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Effect of drying methods on textural and rheological properties of basil seed gum

[1*] Salehi, F. and [2] Kashaninejad, M.

[1]*Department of Food Industry Machines, Bu-Ali Sina University, Hamedan, Iran.*
[2]*Faculty of Food Science and Technology, Gorgan University of Agricultural Sciences and Natural Resources,Gorgan, Iran*

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Abstract

The purpose of the present study was to investigate the influence of different drying techniques on the rheological and textural properties, and color changes of basil seed gum. Basil seed gum solutions were extracted and dried by different methods: oven drying (40-80°C), freeze drying and vacuum oven drying. The effects of these drying methods on the rheological and textural properties, and color changes of basil seed gum were investigated in this study. The results showed that the apparent viscosity of gum solutions (0.6% and shear rate=54s^{-1}) were varied from 0.174 to 0.438Pa.s, and freeze-dried gum exhibited the highest viscosity. Different time independent rheological models (Power law, Bingham, Herschel-Bulkley and Casson) were used to fit the experimental data and the results showed that the Heschel-Bulkley's model was most suitable to describe the flow behavior of basil seed gum over the whole experimental range. The hardness, stickiness, consistency and adhesiveness of basil seed gum gel (3%) were changed from 42.2 to 75.5g, 11.3 to 19.3g, 362.6 to 803.7g.s, and 131.5 to 244.8g.s, respectively, at different drying condition. The results indicated that the freeze-dried gum exhibited the highest hardness and consistency. The rise in temperature had a negative effect on the color changes (high color change (ΔE)) and brightness (low lightness (L^*)) of gum solution.

Introduction

The dispersion of water soluble gums in the aqueous system provides great technical importance, since they can improve the gelling or thickening properties of food products (Salehi *et al.*, 2014). Therefore, it is crucial to understanding of functional characteristics of gum in order to select the appropriate one based on the scope of application. They are also used to emulsify the flavours, provide the elasticity an, retain moisture (Salehi *et al*., 2015). The hydrocolloids extracted from seeds can be used extremely in food formulations because of their afford-ability and easy availability (Zameni *et al.*, 2015).

Ocimum basilicum L. is a mucilaginous plant which is grown in different regions of Asia, Europe, and Middle East, especially in various regions of Iran. The seed from this plant has appreciable amounts of gum with good functional properties which is comparable with commercial food hydrocolloids (Zameni *et al*., 2015). Some potential of the basil seed gum as a new source of hydrocolloid have been recently investigated by Zameni *et al.* (2015). The rheological characteristics play a significant role in the process design (fluid flow, pump sizing, extraction, filtration, extrusion and purification, pasteurization, evaporation and drying process) (Salehi and Kashaninejad, 2014). The viscosity of polysaccharide gums is largely influenced by the particle size and distribution, molecular weight and ratio of soluble to insoluble matters (Larrauri *et al.*, 1997). The textural and rheological properties of plant gums depend on the method and condition of extraction, purification and drying. The drying process can provide a broad range of molecular weight depending on the type and condition of drying, thus varying the viscosity (Nep and Conway, 2011; Amid and Mirhosseini, 2012). Nep and Conway (2011) also demonstrated that the grewia gum showed different degree of viscosity varying from 0.20 to 0.32 Pa.s depending on the drying method. They reported that air-dried grewia gum showed higher viscosity than spray-dried and freeze-dried grewia gum.

In addition, the color of the dried product is an important quality factor, which is affected by the drying conditions. The most commonly used drying techniques applied for plant gums included oven

*Corresponding author.
Email: *F.Salehi@basu.ac.ir, FS1446@Yahoo.com*

drying (Wang *et al*., 2010), spouted bed drying (Cunha *et al*., 2000), microwave vacuum drying (Sundaram and Durance, 2008), freeze drying (Barresi *et al*., 2009; Teixeira-Sá *et al*., 2009), vacuum drying (Wang *et al*., 2009) and spray drying (Amid and Mirhosseini, 2012; Nep and Conway, 2011).

There is no study available in the literatures that investigate the effect of different drying techniques and temperature on the rheological and textural properties of basil seed gum. Hence, the purpose of present study was to investigate the influence of different drying techniques (oven drying (40-80°C), freeze drying and vacuum oven drying) on the rheological and textural properties, and color changes of basil seed gum.

