occurs at control (7.42 cm) follow by low amplitude (2.64 cm) then medium amplitude (2.01 cm) and lastly high amplitude (1.28 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the value of the shrinkage length of the yam tuber also occurs at control (6.36 cm) follow by low amplitude (2.51 cm) then medium amplitude (1.84 cm) and lastly high amplitude (1.52 cm). The result revealed that as the amplitude of vibration is increasing the shrinkage length of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This proved that amplitude has effect on the shrinkage length of yam tuber.

For the effect of time on the mean of the shrinkage length of the yam tuber at end of the end of storage period the Table 2 presents that the highest weight of sprout of the yam tuber occurs at control (7.42 cm) follow by low time (3.17 cm) then medium time (1.61 cm) and lastly high frequency (1.15 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest weight loss of the yam tuber also occurs at control (6.36 cm) follow by low time (3.27 cm) then medium time (1.38 cm) and lastly high time (1.22 cm). The result indicates that as the time of vibration is increasing the shrinkage length of the yam tuber is decreasing both for weight of yam tuber between 3.0 – 5.0 kg. The result revealed that time of vibration has effect on the shrinkage length of yam tuber.

According to the analysis of variance, there were significance difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the shrinkage length 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 significance 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 shrinkage length of the yam tubers studied.

Shrinkage of the top diameter of the yam tubers after storage

It was observed that the top diameter of the yam tuber was decreasing over time throughout the storage period for the control and some of the treated yam. At high frequency, high amplitude and high time interaction the top diameter of the yam tuber did not change throughout the period of storage for both yam tuber whose weight is between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that mechanical vibration can prevent the top diameter of a yam tuber not to change over time during storage period. The maximum value of shrinkage top diameter of the yam tuber recorded at the end of the storage period is 4.1 cm which was obtained from the control.

Table 3 displays result of the effect of the frequency, amplitude and time of vibration on the mean of the shrinkage of the top diameter 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 storage period.

For the effect of frequency on the mean of the shrinkage of the top diameter of the yam tuber at end of the end of storage period the Table 3 shows that the highest shrinkage of the top diameter of the yam tuber occurs at control (3.14 cm) follow by low frequency (2.24 cm) then medium frequency (0.65 cm) and lastly high frequency (0.44 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest shrinkage of the top diameter of the yam tuber also occurs at control (3.39 cm) follow by low frequency (2.23 cm) then medium frequency (0.78 cm) and lastly high frequency (0.37 cm). This reveled that as the frequency of vibration is increasing the shrinkage of the top diameter of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This shows that frequency has effect on the shrinkage of the top diameter of yam tuber.

For the effect of amplitude on the mean of the shrinkage of the top diameter of the yam tuber at end of the end of storage period the Table 3 indicates that the highest magnitude of shrinkage of the top diameter of the yam tuber occurs at control (3.14 cm) follow by low amplitude (1.43 cm) then medium amplitude (1.11 cm) and lastly high amplitude (0.79 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the value of the shrinkage of the top diameter of the yam tuber also occurs at control (3.39 cm) follow by low amplitude (1.40 cm) then medium amplitude (1.16 cm) and lastly high amplitude (0.82 cm). The result revealed that as the amplitude of vibration is increasing the shrinkage of the top diameter of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This proved that amplitude has effect on the shrinkage of the top diameter of yam tuber.

Table 2. Result of the effect of the frequency, amplitude and time of vibration on the mean shrinkage length of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the shrinkage length of the yam tuber, cm	
	For weight of yam tuber between 0.1 kg – 2.9 kg	For weight of yam tuber between 3.0 kg – 5.0 kg
Control	7.42 cm ± 0.12	6.36 cm ± 0.21
Low frequency (1-5 Hz)	3.90 cm ± 0.19	4.30 cm ± 0.22
Medium frequency (60-100 Hz)	1.22 cm ± 0.13	0.83 cm ± 0.07
High frequency (150-200 Hz)	0.81 cm ± 0.08	0.74 cm ± 0.07
Control	7.42 cm ± 0.12	6.36 cm ± 0.21
Low amplitude (5 mm)	2.64 cm ± 0.25	2.51 cm ± 0.25
Medium amplitude (10 mm)	2.01 cm ± 0.19	1.84 cm± 0.21
High amplitude (20 mm)	1.28 cm ± 0.13	1.52 cm ± 0.18
Control	7.42 cm ± 0.12	6.36 cm ± 0.21
Low time (3 minutes)	3.17 cm ± 0.20	3.27 cm± 0.28
Medium time (10 minutes)	1.61 cm ± 0.21	1.38 cm ± 0.14
High time (15 minutes)	1.15 cm ± 0.12	1.22 cm ± 0.13

All data represent means ± standard deviation (S.D.)

