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STORAGE CONDITIONS INFLUENCE ON STANLEY AND BLUEFREE ORGANIC PLUMS QUALITY

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Abstract

The paper presents the influence of storage conditions on two varieties of plums: 'Stanley' and 'Bluefree'. In order to assess the influence of different factors, several indicators were taken into consideration: physiological parameters, quality indicators and bioactive compounds variations. Both 'Stanley' and 'Bluefree' plums varieties were harvested at the end of August 2021 from an organic orchard located in Prahova County and stored in three different conditions: 1) normal atmosphere (NA) with 1°C and 95% relative humidity (RH), 2) controlled atmosphere (CA) conditions with 1°C, 95% RH, 3% O_2 and 5% CO_2, and 3) CA conditions with 1°C, 95% RH, 1.5% O_2, and 10% CO_2. The samples were evaluated in seven different moments: initially (at harvest), after 2, 4, 6, 8, 10, and 12 weeks of storage. For both 'Stanley' and 'Bluefree' varieties, the storage period was shorter in NA than for those stored in CA conditions (2 weeks shorter for 'Stanley' variety and 3 weeks shorter for 'Bluefree' samples). The results showed that total titratable acidity and dry matter content registered similar variation trend during storage period for both samples, stored in all conditions. The obtained results suggest that the plums stored in controlled atmosphere conditions, kept their qualities better and for longer than those stored in NA.

Key words*: antioxidant activity; controlled atmosphere; normal atmosphere; polyphenols; storage.*

INTRODUCTION

Plums are classified in Rosaceae family, like many other stone fruits and they are divided into two groups: Japanese plums and European plums (Okie et al., 2008). It is one of the most cultivated fruit trees in the world, with around 2000 cultivars (Ramming, 1991). Fruits have nutritional value similar to peaches and apricots. These are sources of minerals (Ca, Fe, P, Mg, K) and vitamins (vitamin A, riboflavin and niacin from the group of B vitamins, vitamin C and folic acid - folacin) (Ramming & Cociu, 1991).

European plum it`s the most cultivated plum in Europe, because of the adaptability in cooler areas (Hartmann and Neumüller, 2009). Some of the proprieties does make European plums so popular are the size, shape and color of the fruits, but also the flesh of the fruits and it`s proprieties, along with its high content of flavonoids, anthocyanins and other phenolic compounds (Hartmann and Neumüller, 2009). Plums can be consumed fresh or as dried fruits, juices and jams.

According to FAOSTAT, in Romania, in 2020, plums were cultivated at an area of 67,010 ha.

Plum in Romania is the number one cultivated specie in the fruit growing sector because of the good adaptability to climatic conditions and soils (Butac et al., 2019).

'Bluefree' is a variety of plum with an early fruiting and high productivity. The fruits have a dark blue skin, with a light waxy bloom. The fleshy part has a greenish-yellow color that turns yellow when it is ripe for consumption. Also, these are very aromatic, have a slightly low firmness and an unmistakable pleasant taste. 'Stanley' is a variety of plums that ripens in late summer or early fall; the fruits are large, have dark blue skin with greenish-yellow pulp. They are sweet, juicy and suitable for consumption as such or for preservation (Asanica and Hoza, 2013).

In order to reduce the losses and to extend the postharvest life of organic plums, the controlled atmosphere conditions as postharvest technologies are more used (Peano et al., 2010).

The aim of this paper is to evaluate quality indicators of two plums varieties in three different storage conditions.

MATERIALS AND METHODS

Samples

Two varieties of organic plums, 'Stanley' (Figure 1) and 'Bluefree' (Figure 2), were harvested in August 2021 from an orchard located in Prahova County. After the harvest, the fruits were transported to Postharvest Technologies Laboratory from Research Center for Studies of Food Quality and Agricultural Products.

After the initial analyses performed in the lab, the fruits were split and stored in three different conditions: 1) normal atmosphere (NA) with 1°C and 95% RH, 2) controlled atmosphere conditions with 1°C, 95% RH, 3% and 5% CO_2 (CA 5% CO_2), and 3) controlled atmosphere conditions with 1°C, 95% RH, 1.5% O_2, and 10% CO_2 (CA 10% CO_2).

