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Design and development of grader for Kagzi-lime

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■ **ABSTRACT :** A Kagzi-lime fruit grader was developed using concentric screen principle. The machine consists of feeding, grading, collection and power transmission units. The dimensions of the machine are 1200 mm x 700 mm x 700 mm with a cost of approximately Rs. 25,000. The Kagzi-lime fruit were graded into three grades *viz.,* Grade-I – above 40 mm, Grade-II- between 40 to 36 mm and Grade-III- below-36 mm. The maximum grading efficiency of 95 per cent at 14 rpm of the speed of grading unit and 7 degree feed trough angle with actual capacity was found 354.45 kg/h. and Rs. 6.62/qt cost of grading. In absence of electricity (on farm) manually operated grader is also suitable to marginal farmers with 86 per cent grading efficiency and Rs. 12.23/qt cost of grading.

■ **KEY WORDS :** Design, Screen grader, Kagzi-lime, Cost analysis

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India is the second largest producer of fruits and vegetables in the world, accounting for about 16 per cent of global vegetable production and 10 per cent of world fruit production. India's production of fruits and vegetables, currently, stands at 64 million tonnes and 126 million tonnes, respectively, making up for around 12 per cent and 14 per cent of world production, in the respective sector.

The horticultural product has inherent variability in size at harvest that differentiates them in value. For the ease of buyer it is necessary to grade them according to some objective standard. Therefore, it is need of the time to provide facilities at the doorstep of the farming community so that they may be able to market better quality horticultural products. In post-harvest handling, conveying and grading are two most important operations responsible for mechanical injury. Fresh crop and damage free post-harvest handling of fruits and vegetables were considered basic requirements to increase the farmer's profit margin.

Grading is one of the important operations done at the farmer level. The separation based on a multiple parameters like size, shape, colour, weight, etc. Grading on the basis of size and quality is essential preliminary to marketing of fruit and vegetables grown in commercial holding. Proper marketing system is being developed in our country to compute the international market, especially at present when world has turned into a global village and World Trade Organization (WTO) has specified its standards to meet the international trade contract. To achieve the access to the market aboard, traded commodity must be according to standards specified by WTO and that is only possible by the direct linkage between consumer demand in the import countries and producers in the exporting countries.

Generally, Kagzi-lime fruit lot is separated by hand with the help of labour of different age groups. It results in uneven grading, time consuming, labour intensive, slow, non-consistent and costly operation. Therefore, farmers are looking forward to have an appropriate Kagzi-lime grading machine in order to alleviate the labour shortage and obtain a better quality of agricultural products.

Mechanical grading of fruit is efficient and provides uniform grading of fruits. In mechanical fruit graders, divergence roller type, oscillating screens, rotary screen, weight graders are used in our country. Some graders are less efficient and some are costly. The divergence roller type fruit grader is commonly used in Maharashtra for grading of onion, potatoes, sapota, oranges, etc. But no any special type of lemon grader is available in market. Therefore, this study was carried out with the following objectives:

– To design and development of grader for Kagzi-lime.
– To test the performance for grading Kagzi-lime on the size of the product.

■ METHODOLOGY

To meet the objectives the study was planned to conducted in two phases.

PhaseI :

Design and development of Kagzi-lime fruit grader.

Phase II :

To evaluate its performance by studying the effects of different machine parameters on fruit

Phase I :

Design of machine elements :

The fruit grader was designed Fig. A and its main components were main frame, power transmission unit, feeding trough, grading screen unit, collection unit. The dimensions of these components were selected by adopting the following design procedure.

Capacity of feed trough :

The trapezoidal shape trough was designed to feed the Kagzi-lime to be graded. It was constructed using Ms-sheet (Gauge-22). The detailed design dimensions of the hopper presented in Fig. A (1 and 2) . By considering the volume of feeding trough and bulk density of Kagzi-lime, the capacity of the feeding trough was determined as follows :

$$Q = V \times \rho$$

where,

Q= Feeding trough capacity, kg.

ρ= Average bulk-density of Kagzi-lime (kg /m^{3}).

