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PHYSICAL PROPERTIES OF ROSELLE CALYCES (*HIBISCUS SABDARIFFA L.*)

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ABSTRACT

The physical and mechanical characteristics of freshly harvested Roselle calyces were evaluated with the aid of literature and other standard procedures. The physical properties included the length, width, thickness, sphericity, geometric mean diameter, true density, bulk density, porosity, and color of Roselle calyces. The length, width, and thickness of the calyces were found to be in the ranges of 34.53 to 45.23 mm, 20.35 to 25.39 mm, and 2.01 to 5.54 mm and the values of sphericity and geometric mean diameter were found to be 11.22 to 18.66 mm and 0.32 to 0.41 as well as the bulk density, true density, and porosity of the hollow calyces were measured to be 128to140 kg/m^3, 455 to 476 kg/m^3, and 71.87 to 70.59 %, respectively. The color of Roselle calyces L*, a*, and b* were found 18.06 to 39.56, 11.66 to 28.72, and 8.25 to 16.44, respectively. The mechanical properties of roselle calyces were found to be the angle of repose and coefficient of static friction were found 44.45 to 55.26^0 and 0.98 to 1.44 respectively of the hollow Roselle calyces.
Keywords **:** Roselle calyces, physical properties, mechanical properties, Fresh calyces.

Introduction

Roselle (*Hibiscus sabdariffa* L.) belongs to the family Malvaceae, locally called “lal bondi”, is an important annual crop grown successfully in tropical and subtropical climates. The plant is particularly valued for its vibrant red calyces, which are used in various culinary and medicinal applications.

As part of the plant’s flower system, the calyx consists of the group of sepals which surround and protect the flower petals (Mezato Jimenez *et al*., 2008).

India, Indonesia, Sudan, Egypt, Mexico and Malaysia, are the countries where commercially cultivate Roselle. In India roselle is requiring well to drained, loamy soils with a pH of 5.5 to 6.8. It prefers a warm environment with temperatures ranging from 25°C to 30°C and needs adequate rainfall of about 140 to 270 mm per month during the growing season. The crop is typically sown in the rainy season, between May and June, or in the rabi season from February to March in regions that receive both monsoons. The plant is primarily cultivated for its calyces, which are rich in anthocyanins, vitamins, and minerals, making them valuable for both culinary and medicinal applications.

The production of Roselle involves specific agricultural practices that enhance its growth and yield. Successful cultivation requires understanding the ideal climatic conditions, soil types, and proper management techniques. As a cash crop, Roselle presents significant opportunities for farmers, particularly in regions where it can be integrated into existing agricultural systems.

Beyond production, the transformation of Roselle into value to added products plays a crucial role in maximizing its economic potential. These products range from beverages, jams, and jellies to herbal teas and dietary supplements. The processing methods not only enhance the shelf life of roselle but also expand

its market reach, catering to health to conscious consumers worldwide.

Therefore, the aim of this study is to determine physical and mechanical properties of fresh roselle calyces grown in Maharashtra.

Material and Methods

Roselle calyces were obtained from the Department of Watershed, Dr. PDKV, Akola, Maharashtra, India.