Organic plums samples were analyzed in six different moments, for 'Stanley' variety stored in NA conditions, five moments for 'Bluefree' variety stored in NA. For both varieties stored in CA with 5% CO_2 and CA with 10% CO_2, seven moments of analyses were performed.

Figure 1. Initial moment of analysis - Stanley variety

Figure 2. Initial moment of analysis - Bluefree variety

Chemicals

Methanol used to determine total phenolic content was bought from Honeywell (Riedel-de Haën, Seelze, Germany).

Folin & Ciocalteu's reagent were purchased from Sigma-Aldrich Chemie GmbH (Riedstrasse, Steinheim).

Sodium carbonate anhydrous was bought from Lach-Ner s.r.o (Neratovice, Czech Republic).

For antioxidant activity determination, DPPH (1.1-diphenyl-2-picrylhydrazyl) and Trolox (6 - hydroxy - 2, 5, 7, 8 - tetramethylchroman - 2 - carboxylic acid) from Acros Organics, Fisher Scientific (Geel, Belgium).

Gallic acid was purchased from Carl Roth and Sodium hydroxide 0.1N was from Cristal R Chim S.R.L. (Bucharest, Romania) and anhydrous sodium carbonate was purchased from Lach-Ner, s.r.o. (Neratovice, Czech Republic).

Ultrapure water used it was made with a Milli-Q equipment (Millipore, Bedford, MA).

Quality indicators

Quality indicators were represented by total titratable acidity (TTA), pH, firmness, total soluble solids (TSS) and dry matter content (DM), methods being described forward.

TTA and pH analysis were performed using the automatic titrometer TitroLine, equipped with pH electrode. The analysis consists in weighting approximately 5 g of fresh homogenized sample mixed with 25 mL of bidistilled water, measuring the initially pH values and then titration with 0.1N NaOH until the final pH is 8.1 according with AOAC Official Method 942.15. For TTA, results were expressed in g malic acid /100g of fresh fruit similar with Petre et al. (2021).

Firmness results were obtained and expressed in kg/cm² using a digital penetrometer (53205 TR Italy) equipped with 8 mm piston.

The analysis of total soluble solids (TSS) were performed using Kruss DR301-95 digital refractometer (Cătuneanu et al., 2017).

Dry matter results were obtain using UN110 Memmert oven and drying approximately 1 g of sample at 105°C (Stan et al., 2020) until constant weight.

Phenolic content and antioxidant activity

For total polyphenol content (TPC) quantitative determination was used the Folin-Ciocâlteu method protocol. Extraction consist in trituration of 1 g fresh sample with 10 mL of

70% methanol and incubated overnight at dark and room temperature (approx. 22°C) in centrifuge tubes of 15 mL. Next day, the extraction continue with homogenization at 500 rpm for 1 h and, then centrifugation at 7000 rpm for 5 min at 4°C. The supernatant was recovered in 50 mL centrifuge tubes and the residue re-extracted two more times until the final volume of the extract of 30 mL. First step of determination of total polyphenolic content is by mixing 0.5 mL of extract with 2.5 mL of Folin-Ciocâlteu reagent and incubated for 2 minutes at room temperature (aprox. 22°C). Second step is represented by adding 2 mL of 7.5% sodium carbonate solution (Na_2CO_3) and incubate the mix at 50°C for 15 minutes. The third and final step is based on the absorbance read at Specord 210 Plus UV-VIS spectrophotometer (Analytik Jena, Jena, Germany) at the 760 nm wavelength. Results are expressed in mg GAE/100 g fresh weight.

Antioxidant activity determination was used the DPPH (2,2-diphenyl- 1-picrylhydrazyl) method, similar as Bujor et al. (2016) with variations presented forward. Mixing 0.2 mL of extract with 2 mL of 0.2 mM solution of DPPH in methanol and incubated in dark for 30 minutes, with homogenising. The absorbance of the samples was measured at 515 nm wavelength. Results were expressed as mg Trolox/100 g FW. Methanol was the blank reference used.

Statistical analysis

Statistical analysis of obtained data was standard deviation, represent the average of three replicates from the same sample with independent preparation.

RESULTS AND DISCUSSIONS

Quality indicators

Both varieties of plums registered quality indicators variation in all storage conditions.

