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Preparation of Roselle (*Hibiscus sabdariffa* L.) Powder by Different Drying Methods

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Abstract

The experiment was conducted during November, 2024 to 2025 at the Department of Postharvest Management, Kittur Rani Channamma College of Horticulture, University of Horticultural Sciences, Bagalkot, Arabhavi, Belagavi District, Karnataka, to study the influence of pre-treatments and different drying methods on the quality of roselle powder. The roselle powder was prepared by following a Factorial Completely Randomized Design (FCRD) consisting of twelve treatments with three replications. The experiment included two factors: pre-treatments (without blanching, steam blanching for one minute and steam blanching for two minutes) and drying methods (sun drying, shade drying, solar drying and cabinet drying at 60°C). The samples were analysed to determine the effects of these treatments on the physical parameter's recovery (%), moisture content (%) and water activity and chemical parameters including anthocyanin (mg 100 g^{-1}), total phenols (mg GAE 100 g^{-1}) and antioxidant activity (%) of the end product. Among the various treatments, the roselle powder that was prepared with steam blanching for one minute followed by cabinet drying at 60°C was found to be superior with respect to both physical and chemical properties. It showed desirable physical characteristics with a recovery of 10.50%, a moisture content of 10.14% and a water activity of 0.29. The chemical composition recorded higher values with anthocyanin content of 243.15 mg 100 g^{-1}, total phenols of 321.50 mg GAE 100 g^{-1}, and antioxidant activity of 71.39%, indicating better colour stability and improved nutritional quality.

Keywords: Roselle, drying, pre-treatment, anthocyanin

1. Introduction

Roselle (*Hibiscus sabdariffa* L.) belongs to the family Malvaceae (2n=4x=72), locally called "karkade'', is an important crop native to tropical regions of Africa and Asia (Nwaiwu et al., 2020). The commercially important part of the plant is the fleshy calyx (sepals) surrounding the fruit (capsules). The flower begins to open progressively from lower to upper portion of plant and are ready for picking in November–December and picking season lasts for about twomonths. In India, roselle is grown in Punjab, Uttar Pradesh, Bihar, West Bengal, Assam,Orissa, Maharashtra, Karnataka and Andhra Pradesh as monsoon crop. The different parts of roselle areleaves, seeds and calyces that have been used for making a fine textured sauce or juice, syrup, jam, marmalade, chutney or jelly. The 100 g of fresh calyces contains (49 Kcal) calories, (84.5%) water, (1.90 g) protein, (0.10 g) fat, (12.30 g) total carbohydrates, (2.30 g) fibre, (1.20 g) ash, (1.73 mg) Ca, (57 mg) P, (2.90 mg) Fe, (300 mg) β-carotene and (14 mg) ascorbic acid (Duke and Atchley, 1984).

Roselle flowering occurred for a short period (November–December) and the calyces, being highly perishable, could not be stored fresh for long (Gomaa and Nahed, 2016). Drying served as a simple method for long-term preservation and powder preparation. The calyces contained mucilage, calcium citrate and ascorbic acid, with delphinidin 3-sambubioside as the main reddish-violet pigment (Babalola et al., 2001). They were rich in antioxidants, flavonoids and phenolic compounds contributing to health benefits (Ojulari et al., 2019) and were traditionally used to treat sore throat and heal wounds (Singh et al., 2017).

Colour greatly influenced consumer perception of product quality and safety. Due to health concerns, natural colorants were increasingly preferred in foods, medicines, and cosmetics for their visual and therapeutic benefits. Roselle (*Hibiscus sabdariffa*) was considered a valuable source of natural red pigment, primarily anthocyanins, which were water-soluble, making their extraction simple and cost-effective (Wu et al., 2018). Owing to its rich colour and medicinal properties, Roselle extracts served as functional natural ingredients in various products. However, in order to facilitate its utilization as a colouring agent, it is necessary to judge the suitability of roselle water extracts for change in colour characteristics (Waghmare et al., 2011). Roselle is a plant which can be used to improve the quality of food products. Calyces are rich in vitamin C, minerals and other antioxidants such as anthocyanin, flavonoids and phenols (Sabet et al., 2020). The strong antioxidant property of anthocyanin contributes to its value in preventing cardiovascular diseases, neuronal diseases and cancer (Chen et al., 2022).

