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 (*Dioscorea spp)* 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. 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 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. The results revealed that the highest weight loss of the yam tuber occurred at control of 600.00 g followed by low frequency of 305.56 g then medium frequency of 88.88 g

and lastly high frequency of 50.00 g for yam tuber whose weight was between 0.1 – 2.9 kg, so also similar trend was observed for amplitude and time of vibration. The results for weight of yam between 3.0 – 5.0 kg showed that the highest weight loss of the yam tuber occurred at control of 660.71 g followed by low frequency of 277.78 g then medium frequency of 116.67 g and lastly high frequency of 61.10 g, and similar for amplitude and time of vibration. All the physical properties of yam tubers examined followed the same trend. 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. Based on the statistical analysis of the results, there was no significant difference at $p < 0.05$ of the weight of 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 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.

1.0 INTRODUCTION

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. The sperm (living thing) from the male species of any of these organisms mention above collides with an ovary or egg (living thing) of closely related species (Suarez, 2016; Miller, 2018; Carlson, 2019), after collision, interference set in between the sperm and the egg (ovary). During the interference process, there is exchange of energy between the sperm and the eggs (mitosis). Other external factors (oxygen, temperature (heat), water (humidity)) interfere in the process. All these external factors must also have direct collisions with these collided sperm and egg and energy is absorbed or exchange during the process. If there is constructive interference between these living (egg and sperm) and (oxygen, temperature, water) non-livings another stage set in which is referred to as cell division. The cells of the interfere egg and sperm start to divide (cell division) and multiply as results of the collision and constructive inference between living and non-living things. Constructive inference always results to cells growth, division and multiplication. Destructive interference results to cell dormant, inhibition or death of the cell. As the cells start to multiply a new organism emerge.

Bacterium a unicellular micro-organism (Idodo – Umeh, 1996; Nweze, 2004; Michael, 2012; Ramalingam, 2016), collide (meet) with spoil food. Feed on it (interference occur) in the process which result to exchange (absorption) of energy. Other external factors interfere in the process (oxygen (aerobic bacteria), temperature, water) interfere in the process. All these external factors must also have direct collision with these bacterium and spoil food and energy is absorbed or exchange during the process. If there is constructive interference between these living (bacterium), spoil food (non-living) and oxygen, temperature and water (non-livings) another stage is set in which is referred as cell division. The cells of the bacteria start to divide (cell division) and multiply as results of the collision and constructive inference between living and non-living things. The cells division and multiplication result to creation of bacterial cells.

For plant kingdom, creation of new plant comes as a result of collision and constructive interference both for sexual and asexual propagations. For sexual propagation to occurs, the pollen grain from the male anther must collide with the female stigma papillae which the pollen grain germinates and fertilizes the ovule of the flower for the establishment of the seeds and fruits (Lu *et al.*, 2011; Joly *et al.*, 2019; Salomon – Torres *et al*., 2021). After collision, interference takes places and exchange of energy. If constructive inference is met the cells starts to divide and multiply which would eventually bring about emergence of new living thing called seed. Seed must collide and interfere with the surrounding for germination or emergence of new living thing to be created. Planting the seed in the soil is collision where the seed interfere with the soil for nutrient, water, oxygen. In the process there is exchange or absorption of energy by any of the two parts (Megersa, 2017). The oxygen, nutrient and oxygen must also collide with cells. This means that all the factors that must bring about the new organism must collide for the emergence of the new living thing.

For asexual reproduction of plants from cutting, grafting, layering and budding also occur as results of collision and constructive interference between the living and the non-living (Yadav and Singh, 2021; Awotedu *et al.*, 2021). For grafting method of asexual propagation, two plants are cut and joined together. The plant hormone detects wounding which responses rapidly. The cell divide and the tissue and vasculature differentiate through a remarkable progress of regeneration around the cut site which form new organs and tissue when placed on growth media containing high levels of plant hormones (Birnbaum and Alvarado, 2008; Sugimoto *et al.*,2011; Melnyk, 2017).

In asexual propagation using laying method, there must be collision (meet) between the branches of the plant (that want to undergo layering as asexual propagation with the soil (Trinklein, 2021). The interference of the plant and the soil lead to exchange of energy (absorption of nutrient from the soil) lead to cell division (Division) (Easton *et al.*, 2019). Afterward multiplication of the cells set in (growth or constructive interference). The constructive interference produces adventitious roots at the base of the layering plant (Yadav and Singh, 2021; Perera *et al.*, 2020). 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 (Onyenwoke and Simonyan, 2014; 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.

Benefits of Yams

Yam composed of soluble, fermentable, and highly viscous dietary fiber called Glucomannan (GM) (Keithley and Swanson, 2005; Keithley *et al.,* 2013). It is basically derived from the root of elephant yam known as konjac (*Amorphophallus konjac*). At doses of $2 - 4$ g per day, GM was well-tolerated and resulted in significant weight loss in overweight and obese individuals (Keithley and Swanson, 2005). Yam can also be viewed as a cancer deterent especially of the colon cancer (Son *et al.,* 2014). Dietary fiber helps reduces constipation, decrease bad low-density lipoprotein (LDL) cholesterol level by binding to it in the intestines and lower colon cancer risk by preventing toxic compounds in the food from adhering to the colon mucosa (Fernande, 2001; Chen *et al.,* 2001;

Gallaher *et al.,* 2002; Otles and Ozgoz, 2014). Additional, being a good source of complex carbohydrate, it helps to regulate steady rise in blood sugar levels (Ramirez and Garcia, 2019). For the same reason, yam is recommended as low glycemic index health food (Okeoghene *et al.,* 2013). It may improve glycemic parameters by inhibiting appetite and slowing intestinal absorption due to increased viscosity (Jenkins *et al.,* 1994; Vuksan *et al.,* 1999; Vuksan *et al.,* 2000; Chearskul *et al.,* 2009).

The tuber is an excellent source of the B – complex group of vitamins (Ogidi *et al.,* 2017; Morse, 2021). It provides adequate daily requirements of pyridoxine (vitamin B6), thiamin (vitamin B 1), riboflavin (Vitamin B 2), folic acid (Vitamin B 9), pantothenic acid (Vitamin B 5), cyanocobalamine (Vitamin B 12) and niacin (Vitamin B 3) (Laquale, 2006; Okwu and Ndu, 2006; Zhang *et al.,* 2018). These vitamins mediate various metabolic functions in the body. Vitamin B6 which is needed by the body to break down a substance called homocysteine, which can damage blood vessels wall (Halka *et al.,* 2019). High levels of homocysteine can also lead to heart attack despite having low levels of cholesterol. Thus, have a good supply of vitamin B6 in the body is believe to reduce the risk of developing heart diseases (Fitzpatrick, 2011). The β – carotene and vitamin C in this tuber work well to get rid of cancer-friendly free radicals (Pawlowska *et al.,* 2019). Free radicals can damage the body in reaction with DNA, so the antioxidants (Vitamin C and β – carotene) work to reduce the damage caused by these free radicals (Lobo *et al.,* 2010; Dizdaroglu and Jaruga, 2012; McLaughlin, 2013; Salehi *et al.,* 2018). It is also an excellent food for those suffering from arthritis and asthma (Dufie *et al*., 2013).

Diabetic patient can eat yam without worrying about the rise in blood sugar (Enemchukwu *et al.,* 2016). Glycemic index of a food reflects the food's effect on a person's blood glucose level (Hatekar and Ghodke, 2009; Bobadoye and Enujiugha, 2016). Fast glucose absorption is not desirable, so yam raises the blood sugar level slowly as compared to simple sugars and is therefore highly recommended as a low glycemic index healthy food.

Daily consumption of yam juice can increase nutrient absorption of the body. It also protects valuable enzymes needed by the body for healthier cells and maintains the good condition of the body. By drinking yam juice, all the vitamins and nutrients of it can be easily absorbed by the body in its liquid form.

Yams also have the ability to increase learning and memory capacity in the human brain. Tohda *et al.* (2017) reported that people who consumed yam for 6 weeks regularly noticed a significant enhancement in the cognitive abilities and function of healthy human adults. This is mainly due to the antioxidant compound present in yams. It can also help to cure Alzheimer's disease (Turner *et al.,* 2015).

