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Performance Evaluation on the Utilization of an Established Variable Amplitude and Frequency of Vibrating Container for Potential Application in Slowing Down Sprouting in Yam

Osanyinpeju, K.L., Aderinlewo, A.A., Dairo, O.U., Adetunji, O.R. and Ajisegiri, E.S.A.

Abstract: A variable amplitude and frequency of mechanical vibrating container working on cam and follower mechanism have been established. This study carried out a performance evaluation on the utilization of the established vibrating container for potential application in slowing down sprouting in yam. The vibrating container is electrically operated and a variable speed electric motor of 15, 000 rpm was selected for the machine. The performance parameters of the established mechanical vibrating container investigated were percentage maximum displacement and velocity of the vibration at different combined stages of amplitudes and frequencies. The percentage achievable maximum displacement of vibration measured for theoretical amplitude of cams of 5 mm, 10 mm and 20 mm were 89.40 %, 87.10 % and 72.7 % respectively for low frequency; 91.60 %, 88.40 % and 81.70 % respectively for medium frequency; and 93.20 %, 90.90 % and 86.50 % respectively for high frequency. The percentage achievable maximum velocity of vibration measured for theoretical amplitude of cams of 5 mm, 10 mm and 20 mm were 72.6 %, 71.40 % and 69.11 % respectively for low frequency; 79.81 %, 74.88 % and 70.96 % respectively for medium frequency; and 81.20 %, 77.52 % and 73.69 % respectively for high frequency. The results show that the established mechanical vibrating container has effective and suitable performances. The vibrator thus shows a good potential to effectively slow down sprouting when operated under load condition. It could help in slowing down sprouting in yams.

Keywords: Displacement, FUNAAB, Velocity, Vibrating container, Yam tuber

I. Introduction

Yam which is the regular food of Africans, has high carbohydrate content [1 - 5]. When yam is prepared and eaten, it can sustain someone for a long period of time and it has a nice taste. The level of protein in yam tuber is higher than that of sweet potato and cassava [6-9]. The usefulness of yam tuber to human can never be overemphasized as it is also used for industrial and medicinal purposes [10 -15]. Some tubers are projected into the manufacturing of sex hormones, diosgenin, and diaoscorin [16 -18]. Storage period of yam tuber is shortening due to sprouting which threatens the quality of the yam tuber and reduce the weight of the yam tuber overtime [19-23]. There is a sudden increase in the level of the pathogen attack as sprouting emerges in the yam tuber and this makes it to deteriorate at a fast rate [24 - 27].

Osanyinpeju, K.L., Aderinlewo, A.A., Dairo, O.U. and Ajisegiri, E.S.A. (Department of Agricultural and Bio-Resources Engineering (ABE), COLENG, Federal University of Agriculture, Alabata, Abeokuta, Ogun State, Nigeria)
Adetunji, O.R. (Department of Mechanical Engineering (MCE), COLENG, Federal University of Agriculture, Alabata, Abeokuta, Ogun State, Nigeria)
Corresponding author: amkifilideenosanyinpeju@gmail.com
Phone Number: 07063856386, 07083506769
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Addressing the issue of yam sprouting is very expedient as it would increase the shelf life and availability of yam tubers for human consumption. The collision and interference of energy with matter has the possibility of bringing about transformation in the matter provided that the energy is able to have direct contact and collision with the particles of the matter [28]. The use of chemical energy which was successfully used to control sprouting in sweet potatoes (matters) had been reported not to be successful in controlling sprouting in yam tubers [29, 30]. This is as a result of chemical energy not having direct contact and collision with the points where the sprouting emerges from the yam tuber.

Mechanical vibration is a form of energy which sets every particle of the matter in which it is in contact with into oscillation [31]. It induces forced vibration into the matter which makes the frequency of the vibrator to tally with the frequency at which the particle of the matter in contact with the vibrator vibrates. The application of this mechanical vibration method to the sprouting and dormancy of yam tuber would ascertain the extent at which it would influence the physical properties of yam tubers and sprout [32]. This study would show the correlation of yam tuber to vibration environment. [33] fabricated fixed amplitude with variable frequency mechanical vibrating table in Turkey. The vibration produced sinusoidal motion. [34] proposed eccentric wheeled mechanical vibrating table. The achievable frequency of vibration of the proposed vibrating table by [34] is at the ranged of 0 – 100 Hz.

