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Some Physico-Chemical Properties of Sweet Orange Fruit and Juice with Relevance to Membrane Processing

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ABSTRACT

Physico-chemical properties of sweet orange fruits as well as juice need to be known to predict certain parameters required for membrane processing, design membrane filtration equipment and predicting performance. Sweet oranges fruits were graded based on weight in three grades. Engineering properties such as physical dimensions, fruit mass, sphericity, surface area, juice content, colour, viscosity, total soluble solids were found to significantly differ at 5% level among three grades. Juice density and clarity were non-significant. The mean juice content obtained for grade II fruits was more (43.66%) in comparison with other grades. Polynomial model was identified as the best between fruit weight and juice content for grade I and grade III fruits. Quadratic modelwas best between total soluble solids (TSS) and viscosity of juice (R^2 =0.894).

Keywords : *Absorbance, Clarity, Colour, Membrane processing, Total soluble solids, Transmittance, turbidity, Viscosity.*

Sweet oranges are juice-laden notable for their fragrance, vitamin C content (Puri *et al*., 2008; Kumar *et al*., 2012). Sweet oranges can be kept for more than a week without any quality deterioration but they lose their marketable appearance if stored at ordinary conditions leading to low remunerative prices. The magnitude of post-harvest losses of citrus fruits in India is estimated to be 25-30% as against 5-10% in developed citrus growing countries (Sonkar *et al*., 2008). About 95% of the fruit is essentially sold as fresh for juice purpose, and as only few processing facilities exist in the country. This reflects absence of adequate post-harvest technologies at commercial scale required for processing and preserving fresh quality. However, there is an increasing growing demand from the consumers regarding the use of fruits in the form of concentrated juice, dry powder, jam and jelly. In recent years, there is an increasing growing demand from the consumers to use of sweet oranges in the form of clarified or concentrated juices. As an alternative for thermal processing, membrane processing has gained a lot of importance in recent years. However, membrane processing has been used for clarifying/fractionating and/or purifying fruit juices and concentrating and for enhancing process efficiency and profitability. Certain physico-chemical properties of sweet orange fruits as well as juice need to be known to predict certain parameters required for processing and predicting performance and to design membrane filtration equipment. An appropriate design of operating units is essential for optimum processing, to prevent facilities becoming over-dimensioned and to subsequently reduce or prevent the wasteful use of economic resources. Hence, the present work was undertaken to study certain physico-chemical properties that have relevance for membrane processing of sweet orange juice either for clarification or for concentration.

MATERIAL AND METHODS

Freshly harvested sweet orange fruits (Variety: *Sathgudi*) used for the study were obtained from local market. The good healthy and matured fruits harvested a day before were selected for the study. The fruits were cleaned with water to remove all dirt adhering to it and then shade dried at room temperature to remove adhered moisture. For determining juice properties, various preparatory activities included cutting, juice extraction using press type hand operated sweet orange juice extractor (Make: Basant), pre-filtration using muslin cloth, addition of sodium benzoate @ 0.1% as a preservative (Shahnawaz *et al*., 2013) were carried out.

Sweet orange fruits (*Citrus sinensis*) were purchased and graded according to weight of the fruit as : grade I (large), grade II (medium) and grade III (small) depending upon weight of each fruit (Sharifi *et al.,* 2007; Avhad and Turkane, 2013). From the whole lot, about 150 fruits were randomly selected and graded based on size and weight (< 150 g as grade III; 150 – 275 g as grade II and > 275 g as grade I). Engineering properties such as physical dimensions, fruit mass, sphericity, surface area, juice content, turbidity, viscosity, total soluble solids were determined and procedure followed has been detailed below:

Principle axial dimensions

Three axial dimensions namely as length, width and thickness were measured using a digital calipers (plate 1) with sensitivity of 0.01 mm (Plate 3.2). Dimension 'A' is the main (length) diameter, '*B'*(width) is the longest dimension perpendicular to '*A'* and '*C'* (thickness) is the longest dimension perpendicular to 'A' and '*B'* (Kheiralipour *et al*., 2008).