Yams contain complex carbohydrates and fibre which gradually slow the rate at which sugars are released and absorbed in the mainstream (Yalindua *et al.,* 2021). Being high in fibre, yam keeps you full without putting on those extra kilos. Yams are also a good source of manganese, a mineral that aids carbohydrates metabolism and is very important for energy production and antioxidant defenses (Baah, 2009). Fresh root also contains good amounts of antioxidant vitamin, vitamin − C; providing about 29 % of recommended levels per 100 g. It also has anti − inflammatory properties (Son *et al.*, 2014; Dey *et al.*, 2016). Vitamin – C plays some important roles as anti – aging, immune function booster, wound healing, and bone growth. β – carotene, vitamin C, vitamin B 6 and antioxidants can help to prevent wrinkles and other signs of aging (Carr and Maggini, 2017; Cerullo *et al.,* 2020).

The vitamins present in yam mediate various metabolic functions in the body. Yam contains small amounts of vitamin – A, and β – carotene levels (Price *et al.*, 2018). Carotenes convert into vitamin – A inside the body (Hickenbottom *et al.*, 2002; Novotny *et al.*, 2010). Carotenes and vitamin are powerful antioxidants compounds. Vitamin – A maintains healthy mucosa and skin, improves vision, maintenance of body linings, immune defenses, skin and bone growth and protection from lung and oral cavity cancers (Rathee *et al.*, 2016).

The yam tuber indeed is one of the good sources of minerals such as copper, calcium, potassium, iron, manganese, and phosphorus (Shajeela *et al.*, 2011; Ramirez and Garcia, 2019).

Haytowitz *et al.* (2019) reported that 100 g of yam tuber provides about 816 mg of potassium. Potassium is an important component of cell and body fluids which helps controlling heart rate and blood pressure by countering hypertensive effects of sodium (Aburto *et al.,* 2013; Jayedi *et al.*, 2019; O'Donnell *et al.*, 2019; Goncalves and Abreu, 2020). Low intake of potassium-rich food can also lead to hypertension (Dyer *et al.,* 1994; Palaniveloo *et al.*, 2021). Osredkar and Sustar (2011) indicate that copper plays a role in the production of red blood cells and hemoglobin. The body uses manganese as a co-factor for the anti-oxidant enzyme, superoxide dismutase (Aschner *et al.,* 2007; Ayub *et al.*, 2019). Iron is required for red blood cell formation (Rishi and Subramaniam, 2017).

Yam tubers contain a high amount of antioxidants which protect the skin from harsh sun rays and environmental hazards. It stimulates the production of the skin collagen and brings smoothness and elasticity of the skin. Yam also renews damaged skin and improves the appearance of the skin.

Yam is considered as an excellent source of natural health promoting compounds like antocyanins and β – carotene (Moriya *et al.*, 2015). It also contains vitamin A which is highly beneficial for cell growth, including growth of hair. A deficiency in β − carotene can lead to dry, dull and lifeless hair which flakes off into dandruff. Yam will also prevent premature graying as it contains a good amount of Vitamin B6 which creates melanin and give the hair its colour (Meng *et al.*, 2012).

Iron in yam helps the red blood cells to carry oxygen and promote blood circulation in the scalps (Abbaspour *et al.*, 2014). Low levels of iron in the body can lead to hair loss and baldness in both men and women (Leiva – Salinas *et al.,* 2020). Thus, regular consumption of yam will prevent hair loss and will promote hair growth.

Yam contains bioactive compounds such as dioscorine, diosgenin and water soluble polysaccharides (Shah, *et al.*, 2012; Harijono *et al.*, 2013; Rosida *et al.*, 2016). Dioscorine, water soluble storage protein found in yam is known to benefit people suffering from hypertension (Harijono *et al.*, 2012). Dioscorine inhibits ACE (angiotensin converting enzyme) activity which therefore leads to reduce blood pressure and plays an important role in management of hypertension (Liu *et al.*, 2007). Dioscorin accounts for about 90 % of the extractable water soluble protein found in Dioscorea species as estimated by immunostaining method (Hsu *et al.,* 2002; Shih *et al.,* 2015). Diosgenin is a sapogenin steroid compound that can be absorbed through the gut and plays important role in the control of cholesterol metabolism (Jesus *et al.,* 2016; Sun *et al.,* 2021). They are good sources of the unique fat – like structure called diosgenin, a hormone-like molecule with probably anti-cancer effects (Sethi *et al.,* 2018).

The chemical composition of the yam tuber varies with species and cultivars. It may also vary depending on the environmental conditions under which the tuber is produced. The dry matter of the tuber is one third of its weight and the rest is water. There is a gradient of increase in percentage of moisture (and a decrease in percentage of dry matter) from head to tail.

Carbohydrates are the major dry matter components of yams. Most of this carbohydrate is starch, and is mainly Amylopectin, and exist as starch grains. The protein content of yam is low ranging from 1 – 2 % of fresh weight and is low in sulphur containing amino acids (cysteine asnd methionine), but the overall rating for essential amino acids is high and superior to sweetpotato (Bhandari *et al.,* 2003; O'Sullivan, 2010). Vitamins and minerals (ash) are minor components of yam tuber. Significant amount of Vitamin C are present. Traces of Vitamin A and B are present. The mineral fraction contains calcium, iron and phosphorus among components. Certain yam species contain alkaloids (e.g. Diosgenin) which are extracted for pharmaceutical use (Kanu *et al.*, 2018).

From a nutritional stand point, yam is better than cassava on account of its higher vitamin C (40 – 120 mg/g edible portion) and crude protein content (40 – 140 g/kg dry matter) (Opera, 1999; Baah *et al.*, 2009). It is considered to be the most nutritious of the tropical root crops (Alamu *et al.*, 2020).

1.1 Environmental stress of Yam tubers

Plant, crop and seed response to environmental (physical) abiotic stresses (Ganfwar *et al.,* 2014) such as water, salt, drought, temperature, heavy metal stress (Thao *et al,* 2015), humidity, heat, cold, sound vibration (music or ultrasound), wind, ultraviolet radiation and pressure (Vivek *et al.,* 2016; Shabir *et al.,* 2016; Mishra *et al.,* 2016), 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.

1.2 Hormones responsible for the control of dormancy and sprouting in yam tubers

The hormones in plant that are responsible for the control of the response of the plant to the environmental stresses are indole-3-acetic acid or IAA (auxin), cytokinin, gibberellins, abscisic acid and ethylene (Sandall, 2011), salicylic acid (Ganfwar *et al.,* 2014), strigolactones, brassinoteroids, jasmonic acid-related compounds (Yamaguchi *et al.*, 2010; Davies, 2010) and nitrous (nitric) oxide (Miransari, 2016). The phytohormones (plant growth regulators) are naturally occurring synthesis chemical within the root and tuber crop (i.e. endogenously) 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)).

Control of dormancy is attributed to three groups of plant growth regulators namely abscisic acid (ABA), gibberellins (GA) and cytokinins (Arteca, 1996). Yam response to plant growth regulators application similarly differs from that of many other plants. 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 (Cheema, 2010; Davies, 2010; Awologbi and Hamadina, 2015), the tuber cells are metabolically quiescent (all metabolic activities stopped) (Osagie, 1992; 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, the resumes of sprouting inevitably constituting an inroad to 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 (Tortoe *et al.,* 2015, Ile *et al.,* 2016) and harvested in August – November depending on the variety in Nigeria (Tortoe *et al.*, 2015).

Various authors agree that the level of ABA is highest in freshly harvested tubers and that the level declines during storage (Suttle and Hulstrand, 1994; Arteca, 1996; Suttle, 1996, Cheema, 2010). It has been suggested that it is only the initial level of ABA that is important in triggering dormancy (Hilhorst and Toorop, 1997; Biemelt *et al.*, 2000), but Nambara *et al.* (2010), Suttle (2004a) and Ali *et al.* (2021) are of the opinion that ABA is also important in maintaining dormancy. Abscisic acid (ABA) is a naturally occurring growth inhibitor present in all organs of higher plants. ABA (a terpenoid) is produced in the chloroplasts and other plastids (Arteca, 1996). ABA acts on various processes in plants, such as stomatal opening and closure, abscission, cold stress, and dormancy (Arteca, 1996).