Materials and Methods

Extraction of gum

Basil seeds were purchased from a local market in Gorgan, Iran. The cleaned basil seeds were soaked in distilled water (pH=7 and water/seed ratio 20:1) at 25°C for 20min. Separation of the hydrocolloid from the swollen seeds was achieved by passing the seeds through an extractor equipped (Panasonic, MJ-J176P, Japan) with a rotating plate that scraped the gum layer on the seed surface (Salehi *et al*., 2014). The crude gums (extracted mucilage) were filtered and passed through a 25 mesh sieve (0.71mm diameter) and then collected. The extracted mucilage with concentration of 0.6% w/w was considered as the control sample (CS).

Drying methods

Three drying techniques of: oven drying (40-80°C), freeze drying and vacuum oven drying were selected.

Oven drying

The dispersions of basil seed gum were dried in an air circulated oven at 40, 50, 60, 70 and 80°C (convection oven, Memmert Universal, Schwabach, Germany) for 48h. The dried samples were milled and passed through a 35mesh sieve (0.50 mm diameter). Then, the milled powder was weighed and stored in the air-tight bottle prior to the investigation.

Freeze drying

The freeze drying was carried out by using a freeze dryer (Operon freeze-dryer, Operon Co Ltd, Korea). The cups of basil seed gum dispersions were transferred into freeze dryer chamber for 48h (Salehi and Kashaninejad, 2015). The freeze-dried basil gum was milled and passed through a 35 mesh sieve (0.50 mm diameter) and packed in the air-tight bottles prior to the investigation.

Vacuum oven drying

The extracted basil seed gum was dried in a vacuum oven dryer (Vacuum oven VO, Memmert Universal, Schwabach, Germany) for 48 h. The vacuum and temperature were maintained at 100mbar and 50°C, respectively (Salehi and Kashaninejad, 2015). The dried sample was milled and passed through a 35mesh sieve (0.50 mm diameter). Then, the milled powder was weighed and stored in the air-tight bottle prior to the investigation.

Sample preparation for texture, viscometer and image analysis

Dispersion of basil seed gum (w/w) were prepared by dispersing the basil seed gum in distilled water, and two levels of concentration were employed: 0.6% (w/w) for evaluation of shear rate dependency and image processing, and 3% (w/w) for investigation of the textural properties of basil seed gums. The prepared solutions were kept for 24 h at room temperature to complete hydration of the gum.

Apparent viscosity

The viscosity of crude and dried basil seed gum was measured using a rotational viscosimeter manufactured by Brookfield Engineering Laboratories (Brookfield, model RVDV- II+ pro, USA) after 24 h of hydration of the gum solution (about 600 ml for every experiment). The rheological parameters of basil seed gum at different logarithmic shear rate of 0.6 to 120s^{-1} were studied using spindle No.S02 at 18 rotations and 25°C. Shear rate and shear stress values were calculated using the viscosity data according to Mitchka's equations (Mitschka, 1982). Different viscous flow models (Power law, Bingham, Herschel-Bulkley and Casson) were used to fit the experimental shear stress-shear rate data of basil seed gum solution (Salehi and Kashaninejad, 2015):

Modeling of rheological behavior

Power law model:

$$\tau = k_p \dot{\gamma}^{n_p} \quad (1)$$

Where τ is shear stress (Pa), k_p is the power law consistency coefficient (Pa.s^n), is the shear rate (s^{-1}) and n_p is the power law flow behavior index (dimensionless).

Bingham's model:

$$\tau = \tau_{0B} + \eta_B \dot{\gamma} \quad (2)$$

Where η_B is called the Bingham plastic viscosity (Pa.s) and τ_{0B} is the Bingham yield stress (Pa).

Herschel-Bulkley's model:

$$\tau = \tau_{0H} + k_H \dot{\gamma}^{n_H} \quad (3)$$

Where k_H is the consistency coefficient (Pa.s^n), τ_{0H} is the yield stress (Pa) and n_H is the flow behavior index for Herschel-Bulkley model.