Experiment were performed during 91 days of storage, but physiological disorders appear after 56 days of storage of in NA conditions (for ‘Bluefree’ variety), and 70 days of storage (for ‘Stanley’ variety). In both CA conditions the fruits were kept for 91 days.

pH values of 'Stanley' variety stored in NA decrease from 3.47±0.02 (initially) to 3.32±0.02 after 42 days of storage, but after 70 days of storage, at final moment of analyses increase to 3.66±0.01. In both CA conditions, pH values remain constant until last two moments, when increase to 3.72-3.74 (Table 1).

The initially TTA values of ‘Stanley’ variety were 1.11±0.04 g malic acid/100 g FW (Table 1), after 70 days of storage in NA, the TTA values decrease to 0.93 ±0.01 g malic acid/100 g FW, which means the acidity of plums decreases. 'Bluefree' variety stored in NA conditions show similar variation of TTA after 56 days of storage. For ‘Stanley’ variety samples stored in both CA, TTA values maintain constant until 56 days of storage, at the next two moments of analyses, TTA values decreases.

For ‘Bluefree’ variety, stored in both CA, TTA values maintain constant until 42 days of storage, at the next moment of analyses TTA values slightly increase. TSS values showed constant increases to all samples, in all storage conditions, fruits dehydrating considerable after 56 days of storage for 'Stanley' variety, and after 42 days of storage for 'Bluefree' variety, which increase the concentration of total soluble solids. During the storage period, the value of TSS for the fruits stored in NA with 1°C, 95% RH increase much more compared to the fruits stored in CA 1°C, 95% RH, 3% O_2 and 5% CO_2 and CA 1°C, 95% RH, 1.5% O_2, and 10% CO_2. Dry matter values maintain constant until 28 days of storage for 'Stanley' variety stored in NA and CA with 1°C, 95% RH, 3% O_2 and 5% CO_2 until 70 days of storage, after that dry matter content increase in all conditions. For ‘Bluefree’ variety, dry matter content increase after 42 days in NA and CA with 1°C, 95% RH, 3% O_2 and 5% CO_2, for samples stored in CA with 1°C, 95% RH, 1.5% O_2, and 10% CO_2.

The firmness values of ‘Stanley’ variety, recorded an important decrease in NA and CA with 1°C, 95% RH, 1.5% O_2, and 10% CO_2 after 42 days of storage, samples stored in CA with 1°C, 95% RH, 3% O_2 and 5% suffers massive decrease after 70 days of storage. Firmness values of 'Bluefree' variety showed a constant decrease from 4.73±0.41 kg/cm² to 1.07±0.17 kg/cm² after 28 days of storage. In both CA conditions, firmness values suffered a slight decrease, but maintain constant during storage period (Table 2).

Table 1. Variation of pH, total titratable acidity (TTA), total soluble solids (TSS), and dry matter (DM) content during storage of 'Stanley' variety

Variety	Storage conditions	Analysis moment (days)	pH	TTA (g malic acid/ 100g FW)	Total soluble solids (%)	Dry matter (%)	Firmness (kg/cm²)
Stanley	NA with 1°C, 95% RH	0	3.47 ±0.02	1.11±0.04	12.68±0.91	22.75±0.46	3.77±0.29
		14	3.42±0.08	1.00±0.02	12.85±0.71	23.19±0.72	3.35±0.39
		28	3.46±0.03	1.06±0.01	12.82±0.60	25.36±0.51	2.51±0.73
		42	3.32±0.02	1.00±0.006	13.19±0.68	23.46±0.72	1.65±0.46
		56	3.38±0.04	1.05±0.01	13.38±0.63	23.28±0.27	1.62±0.71
		70	3.66±0.01	0.93±0.01	13.47±13.02	23.32±0.25	1.01±0.54
		91	After 70 days analyses, no healthy fruits remained				
	CA 5% CO_2, 3% O_2, 1°C, 95% RH	0	3.41±0.02	0.97±0.01	12.60±0.50	24.7±0.80	3.40±0.60
		14	3.44±0.03	1.07±0.01	13.79±0.73	23.64±0.83	3.74±0.52
		28	3.37±0.05	0.96±0.02	14.35±0.72	25.08±0.81	3.82±0.38
		42	3.36±0.03	1.03±0.04	13.24±0.43	23.12±1.32	3.20±0.52
		56	3.73±0.01	0.92±0.01	13.27±0.62	24.14±0.19	2.96±0.64
		70	3.72±0.01	0.93±0.02	13.12±0.55	25.46±2.11	2.74±0.74
	CA 10% CO_2, 3% O_2, 1°C, 95% RH	0	3.43±0.03	1.06±0.03	13.51±1.02	25.21±1.09	3.24±0.50
		14	3.41±0.02	1.00±0.03	12.74±0.57	23.71±0.67	3.15±0.73
		28	3.37±0.02	1.03±0.03	13.01±0.74	21.68±0.20	3.02±0.33
		42	3.40±0.07	0.96±0.01	13.34±0.46	22.59±0.52	2.55±0.34
		56	3.74±0.04	0.95±0.01	13.49±0.65	27.88±1.42	2.43±0.74
		70	3.74±0.04	0.81±0.01	12.76±0.64	24.12±1.37	2.09±0.47