V= Volume of feed trough, m^3.

$$= \frac{(0.4 + 0.1) \times 0.32 \times 0.1}{2}$$

$$= 0.008\,m^3$$

$$\therefore \text{Capacity } Q = 0.008 \times 563.54$$

$$= 4.5\,kg$$

Inlet diameter of grading unit (Biradar, 2004) :

=2 x opening of feed trough (cm) + Shaft diameter (cm) + end clearance (cm)

$$= 2 \times 10 + 3.8 + 1$$

$$= 25.8 \approx 26 \text{ cm}$$

Determination of capacity of grader for Kagzi-lime:

Considering the grading screen has 30 cm diameter and effective width of the grading unit was calculated by using following formula (Khurmi and Gupta, 2003):

$$\text{Width of sector} = \frac{\theta}{360} 2\pi r$$

where,

θ – Angle subtended by sector of screen.

r – Radius of grading screen (cm).

$$= \frac{80}{360} \times 2\,\pi \times 15$$

$$= 20.93 \approx 21\,cm$$

Considering average size of fruit (equatorial diameter of large, medium and small) fruit as 3.87 cm. Number of fruits that can be accommodated on 21 cm wide screen (Mangaraj *et al*., 2009) is :

$$\text{No. of fruits} = \frac{21}{3.87} = 5.43 \approx 5$$

Considering spherical shape of Kagzi-lime fruit and grader speed as 11.31 m/min. The theoretical volume of fruit to be handled in one hour (Mangaraj *et al*., 2009).

$$Q_t = n \times A \times v$$

where,

Q_t= Theoretical volume of fruit (m^3/hr).

A = Area of cross section of fruit (m^2).

ν = Velocity of grading unit (m/hr).

$$Q_t = 5 \times \frac{\pi}{4} \times (0.0387)^2 \times 678.67$$

$$= 3.99 \approx 4\,m^3/hr$$

Considering 25 per cent effective space occupied by the fruits, since all the fruit will not be in close contact.

$$\therefore Q_a = Q_t \times 0.25$$

where,

Q_a= Actual volume rate (m^3/h)

Q_t = Theoretical volume rate (m^3/h).

$$Q_a Z 4 \times 0.25$$

$$= 1\, m^3/hr$$

$$\therefore \text{Capacity of grader} = Q_a \times \rho$$

where,

ρ - Average bulk density of Kagzi-lime (kg/m^3).

$$= 1 \times 563.54$$

$$= 563.56 \text{ kg/hr}$$

Power requirement :

The total power required to rotate the grading unit is given by :

$$P = \frac{2\pi NT}{4500 \times \eta}$$

where,

P= Power in hp,

N= Revolutions of the grading unit shaft,

T= Torque on grading unit in kg-m,

η= Efficiency.

Torque on the grading unit :

T= Total load x average radius of grading unit.

Load capacity of grading unit :

= Volume of grading unit, m^3 x average bulk density of Kagzi-lime, kg/m^3

$$= 80 \times 21 \times 3.87 \times 10^{-6} \times 563.54$$

$$= 3.66 \approx 4 \text{ kg}$$

Total load= weight of material used for making grading unit + load capacity of grading unit.

$$= 55 + 4 = 59 \text{ kg}$$

Now, average radius of grading unit :

$$= \frac{27.5 + 22.5 + 15}{3}$$

$$= 21.67 \text{ cm}$$

$$= 0.22 \text{ m}$$

$$\text{Torque} = 69 \times 0.22 = 12.78 \text{ kg} - \text{m}$$

$$\therefore \text{Power requirment}, P = \frac{2 \times \pi \times 18 \times 12.78}{4500 \times 0.7}$$

$$= 0.459$$

$$= 0.5 \text{ hp}$$

Therefore, 0.5 hp motor can be used.

Determination of diameter of driven pulley :

Selecting the diameter of drive pulley 75 mm and considering the diameter of three driven pulleys the required rpm of driven pulley was reduced to 14, 18, and 23 rpm from 750 rpm by changing the pulley size 250 mm, 200 mm and 150 mm, respectively. Velocity ratio 'V' belt (Khurmi and Gupta, 2003).

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

where,

D_1 = Diameter of drive pulley (cm),

D_2 = Diameter of driven pulley (cm),

N_1 = Revolutions of drive pulley (rpm),

N_2 = Revolutions of driven pulley (rpm).