Plate 1 : Free Roselle Calyces

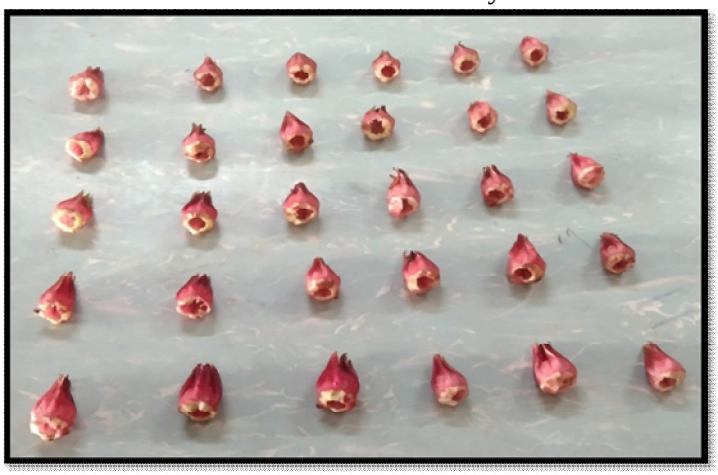

Plate 2 : Hollow Roselle Calyces

Fig. 3 : Whole roselles

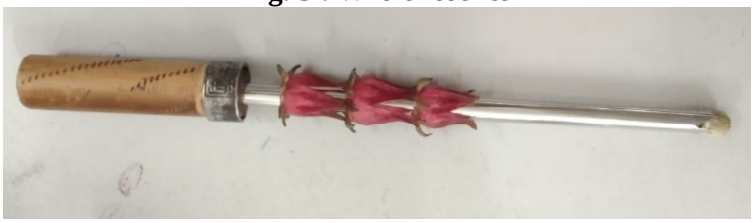

Plate 4 : The tool fabricates to detached seed from whole roselles

Moisture content determination

The moisture content of the free calyces, hollow calyces and whole roselles were determined following the method commonly used for medicinal and herbal plants (Soysal and Oztekin, 2001; Park *et al*., 2002). In this procedure, samples were first weighed and then dried in a oven at 105°C for 24 hours. After drying, they were cooled and reweighed to calculate the amount of water lost. The moisture content (on a wet basis) was expressed as the ratio of the weight of water removed to the initial weight of the fresh calyxes. All measurements were carried out in triplicate to ensure accuracy.

Measurement of Length, Width and Thickness

Thirty roselle hollow calyces which separated by fabricated hand tool (plate 4) were randomly selected roselle flower. The three principal dimensions of the free calyces, hollow calyces and whole roselles namely the length, width and thickness were measured with a vernier calliper.

Determination of Geometric Mean Diameter

The geometric mean diameter (D_g) of the whole roselles and free and hollow calyces were evaluated using the relationship given by Mohsenin (1978).

$$D_g = LWT^{1/3}$$

Determination of Sphericity

The sphericity was determined with the equation as follows by Mohsenin (1986).

$$\emptyset = \frac{Dg}{L} = \frac{LWT^{1/3}}{L}$$

Determination of Volume and True Density

Volume (V) and true density (ρ_t), was obtained by liquid displacement method using toluene as liquid (Mohsenin, 1986), of whole roselles, free and hollow roselle calyces was determined, measuring cylinder (1000±10ml) was taken and the 50 g mass of calyces was obtained using an electric weighing balance then filled the cylinder about 500ml and the 50 g of whole, free and hollow calyces added in it one by one for five times of each and the displaced volume was noted.

The formula for true density as follows:

$$True\ Density = \frac{Weight\ of\ calyces\ (g)}{Displacement\ in\ Volume\ (m^3)}$$

Bulk Density Determination

To determine bulk density of free calyces, hollow calyces and whole roselles, an empty container of known volume was loosely filled from a height of 15cm. The mass of the container and its contents were then determined using an electronic balance. The bulk density was calculated as ratio of mass of object to

volume of the container. This procedure was repeated five times (Mohsenin, 1986).

Determination of Porosity

The porosity was determined using the following equation Bagherpour *et al*., 2010; Emadi and Saiedirad, 2011; Kibar *et al*., 2014.

$$Porosity = 1 - \frac{Bulk\ Density}{True\ Density}$$

Colour

The colour of calyces was measured by using a chromameter. A Colorimeter or Chroma Meter is an instrument used to measure the colour of an object, a widely accepted standard in scientific research for describing color. This system quantifies color using three parameters: L*, which represents lightness on a scale from 0 (black) to 100 (white); a*, which indicates the position between green (negative values) and red (positive values); and b*, which measures the position between blue (negative values) and yellow (positive values) (McGuire, 1992). These parameters were obtained using a colorimeter/spectrophotometer, providing objective and reproducible color data for the Free, Hollow, and Whole roselles analysed in the study. calyces have characteristic intense red colouration due to the presence of anthocyanins. which could be utilised as colouring agent in pharmaceutical products and food products.

Determination of Mechanical Properties

Some of the mechanical properties, coefficient of static Friction on different surfaces as well as angle of repose of the free calyces, hollow calyces and whole roselles were determined.

Coefficient of static friction

The coefficient of static friction of the free calyces, hollow calyces and whole roselles were measured on three surfaces which included Ss sheet, Ms sheet and wood sheet using an inclined plane apparatus (Mohsenin, 1986). The table with calyx sample was slowly raised and the angle of inclination to the horizontal at which the sample slides was noted by the protractor attached to the system. The quotient of the angle read is taken as friction coefficient.

