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Effect of Irrigation Regimes on the Engineering Properties of Tomato Fruits

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ABSTRACT: *The knowledge of engineering properties of an agricultural crop is very important in the design of its handling, harvesting, transportation, and processing equipment. This study therefore aim at providing data for the machine designers who may want to design a functioning equipment for mechanizing tomato fruit production. The tomato (Lycopersiconesculentum) was planted on the experimental farm of Department of Agricultural Engineering, LAUTECH, Ogbomoso, Oyo state, Nigeria, using drip irrigation system. The plant was harvested, sorted and graded into different sizes. The engineering properties which includes, length, breadth, thickness, weight, sphericity, angle of repose and coefficient of friction were investigated using standard methods. The results showed that the highest length (48.87 mm), breadth (40.48 mm), thickness (42.13 mm) and weight (33.31 mm) was obtained with the 3 days irrigation frequency while least length (44.1 mm), breadth (35.03 mm), thickness (38.1 mm) and weight (31.9 mm) was recorded when the irrigation frequency was 7 days. The highest angle of repose (20.98°) was recorded when the irrigation frequency was 50% ETc (crop water use) and 7days irrigation interval. Also the highest coefficient of friction (0.40) was observed when the irrigation frequency was 3 days and 100% ETc. the statistical evaluation of the results showed that all this properties were statistically significant (p<0). It is therefore concluded that when designing tomato handling equipment, the effect of irrigation scheduling should be taken into consideration.*

KEYWORDS- *Irrigation scheduling, Physical properties, Mechanical properties, Drip irrigation and Crop water use*

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I. INTRODUCTION

Tomato (*Lycopersiconesculentum*) has its origin in the South American Andes but currently its acceptance has covered the whole globe [1]. 33.8 million tons of the fruits were produced in 2008 [2]. There are small cherry tomatoes, bright yellow tomatoes, Italian pear-shaped tomatoes, and the green tomato. They have fleshy internal segments filled with slippery seeds surrounded by a watery matrix. They can be red, pink, yellow, orange/tangerine, green, purple, brown, or black in color. The fruit is called different names in different society, for example tomate (Spain, France), tomat (Indonesia), faanke’e (China), tomati (West Africa), tomatl (Nahuatl), jitomate (Mexico), pomodoro (Italy), nyanya (Swahili) [3] .

Tomato is a rich source of minerals, vitamins, and organic acid, essential amino acids and dietary fibers. The fruit is known as productive as well as protective food. It is a rich source of vitamin A (in the form of beta-carotene), K, B6, E and C; it contains minerals like iron, phosphorus, copper, potassium, manganese, and phosphorus [4]. They are also one of the main ingredients in hundreds of dishes and products that are sold in supermarkets throughout the developed world [5]. It grows well during the raining season but also very perishable. They are used in making soup, so it is needed round the year.

Tomato is not always readily available in dry season, it is perishable and needed round the year, and therefore there is need for irrigation. Some research work has been reported on the mechanization of tomato production [6 and 7], engineering properties [8, 9,10, 11, 12 and 13], and chemical and physiological properties of tomato [14, 15, 16 and 17], but less work has been reported on the effect of irrigation scheduling and water depth application on the engineering properties of tomato. To reduce human labour in the mechanization of tomato production, research on the effect of the production process on the engineering properties of the tomato fruits is needed for the proper design and selection of handling equipment for the crop [18 and 19].

Engineering properties are the properties which are necessary in the design of Agricultural equipment. Recently scientists have made great efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in process and control engineering.Various types of cleaning, grading and separation equipment are designed on the basis of engineering properties. The present study therefore investigated the effect of irrigation frequency and depth of water application on the selected engineering properties of tomato.

II. MATERIALS AND METHODS

2.1. Materials

The tomato (*Lycopersiconesculentum*) was planted on the experimental farm of Department of Agricultural Engineering, LAUTECH, Ogbomosho, Oyo state, using drip irrigation system and harvested, sorted and graded into different sizes. The dimensional parameters consisting of length, breadth, thickness and weight of the tomato fruits were measured and analyzed.