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). ABA plays a pivotal role in the protection against cold stress (Arteca, 1996) and it has been proven that shorter days trigger the production of ABA (Gardner *et al.*, 1985). Leclerc *et al.* (1995) stated that small microtubers had a higher ABA content than field grown tubers and that the higher content was the reason for the longer dormant period. According to Cheema (2010) it is not necessarily the level of ABA, but the ratio of ABA to gibberellins that is the regulatory factor in maintaining dormancy. If the ratio is in favour of gibberellins, sprouting will commence and dormancy will be terminated (Cheema, 2010). ABA is required to initiate dormancy, but there is not a definite level below which ABA must decrease for sprouting to commence (Claassens and Vreugdenhil, 2000). Hemberg (1985) suggested that ABA is involved in the inhibition of DNA and RNA synthesis, while gibberellins (GA) are involved in the acceleration of DNA and RNA synthesis. So, it appears that ABA can maintain dormancy and GA can promote sprout growth.

Auxins (IAA) appear to be key players in maintaining apical dominance and promoting root formation. The abscisic acid (ABA) are responsible for dormancy in yam tuber and is often regarded as being inhibitor while gibberellins and cytokinins are responsible for sprouting and stem elongation in yam tuber (Arteca, 1996, Cheema, 2010). ABA is intimately involved with plant responses to a wide range of environmental stress. ABA acts antagonistically to

GAs in yam tuber. Plant hormones are not directly involved in metabolic or developmental processes but they act at concentrations to modify those processes.

Abscisic acid acts as a mediator in crop responses to many stresses. In response to different abiotic stresses crop adapt many strategies which ultimately enhance the plant growth and productivity. Abscisic acid is known to mediate signals in crop cells subjected to environmental stress. These signals can bring about expression of stress related genes. Absicsic acid has been proposed to play an important role in stress responses and/or adaptation. Absicsic acid is a major internal signal enabling plant to survive adverse environmental stress. A signal is generated by abscisic acid during a plant’s life cycle in order to control seed germination and development processes.

The control of the synthesis of these hormones in yam tuber had not yielded any success.

The various sources of vibration are electromagnetic radiations, sound waves (ultrasonic sound), music and mechanical vibration from vibrating bodies. A lot of researches had been carried out on the effect and interaction of sound wave, electromagnetic radiation and music on micro-organism, macro-organism (plant and animal), crops, insect and roots and tubers crops.

2.0 MATERIALS AND METHODS

2.1 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. A total of one hundred and eight tubers were subjected to vibration and remaining thirty – two tubers were taken as control. The tubers were stored for ten weeks after vibration in the Agricultural and Bio-Resources Engineering processing laboratory of Agricultural Engineering department at Federal University of Agriculture, Abeokuta and the physical properties of the yam tubers and sprouts were monitored and the records were taken every week during the storage period.

2.2 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. The first factor (frequency of vibration) has three levels (low (1 – 5 Hz), medium (60 – 100 Hz) and high (150 – 200 Hz)), second factor (amplitude of vibration) has three levels (low (5 mm), medium (10 mm) and high (20 mm)), the third factor (time duration of vibration) has three levels (low (3 minutes), medium (10 minutes) and high (15 minutes)) and the fourth factor (weight of the yam tuber) has two levels (small (0.1 – 2.9 kg) and big (3.0 – 5.0 kg)).

A full 3 × 3 × 3 × 2 factorial design experiment based on complete randomized block (CRBD) design with fifty-four treatments and two replicates was conducted. 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 experimental factorial design for the study required fifty-four treatments combinations. For each treatment combination two replicates making a total of hundred and eight observations (runs). The yam tubers were evaluated for every one week to ten weeks (25/01/2020 to 29/03/2020). One and forty yam tubers were used for the experimental work. The variety of yam tube used for the experiment was white yam (*Dioscorea rotundata*). The yam tubers were selected based on easy accessibility. The vibrated yam tubers were stored in the inside the processing laboratory of the Agricultural and Bio Resource Engineering department of Federal University of Agriculture, Abeokuta.

The storage of the vibrated yam tubers were carried in a natural environment place where each yam tubers were placed on planks of wood under prevailing ambient conditions with temperature ranging from 24.2 to 32.6 ℃. The laboratory was well ventilated. During the two months and two weeks the store yam tubers were inspected at weekly intervals throughout the storage period. The yam tubers were labeled for easy identification and observation.

2.2.1 Independent variables (Factors) of the experimental design

- Frequency of vibration
- Amplitude of vibration
- Time of duration of vibration
- Weight of the yam tuber

2.2.2 Levels of the each of the main factors of the experimental design

2.2.2.1 Levels of the frequency of vibration

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. Also, a low, medium and very high frequency were considered.

1. Low frequency (1 – 5 Hz) 2. Medium frequency (60 – 100 Hz) 3. High frequency (150 – 200 Hz)

2.2.2.2 Levels of the amplitude of vibration

The selection of the amplitude range for the yam vibration was based on the possible and achievable amplitude range reported for mechanical vibrator. Nitinkumar *et al.* (2014) reported that maximum displacement (amplitude) of mechanical vibrator (using eccentric and connecting link, scotch yoke, cam and follower or rotating unbalance mass mechanism) achievable is 25 mm. Also, low, medium and very high amplitude were considered.

1) 5 mm 2) 10 mm 3) 20 mm

2.2.2.3 Levels of the time duration of the vibration

The time durations of the vibration of the experimental design were selected for short, medium and long time duration. For each treatment, the timing of vibration was continuous till the time of vibration lapse. The levels of the time duration of the vibration were

1) 3 minutes 2) 10 minutes 3) 15 minutes

2.2.2.4 Levels of weight of the yam tuber

The weight of the yam tuber was selected for small and large weight. The levels of the yam tuber were

1) Small weight (0.1 kg – 2.9 kg) 2) large weight (3.0 kg – 5.0 kg)

2.2.3 Effect of the vibration frequency, amplitude and time duration on the physical properties of the yam tubers

The physical properties of the vibrated yam tuber that were examined during and after the storage period were:

- The weight loss of the yam tuber
- The shrinkage length of the yam tuber
- The shrinkage of the top diameter of the yam tuber
- The swell value of the middle diameter of the yam tuber
- The shrinkage of the bottom diameter of the yam tuber

2.2.4 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 $^{\text{th}}$ 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 10th 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 1 st day of storage $-$ Length of the yam tuber in the 10 $^{\text{th}}$ 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 10th 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 1 st day of storage $-$ Top diameter of the yam tuber in the 10 $^{\text{th}}$ 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 diameter of the yam tuber in the 1^{st} day of storage (4)

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 = Bottom diameter of the yam tuber in the 1^{st} day of storage – Bottom diameter of the yam tuber in the 10^{th} day of storage (4)

2.2.5 Vibration of the yam tuber and assigning of number to the yam tubers

For easy identification of the yam tubers the tubers were numbered. The factors of the experimental design are frequency, amplitude, time of vibration and the weight of the yam tuber. 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. The levels of the frequency of vibration were low frequency FL (1 – 5 Hz), medium frequency FM (60 – 100 Hz) and high frequency FH (150 – 200 Hz). The levels of the amplitude of vibrations were low amplitude AL (5 mm), medium amplitude AM (10 mm) and high amplitude AH (20 mm). The levels of time of vibration were low time TL

(3 minutes), medium time TM (10 minutes) and high time TM (15 minutes). The levels of weight of the yam tuber were small weight (0.1 kg – 2.9 kg) and large weight (3.0 kg – 5.0 kg).

2.3 Storage of the vibrated and untreated yam tubers

After the treatment the vibrated and untreated yam tuber were stored in the Agricultural and Bio-Resources Engineering processing laboratory of Agricultural Engineering department at Federal University of Agriculture, Abeokuta for 10 weeks stating from 25/01/2020 to 29/03/2020. Plank of woods were placed on the laboratory table then the yams tuber were placed on the plank of woods. The yam tubers were monitored and recorded every week throughout the period of storage.

3.0 RESULTS AND DISCUSSIONS

3.1 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).

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.