[35] indicated that in Ankara, Turkey market, the smallest and largest dimension of vibrating tables found were 400 mm × 380 mm × 450 mm and 1260 mm × 1270 mm × 1200 mm respectively. They put forward that the smallest and the largest power rating of the vibrators found were 170 W and 746 W respectively. [35] designed and manufactured a vibrating table for removing air bubbles during the manufacturing of composite materials. The fabricated vibrating table has dimension of 560 mm × 340 mm × 400 mm. The developed vibrating table used unbalanced mass mechanism. The mass was fixed to the shaft of a 1.5 KW and 2820 rev/min three – phase electric motor to generate the unbalance mechanism.

[36] developed and carried out performance evaluation of an improved vibrating container for the production of wood – cement board in Ibadan, Nigeria. Their study was to improve the performance of an existing vibrating container. The vibrating machine worked on unbalance mass mechanism with eccentricity of mass 1.64 kg operating at angular velocity of 1500 rpm and amplitude of 0.4 mm. [36] indicated that the vibrating machine is electrically – operated which is capable of handling a load of 100 N.

A variable amplitude and frequency of mechanical vibrating container working on cam and follower mechanism has been established. After the construction of the variable amplitude and frequency of the mechanical vibrating container, performance evaluation was conducted on the machine to determine the performance efficiency on the cam developed and the overall machine. This was done to ascertain the workability and optimal efficiency of the operation of the developed mechanical yam vibrating container since the developed machine was going to embark on vigorous and tedious task in the other aspect of the study which was not presented in this paperwork in order to safeguard any failure that may occur during the vibration analysis of the yam tubers. Necessary modifications were made on the machine. For all the combinations of the levels of the amplitudes and frequencies of vibration for this research work, no yam tuber was loaded in the vibrating container. The scope of this research work was limited to no load performance evaluation on the established vibrating container. Further study can be carried out to determine the performance evaluation on the established vibrating chamber where the vibrating container is loaded with yam tubers.

This study carried out a performance evaluation on the utilization of the established vibrating container for **potential application in slowing down** sprouting in yam.

II. Materials and Methods

A. Methodology used in the Selection of the Variable Speed Electric Motor of the Vibrating Container

[37] recommended that frequency of mechanical vibrating container should not exceed 200 Hz for the machine to work effectively. Based on the recommendation by [37], the maximum frequency set for the established mechanical vibrating container was 200 Hz. The minimum variable speed of the electric motor needed to generate the maximum frequency for the mechanical vibrating container was obtained from the mathematical relationship presented by [38] as shown in Eq. 1, 2.

$$f_{vibration} = \frac{\omega}{60} \qquad \text{Eq. 1}$$

$$\omega = f_{vibration} \times 60 \qquad \text{Eq. 2}$$

Where, $f_{vibration}$ is the maximum frequency for the mechanical vibrating container, Hz and ω is the minimum variable speed of the electric motor needed to generate the maximum frequency for the mechanical vibrating container.

Since the maximum frequency set for the established mechanical vibrating container was 200 Hz, then the minimum variable speed of the electric motor needed was determined in Eq. 3, 4.

$$\omega = 200 \times 60 \qquad \text{Eq. 3}$$

$$\omega = 1200 \text{ rpm} \qquad \text{Eq. 4}$$

For effective operation of the vibrating container, a variable speed of electric motor greater than 1200 rpm was considered. So, for the machine to perform well, a variable speed of electric motor of 1500 rpm was selected.

B. Installation of the Established Mechanical Vibrating Container

The established mechanical vibrating container was installed in the central workshop of COLENG, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria where the no load test condition was carried out on it. Figures 1 presents the isometric view of the mechanical vibrating container while Figure 2 shows the first angle projection of the orthographic view of the mechanical container.