2.2. Experimental Design

To investigate the effect of irrigation regime on the engineering properties of tomatoes, a 2x3x3 factorial design was done. The factors used with their levels are **irrigation frequency** (7 days, 5 days and 3 days) and **irrigation depth** (100%, 75% and 50% Etc). The water requirement for tomatoes was calculated using [20] which has been used by [21]. The equation is as presented in Equation 1.

$$ET_c = \frac{(I - Q - \Delta S + R_0)}{A} \quad (1)$$

Where ETc is evapotranspiration or crop water use (mm);

I is irrigation water added, (cm^3);

Q is deep percolation (cm^3), measured from the base of the buckets;

ΔS is soil water storage change (cm^3), the difference between bucket weights every 24 h;

Ro is runoff (cm^3), (=0 in this study because there was no runoff from the buckets); and

A is cross sectional area of the bucket (cm^2); 10 is a conversion factor from cm/d to mm/d.

2.3. *Determination of Physical Properties*

The physical properties such as length, breadth, weight, thickness, geometrical and sphericity were determined in this research work.

2.3.1. *Determination of Size and Shape of the Fruit*

The **size** of the tomato was measured using a digital Vernier caliper. The three orientation of the fruit identified are length (L), width (W), and thickness (T). The geometrical mean diameter was determine by using the method of [22 and 23]. The sphericity (ψ) was determined using the method of [24]. The axial dimensions were measured 100 times and the average values was used in calculation of the geometrical diameter and the sphericity.

$$D_g = (LBT)^{1/3} \quad (2)$$

$$\Psi = \frac{(LBT)^{1/3}}{L} \quad (3)$$

The fruit **volume** was calculated using Equation 3.

$$V = \frac{\pi B^2 \ L^2}{6\,(2L - B)} \quad (4)$$

Where *V* is the volume B is

$$B = (WT)^{0.5} \quad (5)$$

The relationship has been used to find the volume of okra and pine nuts [27 and 28].

2.3.2. Determination of true and bulk densities

The true density of the seed was determined by the water displacement technique [25]. Twenty randomly selected *T.cucumerina* seeds were weighed and lowered into a graduated measuring cylinder containing 30 ml of water. It was ensured that the seeds were submerged during immersion in water. The net volumetric water displacement was recorded. The true density, ρ_t was then calculated using the equation below:

$$\rho_t = m/v \quad (6)$$

Where *m* is the mass of the seed (in kg) and v is the volume of the seed (in m^3).

For bulk density measurement, an empty cylindrical container of 1000 ml volume was filled with the seeds at a height of about 15 cm, striking the top of the level and then weighing the content, the bulk weight was then recorded. This was done in 10 replications. Using the equation above, the bulk density (ρ_b) was then calculated for each of the replications.

2.4. Determination of Mechanical Properties

The mechanical properties were determined using standard methods.

2.4.1. Angle of repose

The angle of repose was determined by filling a vertical cylinder with the fruit and carefully lifted [22, 24]. The height of the conical heap formed thereafter was measured (Fig. 1).

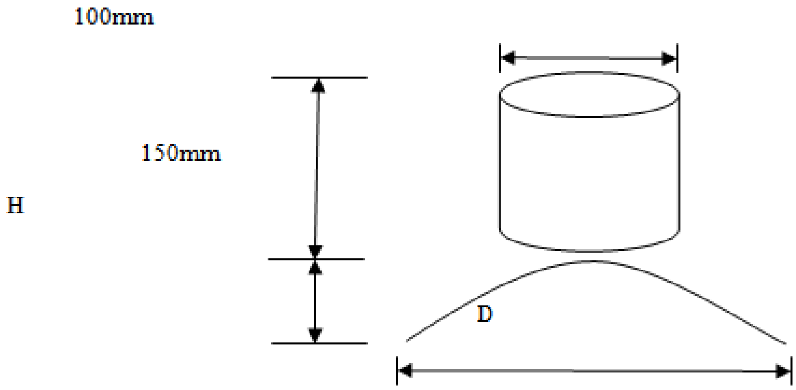

Fig. 1: Determination of angle of repose

Then, the angle of repose was calculated from the known diameter of the platform (DP) by using trigonometric ratio as follows:

