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FULL PAPER

The effect of blanching and foam mat drying on the physico-chemical characteristics of white sweet potato (*Ipomoea batatas* L.) inulin

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Abstract

White sweet potato (*Ipomoea batatas* L.) is one of the tubers that have the potential to produce inulin and largely abundant in Indonesia. Several factors can affect the physical and chemical characteristics of inulin including the preliminary treatment and the drying method. The purpose of this study was to determine the effect of blanching and foam mat drying method on the physical and chemical characteristics of white sweet potato inulin. The physical and chemical characteristics evaluated include solubility, total sugar, sugar reductions, discussed inulin and inulin molecular weight. The experimental design in this study used a Completely Randomized Design (CRD) with two factors, namely blanching and differences in egg white composition (2%; 6%; and 10%). The data were processed statistically using One-Way ANOVA with a significance level of 5%. The results showed that blanching and foam mat drying can affect the yield, solubility, water absorption, moisture content, and molecular weight of inulin. The blanched and unblanched samples with an increase in albumen concentration will reduce the yield, moisture content and molecular weight and increase solubility and water absorption. All blanched formulations produced higher yield, moisture content, solubility, and water absorption than the unblanched formulation.

1. Introduction

Inulin is a prebiotic dietary fiber carbohydrate-based fat substitute that is capable of increasing the viscosity and gel form, providing mouthfeel and texture, and improving water holding capacity (Öztürk and Serdaroglu, 2016). Inulin consists of long chains of 2-60 fructose molecules, which are connected by β-(2-1) bonds. Fructose molecules are associated with glucose molecules with α-bonds (1-2). Inulin can easily be mixed with other ingredients and dissolve in water (Roberfroid, 2007).

According to the Data and Information Center of the Ministry of Industry of the Republic of Indonesia in 2011, Indonesia's imports of inulin in 2005 worthed USD 160.7 million and this value increased almost two times in 2009; the value of Indonesia's imports of inulin amounted up to USD 306.5 million (Ministry of Industry of Indonesia, 2011). The ingredients for the production of commercial inulin are Jerusalem artichoke (*Helianthus tuberosus*) and chichory (*Chicoryum intybus L.*) plants, but these two plants cannot be found in Indonesia due to climate reasons (Indriyanti *et al*., 2015). Meanwhile in Indonesia, the exploration of inulin source from local plants can be obtained from dahlia tubers (*Dahlia L. sp.*), Gembili (*Dioscorea esculenta*), and jicama (*Pachyrhizus erosus*) (Gupta *et al*., 2003).

Inulin is widely available on stem tubers which are one source of carbohydrate (Van De Wiele *et al*., 2007). Sweet potato is one of the tubers that have the potential to contain inulin and which is tremendously abundant in Indonesia. According to the Ministry of Agriculture of The Republic of Indonesia (2016), the national sweet potato production from 2011-2015 had an average production of ±2.334 million tons/year putting West Java Province as the largest producer. Central Java Province has a fairly high number of sweet potato production, namely with an average production of ±167,870 thousand tons/year.

Based on Arfiani (2016) study, white sweet potatoes have inulin purity of ±5.5%. So, that research was done on extraction, isolation, and characterization of inulin in white sweet potatoes. According to Inchuen *et al*. (2014), the enzymatic activity in raw tubers during the drying process is related to inulin degradation and browning reactions. Blanching is known to obstruct the activity of the polyphenol oxidase enzyme (Takeuchi and

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Nagashima, 2011). Besides blanching, the inulin produced is also influenced by the drying method (Termrittikul *et al*., 2018).

Foam mat drying is a method of drying liquid material which is previously made into foam by adding foaming agent, by stirring or shaking, then drying process (Mounir, 2017). The material dried by foam mat drying method characteristics is the crumb structure, which easily absorbs water and dissolves in water (Winarti *et al*., 2013). The addition of foaming agents and fillers can affect the physical and chemical characteristics of inulin. The purpose of this study is to determine the combination effect of blanching and foam mat method on the physical and chemical characteristics of white sweet potato (*Ipomoea batatas* L.) inulin since previous studies only carried out the treatment by separately using blanching and foam mat drying methods.

