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PHYSICAL AND MECHANICAL PROPERTIES OF *Citrus aurantiifolia* Swingle VAR. Pramalini (KAGZI-LIME)

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Abstract- Kagzi- lime (*Citrus aurantifolia)* is a citrus fruit variety in Maharashtra, Andhra Pradesh and Karnataka state of India available in small to medium size, its pulp is juicy greenish with strong adherence to the yellowish, green, thin or papery and shiny. It is mainly used for processing purpose. Physical and frictional characteristics were determined in laboratories. It includes, linear dimensions, mass, bulk density, Sphericity, rolling angle, static co-efficient of friction and dynamic co-efficient of friction were determined for the Kagzi-lime. Polar diameter of Kagzi-lime was in the range of 3.33 cm to 4.48 cm whereas equatorial diameter was in the range of 3.34 cm to 4.47 cm. The maximum thickness value was in the range of 3.34 cm to 4.35 cm whereas weight of Kagzi-lime was in the range of 21.90 gm to 46.32 gm. The bulk density of Kagzi-lime was in the range of 551.80 kg/m^3 to 585.83 kg/m^3 and sphericity varied between 97.5 to 99.1 per cent, respectively. The highest rolling angle was found on plywood surface (8.05 degree) and lowest on aluminum surface (6.65 degree) was recorded for the Kagzi-lime fruit.

Keywords- Kagzi-lime, Physical properties, frictional properties

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Introduction

Lemons are less poplar than the lime in India. Acid-lime stands second next to Nagpur-santra in Western Vidarbha region of Maharashtra state. Acid-lime is tropical in its climatic requirement. Maharashtra produces 12% of the total production of lime/lemon in the country and is the third largest producer in the country.The state produces 0.26 m MT of lime/lemon from an area of 0.04 m. ha. with productivity of 6.0 MT/ha [1] . A well drained soil with a pH of 6.5 to 7.0 is ideal for better growth and yield. In Maharashtra, *Pramalini, Vikram* are two varieties identified by clonal selection. These have been released for commercial cultivation as they are *Canker-free* and *Prolific-bearer*. The improved varieties are *Pramalini, Vikram, Chakradhar, PKM1, Seedless lime* and *Tahiti lime*. A good acid lime plant (7-year old) may yield 2000-5000 fruits annually. The average yield being 3000 to 3,500 fruits/tree. Harvesting of lime and lemons differs with different species, verities and regions of cultivation. The peak season of harvesting is from March to April and lean season May to June in Maharashtra. The storage life of lemon fruit is between 6 to 8 weeks at temperature 9 to10^{0}C and 85 to 90 % relative humidity [2].

The scientific classification of *Citrus Aurantifolia* is from Kingdom: Plantae, Order: Sapindales, Family: Rutaceae, Genus: *Citrus*. The important species are *Citrus aurantifolia- Key lime, Citrus maxima-Pomelo, Citrus medica-Citron, Citrus reticulate- Mandarin orange.* .Kagzi- lime (*Citrus aurantifolia)* is a citrus fruit variety available in small to medium size, its pulp is juicy greenish with strong adherence to the yellowish, green, thin or papery and shiny. Lime and lemons are harvested with shades of green and yellow colour which are not acceptable in the market. Therefore, harvested fruits are degreened. Degreening of citurs fruit in India is achieved with the aid of calcium carbonate crystals. They are harvested with a pole harvester having an iron hook and a net at packing sheds as soon as possible. They should never be allowed to stay under the sun for a long time. Kagzi-limes are oval or spherical in shape with smooth porous skin. In the ripening chambers calcium carbide releases ethylene gas which changes green colour and allows the development of yellow colour without affecting the quality of fruits [3].

Per capita consumption of the lime in world is around 1.30 kg/year on national map [4]. The fruit of acid lime are available at throw away prices due to glut in the market at time in the month of August and September. The fruit has valued not only for its nutritional and medicinal qualities but also extensively used for the preparation of value added products, like squashes, syrup, cordials, pickles, manufacture of citric acid and for culinary uses in the daily diet of Indians. Per day requirement of ascorbic acid for an adults to maintain the skin and teeth, to resist stress and infection is 70-90 mg [5]. The importance of flavonoids of citrus fruit is well documented including the ability to prevent red blood cell clumping and capillary fragility, anti-cancer and anti- viral activity. The lime peel oil has wide application as flavoring agent in food industry. The products and by-products developed from the fruit of Kagzi-lime are comparatively well known on commercial scale.