$$\theta = \tan^{-1}(\frac{2H}{D}) \quad (7)$$

Where D is diameter; and
H is height

2.4.2. Coefficient of friction

Static coefficient of friction is the tangent of the angle of the inclined surface upon which the friction force tangential to the surface and the component of weight normal to the surfaces acting. This method has been used by 26 and 25. Some tomato fruits were spread on the inclined plane and the inclination of the plane to the horizontal was gradually increased until the tomato fruits started sliding down the plane. The angle between the surface and the horizontal was noted. The tangent value of the angle measured was recorded as the coefficient of the friction of the tomato fruits.

Coefficient of friction= $\tan\theta$

$where\ \theta$ is the angle at which the tomato fruits started to role.

III. RESULTS AND DISCUSSIONS

The results of the effect of irrigation frequency and depth of application on the engineering properties of tomatoes fruit using 2x3x3 factorial is as presented below:

3.1. Effect of Irrigation Scheduling on the Physical Properties of the Tomato Fruit

The physical properties investigated in this experiment are length, breadth, weight and thickness volume, geometrical diameter bulk density and sphericity. The results of these physical properties are discussed below.

3.1.1. Effect of irrigation scheduling on the length of the tomato fruits

The result of effect of irrigation scheduling on the length of tomato fruits is as presented in Table 1.

Table 1: Effect of irrigation scheduling on the Length of tomato fruits

	D_1	D_2	D_3
F_1	45.85±5.13	44.05±5.32	44.1±7.15
F_2	46.34±5.13	46.87±7.30	44.25±11.13
F_3	48.87±7.86	48.73±4.69	46.03±7.66

Note: F_1= 7 days irrigation interval; F_2=5 days irrigation interval; F_3= 3 days irrigation interval; D_1= 100% depth of crop water requirement D_2= 75% depth of crop water requirement; D_3= 50% depth of crop water requirement

The highest length of the tomato fruits (48.87 mm) was attained when the water frequency was 3 days and 100% depth of crop water application. It was also observed that the least length (44.1 mm) was recorded when the water frequency was 7 days and 50% depth of crop water application**.** The result shows that as the depth of water application is increasing the length of the tomato is also increasing. This was also observed for water application frequency; the higher the application frequency the higher the length. This increase in length may be due to increase in size deu to application of more water. The length reported here is less than 53.28 mm reported by [29] and 57.20 mm reported by [11]. This variation may be due to variety. The result was subjected to statistical evaluation and it was observed that the effect of irrigation frequency and the depth of crop water requirement is significant (p<0.05) on length of the tomato fruits. The result was in agreement with the report of [30] who reported different yield for different irrigated tomato.

3.1.2. The effect of irrigation scheduling on the breadth of the tomato fruits

The result of effect of irrigation scheduling on the breadth of the tomato fruits is as presented in Table 2. The highest breadth (40.48 mm) of the tomato fruits was attained when the water frequency was 3 days at 50% depth of crop water application.

Table 2: Effect of irrigation scheduling on the Breadth of tomato fruits

	100%	75%	50%
F1	35.38±5.33	35.40±4.15	35.51±6.94
F2	38.53±6.90	35.77±6.44	36.85±5.03
F3	38.63±3.31	37.97±4.2	40.48±4.15

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

It was also observed that the least breadth (35.38 mm) was recorded when the irrigation frequency was 7 days at 100% depth of crop water application. This result was found lower than the range (57.8- 46.4 mm) reported by [29]and (46.4 mm) reported by [11]. The difference in the breadth may be as a result of variety and cultivation method. This result was subjected to statistical evaluation and it was observed that the depth of water application was significant (p<0.05) while the irrigation frequency was not significant (p<0.05) on breadth of the tomato fruits.