Plate 1. Measurement of linear dimensions using digital calipers

Mean Geometrical Diameter

Mean geometrical diameter was calculated using equation 1 (Mohsenin, 1986)

$$GM = \sqrt[3]{ABC} \qquad \dots (1)$$

Where, GM = Mean geometrical diameter,

A = Length, mm,

B = Width, mm,

C = Thickness, mm

Sphericity

Sphericity is the ratio of volume of solid to the volume of circumscribed sphere that has a diameter equal to the longest diameter of the solid so that it can circumscribe the solid sample (Mohsenin, 1986). Sphericity was obtained from equation 2 (Sharifi *et al.,* 2007).

$$S_{ph} = GM/\text{ major axial dimension (A)} \qquad \dots (2)$$

Surface Area

The Surface area (S) was calculated using the equation 3 as given below (Sharifi *et al.,* 2007).

$$S = ð \times (GM)^2 \qquad \dots (3)$$

Weight of Fruit

Fruit weight (M) was measured using a digital balance with accuracy of ± 1 g.

Juice Content

Juice content was expressed as :

$$\text{Juice yield (\%, w/w)} = \frac{\text{Weight of the juice}}{\text{Weight of the fruit}} \times 100 \qquad \dots (4)$$

Total Soluble Solids (TSS)

Total soluble solids of the extracted juice was determined using Hand Held pocket Refractometer (Make : Atago, Model : PAL-1, Range :0-53° Brix), Accuracy : ±0.2° Brix, with automatic temperature compensation).The extracted juice samples were brought to ambient temperature. The prisms of the refractometer before each reading was cleaned with distilled water and soft tissue. Aliquot of sample (~3 drops i.e., 0.3 ml) was applied to the refractometer prism, avoiding bubbles and large pulp particles. START button was pressed to read the total soluble solids reading.

Viscosity

Viscosity of the fruit juice was determined by using Digital Viscometer (Make: Brookefield, Model:DV1MLV). Classical Brookfield viscometers employ the principle of rotational viscometry - the torque required to turn an object, such as a spindle, in a fluid indicates the viscosity of the fluid. Torque is applied through a calibrated bob spindle immersed in test fluid and the spring deflection measures the viscous drag of the fluid against the spindle. The amount of viscous drag is proportional to the amount of torque required to rotate the spindle and thus to the viscosity of a Newtonian fluid. The sweet orange juice whose viscosity to be measured was placed in 600 mL griffin beaker. Initially, viscometer was levelled. The guard leg was attached and standard LV 61 spindle was attached to the spindle lower shaft in the groove provided. After motor of the viscometer was switched on, spindle number was entered. The beaker was placed so that spindle was at the centre of the beaker. The reading of viscosity was recorded. The spindle and guard leg were removed before cleaning. The spindles and guard leg after each use were cleaned thoroughly. Successful test methods will deliver a % torque reading between 10 and 100 and viscosity in centi poise (cp) or mPas.

pH

The pH measurement was performed using a digital pH meter (Make: Eco Tester pH1). The device having the glass electrode was placed inside the homogenized sample of sweet orange juice and the value was registered once it had stabilized.

Clarity (%)

The clarity of the feed / permeate solution was measured by using UV-Vis Spectrophotometer (Make: Rayleigh) and as per procedure given by Amador (2011). The spectrophotometer was adjusted to 100% light transmission at 650 nm against distilled water in a cuvet or test tube cuvet. Test tube cuvet was decanted and filled with juice sample to be measured. Per cent light transmission of the juice sample was measured and observations were noted down.

Colour

The colour of the feed / permeate solution was measured by using UV-Vis Spectrophotometer (Make: Rayleigh) and as per procedure given by Amador (2011) and Rai *et al*., (2010). The spectrophotometer was adjusted to 0% light absorbance at 420 nm against distilled water in a cuvet or test tube cuvet. Test tube cuvet was decanted and filled with juice sample to be measured. Per cent light transmission of the juice sample was measured and observations were noted down.

Juice density

Juice density was calculated by dividing weight of juice (g) with the volume of juice (mL).