Theoretical velocity of grading unit :

$$V = \frac{\pi DN}{60} = \frac{\pi \times 0.2 \times 18}{60}$$

$$= 0.1884 \text{ m/sec}$$

$$= 11.31 \text{ m/sec}$$

Theoretical design of V-belt :

$$\text{Velocity of belt} = \frac{\pi \times D_1 \times N_1}{60}$$

$$= \frac{\pi \times 0.075 \times 750}{60}$$

$$= 2.944 \text{ m/sec}$$

where,

D_1 = Diemeter of drive pulley= 0.075m

N_1 = Revolutions of drive pulley= 750

V = Velocity of belt cm/ sec.

Theoretical velocity is less than the optimum value 10 m/ sec hence, accepted (Khurmi and Gupta, 2003).

Theoretical design of shaft :

In order to transmit required torque of 1278 kg-cm the diameter of the shaft worked out by the following equation (Khurmi and Gupta, 2003).

$$D = \sqrt[3]{\frac{16 \times T}{S_s \times \pi}}$$

where,

D = Diameter of grading unit driving shaft (cm),

T = Torque on shaft (kg-cm),

S_s = Safe shear stress.

Ultimate safe stress = 3523 kg/cm^2 (Stanton and Wintson, 1977)

$$= \frac{\text{Ultimate safe stress}}{\text{Factor of safety}}$$

$$= \frac{3523}{3}$$

$$= 440.375 \text{ kg / cm}^2$$

$$\therefore D = \sqrt[3]{\frac{16 \times 1278}{440.37 \times \pi}}$$

$$-2.45 \text{ cm}$$

The actual diameter of the shaft used to drive the grading unit had 3.8 cm diameter as compared to 2.45 cm diameter theoretically calculated. Thus, the design of shaft considered safe.

Development of main frame :

The frame is having dimension of 1200 mm x 700 mm x 700 mm and size of MS angle is 40 mm x 40 mm x 4 mm. The pulleys, pedestal bearings, driving shaft, grading unit, collection units are mounted on this frame. All these accessories are mounted with the help of hexagonal nut and bolts. The detail dimensions are as shown in Fig. A (1, 2 and 3).

Development of power transmission unit :