Angle of Repose

To determine the angle of repose for a heap of roselle calyces, a standardized procedure was followed. A smooth, flat surface was prepared to allow the free formation of a conical heap of calyces. The roselle calyces were poured from a fixed height using a funnel to form the heap. Once the material had settled and the heap achieved stability, the height (h) of the pile from the base to the apex and the radius (r) of the base were measured (Raghavan, G. S. V., & Raji, A., 2007). The angle of repose was then calculated using the formula:

Angle of Repose = $\tan^{to(\theta)}$

$$\theta = \frac{h(Height\ of\ heap)}{r(Radius\ of\ heap)}$$

Results and Discussion

Physical properties

The results of certain physical properties, which were found for free calyces, hollow calyces and whole roselles used in this study, were presented in Table 4. The moisture content of free calyces, hollow calyces and whole roselles were in the range 86.89 to 87.06 %, 85.73 to 87.13% and 79.35 to 83.46% respectively. Dimensions of the length, width and thickness of free calyces, hollow calyces and whole roselles were in the range of 25.38 to 40.57 mm, 33.56 to 45.23 mm and 34.66 to 53.74 mm (Length), 8.58 to 13.85 mm, 20.35 to 25.39 mm and 19.96 to 30.23 mm (Width) & 1.04 to 2.14 mm, 2.01 to 5.54 mm and 17.01 to 28.39 mm (Thickness) respectively, while the geometric mean diameter and sphericity values of free calyces, hollow calyces and whole roselles in the ranges 7.15 to 10.07 mm, 11.48 to 18.50 mm, and 23.56 to 31.81 mm & 0.20 to 0.31, 0.31 to 0.45 and 0.56 to 0.77 respectively.

Table 1 : The Average of Physical and Mechanical properties of Hollow calyces

Sr. No.	Physical properties hollow roselle calyces	
1	Moisture Content (%)	86.46±0.62
2	Length(mm)	37.52±3.11
3	Width (mm)	22.55±1.53
4	Thickness (mm)	3.05±0.86
5	Sphericity	0.36±0.033
6	Geometric Mean Diameter (mm)	13.72±1.65
7	Bulk Desnsity (kg/cm^3)	134.4±6.07
8	True Density (kg/cm^3)	459.8±16.51

9	Porosity (%)	71±1.67		
10	Color	**a***	**L***	**b***
		17.58±2.16	30.25±4.35	10.96±1.46
11	Angle of repose(^{o})	48.75±3.5		
12	Coefficient of static friction	1.14±0.15		
13	Cutting Force	28.89±8.03		

Table 2 : The Average of Physical and Mechanical properties of free calyces

Sr. No.	**Physical properties free roselle calyces**			
1	Moisture Content (%)	86.97±0.11		
2	Length(mm)	32.77±3.84		
3	Width (mm)	11.25±1.28		
4	Thickness (mm)	1.66±0.29		
5	Sphericity	0.26±0.03		
6	Geometric Mean Diameter (mm)	8.43±0.64		
7	Bulk Desnsity (kg/cm^3)	186.4±7.27		
8	True Density (kg/cm^3)	868.8±88.53		
9	Porosity (%)	79±2.86		
10	Color	**a***	**L***	**b***
		22.77±2.61	32.90±4.95	12.12±2.17
11	Angle of repose (^{o})	32.25±3.71		
12	Coefficient of static friction	0.63±0.09		
13	Cutting force	15.89±5.66		

Table 3 : The Average of Physical and Mechanical properties of whole roselles

Sr. No.	**Physical properties whole roselles calyces**			
1	Moisture Content (%)	81.86±1.89		
2	Length(mm)	44.52±4.69		
3	Width (mm)	23.54±2.42		
4	Thickness (mm)	19.89±2.02		
5	Sphericity	0.62±0.04		
6	Geometric Mean Diameter (mm)	27.45±1.92		
7	Bulk Desnsity (kg/cm^3)	268±8.48		
8	True Density (kg/cm^3)	489.6±38.72		
9	Porosity (%)	45±2.86		
10	Color	**a***	**L***	**b***
		19.32±4.84	29.28±4.75	10.99±2.68
11	Angle of repose(^{o})	47.62±3.54		
12	Coefficient of static friction	1.1±0.14		
13	Cutting force	68.98±9.99		