2. Materials and methods

2.1 Materials

The materials used in the extraction, isolation, and characterization stages of inulin were fresh white sweet potato variety from Korea, obtained from Matesih, Karanganyar, Central Java. In addition, other materials required aquadest, 95% ethanol, Na-CMC, and egg white 2%, 6%, and 10%, concentrated H_2SO_4 (Merck KGaA), pure phenol (Merck KGaA), antioxidants (Merck KGaA), DNS (Merck KGaA), NaOH (Merck KGaA), pure phenol (Merck KGaA), Na_2SO_3 (Merck KGaA), Rochelle salt (Merck KGaA), distilled water, and standard inulin from Chicory (Fibruline ex cosucra).

2.2 Preparation of Inulin extraction

Fresh sweet potatoes were washed, peeled and chopped to a thickness of 12 mm. The cut sweet potatoes were then blanched for 1 min to activate the polyphenol oxidase (PPO) enzyme (Inchuen *et al*., 2014). Blanched sweet potatoes were allowed to cool to 25°C for 1 min (Inchuen *et al*., 2014) and dried. The dried sweet potatoes were ground and sifted through the 80-mesh sieves according to SNI 01-3751-2009 regarding the level of refinement of sweet potato flour (Ambarsari *et al*., 2009). The activating of the PPO enzyme will cause the browning reactions in tubers (Inchuen et al., 2014) while the 12 mm thickness was to provide more effective processing (Koswara, 2013).

The insulin extraction process was performed by mixing the flour with distilled water at a ratio of 1: 5 or 0.2 mg/mL (Luwidharto, 2019). The mixture was soaked for 1 hr and heated to 80°C for 30 mins. Then, it was filtered using double layer. The filtrate underwent the evaporation process with a vacuum rotary evaporator at 73°C for 2.5 hrs with a speed of 60 rpm. The extraction process was carried out twice to ensure all inulin was extracted. According to Kosasih (2015), the °Brix value of the inulin extract should be at least 30%.

To isolate the inulin, the evaporated filtrate was immersed in 95% ethanol at a ratio of 1: 2 for 12 hrs. Then, the mixture was centrifuged at 5000 rpm for 15 mins to precipitate.

2.3 Foam mat drying of inulin

The precipitate was dried using the foam mat drying method according to Winarti *et al*. (2013). Prior that, the precipitated inulin was mixed with Na-CMC as the filler and egg white foaming agents at the concentrations of 2%, 6% and 10% to form the foam (Harmayani *et al*., 2011). The foam was then dried in the cabinet dryer for 3 hrs at 60°C.

2.4 Total sugar and sugar reduction of white sweet potato flour

The white sweet potato flour was analyzed for the total sugar and sugar reduction. The total sugar was analyzed by taking 2 mL of the sample which has been diluted beforehand. Then, 0.05 mL of 80% phenol solution was added and vortexed. After that, 5 mL of H_2SO_4 was added, vortexed and left for 10 mins in 25°C water bath. It was then calibrated at 490 nm wavelength. To begin the analysis, 1 mL of the sample was diluted in the test tube with 0.33 mL of Rochelle salt 40% and 1 mL of DNS reagent. The mixture was heated to 99°C for 5 mins until brownish red color. The mixture was then cooled at room temperature and measured at a wavelength of 575 nm with a spectrophotometer (Miller, 1959).

2.5 Inulin solubility

The Whatman filter paper was heated in the 105°C oven for 10 mins. Next, it was taken out and cooled in a desiccator. The heating process was repeated until the weight is visibly constant (A). The product sample of 3.5 g (initial weight/W1) was put into 150 mL of 25°C of water and filtered with the heated filter paper. The filtrate was then dried at 105°C for 3 hrs and then cooled in the desiccator. The final weight was recorded when the weight had reached a constant (B) (Yuwono and Susanto, 2001).

$$Solubility\ (\%) = \frac{(W1 - W2)}{W1} \times 100\%$$

Where W2 = B – A, W1 = initial sample weight, and W2 = final sample weight.