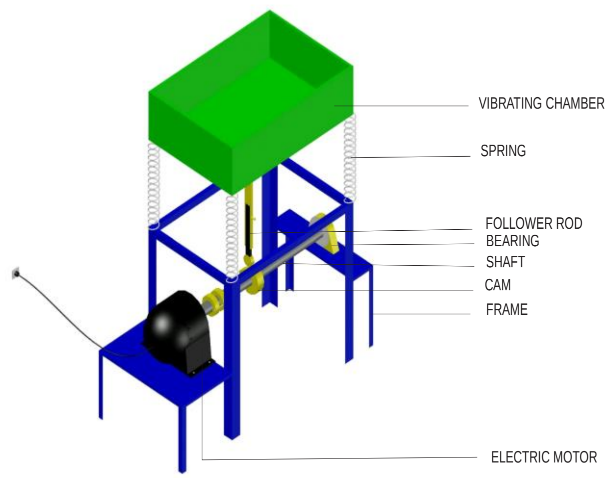

Figure 1: Isometric view of the mechanical vibrating container

C. Instrumentation and Control of the Established Mechanical Vibrating Container

A vibrometer was used to evaluate the vibration parameters (displacement and velocity) of the mechanical vibrator developed. The size and shape of the cam profile were used to vary the displacement and velocity of the vibration of the vibrating container. The highest displacement of the cam peripheral indicates the amplitude of the vibrating container. The three sets of cams established were accomplished with three different amplitudes which were achieved by designing 5 mm, 10 mm and 20 mm of highest displacements respectively for the three sets of cam. Tachometer was used to measure the speed and frequency of the shaft of the electric motor.

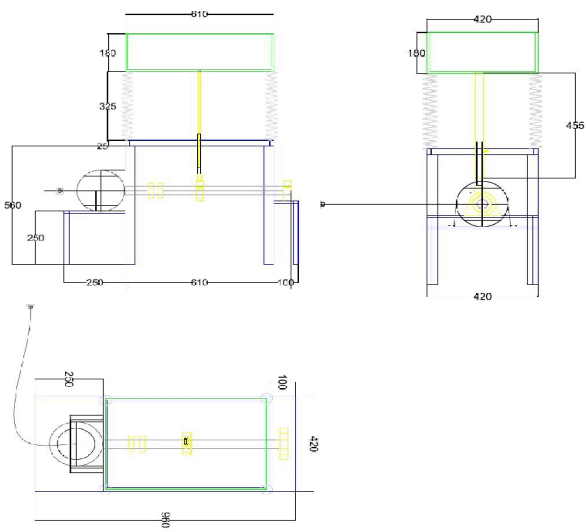

Figure 2: The first angle projection of the orthographic view of the vibrating container.

D. Performance Evaluation on the Utilization of an Established Variable Amplitude and Frequency of Vibrating Container for Slowing Down Sprouting in Yam

Plate 1 indicates the view of the established variable amplitude and frequency of mechanical vibrating container. The shape of the three cams of the vibrating container used for this study were developed and constructed using theoretical values which maximum displacement of the three cams constructed were 5 mm, 10 mm and 20 mm. The purpose of this project is to see whether the 5 mm, 10 mm and 20 mm cams developed for the vibrator would be able to give 5 mm, 10 and 20 mm amplitude of vibration for the vibrating container, if not to what percentage of maximum displacement would the cam be able to transmit to the vibrating container. The cam was installed under the vibrating container. The rotary motion of the cam gave the vibrating container vertical linear motion.

Plate 1: View of the established variable amplitude and frequency of the vibrating container.

The experimental evaluation of the kinematic motion of the displacement and velocity of the vibrating container was carried out using a vibrometer to monitor the variation of the parameters of the kinematic motion that is displacement and velocity for the different combination of levels of amplitudes and frequencies of vibration. The values of the parameters of the kinematic motion measured and recorded were compared to the theoretical calculation of the kinematic motion of the cam obtained. The results obtained showed how best the theoretical calculations and equations generated predicted the real behavior of the vibrating container. The performance efficiencies of the achievable maximum displacement and velocity of the vibration for different combination of levels of amplitudes and frequencies were determined in Eq. 6, 7.

$$\%\text{maximum displacement of the vibration} = \frac{\text{achievable maximum displacement of the vibration}}{\text{theoretical maximum displacement of the cam used}} \quad \text{Eq. 6}$$

$$\%\ \text{maximum velocity of the vibration} = \frac{\text{achievable maximum velocity of the vibration}}{\text{theoretical maximum velocity of the cam used}} \quad \text{Eq. 7}$$

Theoretical amplitude of cams of 5 mm, 10 mm and 20 mm were used for the performance evaluation. Theoretical amplitude of the cam is the measure of the maximum displacement of the cam from the surface of the base circle to the cam profile.