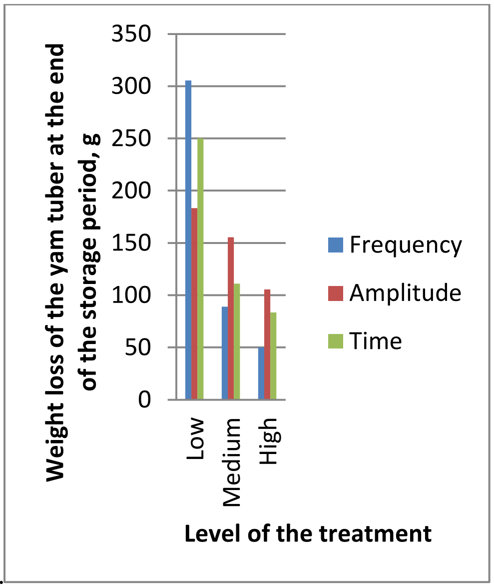
	Mean of the weight loss of the yam tuber, g	
	For weight of yam tuber between 0.1 kg – 2.9 kg	For weight of yam tuber between 3.0 kg – 5.0 kg
Control	600.00 g ± 36.83	660.71 g ± 31.13
Low frequency (1-5 Hz)	305.56 g ± 16.09	277.78 g ± 11.66
Medium frequency (60-100 Hz)	88.88 g ± 11.50	116.67 g ± 11.50
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.)

Figures 1 – 2 show the effects of the frequency, amplitude and time at different levels for the weight loss of the yam tuber for weight of the yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. For weight of yam tuber between 0.1 – 2.9 kg, at low level, the frequency (305.56 g) has the highest value of weight loss of yam tuber

followed by time (250.00 g) then amplitude (183.33 g) while for weight of yam tuber between 3.0 – 5.0 kg, the frequency (277.78 g) also has the highest value of weight loss of yam tuber followed by time (261.11 g) and then amplitude (200.00 g). This shows that at low level, amplitude has the highest effect on the weight loss of yam tuber follow by time then frequency for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (155.55 g) has the highest value of weight loss of yam tuber followed by time (111.11 g) then frequency (88.88 g) while for weight of yam tuber 3.0 – 5.0 kg, the amplitude (144.44 g) also has the highest value of weight loss of yam tuber followed by time (116.67 g) and then frequency (116.67 g). This shows that at medium level, frequency has the highest effect on the weight loss of yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg. However, at medium level, frequency and time have the highest effect on the weight loss of yam tuber follow by amplitude for weight of yam tuber between 3.0 – 5.0 kg.

1.


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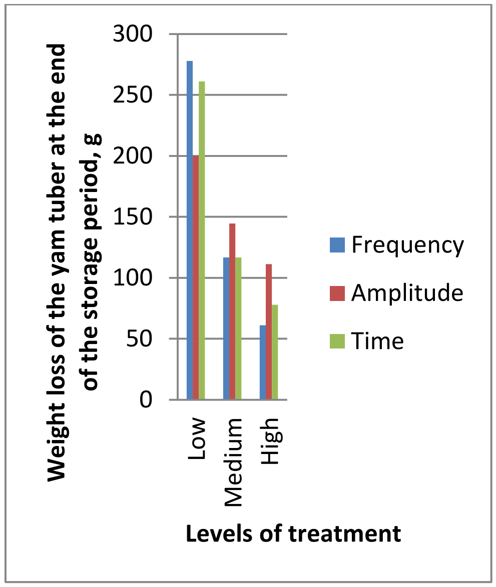


Figure 1. The effects of the frequency, amplitude and time at different levels for the weight loss of the yam at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg.

Figure 2. The effects of the frequency, amplitude and time at different levels for the weight loss of the yam at the end of the storage period for weight of yam tuber between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 kg and 2.9 kg, at high level, the amplitude (105.56 g) has the highest value of weight loss of yam tuber followed by time (83.33 g) then frequency (50.00 g) while for weight of yam tuber between 3.0 kg and 5.0 kg, the amplitude (111.11 g) also has the highest value of weight loss of yam tuber followed by time (77.77 g) and then frequency (61.10 g). This shows that at high level, frequency has the highest effect on the weight loss of yam tuber follow by time then amplitude for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

Table 2 shows results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the weight loss of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg at (α = 0.05). The Table indicates that there is significant different between the low, medium and high levels of frequency of vibration on the weight of yam tuber for weight between 0.1 – 2.9 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the weight loss of yam tuber for weight between 0.1 – 2.9 kg. More so, there is significant difference among the low, medium and high time for weight between 0.1 – 2.9 kg. Furthermore, there is no significant difference among the interaction of frequency and amplitude, interaction of frequency and time, interaction of amplitude and time, interaction of frequency, amplitude and time at (p = 0.05) on the weight loss of yam tuber for weight between 0.1 – 2.9 kg.

Table 3 presents results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the weight loss of the yam tuber for weight of yam tuber between 3.0 – 5.0 kg at (α = 0.05). The Table shows that there is significant different between the low, medium and high levels of frequency of vibration on the weight loss of yam tuber for weight of yam tuber 3.0 – 5.0 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the weight loss of yam tuber for weight 3.0 – 5.0 kg. More so, there is significant difference among the low, medium and high time for weight between 3.0 kg and 5.0 kg. Furthermore, there is no significant difference between the interaction of amplitude and time, interaction of frequency, amplitude and time, interaction of frequency, amplitude and time at (α = 0.05) on the weight loss of yam tuber for weight of yam tuber between 3.0 – 5.0 kg while there is significant difference between the interaction of frequency and time on weight loss of yam tuber for weight 3.0 – 5.0 kg.

Table 4 shows the result from analysis of variance to check the significance difference between the levels of weight for the mean of the weight loss of the yam tuber (α = 0.05). The table shows that for frequency, amplitude and time 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 the weight loss of the yam tuber.

Table 2. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for weight loss of the yam tuber after the storage period for Weight of yam tuber between 0.1 – 2.9 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	682, 592.59	341, 296.30	57.59	3.35	Significant
Amplitude	2	55, 925.93	27, 962.97	4.72	3.35	Significant
Time	2	287, 037.04	143, 518.52	24.22	3.35	Significant
Frequency * Amplitude	4	22, 962.96	5, 740.74	0.97	2.73	Not Significant
Amplitude * Time	4	25, 185.17	6, 296.29	1.06	2.73	Not Significant
Frequency * Time	4	11, 851.85	2, 962.96	0.50	2.73	Not Significant
Frequency * Amplitude * Time	8	9259.27	1, 157.41	0.20	2.31	Not Significant
Error	27	160, 000.00	5, 925.93			
Total	53	1, 254, 814.82				

Table 3. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) plus the control for weight loss of the yam tuber after the storage period for Weight of yam tuber between 3.0 – 5.0 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	449, 259.26	224, 629.63	57.76	3.35	Significant
Amplitude	2	71, 481.48	35, 740.74	9.19	3.35	Significant
Time	2	321, 481.48	160, 740.74	41.33	3.35	Significant
Frequency * Amplitude	4	8, 518.52	2, 129.63	0.55	2.73	Not Significant
Amplitude * Time	4	16, 296.30	4, 074.08	1.05	2.73	Not Significant
Frequency * Time	4	21, 851.85	5, 462.96	1.40	2.73	Significant
Frequency * Amplitude * Time	8	40, 370.37	6, 296.30	1.62	2.31	Not Significant
Error	27	105, 000	3, 888.89			
Total	53	1, 034, 259.26				

Table 4. Results from analysis of variance to check the significance difference between the levels of weight for the mean weight loss of the yam tuber (α = 0.05).

Factor	Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	Weight	1	20.5720	20.57	0.0012	7.71	Not significant
	Error	4	66239.1233	16559.78			
	Total	5	66259.6953				
Amplitude	Weight	1	20.5720	20.57	0.0115	7.71	Not significant
	Error	4	7139.3787	1784.84			
	Total	5	7159.9507				
Time	Weight	1	20.5720	20.57	0.0024	7.71	Not significant
	Error	4	34610.2429	8652.56			
	Total	5	34630.8149				

3.2 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 5 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 5 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

Table 5. 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.)

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.