For the effect of time on the mean of the shrinkage of the top diameter of the yam tuber at end of the end of storage period the Table 3 indicates that the highest shrinkage of the top diameter of the yam tuber occurs at control (3.14 cm) follow by low time (1.76 cm) then medium time (0.91 cm) and lastly high frequency (0.66 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest shrinkage of the top diameter of the yam tuber also occurs at control (3.39 cm) follow by low time (1.58 cm) then medium time (1.16 cm) and lastly high time (0.64 cm). The result indicates that as the time of vibration is increasing the shrinkage of the top diameter of the yam tuber is 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 has effect on the shrinkage of the top of diameter of the yam tuber.

According to the analysis of varianc, there were significance difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the shrinkage length 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 significance 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 shrinkage length of the yam tubers studied.

Table 3: Result of the effect of the frequency, amplitude and time of vibration on the mean shrinkage of the top diameter of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the shrinkage of the top diameter of the yam tuber, cm	
	For weight of yam tuber between 0.1 kg – 2.9 kg	For weight of yam tuber between 3.0 kg – 5.0 kg
Control	3.14 cm ± 0.13	3.39 cm ± 0.25
Low frequency (1-5 Hz)	2.24 cm ± 0.08	2.23 cm ± 0.08
Medium frequency (60-100 Hz)	0.65 cm ± 0.07	0.78 cm ± 0.09
High frequency (150-200 Hz)	0.44 cm ± 0.05	0.37 cm ± 0.09
Control	3.14 cm ± 0.13	3.39 cm ± 0.25
Low amplitude (5 mm)	1.43 cm ± 0.11	1.40 cm ± 0.12
Medium amplitude (10 mm)	1.11 cm ± 0.11	1.16 cm ± 0.12
High amplitude (15 mm)	0.79 cm ± 0.08	0.82 cm± 0.09
Control	3.14 cm ± 0.13	3.39 cm ± 0.25
Low time (3 minutes)	1.76 cm ± 0.11	1.58 cm ± 0.12
Medium time (10 minutes)	0.91 cm ± 0.10	1.16 cm ± 0.13
High time (15 minutes)	0.66 cm ± 0.08	0.64 cm ± 0.07

All data represent means ± standard deviation (S.D.)

Swollen of the middle diameter of the yam tubers after storage

It was observed that the middle diameter of 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 the middle diameter of the yam tuber did not change throughout the period of storage for both yam tuber whose weight is between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This reveals that mechanical vibration can prevent the middle diameter of a yam tuber not to change in size over time during storage period. The maximum of swollen value of the middle diameter of the yam tuber recorded at the end of the storage period is 4.7 cm which was obtained from the control.

Table 4 displays result of the effect of the frequency, amplitude and time of vibration on the mean of the swollen value of the middle diameter 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 storage period. For the effect of frequency on the mean of the swollen value of the middle diameter of the yam tuber at end of the end of storage period the Table 4 reveals that the highest swollen value of the middle diameter of the yam tuber occurs at control (3.72 cm) follow by low frequency (2.53 cm) then medium frequency (0.68 cm) and lastly high frequency (0.56 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest swollen value of the middle diameter of the yam tuber also occurs at control (4.04 cm) follow by low frequency (2.64 cm) then medium frequency (0.79 cm) and lastly high frequency (0.48 cm). This reveled that as the frequency of vibration is increasing the swollen value of the middle diameter of the yam tuber is decreasing for both weight of yam tuber between 0.1 – 2.9 kg and 3.0 – 5.0 kg. This shows that frequency has effect on the swollen value of the middle diameter of yam tuber.

For the effect of amplitude on the mean of the swollen value of the middle diameter of the yam tuber at end of the end of storage period the Table 4 indicates that the highest magnitude of swollen of the middle diameter of the yam tuber occurs at control (3.72 cm) follow by low amplitude (1.63 cm) then medium amplitude (1.23 cm) and lastly high amplitude (0.91 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber

whose weight is 3.0 – 5.0 kg the value of the swollen value of the middle diameter of the yam tuber also occurs at control (4.04 cm) follow by low amplitude (1.67 cm) then medium amplitude (1.32 cm) and lastly high amplitude (0.92 cm). The result revealed that as the amplitude of vibration is increasing the swollen value of the middle diameter of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that amplitude has effect on the swollen value of the middle diameter of the yam tuber.

For the effect of time on the mean of the swollen value of the middle diameter of the yam tuber at end of the end of storage period the Table 4 shows that the highest swollen value of the middle diameter of the yam tuber occurs at control (3.72 cm) follow by low time (2.00 cm) then medium time (0.99 cm) and lastly high frequency (0.78 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the highest swollen value of the middle diameter of the yam tuber also occurs at control (4.04 cm) follow by low time (1.99 cm) then medium time (1.21 cm) and lastly high time (0.71 cm). The result indicates that as the time of vibration is increasing the swollen value of the middle diameter of the yam tuber is decreasing for bot 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 effect on the swollen value of the middle diameter of the yam tuber.