Table 4 : The Average of Physical and Mechanical properties of free calyces, hollow calyces, whole roselles

Sr. No.		**Free Calyces**	**Hollow Calyces**	**Whole roselles**
1	Moisture Content (%)	86.97±0.11	86.46±0.62	81.86±1.89
2	Length(mm)	32.77±3.84	37.52±3.11	44.52±4.69
3	Width (mm)	11.25±1.28	22.55±1.53	23.54±2.42
4	Thickness (mm)	1.66±0.29	3.05±0.86	19.89±2.02
5	Sphericity	0.26±0.03	0.36±0.033	0.62±0.04
6	Geometric Mean Diameter (mm)	8.43±0.64	13.72±1.65	27.45±1.92
7	Bulk Density (kg/cm^3)	186.4±7.27	134.4±6.07	268±8.48
8	True Density (kg/cm^3)	868.8±88.53	459.8±16.51	489.6±38.72
9	Porosity (%)	79±2.86	71±1.67	45±2.86

10	Color, **L***	32.90±4.95	30.25±4.35	29.28±4.75
	a*	22.77±2.61	17.58±2.16	19.32±4.84
	b*	12.12±2.17	10.96±1.46	10.99±2.68
11	Angle of repose(°)	32.25±3.71	48.75±3.5	47.62±3.54
12	Coefficient of static friction	0.63±0.09	1.14±0.15	1.1±0.14
13	Cutting force	15.89±5.66	28.89±8.03	68.98±9.99

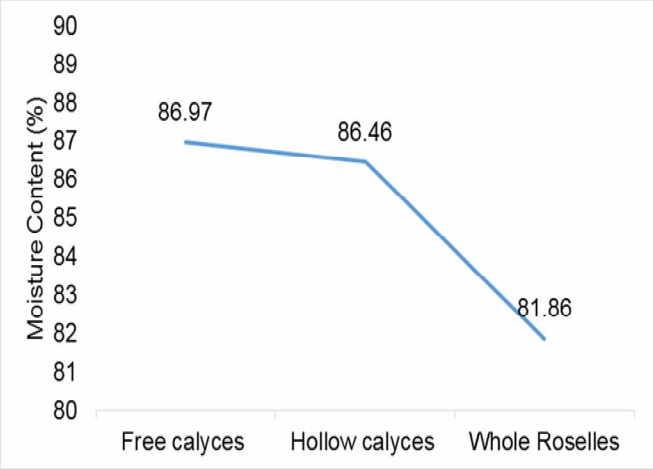

Fig. 1 : Average moisture content of free calyces, hollow calyces & whole roselles

The bulk density, true density, and porosity of Free calyces, hollow calyces and whole roselles were evaluated, and the results are summarized in Table 4. The bulk density of the free, hollow and whole roselles ranged from 180 to 196 kg/m³, 128 to 140 kg/m³ and 260 to 280 kg/m³ respectively. This variation is attributed to differences in structural compactness and how the calyces settle during bulk handling.

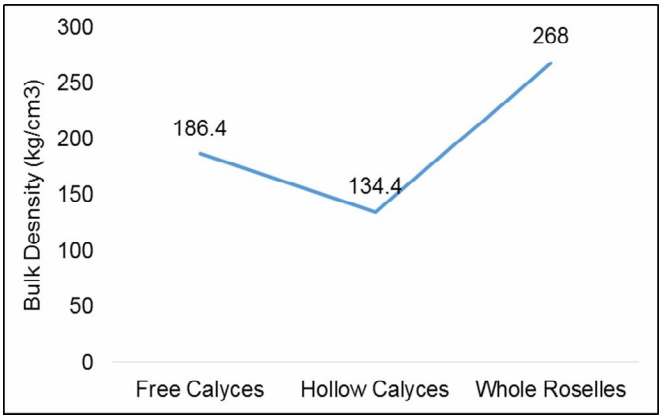

Fig. 2 : Average bulk density of free calyces, hollow calyces & whole roselles

The true density of the free calyces, hollow calyces and whole roselles were ranged from 769 to 1000 kg/m³, 437 to 776 kg/m³ and 476 to 556 kg/m³ respectively, likely due to the presence of internal voids or hollowness.