Drying process is considered one of the most important post-harvest transactions and aims to prolong the storage period and reduce the costs of thepackaging process (Elghany et al., 2022). In addition, a good drying technique can enhance the quality of the product significantly. Every dryingmethod has its own advantages and restrictions (Akther et al., 2023). Roselle powder is a versatile ingredient that can be utilized in a wide range of food, beverage and nutraceutical products due to its attractive red colour, pleasant tangy flavour and rich antioxidant content. It can be effectively incorporated into beverages such as herbal teas, instant drink mixes, fruit juices, smoothies and ready-to-drink health beverages as a natural colorant and flavour enhancer (Chew et al., 2024).

2. Materials and Methods

The experiment was conducted during November, 2024 to 2025 at the Department of Postharvest Management, Kittur Rani Channamma College of Horticulture, University of Horticultural Sciences, Bagalkot, Arabhavi, Belagavi District, Karnataka. Roselle flowers were collected from the field of the Horticultural Research and Extension Centre (HREC), Badakundri (Hidkal Dam), UHS Bagalkot, situated in Hukkeri Taluk, Belagavi District, Karnataka. The selected flowers were uniform in size and shape and were fully matured. The experiment was carried out using a Factorial Completely Randomized Design (FCRD) with three replications and twelve treatments.

2.1. Methodology for the production of roselle powder with pre-treatment and different drying methods

The calyces were separated from the flowers and the seeds were removed manually. Five hundred grams of fresh calyces were used for the treatment. The fresh calyces were subjected to pre-treatments (without steam blanching, steam blanching for 1 minute, and steam blanching for 2 minutes) and different drying methods (sun drying, shade drying, solar drying and cabinet drying at 60°C) as per the treatment details. They were then ground into a fine powder and sieved. The resulting powder was packed in 50-micron aluminium foil pouches and was stored under ambient conditions for subsequent analysis.

Calyces were spread on trays and placed under direct sunlight for two to four days, with the trays covered using muslin cloth to prevent contamination. Shade drying was carried out by keeping the calyces in a well-ventilated shaded area away from sunlight under laboratory conditions for four to six days. Solar drying was performed using a polycarbonate-sheet-covered solar dryer, where the calyces were dried using natural solar heat with internal temperatures ranging from 40 to 60°C. In the cabinet tray drier, the calyces were placed in trays and dried at 60°C for 5 to 8 hours until a constant weight was attained.

2.2. Analysis of physiochemical properties

2.2.1. Moisture content (%)

The moisture content of the roselle powder was measured using a moisture analyser. One gram of each sample was placed in the moisture analyser (Model: 27 P1019319, A and D Company Limited, made in Japan).

2.2.2. Water activity (a_w)

The water activity of the roselle powder was measured using a water activity meter (Model: Novasia AG, Switzerland).

2.2.3. Anthocyanin (mg 100 g^{-1})

The anthocyanin content of the roselle calyces powder was measured by following the procedure adapted from Anonymous (1984). One gram of the sample was mixed with 10 ml of ethanolic HCl and the mixture was transferred into a 100 ml volumetric flask and diluted up to 25 ml with the same acidified ethanol. After the solution was refrigerated overnight at 4°C, the extract was filtered through Whatman filter paper. The absorbance of the clear filtrate was then determined at 535 nm using a spectrophotometer, which corresponded to the peak absorbance of anthocyanin.

$$\text{Total OD 100 g}^{-1} = \frac{\text{OD}_{535} \times \text{Volume made up}}{\text{Weight of sample}} \times 100$$

$$\text{Anthocyanin (mg 100 g}^{-1}) = \frac{\text{Total OD 100 g}^{-1}}{98.2}$$

2.2.4. Total phenols (mg GAE 100 g^{-1})

The total phenolic content of the roselle calyces powder was determined by following the Folin-Ciocalteu Reagent (FCR) method outlined by Sadasivam and Manickam (1996).