RESULTS AND DISCUSSION

Different physico-chemical properties of three grades of sweet orange samples were studied and presented in Table 1. The mean major axial dimensions (dimension A) with standard deviation of the grade I (large), II (medium) and III (small) sweet oranges were measured to be 100.21±15.84, 74.42±11.51, and 60.43±4.81 mm, respectively; mean width values (dimension B) were measured to be 95.91±15.66, 72.22±10.22 and 59.25±4.61 mm, respectively and mean thickness values (dimension C) were measured to be 90.98±16.58, 67.00±9.70 and 54.87±4.17 mm, respectively. It was observed that the linear dimensions of grade I fruits were more when compared to the grade II and grade III fruits. Mean geometrical mean diameters were determined to be 91.33±15.08, 68.15±9.77 and 55.77±3.88 mm, respectively for grade I, grade II and grade III fruits.

Mean values for individual fruit weight of grade I, grade II and grade III sweet oranges were reported to be 297.63±16.88, 190.78±48.43 and 103.65±20.70 g, respectively. Standard deviation of fruit weight for grade II fruits was more in comparison to grade I and grade II fruits indicating that range of variation in fruit weights were more in grade II fruits. Geometrical mean diameters of three grades of fruits were estimated to be 77.32±4.75, 67.05±8.50 and 55.77±3.88 mm, respectively for grade I, grade II and grade III sweet oranges. Sphericity of grade I, grade II and grade III sweet oranges were estimated be 0.93±0.03, 0.93±0.02 and 0.92±0.02 respectively indicating that mean sphericity values were almost similar for three grades of fruits. The values of sphericity were in agreement with sphericity of oranges of grade I, grade II and grade III viz., 0.948, 0.931 and 0.923, respectively as reported by Sharifi *et al*. (2007).

Juice content expressed in per cent (% w/w) basis for grade I, grade II and grade III fruits were determined to be 36.04±3.51, 43.66±2.88 and 34.04±3.46%, respectively. It was observed that the juice content (%) obtained for grade II fruits were more. In case of grade I fruits (> 275 g of fruit weight), increase in fruit weight had been mainly due to increased rind, albedo and flavedo thickness increasing overall fruit weight and not appreciable increase in the juice yield. The reported juice content was in agreement with the average juice content of sweet orange (37.95%) as estimated by Syed *et al*. (2012).

Average total soluble solids (TSS) of grade I, grade II and grade III sweet oranges were estimated as 9.12±0.42, 9.11±0.33 and 8.72±0.28° Brix, respectively. TSS among three grades of sweet orange juices were significant at 5% level. Average pH of grade I, II and III oranges was 4.13±0.32, 4.07±0.03 and 3.92±0.23 respectively. Average pH was found to vary significantly at 5% among different grades of sweet orange juice. Average juice density was estimated for grade I, grade II and grade III sweet oranges juice to be 1.01 ±0.01. Statistical analysis showed that juice density among three different grades of sweet orange fruit juices were non- significant at 5% level.

Average values of clarity expressed in terms of per cent transmission at 650 nm was recorded as 2.96±0.38, 3.15±0.70, 3.16±0.16 %, respectively showing that fresh juice was non–clear and was not allowing light to pass through the juice due to haziness. Clarity of the three grades of juice was found to be non significant at 5% level. Similar results on clarity of mosambi juice were reported by Rai *et al*. (2006)

Similarly, colour expressed as per cent absorbance at 420 nm. Average per cent of absorbance values (colour) of the sweet orange juice for different grades were recorded as 2.01±0.23, 1.90±0.20, 1.95±0.18%, respectively. Colour of sweet orange juice of the three grades of fruit was found to be significant at 5% level. Similar results on colour of mosambi juice were reported by Rai *et al*. (2006)

Further, statistical variance analysis was performed with respect to various attributes of physical, chemical properties of three grades of sweet orange fruits and juice and presented in Table 2. Results indicated that properties such as major principal axial dimension (A), intermediate dimension (B), minor axial dimension (C), geometrical mean diameter (GM), fruit mass, juice content, TSS of the juice, colour, pH of the juice exhibited significantly among three grades at 5% level of significance. Reasons for most of the properties significantly differing among three grades of fruits were attributed mainly due to varying sizes of fruit which depends mainly on fruit mass and its associated properties such as principal major, intermediate and minor dimensions, geometrical mean diameter, juice content, pH and total soluble solids of juice.

Properties such as juice density, clarity measured at 650 nm and turbidity among three grades of the fruit were non-significant at 5% level of significance. Clarity and turbidity of three grades of sweet orange juice were non-significant as haze developed due to juice sacs and other pectin substances that were pulped during juice extraction.