2.6 Inulin water absorption

Sample of 1.5 g (W1) was wrapped with filter paper and tied with a string. The sample was then hung in a har that has been filled with half with water and the jar was sealed tightly. After 5 hrs, the sample was removed and weighed (W2) (Yuwono and Susanto, 2001).

$$Water\ Absorption\ (\%) = \frac{W2 - W1}{W1} \times 100\%$$

2.7 Inulin water content

An empty cup was dried in the oven at 105°C for 10 mins. About 1 – 2 g of sample was weighed into the dried cup and dried in the oven at 105°C for 5 hrs. After drying, the cup was taken out and cooled in the desiccator for 15 mins. The cooled cup was weighed repeatedly until constant (AOAC, 2002).

$$Water\ Content\ (\%) = \frac{W1 - W2}{W1} \times 100\%$$

2.8 Inulin availability and molecular weight

Integrated LC system (Hitachi L 6200) Q-tof mass spectrometer through the ESI (Electrospray Ionisation) system with the scan modes ranging 100 – 1200 mz at 140°C was used. Column C18 Supelco, with a column length of 250 x 2 mm and a particle size of 5 µL was used. Water was used as the solvent at the ratio of 90% methanol to 10% at a flow rate of 1 mL/min. The injection volume was 20 µL (Eichhorn and Knepper, 2001).

2.9 Data analysis

The data obtained are analyzed statistically using the one-way ANOVA SPSS 16.0 method and Duncan's Multiple Range Test (DMRT) to determine significant difference at the level of $\alpha = 0.05$.

3. Results and discussion

3.1 Total sugar and sugar reduction of white sweet potato flour

Based on Table 1, the total value of sugar produced by white sweet potato flour is 15.06% and the sugar reduction is 4.62%. The total sugar is higher and the sugar reduction is lower than that of Koua *et al.* (2018), stating that the total value of white sweet potato sugar ranged from 6.10 - 11.92% and sugar reduction ranged from 0.28 - 0.56%. However, the value of sugar reductions produced by white sweet potato flour is 4.62% which was higher than that of Apolinário *et al.* (2017) who claimed that sugar reduction inulin before extraction and isolation was 2.77% with *Agave sisalana* as raw material. In this study, 4.8% of inulin and 2.77% of sugar reduction were produced. So, white sweet potatoes have the potential to produce inulin and the next step can proceed into the extraction and isolation process.

Table 1. Total sugar and sugar reduction of white sweet potato flour

Analysis	Sample Content (%)	Reference Content of White Sweet Potato Flour (%)
Total Sugar	15.060±0.071	6.10 – 11.92
Sugar reduction	4.620±0.028	0.28 – 0.56

Sample references based on Koua *et al.* (2018).

3.2 Yield

Based on Table 2., the white sweet potato inulin blanching and non-blanching treatment results were obtained with concentration variation of egg albumin at the range of 1.98% to 7.30%. The DMRT test results show that the blanching treatment and variation of egg albumin concentration are significantly different from the yield of white sweet potato inulin because it is located in a different subset. The highest yield value was found in blanching white sweet potato inulin with 2% (F1) egg albumin concentration of 22.533%. The yield of inulin is higher than that of Arfiani (2016) which had the highest white sweet potato yield of 5.5%. The inulin resulted from foam mat drying method is higher than inulin by oven drying method. Haryanto (2007) affirmed that flour processing using a foaming agent will affect the amount of yield because the use of foaming agent causes the total solids of the product to increase and the result to increase as well.

The higher the concentration of the foaming agent, the lower the result will be. This is due to the high amount of air trapped in the foaming agent with high concentration so that water can evaporate easily in the drying process (Harmayani *et al.*, 2011). The increasing concentration of foaming agent (egg albumin) will expand the surface area and give a porous structure of the material so that it will increase the drying speed. The layer on foam dries more quickly than the non-foam layer under the same conditions. Therefore, the results decreased (Kusumah *et al.*, 2017).

It can also be seen that the yield of inulin blanching has a higher value than the yield of non-blanching inulin. This is caused by water absorbed in the blanching process itself (Inchuen *et al.*, 2014). In addition, starch granules also consist of two fractions, amylose and amylopectin which can be separated from hot water, and at temperatures between 55 – 65°C starch granules increase in volume even if they reach the gelatinization temperature (Efendi *et al.*, 2015). The white sweet potato inulin result with foam mat drying method has a positive correlation with its moisture content.