The power transmission system is shown in Fig. A

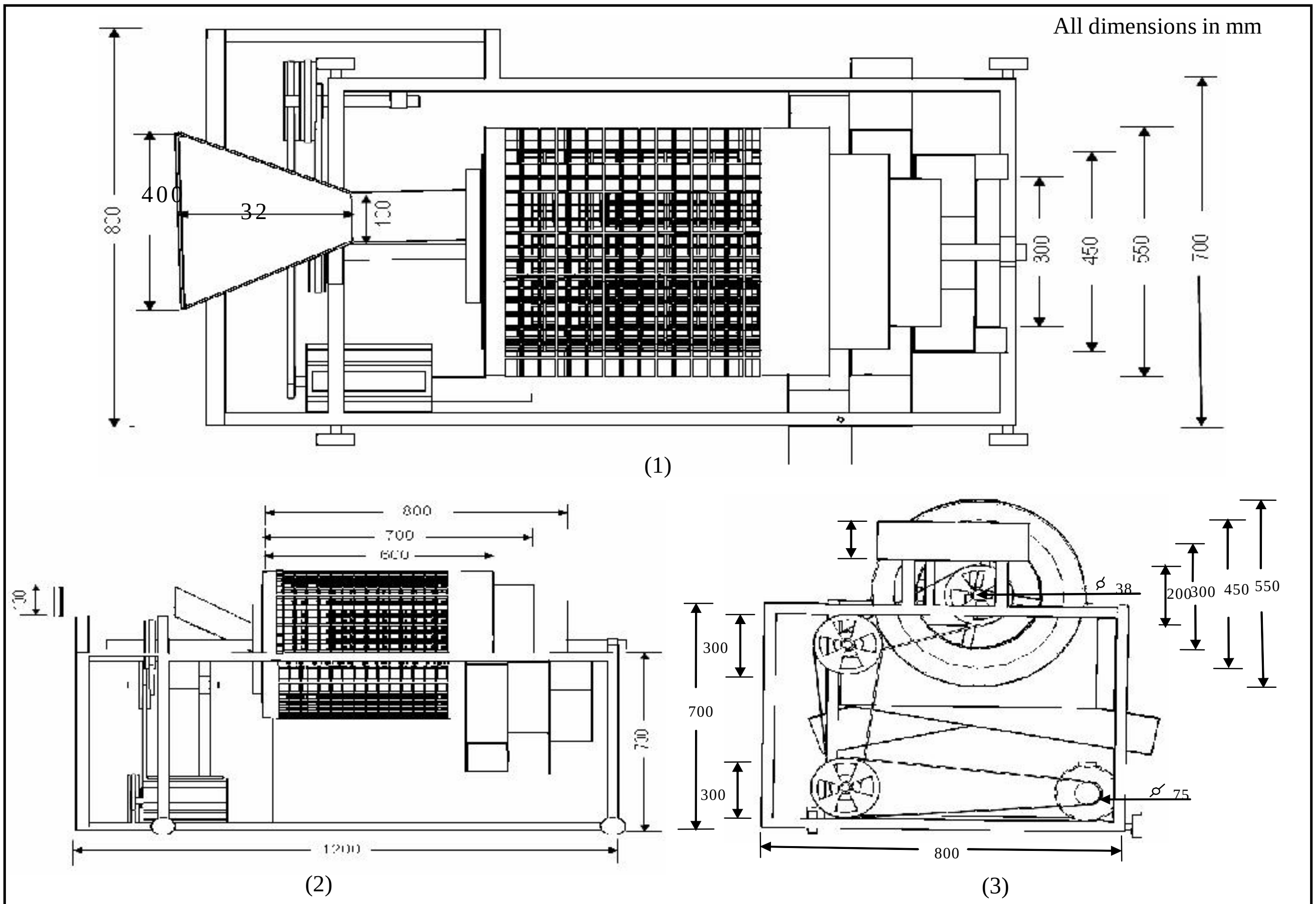


Fig. A : Dimensions of the grading unit

Table A : Measurement of actual rpm of grading unit

Sr.No.	Diameter of pulleys (mm)	Theoretical rpm of grading unit	Actual rpm of grading unit
1.	150	23	22
2.	200	18	17
3.	250	14	14

(3). The electric motor having 0.5 hp was used to drive the grader Kagzi-lime. A synthetic rubber belt of B-type used for transmitting the power from drive pulley to driven pulley.Various pulleys of diameter of 150 mm, 200 mm and 250 mm were used in combination to achieve desired rpm of grading unit. Actual rpm of grading unit was also measured by tachometer and measured values are presented in Table A.

Development of feeding trough :

The trapezoidal shape trough was designed to feed the Kagzi-lime to be graded. It was constructed using Ms-sheet (Gauge-22). The detailed design dimensions of the hopper presented in Fig. A (1 and 2) . By considering the volume of feeding trough and bulk density of Kagzi-lime, the capacity of the feeding trough was determined as follows:

$$Q = V x \rho$$

where,

Q= Feeding trough capacity, kg,

V= Volume of feeding trough, m^3.

ρ = Average bulk-density of Kagzi-lime (kg /m^3).

Development of grading screen unit :

The three cylindrical concentric circular screens with square mesh are used for grading Kagzi-limes. Inlet side covering plate of grading unit was made of 16-gauge MS sheet having outer diameter 60 cm and internal diameter 26 cm. The thermal welded MS circular section bars used to make square mesh screen. The screens are supported on the main shaft with the help of supporting MS pipes on two-fixed position. The screens are detachable, therefore the grading of other fruits like Anola, Sapota and Ber, is possible by standardizing only the screen mesh size according to the physical properties of respective fruits.

The detailed dimensions of the grading unit are as shown in Fig. A (1 and 2) . The grade standards of Kagzi-lime are :

– Grade-I – above 40 mm,

– Grade-II- between 40 to 36 mm,

– Grade-III- below-36 mm.

Development of collection unit :

The material used for making the collection units was 16-gauge MS sheet. The opening of first collection unit is 15 cm x 10 cm, second and third collection unit is 10 cm x 10 cm. The detailed dimensions are shown in Fig A (3).