The results and observations were comparable with the results reported by Joshi and Awate (2016); Dineshkumar and Siddharth (2015); Abdollah (2013); Sharifi *et al*. (2007); Flood *et al*. (2006) for physical properties of orange fruit and Ikegwu and Ekwu (2009); Moresi and Spinosi (1980) for juice density, TSS of orange juice. The methods used by the above authors were also comparable with the methods adopted in the present study.

Table 1: Average physical characteristics of graded sweet oranges

Property	Min/Max/ Mean	Grade I (No of samples- 38 No)	Grade II (No. of samples- 53 No)	Grade III (No. of samples - 59 No)
A (mm)	Min	83	55.17	53.2
	Max	128.67	98.63	73.33
	Mean	100.21±15.84	74.42±11.51	60.43±4.81
	Variance	250.88	132.55	23.1
B (mm)	Min	77.2	54.97	52.25
	Max	126.12	95.19	70.2
	Mean	95.91±15.66	72.22±10.22	59.25±4.61
	Variance	250.88	104.46	21.22
C (mm)	Min	73.8	54	48.07
	Max	123.55	87.55	67.3
	Mean	90.98±16.58	67.0±9.70	54.87±4.17
	Variance	274.85	94.12	17.39
Geometric mean diameter (mm)	Min	75.96	52.36	49.55
	Max	120.14	88.31	65.78
	Mean	91.33±15.08	68.15±9.77	55.77±3.88
	Variance	227.35	95.37	15.05
Sphericity	Min	0.88	0.88	0.85
	Max	0.98	0.98	0.97
	Mean	0.93±0.03	0.93±0.02	0.92±0.02
	Variance	0	0	0
Surface area (mm^2)	Min	18132.75	8684.23	7716.67
	Max	45366.27	24510.21	13599.16
	Mean	26910.73± 9178.16	14892.39± 3771.76	9820.99± 1397.04
	Variance	84238610	19584414.38	1951710.31
Weight (g)	Min	276	150	73.55
	Max	327.22	275	150
	Mean	297.63±16.88	189.65±46.52	103.65±20.70
	Variance	284.87	2163.74	428.43
Juice content (%) (w/w)	Min	30.76	34.26	31.525
	Max	41.86	46.92	45.05
	Mean	36.04±3.51	43.66±2.88	34.04±3.46
	Variance	12.34	8.28	11.95

Table 1. cont....

Total soluble solids (^{o} Brix)	Min	8.60	8.70	7.90
	Max	10.20	10.10	9.50
	Mean	9.12±0.42	9.11±0.33	8.72±0.28
	Variance	0.18	0.11	0.08
pH	Min	3.70	3.60	3.50
	Max	5.00	4.80	4.70
	Mean	4.13±0.32	4.07±0.33	3.92±0.23
	Variance	0.10	0.11	0.05
Juice density (g/cc)	Min	1.01	1.01	1.01
	Max	1.07	1.05	1.05
	Mean	1.03±0.01	1.03±0.01	1.03±0.01
	Variance	0.00	0.00	0.00
Clarity T @650 nm (%)	Min	2.35	2.10	2.14
	Max	4.05	5.10	5.10
	Mean	2.96±0.38	3.15±0.70	3.16±0.16
	Variance	0.14	0.49	0.44
Colour or Absorbance A @ 420 nm (%)	Min	1.58	1.54	1.67
	Max	2.64	2.55	2.43
	Mean	2.01±0.23	1.90±0.20	1.95±0.18
	Variance	0.05	0.04	0.03

Establishment of correlation between fruit and juice on certain parameters

An attempt had been made to establish correlation between fruit weight versus juice content (%) as fruit weight was easy to measure and was taken as independent variable and regression equations were developed for estimation of juice content (%).

Correlation between juice content and fruit weight

A regression analysis was performed to establish relation between fruit weight versus juice content among three grades of sweet orange fruits and were presented in the Figure 1 for grade I, grade II and grade III fruits, respectively.