3.1.3. Effect of irrigation scheduling on the thickness of the tomato fruits

The observation on the effect of irrigation scheduling on the thickness of the tomato fruits is presented in the Table 3.

Table 3: Effect of irrigation scheduling on the Thickness of the tomato fruits

	100%	75%	50%
F1	35.23±6.60	38.1±4.7	38.6±5.27
F2	39.85±9.61	38.72±4.62	39.4±3.96
F3	42.13±4.24	41.55±5.07	40.25±6.85

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

The highest thickness of the tomato fruits (42.13 mm) was observed when the irrigation frequency was 3 days at 100% depth of crop water application. The least thickness (35.23 mm) was also recorded when the water frequency was at 100% depth of crop water application at 7 days irrigation frequency. [29]has reported (45.1 mm) which is in the same range. This result was subjected to statistical evaluation and it was observed that the frequency of water application was significant (p<0.05) while depth of application was not significant (p<0.05) on thickness of the tomato fruits.

3.1.4. Effect of irrigation scheduling on the weight of the tomato fruits

The effect of irrigation scheduling on the weight of the tomato fruits is presented in Table 4.

Table 4: Effect of irrigation scheduling on the Weight of the tomato fruits

	D1 100%	D2 75%	D3 50%
F1	34.98±14.1	33.9±10.89	31.15±9.22
F2	35.52±5.06	33.76±11.36	32.63±12.89
F3	37.68±10.85	35.7.38±7.13	34.31±7.65

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

The highest weight (37.63 g) of the tomato fruits was attained when the irrigation frequency was 3 days at 100% of crop water application. It was also observed that the least weight (31.1 g) was also recorded when the irrigation frequency was 7 days at 50% depth of crop water application. The result shows that as the depth of water application is increasing the tomato weight is also increasing. This was also observed for water application frequency; the higher the application frequency the higher the weight. This increase in weight may be due to availability of more water to the plant at higher depth of water application at higher frequency of water application. This result was lower than 91.1 g reported by [29]and 185.68 g reported for Turkey tomatoes by [31]. This variation may be due to tomato variety.This result was statistically evaluated. It was observed that both the irrigation frequency and depth of water application were significant ($p<0.05$) on the weight of the tomato fruits.

3.1.5. Effect of irrigation scheduling on the volume of the tomato fruits

The result of the experiments on effect of irrigation regime on the volume of the tomato fruit is as presented in Table 5.

Table 5: Effect of irrigation scheduling on the volume of tomato fruits

	D_1	D_2	D_3
F1	138.14±5.33	134.41±4.15	123.73±6.94
F2	166.15±6.90	150.02±6.44	136.85±5.03
F3	189.07±3.31	180.45±4.2	184.37±4.1

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

The highest tomato volume (189.07 cm^3) was recorded when the depth of water application was 100% at 3 days water application frequency, while the least volume (123.73 cm^3) was recorded when the depth of water application was 50% at 7 days water application frequency. The result shows that as the depth of water application is increasing the tomato volume is also increasing. This was also observed for water application frequency; the higher the application frequency the higher the volume. This increase in volume may be due to availably of more water to the plant at higher depth of water application which resulted into higher moisture content of the fruit and resulted into higher volume. The volume reported was within the range reported for tomato by [29] who reported 146 cm^3 and [11] that reported between 140.55 and 176.24 cm^3. The variation in the volume reported may be due to variety and cultivation environment. The result of the statistically evaluation of the experiment shows that both the irrigation frequency and depth of water application were significant ($p<0.05$) on the volume of the tomato fruits.

3.1.6. Effect of irrigation scheduling on the geometric diameter of tomato fruits

The result of the experiment on the effect of irrigation regime on the geometrical diameter of the tomato fruit is as presented in Table 6.