Table 2. Yield, solubility, water absorption, and water content of white sweet potato inulin

Formulation	Yield (%)	Solubility (%)	Water Absorption (%)	Water Content (%)
F0	5.066±0.001[a]	3.9721±0.0835[c]	8.091±0.094[a]	11.358±0.376[c]
F1	22.533±0.001[d]	4.6673±0.8300[c]	11.052±0.805[b]	9.540±0.282[b]
F2	20.323±0.001[c]	4.7146±0.7696[c]	12.479±0.880[c]	9.370±0.366[c]
F3	19.770±0.001[b]	4.7227±0.9668[c]	12.895±0.720[c]	9.363±0.245[c]
F4	7.303±0.004[g]	3.6814±0.8842[b]	7.042±0.960[a]	8.681±0.255[a]
F5	6.801±0.001[f]	3.7278±1.2050[b]	7.750±0.668[a]	8.503±0.384[a]
F6	6.668±0.009[e]	3.7426±1.1690[b]	8.104±0.616[a]	8.242±0.330[a]

Values followed by the same letter notation in the same column are not significantly different according to the DMRT test at the significance level of 5%.

F0: Control; F1: Blanching, egg albumin 2%; F2: Blanching, egg albumin 6%; F3: Blanching, egg albumin 10%; F4: Non-blanching, egg albumin 2%; F5: Non-blanching, egg albumin 6%; F6: Non-blanching, egg albumin 10%

The result of inulin is higher than that of Arfiani (2016) which had the highest white sweet potato yield of 5.5%. Inulin recovery with foam mat drying method was higher than inulin by oven drying method.

3.3 Solubility

Based on Table 2, there is an increase in the value of solubility as the concentration of foaming agents increased in inulin both in the blanched and unblanched samples. This is caused by the high number of hydroxyl group (OH) in inulin so that inulin is polar in nature and can easily dissolve in water. The increase in solubility is caused by trapped air during foam formation, resulting in a more porous (porous) inulin which is easily penetrated by water when dissolved (Winarti *et al*., 2013). Protein egg albumin provides good foaming ability and high foam stability, allowing rapid adsorption on air and water surfaces resulting in a stable foam with high solubility and water absorption (Mounir, 2017). The solubility of inulin is inversely proportional to the degree of polymerization and consequently the higher the degree of polymerization the lower the solubility (Mensink *et al*., 2015).

It can be asserted that foam mat drying can increase inulin solubility. Mounir (2017) affirmed that the material dried by the foam mat drying method has the characteristic of crumb structure, absorbs water easily, and soluble in water. The solubility of white sweet potato blanched inulin is higher than the non-blanched one due to the swelling of starch granules in hope that the hydroxyl group of the starch fraction was able to bind the surrounding water in greater amounts trapped in the sample (Efendi *et al*., 2015). Based on the DMRT test, there was a significant effect between blanching and the concentration of foaming agent on the solubility of white sweet potato inulin because it was located in a different subset. The solubility of white sweet potato inulin using the mat drying method has a positive correlation with water absorption.

The average value of white sweet potato solubility was obtained at 27.84%. This value is higher than the solubility value standard inulin Orafti *GR which is 7.59% and Jerusalem artichoke which is 6.99 – 8.07% (Rubel *et al*., 2018). This difference can be caused by the drying method and the characteristics of the material used.

3.4 Water absorption

There is an increase in water absorption as the concentration of foaming agents increased in blanched inulin and non-blanched (Table 2). According to Inchuen *et al*. (2014), samples with blanching treatment will be easier to absorb water than those unblanched. This is due to the swelling of starch granules so that the hydroxyl groups of starch fractions can bind the surrounding water in greater amounts and are trapped in the sample (Efendi *et al*., 2015). Water absorption of white sweet potato inulin foam mat drying method has a positive correlation with its solubility. Based on the DMRT test, there was a significant effect between blanching and the concentration of foaming agents on the absorption of white sweet potato inulin because it is located in a different subset.