Polynomial curve fitted best for correlation between fruit weight (g) and juice content (%) for grade I fruits with coefficient of determination (R^2) value of 0.855 (correlation coefficient of r^2 of -0.864) (Table 3). Similarly for grade III fruits also polynomial curve fitted best with coefficient of determination (R^2) of 0.853 and coefficient of correlation (r^2) of 0.838. However, for grade II fruits, correlation between fruit weight and juice content was not established as coefficient of determination (R^2) with a low value of 0.451 (r^2 =0.263). A poor fit of experimental data in case of grade II fruits yielding low value of coefficient of determination (R^2) might be attributed due to the fact that the distribution of fruits of were more concentrated in the weight ranges from 150-200 g (67.92%)and 235-275 g (28.30%).

Effect of TSS of the juice on viscosity

An attempt was made to establish correlation between viscosity and TSS of sweet orange juice. Viscosity measurements were not carried out basing on individual fruits as minimum quantity of juice required was 100 ml. Two sweet orange fruits were cut and juice was squeezed and thoroughly mixed so as to make volume more than 100 ml. Total soluble solids and viscosity of the mixed juice were determined and results were presented in the Table 4.

Results showed that mean value of 25 mixed juice samples recorded total soluble solids was 8.608±0.768^o Brix with minimum and maximum value ranging from 7.2–9.5^o Brix. Similarly mean viscosity values of squeezed and mixed juice was ranged between 3.70-6.00 mPas with a mean value of 4.608±0.606 mPas.

A regression analysis was performed to establish relation between total soluble solids (TSS) versus viscosity of sweet orange juice and was presented in the Figure 2. Quadratic curve fitted best for correlation between total soluble solids (TSS) versus viscosity of sweet orange juice with coefficient of determination (R^2) value of 0.894. Similar finding on correlation and quadratic model fit between viscosity

Table 2: Analysis of variance of attributes related to different grades of sweet oranges

Parameter	Source	Sum of squares	Mean sum of squares	F_{stat}	Remarks
Major principal axial dimension (A), mm	Between the grades	36039.94	18019.97	152.39	Significant @ 5% level
	Error	17263.59	118.24		
	Total	53303.54			
Intermediate dimension (B), mm	Between the grades	30673.46	15336.73	145.10	Significant @ 5% level
	Error	15431.55	105.69		
	Total	46105.01			
Minor axial dimension (C), mm	Between the grades	29799.51	14899.76	136.99	Significant @ 5% level
	Error	15878.76	108.75		
	Total	45678.27			
Geometrical mean diameter (GM)	Between the grades	28817.31	14408.65	150.07	Significant @ 5% level
	Error	14017.35	96.01		
	Total	42834.65			
Fruit weight (g)	Between the grades	860798.2	430399.1	400.05	Significant @ 5% level
	Error	157072.3	1075.83		
	Total	1017871			
Juice content (%)	Between the grades	2765.797	1382.89	128.77	Significant @ 5% level
	Error	1567.891	10.73		
	Total	4333.688			
Total Soluble Solids (TSS, ^{o}Brix)	Between the grades	5.878	2.9394	25.55	Significant @ 5% level
	Error	16.793	0.11		
	Total	22.672			
Juice density (kg/m^3)	Between the grades	0.000574	0.000287	2.05	Non Significant @ 5% level
	Error	0.020372	0.00014		
	Total	0.020946			
Clarity (% T_{650})	Between the grades	1.064566	0.532283	1.38	Non Significant @ 5% level
	Error	56.14628	0.384564		
	Total	57.21085			
Colour (%A_{420})	Between the grades	0.26834	0.13417	3.23	Significant @ 5% level
	Error	6.058108	0.041494		
	Total	6.326447			
pH	Between the grades	1.233	0.616	7.09	Significant @ 5% level
	Error	12.685	0.086		
	Total	13.918			

F_{tab} = 3.058

Table 3: Regression equations for correlation

Grade	Regression equation	Coefficient of determination (R^2)	Correlation coefficient (r^2)
Grade I	$-2x10^{-5}x^4 + 0.025x^3 - 11.35x^2 + 2282x - 17174$	0.855	-0.864
Grade II	$-5x10^{-7}x^4 + 0.0004x^3 - 0.131x^2 + 18.69x - 941.6$	0.451	0.263
Grade III	$0.003x^2 - 0.598x + 58.99$	0.853	0.853

Table 4: Analysis of total soluble solids (TSS) and viscosity of sweet orange juice