Table 6: Effect of irrigation scheduling on the diameter of tomato fruits

	100%	75%	50%
F1	3.8±3.30	3.9±1.15	3.9±1.94
F2	4.1±2.90	4.0±2.00	4.0±3.03
F3	4.3±3.31	4.3±1.2	4.3±2.15

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

The effect of the two factors examined (depth of water and frequency of water application) were found to be insignificant ($p<0.05$). The geometrical diameter observed were between 3.8 and 4.3 cm was a little less than 6.59 cm reported for tomato by [11]**.** This variation may be due to variation in tomato type and cultivation system or environment.

3.1.7. Effect of irrigation scheduling on spherity of tomato fruit

The result of the experiment on the effect of irrigation regime on the sphericity of the tomato fruit is as presented in Table 7.

Table 7: Effect of irrigation scheduling on the sphericity of tomato fruits

	100%	75%	50%
F1	0.83±0.03	0.88±0.05	0.86±0.04
F2	0.90±0.01	0.86±0.04	0.90±0.03
F3	0.88±0.01	0.87±0.02	0.94±0.05

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement; F-value= frequency value; ns= not significant.

The tomato sphericity were observed to be between 0.83 and 0.94 which implies that tomato can be referred to as a spherical object. This observation was in the range of 0.94 to 0.95 for spherity reported for four variety of tomato by [11]. The higher the water frequency application the closer the shape to sphere. This result was subjected to statistical evaluation and it was observed that the depth of water application and irrigation frequency were found to be insignificant ($p<0.05$) on the spherity of the tomato fruits.

*3.2. **Effect of Irrigation Scheduling on the Mechanical Properties of the Tomato Fruits**.*

The two mechanical properties investigated in this experiment are angle of repose and coefficient of friction. The results of the mechanical properties are discussed below.

3.2.1. ***Effect of irrigation scheduling on angle of repose***

Effect of irrigation scheduling on the angle of repose of the tomato fruits is given in Table 8.

Table 8: Effect of irrigation scheduling on the Angle of repose of the tomato fruits

	100%	75%	50%
F1	18.42±3.87	19.03±3.21	20.98±4.14
F2	14.78±6.61	17.77±3.43	20.48±1.13
F3	13.18±1.69	14.1±3.51	16.13±5.21

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement

The highest angle of repose (20.98°) for the tomato fruits was observed when the water frequency was 7 days at 50% depth of crop water application while the least angle of repose (13.18) was recorded when the water frequency was at 50% depth of crop water application and 3 days irrigation frequency. This result was subjected to statistical evaluation and it was observed that the depth of water application was significant ($p<0.05$) while the irrigation frequency was found to be insignificant ($p<0.05$) on the angle of repose of the tomato fruits.

3.2.2. Effect of irrigation scheduling on the coefficient of friction of tomato fruits.

The result of the effect of irrigation scheduling on the coefficient of friction of tomato fruits is presented in Table 9.

Table 9: Effect of irrigation scheduling on the Coefficient of friction of the tomato fruit

	100%	75%	50%
F1	0.40±0.11	0.38±0.05	0.38±0.11
F2	0.39±0.09	0.39±0.13	0.39±0.004
F3	0.39±0.04	0.39±0.04	0.38±0.05

Note: F1= 7days irrigation interval; F2=5days irrigation interval; F3= 3days irrigation interval; D1= 100% depth of crop water requirement depth of crop water requirement; D3= 50% depth of crop water requirement

The highest coefficient of friction (0.40) for the tomato fruits was observed when the irrigation frequency was 7 days at 100% depth of crop water application. It was also observed that the least coefficient of friction recorded was when the irrigation frequency was 3 days at 50% depth of crop water application. This result was subjected to statistical evaluation. It was observed that the irrigation frequency and the depth of water application was not significant ($p<0.05$) on coefficient of friction of the tomato fruits.

IV. CONCLUSION

In conclusion, this study demonstrated the impact of the irrigation frequency and the water depth application on the engineering properties of tomato fruit. The irrigation frequency and the depth of water application was found to be significant on the selected engineering properties. It therefore recommended that, during design and selection of handling equipment for the fruit mechanization, these two factors (irrigation frequency and water application depth) should be considered as a very important factor.

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