Casson's model:

$$\tau^{0.5} = \tau_{0C}^{0.5} + \eta_C \dot{\gamma}^{0.5} \quad (4)$$

Where η_C is the plastic viscosity (Pa.s) and τ_{0c} is the yield stress (Pa) for Casson model.

Modeling of data was performed with non-linear and multiple regression analysis functions and parameters associated with different models estimated from the experimental data using Curve Expert program version 1.34.

Textural analysis

The textural analysis of the gum sample was performed using a texture analyzer (TA-XT Plus, Stable Micro Systems Ltd., Surrey, UK) with a 25 mm diameter cylindrical probe and a test speed of 1.0 mms^{-1}. The gums were filled in a bowl with a product height of 50 mm (d=50 mm, h=60 mm). Penetration test was performed up to 15 mm deformation. Other parameters were defined as: pre-test speed 1.0mms^{-1}, post-test speed 1.0 mms^{-1} and trigger force 5 g. All experiments were performed at room temperature (25°C). The texture profile measurements were used to analyze the parameters hardness, stickiness, consistency and adhesiveness. The results were processed with Texture Expert 1.05 (Stable Microsystems) software. For data analyzing a typical time-force diagram was used.

Color measurement

In order to investigate the effect of drying methods on color changes of dried basil seed gum, a computer vision system was applied. In this research, sample illumination was achieved with two fluorescent lights (10W, 40 cm in length), were placed in a wooden box (0.5 m×0.5 m×0.5 m). The interior walls of the box were painted black to minimize background light. A color digital camera (Panasonic, Model DMC-FS42, Japan) was located vertically at a distance of 20cm from the sample.

Since the computer vision system perceived color as RGB signals, which is device-dependent, the images taken were converted into L^* a^* b^* units to ensure color reproducibility. In the L^* a^* b^* space, the color perception is uniform, and therefore, the difference between two colors corresponds approximately to the color difference perceived by the human eye. The parameters measured were L^* (lightness/darkness, ranges from 0 to 100), a^*(redness/greenness, ranges from -100 to 100) and b^* (yellowness/blueness, ranges from -100 to 100). The hue angle (°), hue = arctg (b^*/a^*), expresses the colour nuance and values are defined as follows: red-purple: 0°, yellow: 90°, bluish-green: 180°, and blue: 270°. Hue angle (H) of the films was calculated as follows (Salehi and Kashaninejad, 2015):

$H = \tan^{-1}(b^*/a^*)$ when $a^* > 0$ and $b^* > 0$

$H = 180° + \tan^{-1}(b^*/a^*)$ when $a^* < 0$

$H = 360° + \tan^{-1}(b^*/a^*)$ when $a^* > 0$ and $b^* < 0$

The calculation of color changes (ΔE) for total color difference and C^* (Chroma) for saturation were made with the following equations (Salehi and Kashaninejad, 2015):

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (5)$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (6)$$

In this study, the image analysis of dried gum was performed using Image J software version 1.42e, USA. All experiments were conducted on three replications and the data was presented as a mean of each experiment.

Results and Discussion

Apparent viscosity

The functional properties (viscosity and rheological properties) of gums are greatly sensitive to the drying process (Nep and Conway, 2011). Shear rate dependency of the apparent viscosity of basil seed gum solutions at different drying process is shown in figure 1. It was found that the apparent viscosity of basil seed gum decreased as the shear rate increased (shear thinning or pseudoplastic behavior). The apparent viscosity of basil seed gum decreased from 7.64 to 0.15 Pa.s with increasing shear rate from 0.6 to 120s^{-1} (vacuum oven drying method). Wang *et al.* (2009) also reported the similar pseudoplastic (or shear-thinning) flow behaviour for freeze-dried, oven dried, spray-dried and vacuum oven-dried flaxseed gums, respectively. Previous researchers also found that freeze-dried peach tree gum exhibited the pseudoplastic (or shear-thinning) flow behaviour at different concentrations. As reported by Cui (2005), the viscosity of gum dispersions decreased with