Property	No of samples	Min	Max	Mean	Standard Deviation	Variance
TSS (%Brix)	25	7.2	10.7	8.608	0.768	0.59
Viscosity (mPas)	25	3.7	6.0	4.608	0.606	0.368

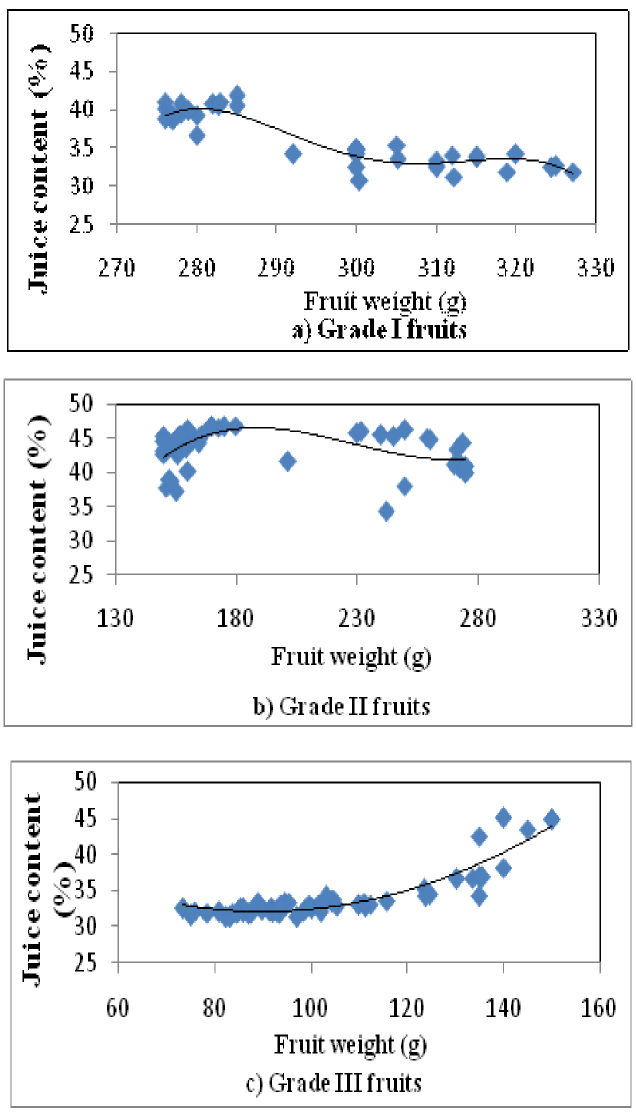

Figure 1. Correlation between juice content (%) and weight of sweet orange fruits, a) grade I, b) grade II and c) grade III

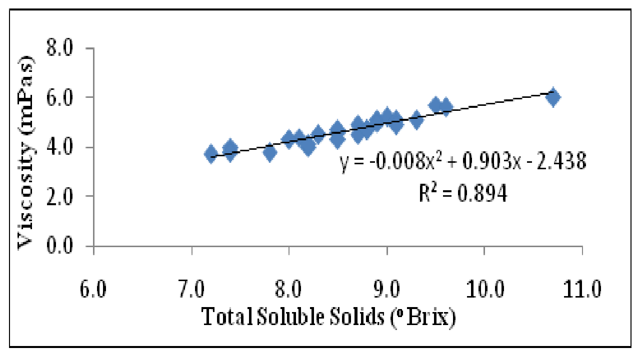

Fig 2. Correlation between viscosity and total soluble solids of sweet orange juice

and concentration of bitter orange juice was reported by Bodzogan (2015).

CONCLUSION

The following conclusions were drawn from the above study :

i) The properties such as principal axial dimensions (A, B and C), geometrical mean diameter, spherecity, surface area, juice content, total soluble solids, pH, and colour(%A_{420}) of three grades of sweet oranges significantly differed at 5% level of significance. However, juice density and clarity (%T_{650}) of three grades of fruits were insignificant.

ii) It was observed that the mean juice content (%) obtained for grade II fruits were more (43.66%) in comparison with other grades.

iii) Polynomial curve fitted best for regression equation between fruit weight and juice content for grade I and grade III fruits.

iv) Quadratic curve fitted best for the experimental data between total soluble solids (TSS) and viscosity.

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