2.2.5. Antioxidant activity (%)

The antioxidant capacity of the dried roselle calyces powder was evaluated by assessing its ability to neutralize the stable free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) as per the procedure suggested by Eghdami et al. (2010)

$$\text{Antioxidant activity (\%)} = \frac{A_{517}\text{ nm of control} - A_{517}\text{ nm of sample}}{A_{517}\text{ nm of control}} \times 100$$

Where A was the absorbance value and the control indicated the DPPH solution.

2.3. Statistical analysis

Roselle powder was prepared by pre-treatments and different drying methods were evaluated using a Factorial Completely Randomized Design. The interpretation of the data followed the methodology outlined by Panse and Sukhatme (1985). An 'F' test was applied with the significance level set at p=0.01 and when significant differences were detected, critical difference (CD) values were calculated accordingly.

3. Results and Discussion

3.1. Effect of pretreatment and different drying methods on moisture content and water activity

The moisture content and water activity (Table 1 and 2) of roselle powders were key determinants of their physical stability, microbial safety and overall shelf life, making them essential indicators of drying performance and product quality. The moisture content and water activity of the dried roselle powder were in the range of 9.77 to 13.28 and 0.29 to 0.33, respectively. Over a storage period of up to three months, these values showed a significant increase. The differences in moisture content across the treatment combinations demonstrated the significant role of both pre-treatments (blanching) and different drying methods in determining the drying efficiency and stability of roselle powder.

The blanching process likely softened the tissue structure, which facilitated better moisture movement during drying. The combination of elevated temperatures and direct solar exposure led to faster evaporation and a more efficient drying process, thereby reducing the final moisture content. With an increase in the level of pre-treatment, there was a decrease in the moisture content and water activity in roselle powder. Similar findings were reported by Kessy et al. (2016) in litchi and by Amoasah et al. (2018) in solar- and sun-dried roselle powder. Comparable observations were noted by Wickramasinghe et al. (2020) in moringa leaf drying. Juhari et al. (2021) observed that roselle samples dried under the sun had higher moisture content than those dried in an oven, and Marak et al. (2021) reported similar findings in shade-dried roselle samples. The results in the present investigation followed a similar trend and were in line with Swetha (2016) in custard apple powder, Chegini and Ghobadian (2005) in

Table 1: Moisture content (%) of roselle powder as influenced by pre-treatments and drying methods during storage

Treatment	Initial					1 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	11.04	13.28	11.54	12.07	11.98	11.28	13.57	11.78	12.34	12.24
P_2	11.03	10.44	10.17	10.14	10.45	11.23	10.63	10.36	10.33	10.64
P_3	9.77	10.53	9.99	10.91	10.30	9.96	10.74	10.20	11.20	10.52
Mean of D	10.61	11.42	10.57	11.04	10.91	10.82	11.65	10.78	11.29	11.13
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	0.06		0.24			0.02		0.10		
D	0.06		0.24			0.02		0.10		
P×D	0.12		0.49			0.05		0.20		
Treatment	2 MAS					3 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	11.54	13.87	12.00	12.53	12.49	11.77	14.13	12.26	12.77	12.73
P_2	11.43	10.83	10.55	10.51	10.83	11.66	11.09	10.76	10.67	11.05
P_3	10.13	10.92	10.38	11.36	10.70	10.36	11.12	10.57	11.58	10.90
Mean of D	11.03	11.87	10.98	11.74	11.36	11.26	12.11	11.20	11.67	11.56
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	0.02		0.07			0.01		0.04		
D	0.02		0.07			0.01		0.04		
P×D	0.03		0.14			0.02		0.09		