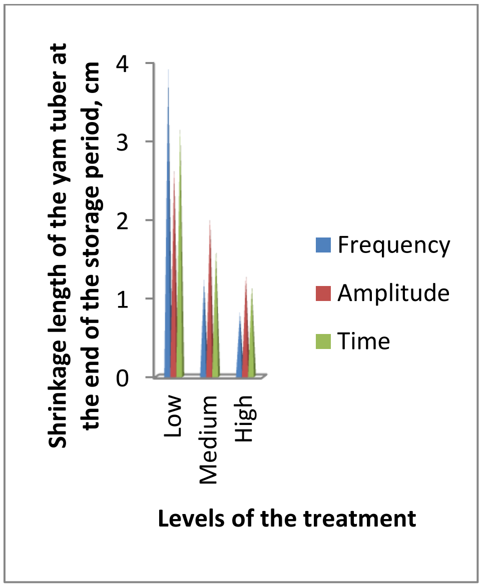
For the effect of amplitude on the mean of the shrinkage length of the yam tuber at end of the end of storage period the Table 5 indicates that the highest magnitude of shrinkage length of the yam tuber occurs at control (7.42 cm) follow by low amplitude (2.64 cm) then medium amplitude (2.01 cm) and 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 5 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.

Figures 3 – 4 show the comparison of the frequency, amplitude and time at different levels for the shrinkage length of the yam tuber for weight of the yam tuber between 0.1 – 3.0 kg and between 3.0 – 5.0 kg. For weight of yam tuber between 0.1 – 2.9 kg, at low level, the frequency (3.90 cm) has the highest value of shrinkage length of yam tuber followed by time (3.17 cm) then amplitude (2.64 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the frequency (4.30 cm) also has the highest value of shrinkage length of yam tuber followed by time (3.27 cm) and then amplitude (2.64 cm). This shows that at low level, amplitude has the highest effect on the shrinkage length of yam tuber follow by time then frequency for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (2.10 cm) has the highest value of shrinkage length of yam tuber followed by time (1.61 cm) then frequency (1.22 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.84 cm) also has the highest value of weight loss of yam tuber followed by time (1.38 cm) and then frequency (0.83 cm). This shows that at medium level, frequency has the highest effect on the shrinkage length of yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg. However, at medium level, frequency also has the highest effect on the shrinkage length of yam tuber follow by time and then amplitude for weight of yam tuber between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at high level, the amplitude (1.28 cm) has the highest value of shrinkage length of yam tuber followed by time (1.15 cm) then frequency (0.81 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.52 cm) also has the highest value of weight loss of yam tuber followed by time (1.22 cm) and then frequency (0.74 cm). This shows that at high level, frequency has the highest effect on the shrinkage of yam tuber follow by time then amplitude for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

3. 

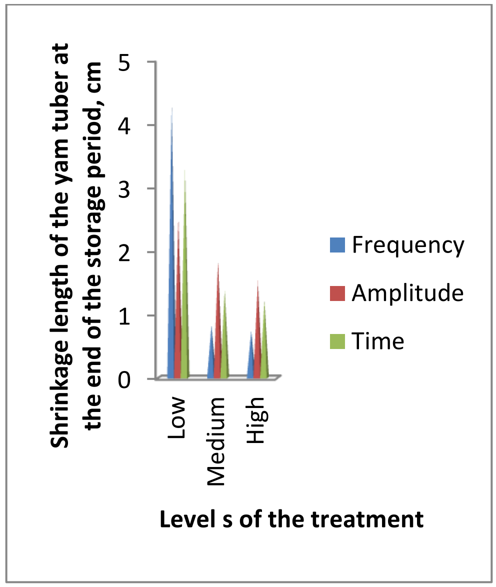
4. 

Figure 3. The effects of the frequency, amplitude and time at different levels for the shrinkage length of the yam tuber at the end of the storage period for weight of yam tuber 0.1 – 2.9 kg .

Figure 4. The effects of the frequency, amplitude and time at different levels for the shrinkage length of the yam tuber at the end of the storage period for weight of yam tuber 3.0 – 5.0 kg.

Table 6 shows results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage length of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg at (α = 0.05). The Table indicates that there is significant different between the low, medium and high levels of frequency of vibration on the shrinkage length of yam tuber for weight between 0.1 – 2.9 kg. Also, there is significant difference between the low, medium and high levels of amplitude of vibration on the shrinkage length of yam tuber for weight between 0.1 – 2.9 kg. More so, there is significant difference among the low, medium and high time of vibration on the shrinkage length of yam tuber for weight between 0.1 – 2.9 kg. Furthermore, there is no significant difference among the interaction of frequency and amplitude, interaction of frequency and time, interaction of amplitude and time, interaction of frequency, amplitude and time at (p = 0.05) on the shrinkage length of yam tuber for weight between 0.1 – 2.9 kg.

Table 6. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage length of the yam tuber at the end of the storage period for Weight of yam tuber between 0.1 – 2.9 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	102.21	51.11	45.63	3.35	Significant
Amplitude	2	16.70	8.35	7.46	3.35	Significant
Time	2	40.67	20.34	10.17	3.35	Significant
Frequency ∗ Amplitude	4	4.02	1.01	0.90	2.73	Not Significant
Amplitude ∗ Time	4	3.00	0.75	0.67	2.73	Not Significant
Frequency ∗ Time	4	4.23	1.06	0.95	2.73	Not Significant
Frequency ∗ Amplitude ∗ Time	8	5.73	0.72	0.64	2.31	Not Significant
Error	27	30.11	1.12			
Total	53	206.67				

Table 7 presents results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage length of the yam tuber for weight of yam tuber between 3.0 kg and 5.0 kg at (α = 0.05). The Table shows that there is significant different between the low, medium and high levels of frequency of vibration on the weight loss of yam tuber for weight of yam tuber between 3.0 – 5.0 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the weight loss of yam tuber for weight between 3.0 – 5.0 kg. More so, there is significant difference among the low, medium and high time for weight between 3.0 – 5.0 kg. Furthermore, there are no significant difference between the interaction of amplitude and time, interaction of frequency, amplitude and time, interaction of frequency, amplitude and time, interaction of frequency, amplitude and time at (α = 0.05) on the shrinkage length of yam tuber for weight of yam tuber between 3.0 – 5.0 kg.

Table 7. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) plus the control for the shrinkage length of the yam tuber at the storage period for Weight of yam tuber between 3.0 – 5.0 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	148.01	74.01	132.16	3.35	Significant
Amplitude	2	9.16	4.58	8.18	3.35	Significant
Time	2	46.78	23.39	41.77	3.35	Significant
Frequency ∗ Amplitude	4	1.83	0.46	0.82	2.73	Not Significant
Amplitude ∗ Time	4	1.78	0.45	0.80	2.73	Not Significant
Frequency ∗ Time	4	17.23	4.31	7.70	2.73	Significant
Frequency ∗ Amplitude ∗ Time	8	4.25	0.53	0.95	2.31	Not Significant
Error	27	15.19	0.56			
Total	53	244.23				

Table 8 displays the result from analysis of variance to check the significance difference between the levels of weight for the mean of the shrinkage length of the yam tuber (α = 0.05). The table shows that for frequency, amplitude and time 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 the shrinkage length of the yam tuber.

3.3 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 8. Results from analysis of variance to check the significance difference between the levels of weight for the mean shrinkage length of the yam tuber (α = 0.05).

Factor	Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	Weight	1	0.0006	0.0006	0.0001	7.71	Not significant
	Error	4	13.8737	3.4684			
	Total	5	13.8743				
Amplitude	Weight	1	0.0006	0.0006	0.0017	7.71	Not significant
	Error	4	1.4369	0.3592			
	Total	5	1.4375				
Time	Weight	1	0.0006	0.0006	0.0005	7.71	Not significant
	Error	4	4.8419	1.2105			
	Total	5	4.8425				

Table 9 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 9 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 9 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.

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 9 indicates that the highest shrinkage of the top diameter of the yam tuber occurs at control (3.14

Table 9. 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.

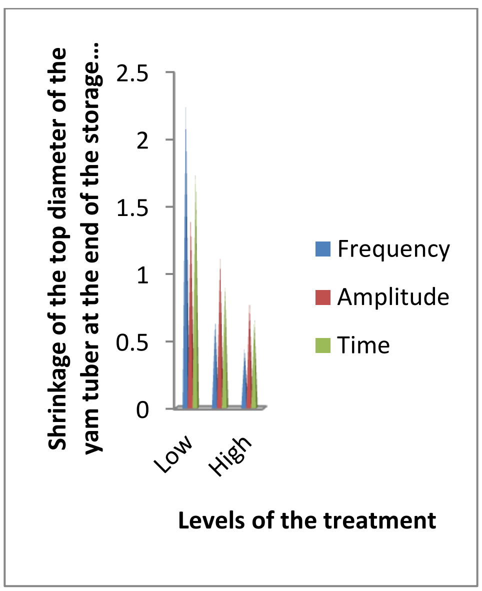
	Mean of the shrinkage of the top diameter of the yam tuber, cm	
	For weight of yam tuber between 0.1 kg – 2.9 kg	For weight of yam tuber between 3.0 kg – 5.0 kg
Control	3.14 cm ± 0.13	3.39 cm ± 0.25
Low frequency (1-5 Hz)	2.24 cm ± 0.08	2.23 cm ± 0.08
Medium frequency (60-100 Hz)	0.65 cm ± 0.07	0.78 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.)