E. Evaluation of the Displacement of the Established Variable Amplitude and Frequency of the Vibrating Container

A vibrometer was used to evaluate the change in displacements of the vibration of the vibrating container. The three levels of amplitudes (5 mm, 10 mm and 20 mm) in combination with three levels of frequencies (low (1 – 5 Hz), medium (60 – 100 Hz) and high (150 – 200 Hz)) were designed for the variable amplitude and frequency of the mechanical vibrating container using three sets of cam. The evaluation of the displacement and amplitude of the combination of the levels of amplitudes and frequencies were carried out by putting the vibrometer into the mechanical vibrating container. The changes in the displacement of the vibration were observed on the display of the vibrometer and values obtained were recorded for a period of 70 seconds for each combination of levels of amplitudes and frequencies.

F. Evaluation of the Velocity of the Established Variable Amplitude and Frequency of the Vibrating Container

A vibrometer was used to evaluate the change in velocity of the vibration of the vibrating container. The three levels of amplitudes (5 mm, 10 mm and 20 mm) in combination with three levels of frequencies (low (1 – 5 Hz), medium (60 – 100 Hz) and high (150 – 200 Hz)) were designed for the variable amplitude and frequency of the mechanical vibrating container using three sets of cam. The evaluation of the velocity and maximum velocity of the combination of the levels of amplitudes and frequencies were carried out by putting the vibrometer into the mechanical vibrating container. The changes in the velocity of the vibration were observed on the display of the vibrometer and values obtained were recorded for a period of 70 seconds for each combination of levels of amplitudes and frequencies.

III. Results and Discussions

A. Change of the Displacement and Amplitude of the Vibration of the Mechanical Vibrating Container

Table 1 presents the maximum and minimum displacement of vibration of the vibrating container at different combination of levels of amplitudes and frequencies. The minimum displacement recorded at low (1 – 5 Hz) frequency and low (5 mm) amplitude, medium (60 – 100 Hz) frequency and low (5 mm) amplitude, high (150 – 200 Hz) frequency and low (5 mm) amplitude were 0.75 mm, 0.95 mm, 1.23 mm respectively. More so, the minimum displacement recorded at low (1 – 5 Hz) frequency and medium (10 mm) amplitude, medium (60 – 100 Hz) frequency and medium (10 mm) amplitude, high (150 – 200 Hz) frequency and medium (10 mm) amplitude were1.75 mm, 1.95 mm, 2.21 mm respectively. Meanwhile, the minimum displacement recorded at low (1 – 5 Hz) frequency and high (20 mm) amplitude, medium (60 – 100 Hz) frequency and high (20 mm) amplitude, high (150 – 200 Hz) frequency and high (20 mm) amplitude were 2.23 mm, 2.67 mm and 3.45 mm respectively.

Table 1. The Maximum and Minimum Displacement of Vibration of the Vibrating Container at Different Combination of Levels of Amplitudes and Frequencies

S/N	Levels of parameters of vibration	Maximum displacement (mm)	Minimum displacement (mm)	Maximum theoretical displacement (mm)
1	Low (1 – 5 Hz) frequency Low (5 mm) amplitude	4.47 (89.40 %)	0.75	5.00
2	Medium (60 – 100 Hz) frequency Low (5 mm) amplitude	4.58 (91.60 %)	0.95	5.00
3	High (150 – 200 Hz) frequency Low (5 mm) amplitude	4.66 (93.20 %)	1.23	5.00
4	Low (1 – 5 Hz) frequency Medium (10 mm) amplitude	8.71 (87.10 %)	1.75	10.00
5	Medium (60 – 100 Hz) frequency Medium (10 mm) amplitude	8.84 (88.40 %)	1.95	10.00
6	High (150 – 200 Hz) frequency Medium (10 mm) amplitude	9.09 (90.9 %)	2.21	10.00
7	Low (1 – 5 Hz) frequency High (20 mm) amplitude	14.54 (72.7 %)	2.23	20.00
8	Medium (60 – 100 Hz) frequency High (20 mm) amplitude	16.34 (81.7 %)	2.67	20.00
9	High (150 – 200 Hz) frequency High (20 mm) amplitude	17.30 (86.50 %)	3.45	20.00