There are two main principle season of production of fruit i.e. February to April and October to December. The fruits are harvested during November to March are round in shape and good test. The rainy season fruits are oblong and have inferior test. The method of harvesting and stage of maturity at harvesting time are vital factors in grading and packing. Therefore, the post harvest management of fruits is of prime importance in order to sustain higher production.

Cleaning, sorting and grading are the important post harvest operations related to the market. It provides basics for buying and selling. In market, size of any fruit has been considered as the main criteria for selling followed by fruit maturity. In post harvest-handling, conveying and grading are two important operations responsible for mechanical injury of fruits. Fresh crop and damage free post-harvest handling of fruits and vegetables were considered basic requirements to increase the farmer's profit.

Singh, et al [6] said that the data availability of physical and frictional properties for Citrus fruit is limited. Tirthakar, et al [7] evaluated the fruit quality of acid lime orchard from fourteen locations of Akola district of Maharashtra. They measured physical parameters, in that length and breadth of fruit ranged between 3.52 to 5.12 cm and 3.41 to 4.93 cm, respectively. The weight and volume of fruit ranged between 32.34 gm to 48.20 gm and 33.79 cc to 48.6 cc, respectively Sharifi, et al [8] measured some physical properties of Orange. FAO [4] measured the physical properties of Apricot kernels as a function of moisture content varies from 2.86 to 13.03 per cent (wet basis).

Materials and Methods

Local variety of Kagzi-lime *(Pramalini)* fruits was procured from local market, Parbhani. Random samples were drawn from a freshly harvested lot of Kagzi-lime. Twenty number of Kagzi-lime in each three size grades: first (large), second (medium) and third (small) were taken as (measurement of physical and frictional properties) study samples. Physical and frictional characteristics were determined in laboratories. It includes, linear dimensions, mass, bulk density, Sphericity, rolling angle, static co-efficient of friction and dynamic co-efficient of friction were determined for the Kagzi-lime. Mean and standard deviation were computed according to the standard methods.

Determination of Physical Characteristics of Kagzi-lime

Linear Dimensions

There are two categories of Kagzi-lime fruit diameter, polar diameter and equatorial diameter. Polar diameter is the distance between the fruit crown and the point of root attachment of the Kagzi-lime. Equatorial diameter is the maximum width of the Kagzi-lime in a plan perpendicular to the polar diameter [9]. Equatorial diameter (De), polar diameter (Dp) and thickness (T) of each twenty fruits were measured for each grade using Vernier calliper with Least count of 0.05 mm.

Bulk Density

The bulk density of sample was computed by the mass of fruit (gm) and volume of fruit (cm^3) [10]. The mass of bulk fruit was determined by using a precise weight balance with accuracy 0.001 gm and volume was computed as length x breadth x thickness of the box used for measuring the bulk weight of fruits.

Sphericity

The fruit shape was expressed in terms of its sphericity. The sphericity index was calculated based on recommendation of Mohsenin, et al [10].

$$\text{Specificity (\%)} = \frac{(Dp \times De \times T)1/S}{Dp} \times 100 \qquad (1)$$

Where,

Dp - Polar diameter (mm).

De - Equatorial diameter (mm).

T - Thickness of kagzi lime (mm).

Determination of Frictional Characteristics of Kagzi-lime

Rolling Angle

To determine the rolling angle, the Kagzi-lime was kept at the centre of the working surface, (horizontal platform) in the most stable position (on their base) to prevent toppling over (top upwardsss). The platform was inclined until the Kagzi-lime begins to roll. When the rolling of Kagzi-lime was started, the position of platform was noted by protractor. For the next test, the platform was brought to the initial horizontal position [11].