Inulin water absorption is caused by free hydroxyl (OH) groups possessed by inulin. The hydroxyl group causes inulin to become hygroscopic and it can bind water more easily (Susanti and Putri, 2014). The increase in inulin water absorption dried by the foam mat drying method is due to a large amount of air trapped during the formation of foam causing more OH groups to be free of inulin molecules so that it is easier to bind water vapor from the surroundings (Harmayani *et al*., 2011). According to Winarti (2013), the dry powder produced from the foam mat drying method has a low density, so it is easy to bind moisture from the surroundings.

The value of white sweet potato inulin water absorption average is 9.76%. This value was higher than the control inulin and Jerusalem artichoke inulin which had values of 8.09% and 5.8 − 7.2%, respectively (Rubel *et al*., 2018). The value of white sweet potato inulin water absorption was lower than foam mat drying gembili tuber inulin which was 34.39% (Winarti *et al*., 2013). The difference in the value of inulin water absorption is due to the characteristics of each different material such as the chemical content (carbohydrate, protein, fiber), drying method, and density (Ntau *et al*., 2017).

3.5 Water content

Based on Table 2, an increase in water content is inversely proportional to the increase in the concentration of foaming agents in the blanching formulation. The formation of foam in the drying process can reduce water levels inulin where the control inulin has a higher water content than other inulin. This is in accordance to with Winarti *et al*. (2013) saying that gas bubbles trapped in the foaming layer can improve the water evaporation process to produce dry powder with low density.

The water content in inulin blanching is higher than non-blanching inulin caused by water absorbed in the blanching process itself (Inchuen *et al*., 2014). The decrease in moisture content is caused by an increase in foaming agents that can increase the surface and porosity of the product, so the evaporation process occurs more quickly (Harmayani *et al*., 2011). A higher concentration of egg albumin will reduce the value of foam density and the longer the time of foaming time the foam density will be lower too because during the process of foaming the air will enter and will be trapped into the liquid phase therebyso that it becomes small bubbles. The development of foam will be higher and can expand the surface of the material and result in a faster drying process (Amalina and Koswara, 2017). The water content of white sweet potato inulin using the foam mat drying method has a positive correlation with its yield. Based on the DMRT test, there is a significant effect between blanching and foaming agent concentration on white sweet potato inulin water content because it was located in a different subset.

The whole sample has an average water content of 8.95% with a dry matter content of 91.05%. Winarti *et al*. (2013) found that gembili inulin water content (foam drying method with 2% foaming agent egg albumin and maltodextrin filler) at 9.29% and the water content of white sweet potato inulin was lower. These results were also lower than the standard inulin of Chicory tubers with inulin dry matter levels of 91.67% (Bouaziz *et al*., 2014) and Dahlia tubers with dry matter content of 92.2% (Melanie *et al*., 2015).

3.6 Inulin availability and molecular weight

In this analysis, standard chicory root inulin Fibruline ex cosucra was used with 91.4% purity to determine the presence of inulin in the sample.

Based on Figure 1, it can be stated that the inulin blanching sample retention time was T 2.64 with molecular weight 282.19 g/mol (F1), 306.58 g/mol (F2), and 248.66 g/mol (F3) in the order of the formulation. Whereas in non-blanching inulin samples the retention time was T 2.67 with a molecular weight of 282.06 g/mol (F4), 274.27 g/mol (F5), and 325.26 g/mol (F6) in the order of the formulation. In the control sample, the sample retention time was T 2.67 with a molecular weight of 285.19 g/mol. The inulin standard had a retention time of T 2.54 with a molecular weight of 253.38 g/mol. Based on these findings, it can be seen that the white sweet potato inulin has more molecular weight than standard inulin and consequently it can be used as a substitute for fat.

4. Conclusion

Based on the results of this study, it can be concluded white sweet potato inulin with a blanching treatment and foam mat drying has brighter appearance compared to inulin without blanching. In addition, the yield, solubility, water absorption, and water content were higher than white sweet potato inulin without blanching. The molecular weight of inulin blanching with foam mat drying is lower than inulin without blanching. Blanching and foam mat drying methods significantly influence the physical and chemical characteristics of white sweet potato (*Ipomoea batatas* L.) inulin.