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.

Figures 5 – 6 show the comparison of the frequency, amplitude and time at different levels for the shrinkage of the top diameter of the yam tuber for weight of the yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. For weight of yam tuber between 0.1 – 2.9 kg, at low level, the frequency (2.24 cm) has the highest value of shrinkage of the top diameter of yam tuber followed by time (1.76 cm) then amplitude (1.43 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the frequency (2.24 cm) also has the highest value of shrinkage of the top diameter of yam tuber followed by time (1.58 cm) and then amplitude (1.40 cm). This shows that at low level, amplitude has the highest effect on the shrinkage of the top diameter of yam tuber follow by time then frequency for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

5.


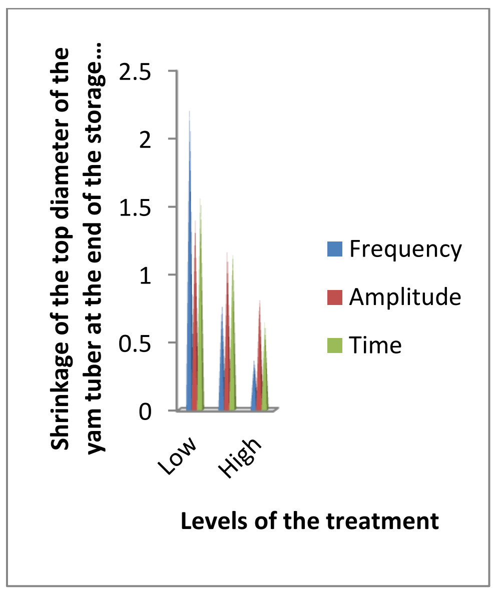
6.


Figure 5. The effects of the frequency, amplitude and time at different levels for the 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.

Figure 6. The effects of the frequency, amplitude and time at different levels for the shrinkage of the top diameter of the yam tuber at the end of the storage period for weight of yam tuber between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (1.11 cm) has the highest value of shrinkage of the top diameter of yam tuber followed by time (0.91 cm cm) then frequency (0.65 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.16 cm) and time (1.16 cm) have the highest value of the shrinkage of the top diameter of the yam tuber followed by frequency (0.78 cm). This shows that at medium level, frequency has the highest effect on the shrinkage of the top diameter of the yam tuber follow by amplitude and time for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at high level, the amplitude (0.79cm) has the highest value of shrinkage of the top diameter of yam tuber followed by time (0.66 cm) then frequency (0.44 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (0.82 cm) also has the highest value of the shrinkage of the top diameter of yam tuber followed by time (0.64 cm) and then frequency (0.37 cm). This shows that at high level, frequency has the highest effect on the shrinkage of the top diameter of the yam tuber follow by time then amplitude for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

Table 10 shows results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage of the top diameter of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg at (α = 0.05). The Table indicates that there is significant different between the low, medium and high levels of frequency of vibration on the shrinkage of the top diameter of yam tuber for weight between 0.1 – 2.9 kg. Also, there is significant difference between the low, medium and high levels of amplitude of vibration on the shrinkage of the top diameter of yam tuber for weight between 0.1 – 2.9 kg. More so, there is significant difference among the low, medium and high time of vibration on the shrinkage of the top diameter of yam tuber for weight between 0.1 – 2.9 kg. Furthermore, there is no significant difference among the interaction of frequency and amplitude, interaction of frequency and time, interaction of amplitude and time, interaction of frequency, amplitude and time at (p = 0.05) on the shrinkage of the top diameter of yam tuber for weight between 0.1 – 2.9 kg.

Table 11 presents results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage of the top diameter of the yam tuber for weight of yam tuber between 3.0 – 5.0 kg at (α = 0.05). The table shows that there is significant different between the low, medium and high levels of frequency of vibration on the weight loss of yam tuber for weight of yam tuber between 3.0 – 5.0 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the weight loss of yam tuber for weight between 3.0 – 5.0 kg. More so, there is significant difference among the low, medium and high time for weight 3.0 – 5.0 kg. Furthermore, there are no significant difference between the interaction of amplitude and time, interaction of frequency, amplitude and time, interaction of frequency, amplitude and time, interaction of frequency, amplitude and time at (α = 0.05) on the shrinkage of the top diameter of yam tuber for weight of yam tuber between 3.0 – 5.0 kg.

Table 12 displays the result from analysis of variance to check the significance difference between the levels of weight for the mean of the shrinkage of the top diameter of the yam tuber (α = 0.05). The Table shows that for frequency, amplitude and time 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 the shrinkage of the top diameter of the yam tuber.

Table 10. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the 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 (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	34.63	17.32	115.47	3.35	Significant
Amplitude	2	3.67	1.84	12.27	3.35	Significant
Time	2	11.93	5.97	39.8	3.35	Significant
Frequency ∗ Amplitude	4	0.63	0.16	1.07	2.73	Not Significant
Amplitude ∗ Time	4	0.77	0.19	1.27	2.73	Not Significant
Frequency ∗ Time	4	0.83	0.21	1.40	2.73	Not Significant
Frequency ∗ Amplitude ∗ Time	8	1.42	0.18	1.20	2.31	Not Significant
Error	27	3.92	0.15			
Total	53	57.80				

Table 11. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) plus the control for the shrinkage of the top diameter of the yam tuber at the storage period for weight of yam tuber between 3.0 – 5.0 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	34.34	17.17	55.39	3.35	Significant
Amplitude	2	2.98	1.49	4.81	3.35	Significant
Time	2	8.05	4.03	13.00	3.35	Significant
Frequency ∗ Amplitude	4	1.06	0.27	0.87	2.73	Not Significant
Amplitude ∗ Time	4	1.27	0.32	1.03	2.73	Not Significant
Frequency ∗ Time	4	2.64	0.66	2.13	2.73	Significant
Frequency ∗ Amplitude ∗ Time	8	1.99	0.25	0.81	2.31	Not Significant
Error	27	8.35	0.31			
Total	53	60.68				

3.4 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 13 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 13 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.

Table 12. Results from analysis of variance to check the significance difference between the levels of weight for the mean shrinkage of the top diameter of the yam tuber (α = 0.05).

Factor	Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	Weight	1	0.0004	0.0004	0.0004	7.71	Not significant
	Error	4	3.8475	0.9619			
	Total	5	3.8479				
Amplitude	Weight	1	0.0004	0.0004	0.0043	7.71	Not significant
	Error	4	0.3747	0.0937			
	Total	5	0.3751				
Time	Weight	1	0.0004	0.0004	0.0014	7.71	Not significant
	Error	4	1.1085	0.2771			
	Total	5	1.1089				

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 13 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 13 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 13. 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

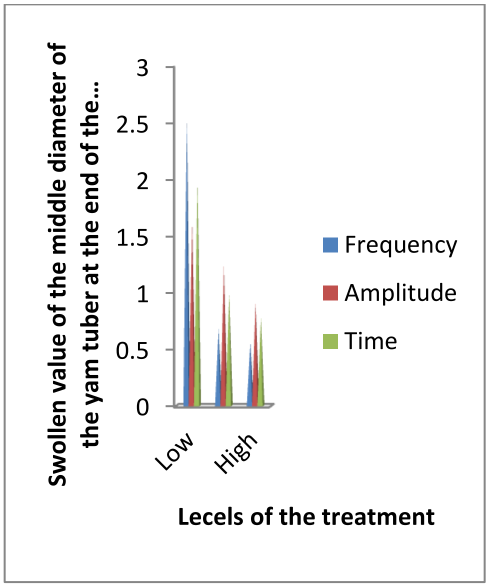
All data represent means ± standard deviation (S.D.)