In this experiment, the rolling angle was measured in three different platforms such as plywood, aluminum and mild steel. Rolling angle was measured with mild steel platform was considered in the design of Kagzi-lime grader.

Co-efficient of Static Friction

The co-efficient of static friction is the tangent of the slope angle of the table measured with a protractor [12]. It was determined on three surfaces i.e. plywood, aluminum and mild steel for Kagzi-lime fruits. A frame made with a rectangular wooden were placed on the surface. The frame was filled with fruits. The table was tilted slowly manually until movement of the whole fruit mass.

Co-efficient of Dynamic Friction

The co-efficient of dynamic friction was the ratio of the force required to slide the fruit over a surface divided by the normal force pressing the fruit against the surface [12]. It was measured for the same material i.e. plywood, aluminum and mild steel for Kagzi-lime fruits. The frame was filled with fruits. The force required to pull that frame was noted in term of weight.

Results and Discussion

The average value of each parameter for Kagzi-lime was measured and presented in [Table-1] and [Table-2]. Based on the average diameter values of Kagzi-lime, the size of fruits are classified into following three grades-

1. Grade-I – above 41mm.
2. Grade-II- between 40 to 36 mm.
3. Grade-III- below-35 mm

[Table-1] shows that, polar diameter of Kagzi-lime was in the range of 33.3 mm to 44.8 mm whereas equatorial diameter was in the range of 33.4 mm to 44.7 mm. The maximum thickness value was in the range of 33.4 mm to 43.5 mm whereas weight of Kagzi-lime was in the range of 21.90 gm to 46.32 gm.

The bulk density of Kagzi-lime was in the range of 551.80 kg/m^3 to 585.83 kg/m^3 and sphericity varied between 97.5 to 99.1 per cent, respectively.

The frictional properties of Kagzi-lime depend on the moisture content of fruit peel [13]. Initial moisture content of Kagzi-lime peel was 43.93 per cent (w.b.). [Table-1] shows the frictional properties of Kagzi-lime on three different surfaces (plywood, aluminum and mild steel). The highest rolling angle was found on plywood surface (8.05 degree) and lowest on aluminum surface (6.65 degree) was recorded for the Kagzi-lime fruit.

Table 1- Physical properties of Kagzi-lime

Particular	Large (G-I)		Medium (G-II)		Small (G-III)	
	Mean	SD	Mean	SD	Mean	SD
Polar diameter (mm)	44.8	3.4	38. 1	0.96	33.3	1.47
Equatorial diameter (mm)	44.7	2.6	38.1	0.95	33.4	1.12
Thickness (mm)	43.5	2.6	37.5	0.85	33.4	1.06
Weight (gm)	46.32	7.9	30.11	1.92	21.9	3.22
Bulk density (kg/m^3)	551.8	0.03	552.99	0.02	585.83	0.04
Sphericity (%)	97.5	3.1	98.2	0.7	99.1	1.2

Table 2- Frictional properties of Kagzi-lime

Particular	Plywood		Mild steel		Aluminum	
	Mean	SD	Mean	SD	Mean	SD
Rolling angle (degree)	8.05	0.8	6.75	0.78	6.65	0.78
Static co-efficient of friction	0.57	0.02	0.64	0.03	0.62	0.02
Dynamic co-efficient of friction	0.45	0.03	0.54	0.13	0.51	0.01

The static co-efficient of friction value varies from 0.57, 0.65, and 0.62 for Kagzi-limes on plywood, mild steel and aluminum, respectively. The dynamic co-efficient of friction value was found highest on mild steel (0.54) and lowest on plywood (0.45) for Kagzi-lime. Approximate values for these properties were noted by Singh, et al [6].