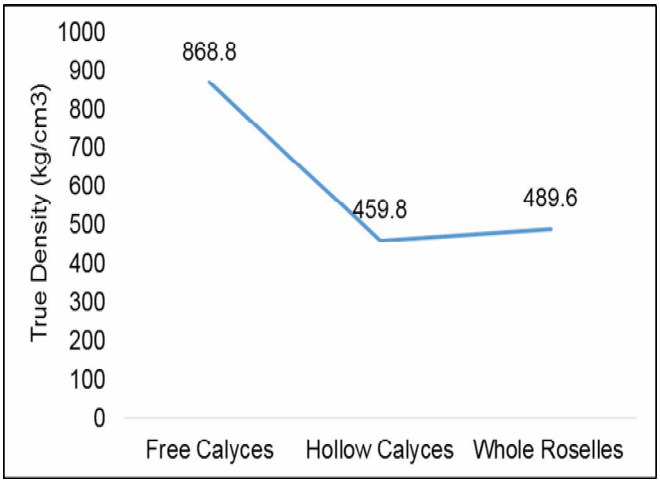

Fig. 3 : Average true density of free calyces, hollow calyces & whole roselles

Porosity of the free calyces, hollow calyces and whole roselles were calculated based on bulk and true densities, ranged from 75 to 80 %, 69 to 73% and 43 to 50% respectively. A higher porosity suggests a greater amount of air space within the bulk material, which can significantly affect processing operations like drying and packaging.

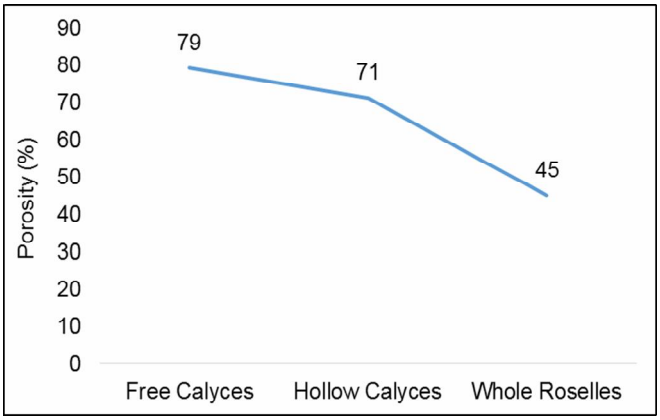

Fig. 4 : Average porosity of free calyces, hollow calyces & whole roselles

The color parameters of free calyces, hollow calyces and whole roselles were determined using the chromameter and are presented in Table 1. The L* values ranged from 18.06 to 39.56. The a* values were positive across all calyx types, ranging from11.66 to 28.72, which confirms the red coloration typical of Roselle calyces. b* values ranged from 8.25 to 16.44, showing a slight shift toward the yellow region of the

spectrum. Variations in L*, a*, and b* values among the calyx types can be attributed to differences in pigmentation concentration and surface structure. These color attributes are important for consumer appeal, quality grading, and processing applications such as natural dye extraction.

Mechanical Properties

The mechanical properties of free calyces, hollow calyces and whole roselles were evaluated in terms of angle of repose and coefficient of static friction to assess their flow behaviour and handling characteristics.

The angle of repose represents the maximum angle at which a material can be piled without sliding and is a key indicator of flowability. In this study, the angle of repose free calyces, hollow calyces and whole roselles were ranged 26.70 to 36.32°,44.45 to 55.26° and 42.05 to 53.59° respectively.

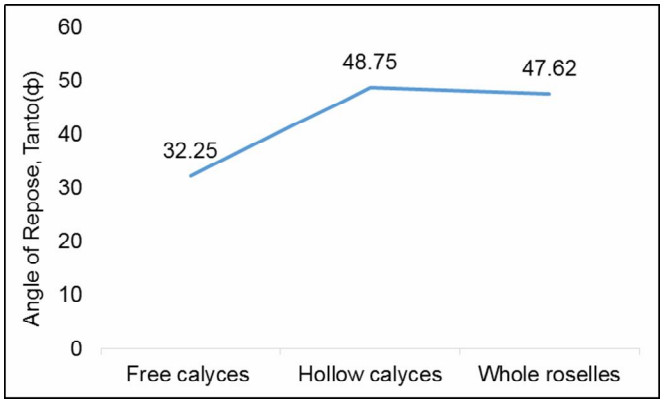

Fig. 5 : Average angle of repose of free calyces, hollow calyces & whole roselles

The coefficient of static friction free calyces, hollow calyces and whole roselles were measured on surfaces such as SS sheet, Ms sheet and plywood, and values ranged from 0.50 to 074, 0.98 to 1.44 and 0.90 to 1.35 respectively. These values reflect the resistance to movement between the calyces and the contact surface.