Three different levels of speed of grading unit and feed trough angle combinations were tested in random order to estimate the effect of above said independent variable on actual capacity, separation efficiency and overall grading efficiency of grader for Kagzi-lime. Performance evaluation of grader for Kagzi-lime was calculated by following formulae (Mangaraj *et al*., 2009).

Actual capacity :

$$Q = \frac{\text{Total weight of fruit graded (kg)}}{\text{Time (hr)}}$$

Separation efficiency :

$$E_s = \frac{N_t - N_u - N_0}{N_t} x 100$$

where,

E_S = Separation efficiency of a particular grade in per cent

N_t = Total number of fruits in the sample.

N_u = Total number of undersize fruits in the sample.

N_o = Total number of oversize fruits in the sample.

Overall grading efficiency :

$$E = \frac{N_t - N_{tm}}{N_t} x 100$$

where,

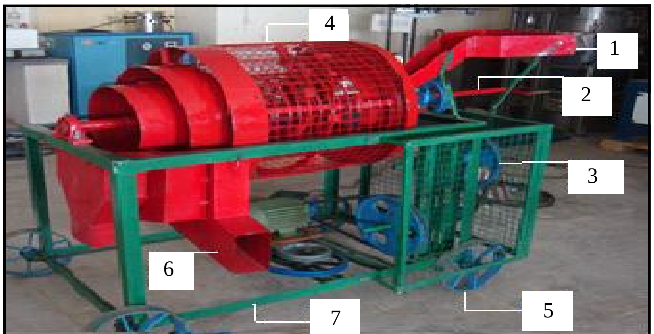
E= Overall grading efficiency of grader for Kagzi-lime.

N_{tm}= Total number of the misclassified fruits in all sample.

RESULTS AND DISCUSSION

A power-operated grader for Kagzi-lime was designed and fabricated in the Department of Agricultural Process Engineering, College and Agricultural Engineering and Technology, MAU, Parbhani. Also the handle arrangement is available in absence of electricity. Fig. 1 shows the isometric view of developed grader for Kagzi-lime.

Kagzi-limes of variety Pramalini were procured from local market. The performance of the machine was evaluated. Effect of varying speed for grading unit and feeding trough angle on actual capacity, separation efficiency and overall grading efficiency was studied.



1. Hopper
2.Handle for manual operation
3. Power transmission unit
4.Grading unit
5.Ground wheels
6.Collection unit
7. Main frame