Evaluation of the Regression Models

The equations were derived through regression analysis and on the basis of the polar diameter as the first and only independent variable the fruit mass was estimated (coefficient of determination = 0.935).

$$y = 22.452x-53.505 \quad R^2 = 0.935 \quad (2)$$

A coefficient of determination of 0.969 was achieved when the equatorial diameter was also added to the model.

$$y = 24.232x - 60.394 \quad R^2 = 0.969 \quad (3)$$

The thickness of was also added to the model with a coefficient of determination of 0.953.

$$y = 26.48x - 67.58 \quad R^2 = 0.953 \quad (4)$$

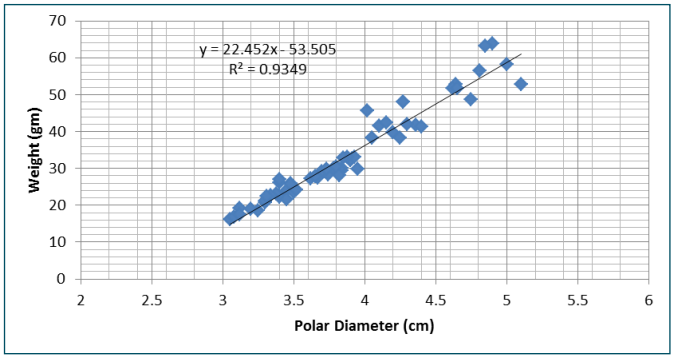

Fig. 1- Relationship between mass of Kagzi-lime with polar diameter

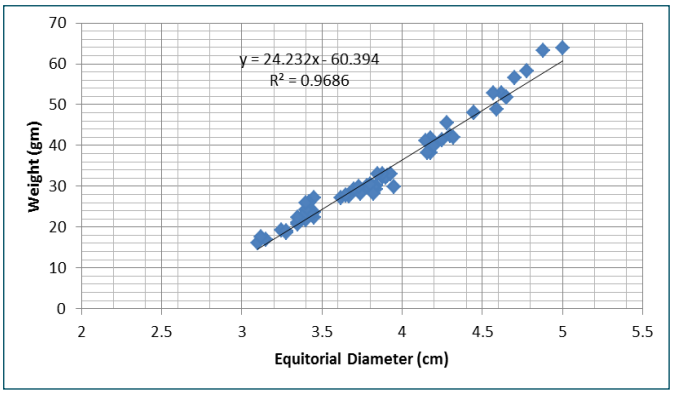

Fig. 2- Relationship between mass of Kagzi-lime equatorial diameter

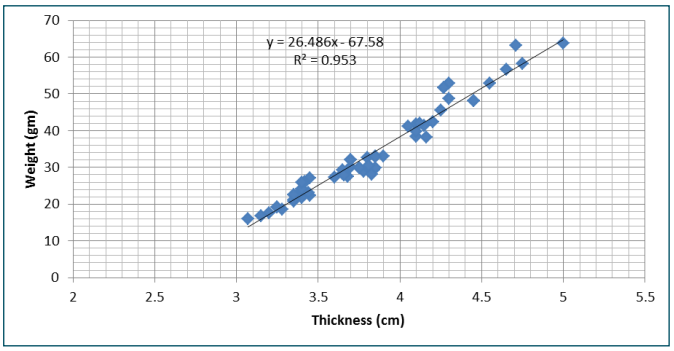

Fig. 3- Relationship between mass of Kagzi-lime with thickness

A linear equation was found to be more responsive to estimate the mass of kagzi-lime based upon any of the independent variables of dimension with respect to any of the polar diameter, equatorial diameter and thickness. These are demonstrated in [Fig-1], [Fig-2] and [Fig-3] in order of their coefficients of determination.

Any of the above variables is in significant correlation with Kagzi-lime mass and can be employed in development of the linear regression for estimation of the Kagzi-lime mass.

Conclusions

The following conclusions were found during experimentation:

The sphericity of fruit was found between 97.5 to 99 percent; therefor shape of fruit is spherical.

The highest rolling angle was found on plywood surface (8.05 degree) and lowest on aluminum surface (6.65 degree) was recorded for the Kagzi-lime fruit.

The static co-efficient of friction value was found highest on mild steel (0.64) and lowest on plywood (0.57) and the dynamic co-efficient of friction value was found highest on mild steel (0.54) and lowest on plywood (0.45) for Kagzi-lime.

A linear model of the Kagzi-lime mass was developed on the basis of the independent variables of polar, equatorial diameters and thickness. The most recommended regression model to fit Kagzi-lime mass was the one based upon the equatorial diameter of lime.

Conflicts of Interest: None declared.

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