MAS: Months after storage; P: Pretreatments; P_1: Withoutblanching; P2: Steam blanching (1 min.); P_3: Steam blanching (2 min.); D: Drying methods; D_1: Sun drying; D_2: Shade drying; D_3: Solar drying; D_4: Cabinet drying at 60°C

Table 2: Water activity of roselle powder as influenced by pre-treatments and drying methods during storage

Treatment	Initial					1 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	0.31	0.33	0.30	0.32	0.31	0.36	0.38	0.35	0.37	0.36
P_2	0.30	0.32	0.30	0.29	0.30	0.35	0.35	0.34	0.34	0.35
P_3	0.30	0.32	0.30	0.31	0.30	0.36	0.37	0.35	0.34	0.35
Mean of D	0.30	0.32	0.30	0.30	0.31	0.35	0.36	0.35	0.35	0.35
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	0.001		0.004			0.001		0.005		
D	0.001		0.004			0.001		0.005		
P×D	0.002		0.009			0.002		0.01		
Treatment	2 MAS					3 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	0.43	0.52	0.42	0.45	0.46	0.49	0.58	0.51	0.52	0.52
P_2	0.43	0.41	0.42	0.44	0.43	0.51	0.48	0.51	0.45	0.49
P_3	0.43	0.46	0.42	0.46	0.44	0.51	0.53	0.51	0.53	0.51
Mean of D	0.43	0.47	0.42	0.45	0.44	0.50	0.53	0.51	0.49	0.50
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	0.001		0.004			0.007		0.002		
D	0.001		0.004			0.007		0.002		
P×D	0.002		0.01			0.001		0.005		

MAS: Months after storage; P: Pretreatments; P_1: Withoutblanching; P2: Steam blanching (1 min.); P_3: Steam blanching (2 min.); D: Drying methods; D_1: Sun drying; D_2: Shade drying; D_3: Solar drying; D_4: Cabinet drying at 60°C

orange juice powder, Rodriguez et al. (2005) in cactus pear juice, and Goula et al. (2004) in tomato powder.

3.2. Effect of pretreatment and different drying methods on anthocyanin, phenols and antioxidant activity of roselle powder

Anthocyanins and phenolic compounds were key bioactive constituents in roselle (*Hibiscus sabdariffa* L.) that played a vital role in its health-promoting, nutritional, and medicinal properties. Anthocyanins, which were responsible for the rich red hue of the calyces, acted as powerful antioxidants that combated free radicals and protected cells from oxidative damage. Likewise, phenolic compounds, including flavonoids and phenolic acids, enhanced the antioxidant capacity of the plant and were recognized for their anti-inflammatory, antimicrobial, and heart-protective effects (Da-Costa-Rocha et al., 2014).

The anthocyanin content ranged from 210.79 to 243.15 mg 100 g^{-1} in the dried roselle powder (Table 3). Over the three-month storage period, these values declined significantly. The maximum anthocyanin content (243.15 mg 100 g^{-1}) was recorded in the treatment P_2D_4 (steam blanching for one minute and cabinet drying at 60°C), which was higher than that obtained from the other drying methods, proving that cabinet drying was more effective than shade drying in preserving anthocyanin content in roselle. This method provided a controlled environment with regulated temperature and limited oxygen exposure, which helped safeguard delicate bioactive compounds like anthocyanins and required only six hours for drying the samples. In contrast, shade drying, though economical and natural, took 5–6 days and exposed the material to air and light, leading to faster degradation of anthocyanins. Since anthocyanins were highly sensitive to light, direct exposure to light and air might have reduced their content.