Table 2. Variation of pH, total titratable acidity (TAA), total soluble solids (TSS), a nd dry matter (DM) content during storage of 'Bluefree' variety

Variety	Storage conditions	Analysis moment (weeks)	pH	TAA (g malic acid/ 100 g FW)	Total soluble solids (%)	Dry matter (%)	Firmness (kg/cm²)
Bluefree	NA with 1°C, 95% RH	0	3.51±0.03	0.97±0.07	12.62±0.98	22.07±0.45	4.63±0.41
		14	3.42±0.03	1.03±0.01	11.82±0.88	24.44±1.42	4.28±0.60
		28	3.43±0.01	0.93±0.01	14.68±0.68	21.26±0.15	1.07±0.17
		42	3.42±0.11	1.01±0.01	13.98±0.82	23.37±0.27	1.08±0.46
		56	3.29±0.00	0.91±0.02	13.59±0.54	24.17±1.04	0.30±0.08
		70	After 56 days analyses, no healthy fruits remained				
		91					
	CA 5% CO_2, 3% O_2, 1°C, 95% RH	14	3.36±0.05	1.02±0.02	12.69±0.52	22.86±49	4.58±0.88
		28	3.42±0.06	1.09±0.01	13.37±0.98	23.55±0.68	3.50±0.56
		42	3.41±0.07	0.99±0.01	13.32±0.51	22.64±0.43	3.90±0.46
		56	3.36±0.02	1.04±0.04	13.53±0.79	26.11±0.51	3.50±0.39
		70	3.34±0.04	1.03±0.02	13.45±0.34	27.23±0.63	3.38±0.26
		91	3.63±0.03	1.06±0.01	12.96±0.54	27.65±0.87	3.35±0.34
	CA 10% CO_2, 3% O_2, 1°C, 95% RH	14	3.37±0.06	0.96±0.02	13.76±0.56	24.25±0.94	3.69±0.66
		28	3.38±0.04	1.11±0.02	12.57±0.98	23.94±1.43	4.14±0.79
		42	3.38±0.07	0.90±0.03	12.94±0.36	22.54±0.15	4.05±0.48
		56	3.32±0.02	1.08±0.01	13.05±0.44	24.15±0.21	3.50±0.65
		70	3.34±0.03	1.04±0.02	12.96±0.23	25.44±0.31	3.34±0.28
		91	3.20±0.01	1.08±0.02	12.38±0.12	26.41±0.54	3.18±0.45

Phenolic content and antioxidant activity

Total phenolic content (TPC) were determined from whole fruit and showed similar behavior for both plum varieties in all three storage conditions. For organic 'Stanley' variety, initially TPC values was 88.88±3.51 mg GAE/100 g FW, results similar with those obtain by Miletic et al. (2012). After 14 days of storage TPC values increase in NA with 1°C, 95% RH up to 112.68±6.14 mg GAE/100 g FW and in CA with 1°C, 95% RH, 1.5% O_2 and 10% CO_2, up to 100.23 mg GAE/100 g FW. In CA with 1°C, 95% RH, 3% O_2 and 5% CO_2, TPC values maintain constant after 14 days of storage

(Figure 3). Highest TPC value, 119.70±5.88 mg GAE/100 g FW were observed at fruits stored in CA with 1°C, 95% RH, 3% O_2 and 5% CO_2, after 91 days of storage, but the most constant values during storage were obtained from samples stored in CA with 1°C, 95% RH, 1.5% O_2 and 10% CO_2.