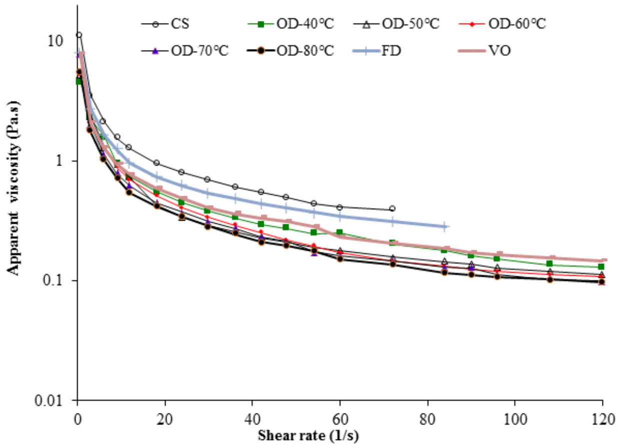

Figure 1. Effect of different drying methods on apparent viscosity of Basil seed gum solution as a function of shear rate; control sample (CS), oven drying (OD), freeze drying (FD), and vacuum oven drying (VO).

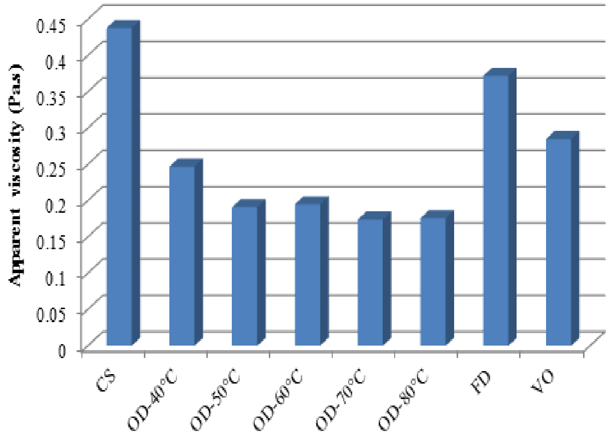

Figure 2. Effect of different drying techniques on apparent viscosity of Basil seed gum (shear rate=54s^{-1}); control sample (CS), oven drying (OD), freeze drying (FD), and vacuum oven drying (VO).

increasing the shear rate due to a decreasing number of chain entanglements at high shear rates.

Drying process of basil seed gum led to decrease in the viscosity (figure 2). The freeze dried gum exhibited the highest viscosity among all dried gums. In the present study, the apparent viscosity of basil seed gum varied from 0.438 to 0.174Pa.s (shear rate=54 s^{-1}) depending on the drying method. The apparent viscosity significantly ($P \leq 0.05$) decreased from 0.247 to 0.176 Pa.s with increasing temperature from 40 to 80°C (shear rate=54 s^{-1}, oven drying method). Wang *et al*. (2009) compared the viscosity of flaxseed gum dried by different techniques. They reported that the viscosity of flaxseed gum varied from 1.382 to 5.087Pa.s. The significant changes ($P \leq 0.05$) of apparent viscosity could be due to the substantial impact of drying process on the chemical composition of basil seed gum. As also explained by Simas-Tosin *et al.* (2010), the presence of free, reducing oligosaccharides, phenolics and inorganic salts, beyond polysaccharide in the gum structure gives a more viscous solution. The effect of different drying methods on the viscosity of polysaccharide gum could be due to different proportions of soluble to insoluble matters. Amid and Mirhosseini (2012) reporeted that the drying methods significantly ($P<0.05$) influence the ratio of soluble to insoluble matters depending on the drying condition, thereby changing the viscosity of powder.

Based on the Power law model, all basil seed gum samples exhibited a pronounced shear-thinning behavior (pseudoplastic), characterized by the flow behavior index values less than 0.34 at all drying condition. The results showed that the k_p values were between 1.96 and 3.93 Pa.s^n and the n_p ranged from 0.17 to 0.34. The parameters obtained for the Bingham model for basil seed gum at different drying method showed that all samples were characterized by a yield stress. The amounts of Bingham yield stress (τ_{0B}) and Bingham viscosity were changed from 2.92 to 5.76Pa and from 0.02 to 0.11Pa.s, respectively.