Furthermore, the maximum displacement recorded at low (1 – 5 Hz) frequency and low (5 mm) amplitude, medium (60 – 100 Hz) frequency and low (5 mm) amplitude, high (150 – 200 Hz) frequency and low (5 mm) amplitude were 4.47 mm, 4.58 mm, 4.66 mm which indicate 89.40 %, 91.60 %, 93.20 % respectively of the maximum theoretical displacement of the cam profile that produced them. Meanwhile, the maximum displacement recorded at low (1 – 5 Hz) frequency and medium (10 mm) amplitude, medium (60 – 100 Hz) frequency and medium (10 mm) amplitude, high (150 – 200 Hz) frequency and medium (10 mm) amplitude were 8.71 mm, 8.84 mm, 9.09 mm which represent 87.10 %, 88.40 %, 90.9 % respectively of the maximum theoretical displacement of the cam profile that produced them. More so, the maximum displacement recorded values at low (1 – 5 Hz) frequency and high (20 mm) amplitude, medium (60 – 100 Hz) frequency and high (20 mm) amplitude, high (150 – 200 Hz) frequency and high (20 mm) amplitude were 14.54 mm, 16.34 mm, 17.30 mm respectively which show 72.70 %, 81.70 %, 86.50 % respectively of the maximum theoretical displacement of the cam profile that produced them.

It was observed that at each level of amplitude, as the frequency was increasing, the maximum displacement obtained was also increasing. For low (5 mm) amplitude, as the frequency increased from low to high the maximum displacement recorded increased from 4.47 mm to 4.66 mm while for medium (10 mm) amplitude, as the frequency increased from low to high the maximum displacement recorded increased from 8.71 mm to 9.09 mm. Meanwhile, for high (20 mm) amplitude, as the frequency increased from low to high the maximum displacement recorded increased from 14.54 mm to 17.30 mm. The established variable amplitude and frequency of the mechanical vibrating container was working on cam and follower mechanism and powered with variable speed elector motor whose speed was between 0 – 15, 000 rpm. [39] established mechanical vibrating exciter which employed cam and follower mechanism. In their work, the maximum amplitude of vibration obtained from their machine is 20 mm for Jerk motion and 11.4 mm for SHM motion. It was stated that the vibration exciter developed can be used for electric motor whose rpm is up to 1000 rpm. [37] designed and tested an unbalanced mass mechanical vibrating exciter which uses unbalanced mass mechanism. It was stated in their work that the drive system for the mechanical vibrating exciter achieved a speed which ranged from 0 rpm to 1440 rpm.

B. Change of the Velocity and the Maximum Velocity of the Vibration of the Vibrating Container

Table 2 shows the maximum and minimum velocity of vibration of the vibrating container at different combination of levels of amplitudes and frequencies. The minimum velocity recorded at low (1 – 5 Hz) frequency and low (5 mm) amplitude, medium (60 – 100 Hz) frequency and low (5mm) amplitude, high (150 – 200 Hz) frequency and low (5 mm) amplitude were 4.10 mm/s, 146.57 mm/s, 321.70 mm/s respectively. Furthermore, the minimum velocity recorded at low (1 – 5 Hz) frequency and medium (10 mm) amplitude, medium (60 – 100 Hz) frequency and medium (10 mm) amplitude, high (150 – 200 Hz) frequency and medium (10 mm) amplitude were 4.20 mm/s, 194.82 mm/s, 467.63 mm/s respectively. More so, the minimum velocity of vibration recorded at low (1 – 5 Hz) frequency and high (20 mm) amplitude, medium (60 – 100 Hz) frequency and high (20 mm) amplitude, high (150 – 200 Hz) frequency and high (20 mm) amplitude were 32.77 mm/s, 228.13 mm/s and 604.51 mm/s respectively.