Fig. 1 : Isometric view of developed grader for Kagzi-lime

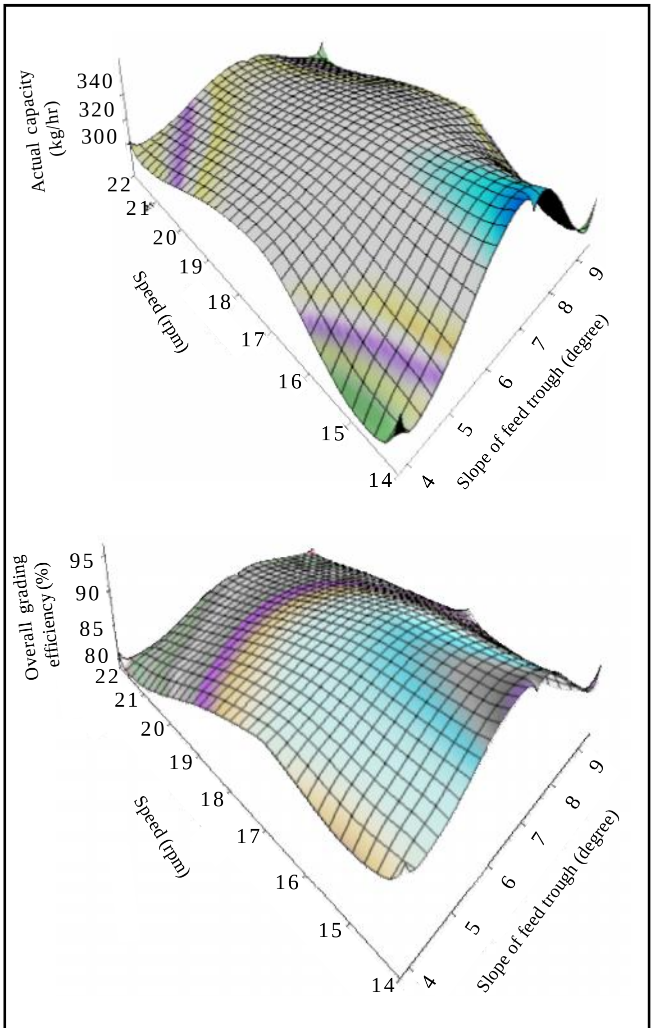


Fig. 2 : Effect of independent variables on actual capacity of grader and overall grading efficiency for Kagzi-lime

The results of performance evaluation of grader as shown in Fig. 2 and reveled that speed of grading unit had maximum influence on the actual capacity and overall grading efficiency. It was observed from results that as speed of grading unit increased the actual capacity and over grading efficiency increased upto certain limit (14 rpm speed). But when speed of grading cylinder and feed trough angle increased beyond 17 rpm and 7 degree, respectively, the Kagzi-lime roll down with high speed from trough towards the inlet of grading cylinder resulting in chocking the inlet and improper grading (Ali *et al.*, 2011).

In power operated grader maximum grading efficiency of 95 per cent with actual capacity 354.45 kg/h of grader for Kagzi-lime was resulted at 14 rpm of the speed of grading unit and 7 degree feed trough angle. Table 1 shows the comparison between operating cost of the power operated grader, manually operated grader and manual grading. Cost of grader is reduced to Rs. 6.62/q of graded Kagzi-lime as compared to Rs. 40/q of graded in manual grading. In handle operated grader, maximum grading efficiency of 86 per cent with actual capacity 267 kg/h of grader for Kagzi-lime was resulted at handle-operated grader of 7 degree feed trough angle. Cost of grader is reduced to Rs.12.23/q of graded Kagzi-lime as compared to Rs.40/q of graded in manual grading. During both grading, damage like brushing or any mechanical injury to the fruit was not observed during grading in Fig. 3.

Fig. 3 : Graded sample of Kagzi-lime in to three grades

Table 1 : Operating cost of the power operated grader, manually operated grader and manual grading

Particulars	Power operated grader	Manually operated grader	Manual grading
Assumed service life	25 years	25 years	----
Annual use	1200 h	1200 h	----
Initial cost	Rs.25, 000	Rs.20, 000	----
Salvage value	10%	10%	----
Interest	10%	10%	----
Taxes shelter	1 %	1 %	----
Repair and maintenance	2%	2%	----
Labour charges	Rs.15/h (for one labour)	Rs.30/h (for two labour)	Rs.20/h (for one labour)
Electricity	Rs.5/h	------	----
Capacity (Average)	354 kg/hr	268 kg/hr	50 kg/hr
Annual overhead charges			
Depreciation	Rs.0.75/h	Rs.0.6/h	----
Interest	Rs.2.08/h	Rs.1.67/h	----
Taxes, shelter	Rs.0.208/h	Rs.0.167/h	----
Total annual overhead cost			
Overhead charges	Rs. 3.038/h	Rs. 2.437/h	-----
Repair and maintenance	Rs.0.417/h	Rs.0.33/h	----
Electricity	Rs.5/h	--------	----
Labour charges	Rs.15/h	Rs.30/h	Rs.20/h
Total cost/hr	Rs.23.45/h	Rs.32.77/h	Rs.20/h
Total cost per quintal of graded Kagzi-lime	Rs. 6.62/q	Rs. 12.23/q	Rs. 40/q

Conclusion :

The grader was designed keeping view farmer's requirement, local availability of material and ease of operation. Performance of the grader was evaluated for actual capacity and grading efficiency found during the operation, the specific conclusion which have emerged from this investigation are as follows:

– Developed power operated grader is most suitable to marginal farmers with respect to 95 per cent grading efficiency and Rs. 6.62/q cost of grading.

– In absence of electricity (on farm) manually operated grader is also suitable to marginal farmers with 86 per cent grading efficiency and Rs. 12.23/q cost of grading.

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