The rheological parameters of basil seed gum obtained by fitting the experimental shear stress-shear rate data to the Heschel-Bulkley model at different drying method are given in Table 1. In this study, τ_{0H}, k_H and n_H values appeared in the range of 0.11-0.87Pa, 1.59-3.32Pa.s^n and 0.15-0.38, respectively. Marcotte *et al*. (2001) and Song *et al.* (2006) reported that the Heschel-Bulkley flow behavior index for xanthan was 0.24 and 0.23, respectively. The parameters in the Casson model determined from regression analysis on data showed that the Casson yield stress, τ_{0C}, ranged from 2.56 to 4.24Pa and the Casson viscosity, η_C, were between 0.07 and 0.19Pa.s.

Textural properties

Large deformation tests have a high correlation with sensory evaluation of texture in gels and have practical importance since foods or gelled systems are subjected to such deformation during processing or consumption and have this capability to predict multidimensional sensory characteristics of food texture (Totosaus *et al.*, 2005). As the basil seed gum is a new source of hydrocolloid, large deformation tests were carried out to obtain more information about the gel characteristics and self associations between its chains during drying. The parameters of penetration tests are summarized in Table 2.

Hardness

The maximum force was taken as an indication of gel hardness, which indicates the strength of gel (Angioloni and Collar, 2009). The hardness values of basil seed gum gel significantly ($P \leq 0.05$) decreased

Table 1. The Heschel-Bulkley model parameters for Basil seed gum at different drying method.

Drying method	τ_{0H} (Pa)	k_H (Pa.s^n)	n_H	r	SE
CS	0.52	3.32	0.32	0.998	0.18
OD-40°C	0.11	2.59	0.23	0.981	0.35
OD-50°C	0.25	1.99	0.23	0.959	0.38
OD-60°C	0.69	2.45	0.15	0.969	0.25
OD-70°C	0.50	1.91	0.21	0.986	0.18
OD-80°C	0.47	1.59	0.24	0.988	0.17
FD	0.79	1.97	0.38	0.999	0.13
VO	0.87	3.22	0.22	0.994	0.23

* Control sample (CS), Oven drying (OD, 50-80°C), freeze drying (FD), vacuum oven (VO).

Table 2. The influence of different drying method on textural properties of Basil seed gum

Drying method	Textural parameters			
	Hardness (g)	Stickiness (g)	Consistency (g.s)	Adhesiveness (g.s)
OD-40°C	67.9	13.1	699.8	131.8
OD-50°C	54.5	12.8	581.2	147.6
OD-60°C	52.6	11.3	478.1	119.0
OD-70°C	47.4	11.9	382.5	148.7
OD-80°C	42.2	12	362.6	131.5
FD	75.5	18.1	803.7	190.8
VO	71.1	19.3	756.3	244.8

* Oven drying (OD, 50-80°C), freeze drying (FD), vacuum oven (VO).

from 67.9 to 42.2 g with increasing temperature from 40 to 80°C (oven drying method) (Table 2). The hardness values of oven dried gum samples were lower than the freeze and vacuum oven dried samples.

Stickiness

Stickiness (g force) is defined as the maximum force necessary to overcome the attractive forces between the surface of the food and the surface of the probe with which the food comes in contact. In this study, the amounts of stickiness significantly ($P \leq 0.05$) were changed from 11.3 to 19.3g.

Consistency

The area under the curve up to the target deformation was taken as a measurement of consistency (Angioloni and Collar, 2009). The internal strength of bonds in basil seed gum gel increased when extracted gum was dried at low temperature that is considerable at freeze drying method (803.7 g.s) (Table 2). The consistency values decreased from 699.8 to 362.6g.s with increasing oven dryer temperature from 40 to 80°C. A comparative study of the effect of hot air drying and microwave vacuum drying on the structure of agricultural products was conducted by Giri and Prasad (2007). It was visible that in the air dried samples there were less opened pores and structures than in samples dried by microwave vacuum, indicating shrinkage and severe degradation of the tissue during hot air drying.