The maximum velocity of vibration recorded at low (1 – 5 Hz) frequency and low (5 mm) amplitude, medium (60 – 100 Hz) frequency and low (5 mm) amplitude, high (150 – 200 Hz) frequency and low (5 mm) amplitude were 21.78 mm/s, 974.40 mm/s, 974.40 mm/s which indicate 72.60 %, 79.81%, 81.20 % respectively of the maximum theoretical velocity of the cam profile that produced them. More so, the maximum velocity of vibration recorded at low (1 – 5 Hz) frequency and medium (10 mm) amplitude, medium (60 – 100 Hz) frequency and medium (10 mm) amplitude, high (150 – 200 Hz) frequency and medium (10 mm) amplitude 42.84 mm/s, 898.56 mm/s, 1860.59 mm/s respectively which show 71.40 %, 74.88 %, 77.52 % respectively of the maximum theoretical velocity of the cam profile that produced them. Furthermore, the maximum velocity of vibration recorded at low (1 – 5 Hz) frequency and high (20 mm) amplitude, medium (60 – 100 Hz) frequency and high (20 mm) amplitude, high (150 – 200 Hz) frequency and high (20 mm) amplitude were 829.36 mm/s, 1702.94 mm/s, 3537.08 mm/s respectively which indicate 69.11 %, 70.96 %, 73.69 % respectively of the maximum theoretical velocity of the cam profile that produced them.

It was observed that at each level of amplitude as the frequency was increasing, the maximum velocity obtained was also increasing. while for medium (10 mm) amplitude, as the frequency increased from low to high the maximum velocity of vibration recorded increased from 42.84 to 1860.59 mm/s. Meanwhile, for high (20 mm) amplitude, as the frequency increased from low to high the maximum velocity of vibration recorded increased from 829.36 mm to 3537.08 mm/s.

Table 2. The Maximum and Minimum Velocity of Vibration of the Vibrating Container at Different Combination of Levels of Amplitudes and Frequencies

S/N	Levels of parameters of vibration	Maximum velocity (mm/s)	Minimum velocity (mm/s)	Maximum theoretical velocity (mm/s)
1	Low (1 – 5 Hz) frequency Low (5 mm) amplitude	21.78 (72.6 %)	4.10	30.00
2	Medium (60 – 100 Hz) frequency Low (5 mm) amplitude	478.84 (79.81 %)	146.57	600.00
3	High (150 – 200 Hz) frequency Low (5 mm) amplitude	974.40 (81.20 %)	321.70	1200.00
4	Low (1 – 5 Hz) frequency Medium (10 mm) amplitude	42.84 (71.40 %)	4.20	60.00
5	Medium (60 – 100 Hz) frequency Medium (10 mm) amplitude	898.56 (74.88 %)	194.82	1200.00
6	High (150 – 200 Hz) frequency Medium (10 mm) amplitude	1860.59 (77.52 %)	467.63	2400.00
7	Low (1 – 5 Hz) frequency High (20 mm) amplitude	829.36 (69.11 %)	32.77	1200.00
8	Medium (60 – 100 Hz) frequency High (20 mm) amplitude	1702.94 (70.96 %)	228.13	2400.00
9	High (150 – 200 Hz) frequency High (20 mm) amplitude	3537.08 (73.69 %)	604.51	4800.00

IV. Conclusion

This study carried out a performance evaluation on the utilization of the established vibrating container for **potential application in slowing down** sprouting in yam. The vibrator is electrically operated and a variable speed electric motor of 15, 000 rpm was selected for the machine. The percentage achievable maximum displacement of vibration measured for theoretical amplitude of cams of 5 mm, 10 mm and 20 mm were 89.40 %, 87.10 % and 72.7 % respectively for low frequency; 91.60 %, 88.40 % and 81.70 % respectively for medium frequency; and 93.20 %, 90.90 % and 86.50 % respectively for high frequency. The percentage achievable maximum velocity of vibration measured for theoretical amplitude of cams of 5 mm, 10 mm and 20 mm were 72.6 %, 71.40 % and 69.11 % respectively for low frequency; 79.81 %, 74.88 % and 70.96 % respectively for medium frequency; and 81.20 %, 77.52 % and 73.69 % respectively for high frequency. The results show that the established mechanical vibrating container has effective and suitable performances. The vibrator thus shows a good potential to effectively slow down sprouting when operated under load condition. It could help in slowing down sprouting in yams.

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