Initially total phenolic content for organic 'Bluefree' variety was 103.83±5.37 mg GAE/100 g FW and increase in all conditions during storage, up to 120.58±4.02 mg GAE/ 100 g FW in NA with 1°C, 95% RH, to 152.98±3.22 mg GAE/100 g FW in CA with 1°C, 95% RH, 3% O_2 and 5% CO_2 and up to 144.87±3.36 mg GAE/100 g FW in CA with 1°C, 95% RH, 1.5% O_2 and 10% CO_2, after 14 days of storage (Figure 4). The results showed most constant values during storage period of TPC were obtained from fruits stored in CA with 1°C, 95% RH, 3% O_2 and 5% CO_2. TPC values start to decrease after 70 days analyses for 'Bluefree' variety stored in both CA conditions, in comparation with previous moments of analyses.

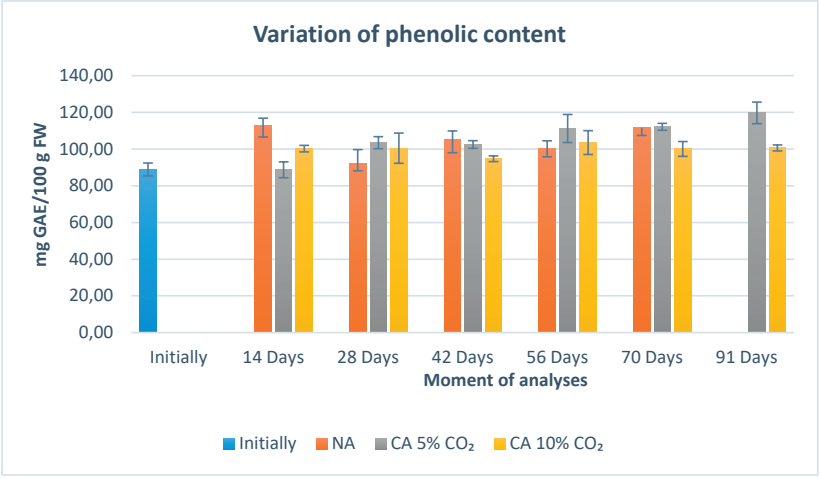

Figure 3. Total phenolic content variations for organic 'Stanley'plums, registered during storage period

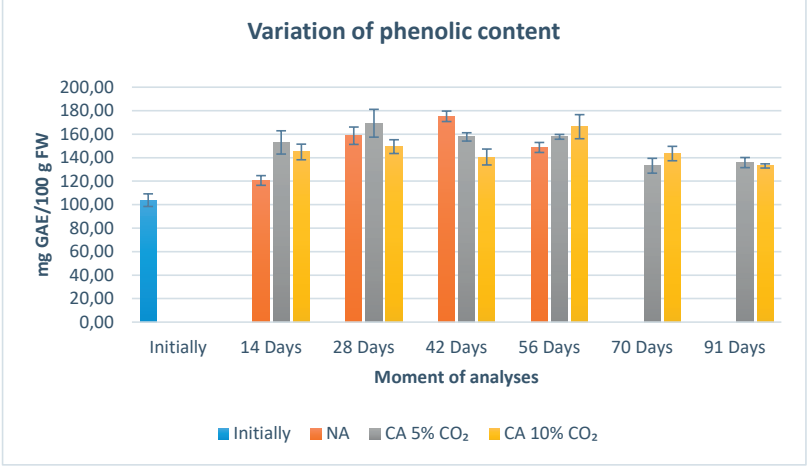

Figure 4. Total phenolic content variations for organic 'Bluefree'variety, registered during storage period

Antioxidant activity of organic 'Stanley' variety increased from 805.89±74.10 mg Trolox/100 g FW (initially moment) up to 1038.42±94.00 mg Trolox/100 g FW after 14 days of storage in NA with 1°C, 95% RH, up to 902.62±11.62 in CA with 1°C, 95% RH, 3% O_2 and 5% CO_2 and up to 897.28±73.01 mg Trolox/100 g FW (Figure 5). 'Bluefree' variety showed a higher antioxidant activity, with values of 971.97±8.19 mg Trolox/100 g FW at the initial moment of analyses. After 14 days of storage antioxidant activity increased up to 1059.78±136.23 mg Trolox/100 g FW in NA with 1° C, 95% RH, up to 1398.66±90.02 mg Trolox/100 g FW in CA with 1°C, 95% RH, 3% O_2 and 5% CO_2 and up to 1339.49±70.25 mg Trolox/100 g FW (Figure 6).