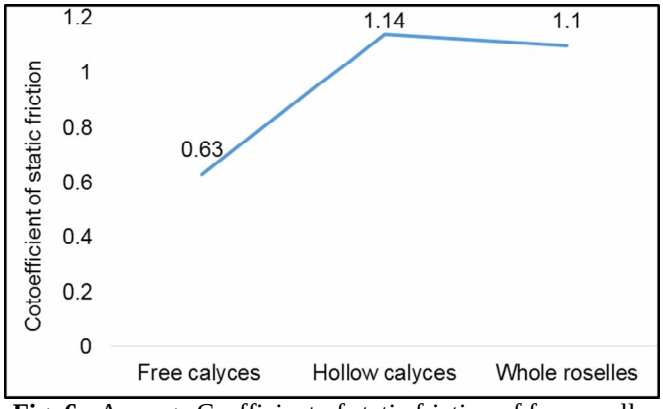

Fig. 6 : Average Coefficient of static friction of free roselle calyces hollow calyces & whole roselles

The cutting force of free calyces, hollow calyces and whole roselles were determined by texture analyser and values ranged from 8.28 to 22.18, 19.25 to 40.62 and 79.68 to 54.82 respectively.

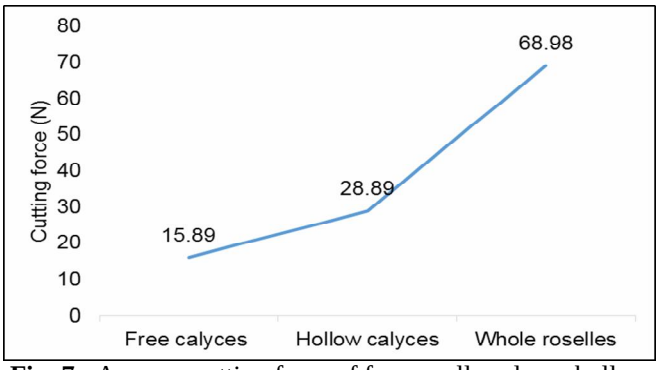

Fig. 7 : Average cutting force of free roselle calyces hollow calyces & whole roselles

Conclusion

This study investigated the physical and mechanical properties of free calyces, hollow calyces and whole roselles, providing valuable insights into their handling, processing, and potential applications. The dimensions of the calyces including length, width, and thickness varied slightly among the different types, indicating differences in size and shape. The geometric mean diameter and sphericity further highlighted the structural diversity of the calyces.

The moisture content in free calyces is slightly higher than hollow calyces, whole roselles had least percentage of moisture content as compared to free and hollow calyces. The bulk density, true density, and porosity showed notable differences among the calyx types. Whole roselles exhibited higher bulk density, while Free calyces had the highest true density. The porosity values reflected the internal structure of the calyces, with free calyces having the highest porosity, which could influence drying and storage behaviour.

Color analysis confirmed the characteristic red coloration of Roselle calyces, with slight variations in lightness, red hue, and yellow undertones among the calyx types. These color attributes are important for quality grading and could be useful for applications such as natural dye extraction.

In terms of mechanical properties, the angle of repose, which indicates flowability, showed variability among the different calyx types. Free calyces exhibited better flowability, while Hollow and Whole roselles had higher angles of repose, suggesting more resistance to flow. The coefficient of static friction, which measures resistance to movement, was highest for hollow roselle, indicating they would be more resistant to sliding during handling and transport, especially on certain surfaces. The cutting force

directly influences the power requirement and strength of the separating mechanism. Whole roselles require higher cutting force due to intact seed capsules while hollow calyces require comparatively less force and free calyces require minimal force.

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