Adhesiveness

Adhesiveness is the ability of the gel sample to become sticky. It is a surface characteristic, which depends on a combined effect of adhesive and

Table 3. Comparison between different drying methods on color change of Basil seed gum

Drying method	ΔE*	L*	a*	b*	Hue value (°)	C*
CS	-	52.87 (±4.01)	-1.10 (±1.21)	3.94 (±3.33)	105.61	4.09
OD-40°C	6.23	46.76 (±3.24)	-1.94 (±1.22)	3.06 (±2.04)	122.33	3.63
OD-50°C	11.09	45.98 (±3.41)	-2.01 (±1.35)	12.59 (±3.74)	99.09	12.75
OD-60°C	7.68	45.21 (±3.32)	-1.30 (±1.33)	3.46 (±3.41)	110.60	3.69
OD-70°C	10.08	42.84 (±3.41)	-0.93 (±1.52)	4.97 (±3.68)	100.57	5.05
OD-80°C	12.16	40.75 (±4.29)	-1.82 (±1.57)	3.19 (±3.28)	119.74	3.67
FD	0.84	52.31 (±3.56)	-1.56 (±1.28)	3.50 (±3.12)	113.96	3.83
VO	3.59	49.41 (±2.84)	-2.03 (±1.18)	3.87 (±2.69)	117.75	4.37

* Control sample (CS), Oven drying (OD, 50-80°C), freeze drying (FD), vacuum oven (VO); L: brightness (+100)/darkness (+0), a: redness (+60)/greenness (-60) coordinate, b: yellowness (+60)/blueness (-60) coordinate, C: chroma.

cohesive forces, viscosity, and viscoelasticity of the sample. This parameter is important because it may influence overall quality, appearance, and shelf life of food (Huang *et al.*, 2007). As shown in Table 2, the basil seed gum gel adhesiveness properties varied from 119.0 to 244.8 g.s at different drying temperatures and methods.

Color assessment

Recently, image analysis has been used as a promising approach to the objective assessment of a dried product's quality. Color usually is the first quality parameter that is evaluated by consumers and is critical in the acceptance of the product. The results of color measurement of basil seed gum solutions dried at different condition are presented in Table 3. The different drying methods caused various degradation of color parameters in basil seed gum. An overall examination of Table 3 has highlighted that changes occur in color parameters ($\Delta E > 0$) and the rise in temperature has a negative effect on the ΔE of gum. As shown in Table 3, the ΔE values significantly ($P \leq 0.05$) were varied from 0.84 to 12.16 at different drying temperatures and methods. It should also be noted that freeze dried gum had low ΔE values compared to the other samples.

The color of oven dried gum was darker (low L^* value) compared to the freeze and vacuum oven dried samples. Table 3 reveals that increasing oven temperature from 40 to 80°C caused a decrease in L^* values from 46.76 to 40.75. Therefore, temperature control in oven drying allowed improvement of gum color. The chroma is measure of chromaticity (C^*), which denotes the purity or saturation of the colour. Chroma parameter values varied from 3.63 to 12.75 at different drying temperatures and methods. Therdthai and Zhou (2009) reported that high temperature during drying of mint leaves could lead to increase ΔE values. The L^* values decreased by increasing drying temperature, which shows diminishing of brightness of gum solution. Generally, hue angle is measured to represent visual attributes. From the results (Table 3), basil seed gum gels were in first quadrant of hue angle (90–180°) and were in the range of yellow hue to bluish-green hue. This hue value of gum gels is an indication that gum is desirable to be used for food packaging purposes, especially for light sensitive packaged materials. Based on the results it can be concluded that freeze drying process can achieve better product quality.

Conclusion

Basil seed has remarkable amounts of gum with good functional properties. In the current study, the effect of different drying methods and temperature on the rheological and textural properties, and color changes of basil seed gum was investigated. The results indicated that all dried basil seed gums showed the pseudoplastic flow behavior (shearthinning fluid). The results revealed that the freeze-dried gum exhibited the highest viscosity among all dried basil seed gums. It can be seen that the Heschel-Bulkley's model was found the most suitable model to describe the flow behavior of basil seed gum solutions over the whole experimental range. The amounts of hardness, stickiness, consistency and adhesiveness of basil seed gum gel (3%) changed from 42.2 to 75.5 g, 11.3 to 19.3 g, 362.6 to 803.7 g.s, and 131.5 to 244.8 g.s at different drying condition. The results indicated that the freeze-dried gum exhibited the highest hardness and consistency. The present study also demonstrated that the color of basil seed gum was influenced by the drying process. The extracted mucilage samples dried in oven at 80ºC were more susceptible to color changes. The color of oven dried gum was darker (low L^* value) compared to the freeze and vacuum oven dried samples.

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