Figures 7 – 8 show the effects of the frequency, amplitude and time at different levels for the swollen value of the middle diameter of the yam tuber for weight of the yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg. For weight of yam tuber between 0.1 – 2.9 kg, at low level, the frequency (2.53 cm) has the highest value of the swollen value of the middle diameter of yam tuber followed by time (2.00 cm) then amplitude (1.63 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the frequency (2.64 cm) also has the highest value of swollen value of the middle diameter of yam tuber followed by time (1.99 cm) and then amplitude (1.67 cm). This shows that at low level, amplitude has the highest effect on the swollen value of the middle diameter of the yam tuber follow by time then frequency for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (1.23 cm) has the highest swollen value of middle diameter of yam tuber followed by time (0.99 cm) then frequency (0.68 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.32 cm) has the highest swollen value of the middle diameter follow by time (1.21 cm) and then followed by frequency (0.79 cm). This shows that at medium level, frequency has the highest effect on the swollen value of the middle diameter of the yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber 0.1 – 2.9 kg, at high level, the amplitude (0.91 cm) has the highest swollen value of middle diameter of yam tuber followed by time (0.78 cm) then frequency (0.48 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (0.92 cm) also has the highest value of the swollen value of the middle diameter tuber followed by time (0.71 cm) and then frequency (0.48 cm). This shows that at high level, frequency has the highest effect on the swollen value of the middle diameter of the yam tuber follow by time then amplitude for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

Table 14 shows results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the swollen value of the middle diameter of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg at (α = 0.05). The Table indicates that there is significant different between the low, medium and high levels of frequency of vibration on the swollen value of the middle diameter of yam tuber for weight between 0.1 – 2.9 kg. Also, there is significant difference between the low, medium and high levels of amplitude of vibration on the swollen value of the middle diameter of yam tuber for weight between 0.1 – 2.9 kg. More so, there is significant difference among the low, medium and high time of vibration on the swollen value of the middle diameter of yam tuber for weight between 0.1 – 2.9 kg. Furthermore, there is no significant difference among the interaction of frequency and amplitude, interaction of frequency and time, interaction of amplitude and time, interaction of frequency, amplitude and time at (p = 0.05) on the swollen value of the middle diameter of yam tuber for weight between 0.1 – 2.9 kg.

7. 

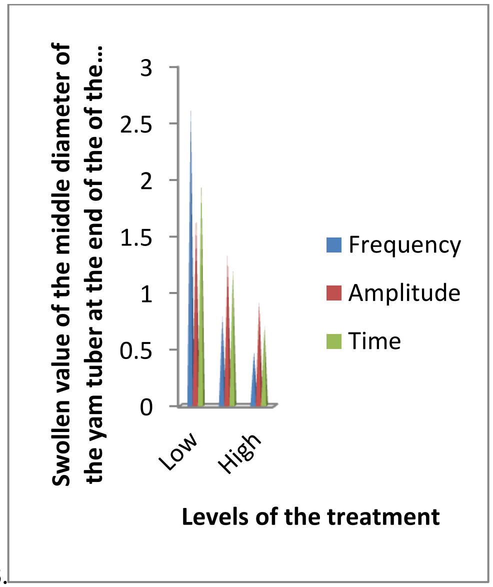
8. 

Figure 7. The effect of the frequency, amplitude and time at different levels for the 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.

Figure 8. The effect of the frequency, amplitude and time at different levels for the swollen value of the middle diameter of the yam tuber at the end of the storage period for weight of yam tuber between 3.0 – 5.0 kg.

Table 15 presents results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the swollen value of the middle diameter of the yam tuber for weight of yam tuber between 3.0 – 5.0 kg at (α = 0.05). The Table shows that there is significant different between the low, medium and high levels of frequency of vibration on the weight loss of yam tuber for weight of yam tuber between 3.0 – 5.0 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the swollen value of the middle diameter of yam tuber for weight between 3.0 – 5.0 kg. More so, there is significant difference among the low, medium and high time for weight between 3.0 – 5.0 kg. There is significant difference between the interaction of frequency and time on the swollen value of the middle diameter of the yam tuber whose weight is between 3.0 – 5.0 kg. Furthermore, there are no significant differences between the interaction of amplitude and time, interaction of frequency and amplitude, interaction of frequency, amplitude and time at (α = 0.05) on the swollen value of middle diameter of yam tuber for weight of yam tuber between 3.0 – 5.0 kg.

Table 14. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the 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 (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	43.82	21.91	115.32	3.35	Significant
Amplitude	2	4.79	2.40	12.63	3.35	Significant
Time	2	15.16	7.58	39.89	3.35	Significant
Frequency ∗ Amplitude	4	0.66	0.17	0.89	2.73	Not Significant
Amplitude ∗ Time	4	0.74	0.19	1.00	2.73	Not Significant
Frequency ∗ Time	4	1.24	0.31	1.63	2.73	Not Significant
Frequency ∗ Amplitude ∗ Time	8	1.47	0.18	0.95	2.31	Not Significant
Error	27	5.09	0.19			
Total	53	72.97				

Table 16 shows the result from analysis of variance to check the significance difference between the levels of weight for the mean of the swollen value of the middle diameter of the yam tuber (α = 0.05). The table reveals that for frequency, amplitude and time 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 the swollen value of the middle diameter of the yam tuber.

Table 15. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) plus the control for the swollen value of the middle diameter of the yam tuber at the end of storage period for Weight of yam tuber between 3.0 – 5.0 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	48.97	24.49	128.89	3.35	Significant
Amplitude	2	5.07	2.54	13.37	3.35	Significant
Time	2	14.93	7.47	39.32	3.35	Significant
Frequency ∗ Amplitude	4	1.17	0.29	1.53	2.73	Not Significant
Amplitude ∗ Time	4	0.73	0.18	0.95	2.73	Not Significant
Frequency ∗ Amplitude ∗ Time	8	1.26	0.16	0.84	2.31	Not Significant
Error	27	5.13	0.19			
Total	53	79.63				

3.5 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 17 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 17 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.

Table 16. Results from analysis of variance to check the significance difference between the levels of weight for the mean swollen value of the middle diameter of the yam tuber (α = 0.05).

Factor	Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	Weight	1	0.0033	0.0033	0.0026	7.71	Not significant
	Error	4	5.1673	1.2918			
	Total	5	5.1706				
Amplitude	Weight	1	0.0033	0.0033	0.0015	7.71	Not significant
	Error	4	9.0923	2.2731			
	Total	5	9.0956				
Time	Weight	1	0.0033	0.0033	0.0078	7.71	Not significant
	Error	4	1.6831	0.4208			
	Total	5	1.6864				

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 17 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). 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 17 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.

Figures 9 – 10 show the effects of the frequency, amplitude and time at different levels for the shrinkage of the bottom diameter of the yam tuber for weight of the yam tuber between 0.1 – 2.9 kg. For weight of yam tuber between 0.1 – 2.9 kg, at low level, the frequency (2.45 cm) has the highest value of shrinkage of the bottom diameter of yam tuber followed by time (2.00 cm) then amplitude (1.59 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the frequency (2.36 cm) also has the highest value of shrinkage of the bottom diameter of yam tuber followed by time (1.68 cm) and then amplitude (1.39 cm). This shows that at low level, amplitude has the highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by time then frequency for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (1.23 cm) has the highest shrinkage value of bottom diameter of yam tuber followed by time (0.99 cm) then frequency (0.68 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.32 cm) has the highest shrinkage value of the bottom diameter follow by time (1.21 cm) and then followed by frequency (0.79 cm). This shows that at medium level, frequency has the highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at high level, the amplitude (0.91 cm) has the highest shrinkage value of bottom diameter of yam tuber followed by time (0.78 cm) then frequency (0.48 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (0.92 cm) also has the highest value of the shrinkage of the bottom diameter of yam tuber followed by time (0.71 cm) and then frequency (0.48 cm). This shows that at high level, frequency has the highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by time then amplitude for both weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

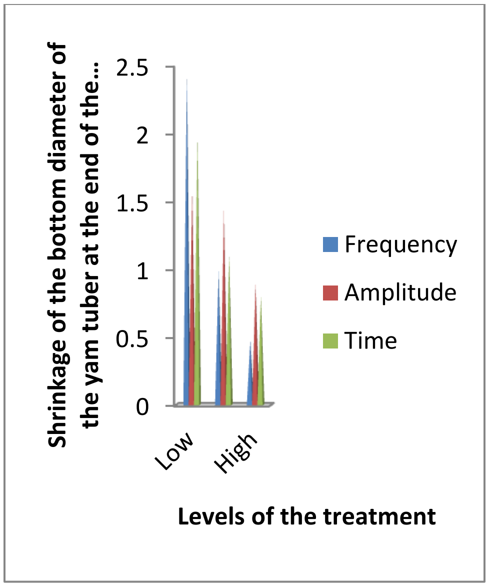
For weight of yam tuber between 0.1 – 2.9 kg, at medium level, the amplitude (1.43 cm) has the highest shrinkage of the bottom diameter of yam tuber followed by time (1.11 cm) then frequency (0.99 cm) while for weight of yam tuber between 3.0 – 5.0 kg, the amplitude (1.24 cm) has the highest shrinkage value of the bottom diameter follow by time (1.19 cm) and then followed by frequency (0.73 cm). This shows that at medium level, frequency has the highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg and between 3.0 – 5.0 kg.