Table 4: Result of the effect of the frequency, amplitude and time of vibration on the mean swollen value of the middle diameter of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the swollen value of the middle diameter of the yam tuber, cm	
	For weight of yam tuber between 0.1 – 2.9 kg	For weight of yam tuber between 3.0 – 5.0 kg
Control	3.72 cm ± 0.06	4.04 cm ± 0.05
Low frequency (1-5 Hz)	2.53 cm ± 0.09	2.64 cm ± 0.11
Medium frequency (60-100 Hz)	0.68 cm ± 0.07	0.79 cm ± 0.07
High frequency (150-200 Hz)	0.56 cm ± 0.07	0.48 cm ± 0.04
Control	3.72 cm ± 0.06	4.04 cm ± 0.05
Low amplitude (5 mm)	1.63 cm ± 0.13	1.67 cm ± 0.13
Medium amplitude (10 mm)	1.23 cm ± 0.12	1.32 cm ± 0.13
High amplitude (20 mm)	0.91 cm ± 0.09	0.92 cm ± 0.11
Control	3.72 cm ± 0.06	4.04 cm ± 0.05
Low time (3 minutes)	2.00 cm ± 0.13	1.99 cm ± 0.14
Medium time (10 minutes)	0.99 cm ± 0.11	1.21 cm ± 0.12
High time (15 minutes)	0.78 cm ± 0.08	0.71 cm ± 0.09

All data represent means ± standard deviation (S.D.)

According to the analysis of varianc, there were significance difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the middle diameter 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 significance 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 middle diameter of the yam tubers studied.

Shrinkage of the bottom diameter of the yam tubers after storage

It was observed that the bottom diameter of the yam tuber was decreasing with time throughout the storage period for the control and some of the treated yam. At high frequency, high amplitude and high time interaction the bottom diameter of the yam tuber did not change throughout the period of storage for both yam tuber whose weight is between 0.1 kg and 2.9 kg and between 3.0 kg and 5.0 kg.

This reveals that mechanical vibration can prevent the bottom diameter of a yam tuber not to change in size over time during storage period. The maximum value of shrinkage bottom diameter of the yam tuber recorded at the end of the storage period is 4.5 cm which was obtained from the control.

Table 5 displays result of the effect of the frequency, amplitude and time of vibration on the mean of the shrinkage value of the bottom diameter 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 storage period. For the effect of frequency on the mean of the shrinkage of the bottom diameter of the yam tuber at end of the end of storage period the Table 5 shows that the highest shrinkage of the bottom diameter of the yam tuber occurs at control (3.62 cm) follow by low frequency (2.45 cm) then medium frequency (0.99 cm) and lastly high frequency (0.48 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is 3.0 – 5.0 kg the highest swell value of the middle diameter of the yam tuber also occurs at control (3.90 cm) follow by low frequency (2.36 cm) then medium frequency (0.73 cm) and lastly high frequency (0.46 cm). This reveled that as the frequency of vibration is increasing the shrinkage value of the bottom diameter of the yam tuber is decreasing for both the weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that frequency has effect on the shrinkage value of the bottom diameter of yam tuber.

For the effect of amplitude on the mean of the shrinkage of the bottom diameter of the yam tuber at end of the end of storage period the Table 5 indicates that the highest magnitude of shrinkage of the bottom diameter of the yam tuber occurs at control (3.62 cm) follow by low amplitude (1.59 cm) then medium amplitude (1.43 cm) and lastly high amplitude (0.90 cm) for yam tuber whose weight is between 0.1 – 2.9 kg while for yam tuber whose weight is between 3.0 – 5.0 kg the value of the shrinkage value of the bottom diameter of the yam tuber also occurs at control (3.90 cm) follow by low amplitude (1.39 cm) then medium amplitude (1.24 cm) and lastly high amplitude (0.92 cm).