Both organic 'Stanley' and 'Bluefree' plums showed increases of antioxidant activity during storage period (until 91 days of storage for 'Stanley' variety and until 56 days of storage for 'Bluefree' variety), variation trend of total phenolic content and antioxidant activity being similar during storage period in all three conditions.

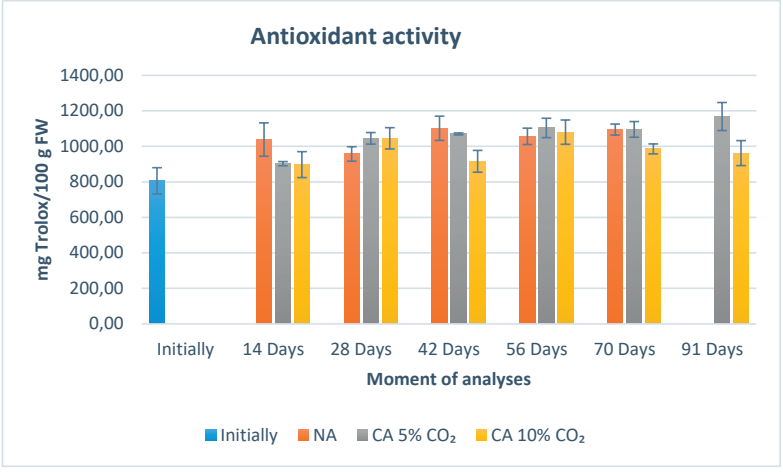

Figure 5. Antioxidant activity variations of organic 'Stanley' variety, registered during storage period

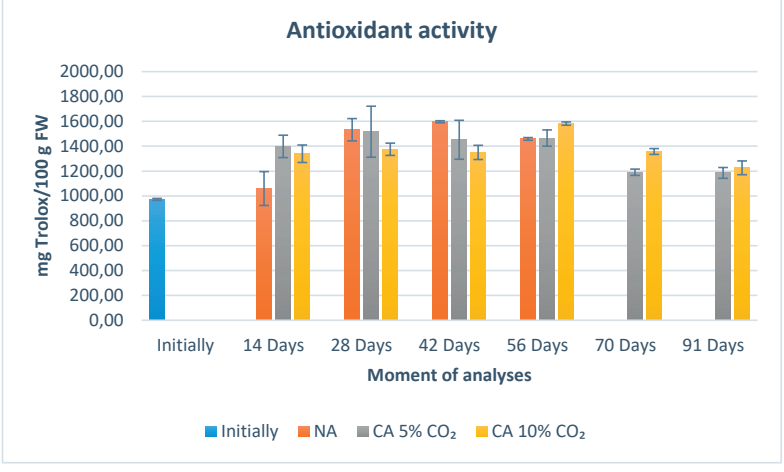

Figure 6. Antioxidant activity variations of organic 'Bluefree' variety, registered during storage period

CONCLUSIONS

In this paper the behavior of the two tested varieties of plums ('Stanley' and 'Bluefree') stored in three different conditions - normal atmosphere storage (NA), CA 5% CO_2 and CA 10% CO_2 was tested.

Compared to the normal atmosphere storage, rooms with controlled atmosphere extended the storage time of the fruits by 21 days for the 'Stanley' variety and 35 days for the 'Bluefree' variety, which may indicate that:

- quality indicators were maintained constant, except for the last two moments of analysis when both varieties presented lower values;
- antioxidant activity and total polyphenol content of 'Stanley' variety showed similar values, except samples from 91 days were fruits showed a slight increase compared to 70 days storage duration.
- antioxidant activity and total polyphenol content of 'Bluefree' variety recorded a decrease after 56 days in both storage conditions (CA 5% CO_2 and CA 10% CO_2) when compared with normal atmosphere storage (NA);

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