For weight of yam tuber between 0.1 – 2.9 kg, at high level, the amplitude (0.92 cm) has the highest shrinkage value of bottom diameter of yam tuber followed by time (0.81 cm) then frequency (0.48 cm) while for weight of yam

Table 17. 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.)



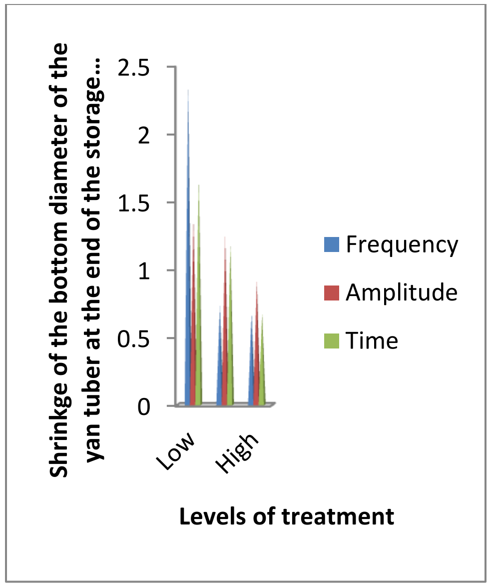


Figure 9. The effects of the frequency, amplitude and time at different levels for the shrinkage of the top diameter of the yam tuber at the end of the storage period for weight of yam tuber between 0.1 – 2.9 kg.

Figure 10. The effects of the frequency, amplitude and time at different levels for the shrinkage of the top diameter of the yam tuber at the end of the storage period for weight of yam tuber between 3.0 – 5.0 kg.

tuber between 3.0 – 5.0 kg, the amplitude (0.92 cm) also has the highest value of the shrinkage of the bottom diameter of yam tuber followed by time (0.46 cm) and then frequency (0.68 cm). This shows that at high level, frequency has the highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by time then amplitude for weight of yam tuber between 0.1 – 2.9 kg while frequency and time have highest effect on the shrinkage value of the bottom diameter of the yam tuber follow by amplitude for weight of yam tuber between 3.0 – 5.0 kg.

Table 18 shows results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage of the bottom diameter of the yam tuber for weight of yam tuber between 0.1 – 2.9 kg at (α=0.05). The Table indicates that there is significant different between the low, medium and high levels of frequency of vibration on the shrinkage value of the bottom diameter of yam tuber for weight between 0.1 – 2.9 kg. Also, there is significant difference between the low, medium and high levels of amplitude of vibration on the shrinkage value of the bottom diameter of yam tuber for weight between 0.1 – 2.9 kg. More so, there is significant difference among the low, medium and high time of vibration on the shrinkage value of the bottom diameter of yam tuber for weight between 0.1 – 2.9 kg. There is no significant difference among the interaction of frequency and time at (p = 0.05) on the value of shrinkage of the bottom diameter of yam tuber for weight between 0.1 – 2.9 kg. Furthermore, there is no significant difference among the interaction of frequency and amplitude, interaction of amplitude and time, interaction of frequency, amplitude and time at (p = 0.05) on the shrinkage value of the bottom diameter of yam tuber for weight between 0.1 – 2.9 kg.

Table 19 presents results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage value of the bottom diameter of the yam tuber for weight of yam tuber between 3.0 – 5.0 kg at (α = 0.05). The Table shows that there is significant different between the low, medium and high levels of frequency of vibration on the shrinkage value of the bottom diameter of yam tuber for weight of yam tuber between 3.0 – 5.0 kg. Also there is significant difference between the low, medium and high levels of amplitude of vibration on the shrinkage of the bottom diameter of yam tuber for weight between 3.0 – 5.0 kg. More so, there is significant difference among the low, medium and high time for weight between 3.0 – 5.0 kg. There is significant difference between the interaction of frequency and time on the shrinkage value of the bottom diameter of the yam tuber whose weight is between 3.0 – 5.0 kg. Furthermore, there are no significant differences between the interaction of amplitude and time, interaction of frequency and amplitude, interaction of frequency, amplitude and time at (α = 0.05) on the shrinkage of the bottom diameter of yam tuber for weight of yam tuber between 3.0 – 5.0 kg.

Table 20 shows the result from analysis of variance to check the significance difference between the levels of weight for the mean of the shrinkage value of the bottom diameter of the yam tuber (α = 0.05). The Table reveals that for frequency, amplitude and time 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 the shrinkage value of the bottom diameter of the yam tuber. Plate 1, 2 and 3show the view of the yam tubers in the first week of storage, the view of the some of the sprouted and unsprouted yam tuber on week 5 of storage and the view of the yam tubers on week 7 of storage respectively

Table 18. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) using complete randomized block design (CRBD) for the shrinkage value 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 (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	37.42	18.71	85.05	3.35	Significant
Amplitude	2	4.67	2.34	10.64	3.35	Significant
Time	2	13.80	6.90	31.36	3.35	Significant
Frequency ∗ Amplitude	4	0.92	0.23	1.05	2.73	Not Significant
Amplitude ∗ Time	4	0.43	0.11	0.50	2.73	Not Significant
Frequency ∗ Time	4	2.39	0.60	2.73	2.73	Significant
Frequency ∗ Amplitude ∗ Time	8	1.49	0.19	0.86	2.31	Not Significant
Error	27	5.89	0.22			
Total	53	67.01				

Table 19. Results from a three way analysis of variance with factorial arrangement of factors (Frequency, Amplitude and Time) plus the control for the shrinkage value of the bottom diameter of the yam tuber at the end of storage period for Weight of yam tuber between 3.0 – 5.0 kg (α = 0.05).

Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	2	48.97	24.49	128.89	3.35	Significant
Amplitude	2	5.07	2.54	13.37	3.35	Significant
Time	2	14.93	7.47	39.32	3.35	Significant
Frequency ∗ Amplitude	4	1.17	0.29	1.53	2.73	Not Significant
Amplitude ∗ Time	4	0.73	0.18	0.95	2.73	Not Significant
Frequency ∗ Time	4	2.37	0.59	3.11	2.73	Significant
Frequency ∗ Amplitude ∗ Time	8	1.26	0.16	0.84	2.31	Not Significant
Error	27	5.13	0.19			
Total	53	79.63				

4.0 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

Table 20. Results from analysis of variance to check the significance difference between the levels of weight for the mean shrinkage of the bottom diameter of the yam tuber (α = 0.05).

Factor	Sources	Degree of freedom	Sum of square	Mean of square	F-value	F- critical	Significant
Frequency	Weight	1	0.0228	0.0228	0.0217	7.71	Not significant
	Error	4	4.2042	1.0511			
	Total	5	4.2270				
Amplitude	Weight	1	0.0228	0.0228	0.2423	7.71	Not significant
	Error	4	0.3762	0.0941			
	Total	5	0.3990				
Time	Weight	1	0.0228	0.0228	0.0720	7.71	Not significant
	Error	4	1.2662	0.3166			
	Total	5	1.2890				

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.

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

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

5.0 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. A mechanical yam vibrator having adjustable frequencies and amplitudes developed with vibrating chamber of capacity size of 670 mm × 570 mm × 180 mm which can contain four tubers of yam at a time was used for the vibration of the yam tubers. 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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