Steam-blanched roselle samples retained higher anthocyanin levels compared to unblanched samples, as the blanching process inactivated polyphenol oxidase and peroxidase enzymes responsible for anthocyanin degradation. Patras et al. (2010) reported that blanching helped stabilize anthocyanins in fruits and vegetables by preventing enzymatic degradation. Similar findings were reported by Gartaula and Karki (2010), who observed higher anthocyanin content in oven-dried roselle calyces, and by Sujiman and Maksum (2019) in cabinet- and sun-dried roselle. An et al. (2022) in *Acanthopanax sessiliflorus* after hot-air blanching and drying. Tan et al. (2022) studied anthocyanin degradation in blood-flesh peach during hot-air drying. Motegaonkar et al. (2024) studied the effect of blanching and drying on anthocyanin content in black carrot

Table 3: Anthocyanin (mg 100 g^{-1}) content of roselle powder as influenced by pre-treatments and drying methods during storage

Treatment	Initial					1 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	235.60	238.38	210.79	241.22	231.50	230.91	237.86	208.16	237.81	228.69
P_2	230.69	241.24	216.08	243.15	232.79	228.14	239.15	212.94	240.55	230.2
P_3	241.48	238.73	226.06	240.75	236.76	237.14	236.66	223.65	238.16	233.90
Mean of D	235.93	239.45	217.64	241.71	233.68	232.06	237.89	214.92	238.84	230.93
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	0.62		2.46			0.93		3.68		
D	0.62		2.46			0.93		3.68		
P×D	1.24		4.92			1.86		7.36		
Treatment	2 MAS					3 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	228.01	235.20	201.96	236.76	225.48	225.78	233.41	200.54	234.52	223.56
P_2	224.34	234.83	210.61	229.89	224.92	222.33	231.83	207.15	226.70	222.00
P_3	235.81	232.00	219.27	234.07	230.29	234.17	228.89	217.9	233.75	228.55
Mean of D	229.39	234.01	210.61	233.57	226.90	227.43	231.37	208.36	231.65	224.70
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	1.20		4.75			0.95		3.77		
D	1.20		4.75			0.95		3.77		
P×D	2.40		9.51			1.90		7.55		

MAS: Months after storage; P: Pretreatments; P_1: Withoutblanching; P2: Steam blanching (1 min.); P_3: Steam blanching (2 min.); D: Drying methods; D_1: Sun drying; D_2: Shade drying; D_3: Solar drying; D_4: Cabinet drying at 60°C

shreds.Pauletto et al. (2025) in dried jabuticaba peel powder.

Changes in the total phenols and antioxidant activity during three months of storage were shown in Table 4 and Table 5, respectively. Total phenols (336.85 mg GAE 100 g^{-1}) and antioxidant activity (84.13%) were reported to be maximum in the P_2D_2 treatment (steam blanching for 1 minute and shade drying) at the beginning, while minimum total phenols (271.90 mg GAE 100 g^{-1}) and antioxidant activity (63.68%) were reported in the P_1D_1 combination. Tsai and Huang (2004) indicated that the antioxidant activity of roselle extract had a strong correlation with anthocyanin content. Similarly, better retention of phenolic compounds in litchi was observed in steam blanching followed by drying, as reported by Kessy et al. (2016) and Wojdyło et al. (2019) in jujube fruits. Steam

Table 4: Total phenols (mg GAE 100 g^{-1}) content of roselle powder as influenced by pre-treatments and drying methods during storage

Treatment	Initial					1 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	274.71	324.37	287.01	315.75	300.46	274.05	323.04	286.68	315.06	299.70
P_2	271.90	336.85	296.62	321.50	306.71	271.25	336.15	296.36	320.55	306.08
P_3	273.23	319.58	292.76	293.60	294.82	272.90	317.91	292.54	292.54	293.97
Mean of D	273.28	326.92	292.13	310.32	300.66	272.76	325.70	291.86	291.86	299.92
	SEm±		CD (p=0.01)			SEm±		CD (p=0.01)		
P	1.79		7.10			1.62		6.44		
D	1.79		7.10			1.62		6.44		
P×D	3.59		14.20			3.25		12.89		

Table 4: Continue...