Table 5: Result of the effect of the frequency, amplitude and time of vibration on the mean shrinkage of the bottom diameter of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

	Mean of the shrinkage of the bottom diameter of the yam tuber, cm	
	For weight of yam tuber between 0.1 – 2.9 kg	For weight of yam tuber between 3.0 – 5.0 kg
Control	3.62 cm ± 0.16	3.90 cm ± 0.21
Low frequency (1 – 5 Hz)	2.45 cm ± 0.09	2.36 cm ± 0.09
Medium frequency (60 – 100 Hz)	0.99 cm ± 0.09	0.73 cm ± 0.05
High frequency (150 – 200 Hz)	0.48 cm ± 0.03	0.46 cm ± 0.03
Control	3.62 cm ± 0.16	3.90 cm ± 0.21
Low amplitude (5 mm)	1.59 cm ± 0.12	1.39 cm ± 0.12
Medium amplitude (10 mm)	1.43 cm ± 0.12	1.24 cm ± 0.11
High amplitude (20 mm)	0.90 cm ± 0.09	0.92 cm ± 0.08
Control	3.62 cm ± 0.16	3.90 cm ± 0.21
Low time (3 minutes)	2.00 cm ± 0.12	1.68 cm ± 0.13
Medium time (10 minutes)	1.11 cm ± 0.11	1.19 cm ± 0.10
High time (15 minutes)	0.81 cm ± 0.08	0.68 cm ± 0.06

All data represent means ± standard deviation (S.D.)

The result revealed that as the amplitude of vibration is increasing the shrinkage value of the bottom diameter of the yam tuber is decreasing both for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. This indicates that amplitude has effect on the shrinkage value of the bottom diameter of the yam tuber.

For the effect of time on the mean of the shrinkage of the bottom diameter of the yam tuber at end of the end of storage period the Table 4 shows that the highest shrinkage value of the bottom diameter of the yam tuber occurs at control (3.62 cm) follow by low time (2.00 cm) then medium time (1.11 cm) and lastly high frequency (0.81 cm) for yam tuber whose weight is between 0.1 – 2.9 kg

while for yam tuber whose weight is between 3.0 – 5.0 kg the highest shrinkage of the bottom diameter of the yam tuber also occurs at control (3.90 cm) follow by low time (1.68 cm) then medium time (1.19 cm) and lastly high time (0.68 cm).

The result indicates that as the time of vibration is increasing the shrinkage value of the bottom diameter of the yam tuber is 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 effect on the shrinkage value of the bottom diameter of the yam tuber. According to the analysis of varianc, there were significance difference ($p < 0.05$) between the low, medium and high levels of frequency, amplitude and time of vibration for the shrinkage of the bottom diameter 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 significance 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 middle diameter of the yam tubers studied.

Plate 1: the view of the yam tubers in the first week of storage
Plate 2: the view of the some of the sprouted and unsprouted yam tuber on week 5 of storage
Plate 3: the view of the yam tubers on week 7 of storage

SUMMARY OF DISCUSSION

It was observed that there was weight loss in some of the yam tuber during storage period which was in accordance to the report of Lawal *et. al.* (2011) and Imeh *et al.* (2012) for effect of gamma ray on yam tubers. It was gathered from the results that there were shrinkage of length, top and bottom diameter and swollen of the middle diameter of some of the yam tuber during storage.

It was also found that that increasing in the frequency, amplitude and time of vibration the weight loss, shrinkage length, shrinkage top and bottom diameter and the swell value of middle diameter of the yam tuber decreases which agreed with the report of Lawal *et al.* (2011) on the effect of gamma radiation on yam tubers.

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 between the low, medium and high levels of frequency, amplitude and time of vibration for each of physical properties 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 significance 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 all the physical properties of yam sprouts and yam tubers studied. Plate 4, 5 and 6 indicate the view of the unsprouted, slightly and highly sprouted yam tuber on week 10 of storage, closer view of the unsprouted, slightly and highly sprouted yam tuber on week 10 of storage and the view of the yam tubers on week 10 of storage respectively.

The vibration of yam tubers results into the vibration of all the particles of the yam tubers. At high frequency, amplitude and long duration time would lead to stress to the yam tubers which can lead to secretion of abscisic acid (ABA); hormones that is responsible for the inhibition of yam tubers. The higher the secretion of the asbcisic acid (ABA); the increase in duration of the dormancy of the yam tubers.

Plate 4: the view of the unsprouted, slightly and highly sprouted yam tuber on week 10 of storage
Plate 5: closer view of the unsprouted, slightly and highly sprouted yam tuber on week 10 of storage
Plate 6: the view of the yam tubers on week 10 of storage

CONCLUSION

The study Investigated of Vibration Technique for the Control of Physical Properties of Yam Tubers (*dioscorea spp)* during Storage in South West Nigeria Weather Conditions. From the results obtained from this research as the frequency, amplitude and time of vibration were increasing the weight loss, swollen value of the middle diameter and shrinkage of the length, top and bottom diameter of the white yam tuber were decreasing for both weight of yam of 0.1 – 2.9 kg and 3.0 - 5.0 kg. It is indicated in the study that there are 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 yam tubers examined for both weight of white yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. It is found that there is 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 study has shown that mechanical vibration has a great effect on the physical properties of white yam tubers. The results revealed that mechanical vibration affect the physical properties of the yam tubers during storage. The study shows that mechanical vibration helps in slowing down change in the physical properties of yam tuber during storage.

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