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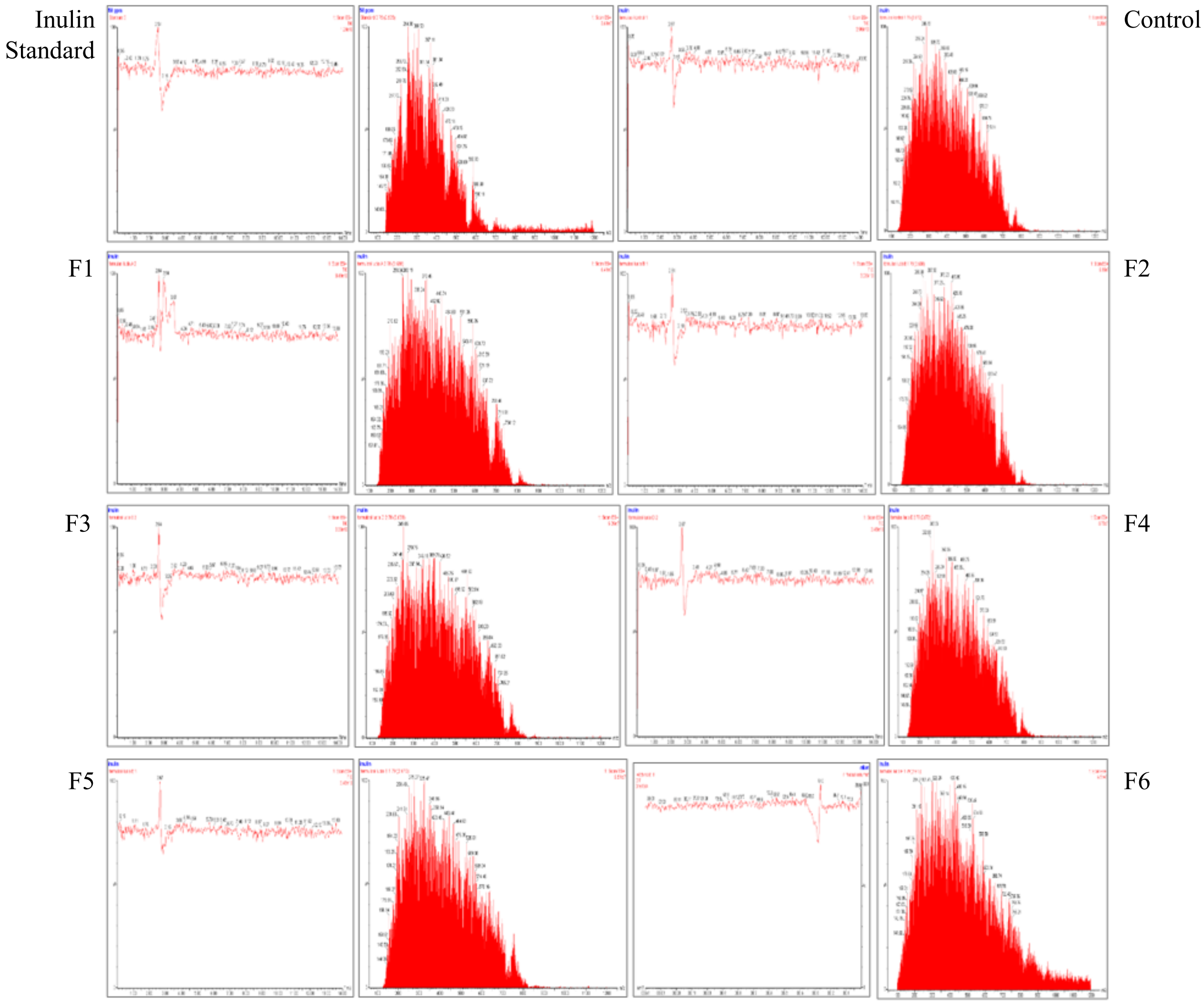

Figure 1. Chromatogram and spectrum of inulin standard, Control, F1, F2, F3, F4, F5, and F6 respectively.

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