Treatment	2 MAS					3 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	273.38	322.37	286.35	314.73	299.29	272.17	320.54	285.01	314.06	297.94
P_2	270.92	335.84	296.03	320.22	305.75	268.73	334.50	294.70	320.19	304.53
P_3	272.56	317.65	291.90	291.42	293.38	271.90	316.32	291.12	290.75	292.52
Mean of D	272.29	325.29	291.43	308.79	299.45	270.93	323.79	290.27	308.33	298.33
	SEm±		CD (*p*=0.01)			SEm±		CD (*p*=0.01)		
P	1.62		6.44			1.32		5.24		
D	1.62		6.44			1.32		5.24		
P×D	3.25		12.88			2.65		10.49		

MAS: Months after storage; P: Pretreatments; P_1: Withoutblanching; P2: Steam blanching (1 min.); P_3: Steam blanching (2 min.); D: Drying methods; D_1: Sun drying; D_2: Shade drying; D_3: Solar drying; D_4: Cabinet drying at 60°C

Table 5: Antioxidant activity (%) of roselle powder as influenced by pre-treatments and drying methods during storage

Treatment	Initial					1 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	63.68	81.77	75.24	67.18	71.97	62.11	80.59	74.95	66.50	71.04
P_2	74.98	84.13	82.92	71.39	78.35	72.09	83.19	81.72	70.37	76.84
P_3	74.10	77.41	80.47	72.43	76.10	72.55	75.09	79.00	71.88	74.63
Mean of D	70.92	81.10	79.54	70.33	75.47	68.92	79.62	78.56	69.58	74.17
	SEm±		CD (*p*=0.01)			SEm±		CD (*p*=0.01)		
P	0.34		1.38			0.52		2.09		
D	0.34		1.38			0.2		2.09		
P×D	0.69		2.76			1.05		4.18		
Treatment	2 MAS					3 MAS				
	D_1	D_2	D_3	D_4	Mean of P	D_1	D_2	D_3	D_4	Mean of P
P_1	59.58	78.35	72.43	64.07	68.61	58.23	76.95	70.78	62.81	67.19
P_2	71.03	81.44	80.35	68.72	75.38	69.17	79.70	78.53	66.65	73.51
P_3	71.06	73.82	78.95	69.35	73.29	69.70	72.64	75.06	67.59	71.25
Mean of D	67.22	77.87	77.25	67.38	72.43	65.81	76.43	74.79	65.68	70.68
	SEm±		CD (*p*=0.01)			SEm±		CD (*p*=0.01)		
P	0.86		3.43			0.86		3.42		
D	0.86		3.43			0.86		3.42		
P×D	1.73		6.86			1.7		7.12		

MAS: Months after storage; P: Pretreatments; P_1: Withoutblanching; P2: Steam blanching (1 min.); P_3: Steam blanching (2 min.); D: Drying methods; D_1: Sun drying; D_2: Shade drying; D_3: Solar drying; D_4: Cabinet drying at 60°C

blanching helped to deactivate the enzymes that caused oxidation (Nobosse et al., 2017). Overall, steam blanching for one minute before drying helped in better retention of physicochemical properties (Liu et al., 2019). Sujiman and Maksum (2019) reported an antioxidant activity of 74.67% in cabinet-dried roselle samples. The findings indicated that steam blanching before oven drying enhanced the extraction of phenolic compounds and increased DPPH radical scavengingactivity and greater ferric reducingantioxidant capacity Haw et al. (2020). Akther et al. (2023) in mango, while Hashim et al. (2024) reported higher antioxidant activity in dried roselle. Babaei et al. (2025) in Capparis spinosa fruits.

4. Conclusion

Roselle powder obtained from steam blanching for one minute with cabinet drying at 60°C (P_2D_4) proved to be effective in preserving the physicochemical parameters, with a moisture content of 10.14%, water activity of 0.29, anthocyanin content of 243.15 mg 100 g^{-1}, total phenols of 321.50 mg GAE 100 g^{-1}, and antioxidant activity of 71.39%. Novel drying methods such as microwave-assisted, infrared, and freeze-drying were suggested to be explored for the extraction of pigments and drying. The roselle powder could be utilized for the production of other products such as rasam mix, puliogare mix, etc.

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