Effects of dough resting time and saturated steam pre-treatment on the textural properties of superheated steam processed instant Asian noodles

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Pronyk, C., Cenkowski, S., Muir, W. E., Lukow, O.M., Wyatt, J. and Nicholson, D. 2008. **Effects of dough resting time and saturated steam pre-treatment on the textural properties of superheated steam processed instant Asian noodles.** Canadian Biosystems Engineering/Le génie des biosystèms au Canada **50**: 3.21–3.26. Evaluation of new processing methods for dried or instant Asian noodle products is difficult when working with limited quantities of flour, and small sample sizes to determine fundamental drying and textural characteristics. When evaluating new processing techniques it would be beneficial to utilize the same noodle sheet for as long as possible to reduce the variability between noodle sheets. As well, it may be necessary to process noodles in saturated steam to partially gelatinize starch before drying, as is done in industry. Results from these experiments showed there was no change due to resting time in the textural properties of adhesiveness, springiness, and cohesiveness for noodles processed only in superheated steam. Hardness and chewiness were lower only for the resting time of 20 min. Pre-treatment with saturated steam before superheated steam processing resulted in a harder, less cohesive and elastic noodle. The combined gelatinization of amylopectin and amylose-lipid was approximately 89% for superheated steam processed noodles and 90% for noodles pre-treated with saturated steam before processing. Thus, superheated steam processing alone was successful in gelatinizing starch. **Keywords:** superheated steam, resting time, starch gelatinization, textural properties, noodles.

L'évaluation de nouvelles méthodes pour la fabrication de nouilles asiatiques sèches ou instantanées s'avère difficile lorsqu'on travaille avec des quantités limitées de farine et des échantillons de petites tailles dans le but de déterminer les caractéristiques fondamentales au niveau du séchage et de la texture. Lors de l'évaluation des nouvelles méthodes de fabrication, il pourrait être bénéfique d'utiliser la même feuille de nouilles le plus longtemps possible dans le but réduire la variabilité qui existe entre des feuilles de nouilles différentes. De plus, il peut être nécessaire de traiter les nouilles à la vapeur saturée dans le but de gélatiniser partiellement la fécule avant le séchage comme c'est pratique courante en industrie. Les résultats de ces expériences ont montré que le temps de repos n'a eu aucun effet au niveau des propriétés texturales d'adhésion, de souplesse et de cohésion dans le cas de nouilles fabriquées seulement dans de la vapeur surchauffée. La dureté et la masticabilité se sont avérées plus faibles seulement pour les temps de repos de 20 min. Les nouilles soumises à un pré-traitement à la vapeur saturée appliqué avant le traitement avec de la vapeur surchauffée étaient plus dures, moins cohésives et moins élastiques. La gélatination combinée de l'amylopectine et de l'amylose-lipide était approximativement de 89% pour les nouilles fabriquées à l'aide d'un processus à la vapeur surchauffée et 90% pour les nouilles pré-traitées avec de la vapeur saturés avant la fabrication. Par conséquent, le traitement à la vapeur surchauffée sans autre traitement a permis de gélatiniser la fécule. **Mots clés:** vapeur surchauffée, temps de repos, gélatination de la fécule, propriétés texturales, nouilles.

INTRODUCTION

Currently, our laboratory in the Department of Biosystems Engineering at the University of Manitoba is studying the novel method of using superheated steam to process Asian noodles to create a fat-free instant product (Markowski et al. 2003; Pronyk et al. 2004). Superheated steam is able to dry and create an instant product because it is steam that has been given additional sensible heat to raise its temperature above the corresponding saturation temperature at a given pressure. Unlike saturated steam, a drop in temperature will not result in condensation of the steam as long as the temperature is still greater than the saturation temperature at the processing pressure. When processing at high temperatures using superheated steam, Asian noodles dry rapidly and become partially cooked, creating an instant noodle without the necessity of frying in oil. Elimination of oil in the frying of instant noodles may alleviate health concerns about the fat content and presence of trans fatty acids from partially hydrogenated and hydrogenated oils while providing the consumer with a convenient and healthy food product. Acceptance of instant noodles processed in superheated steam is largely dependent on obtaining good textural properties.

Determination of the fundamental drying and textural characteristics of superheated steam processing of instant Asian noodles is a difficult undertaking. A systematic and thorough study would require large numbers of small samples because of the size of the superheated steam system available. In comparison, the amount of material to mix and sheet the dough necessary to create noodles for processing is large. All of this is exasperated by the limited amount of flour available to complete all of the experiments. Some of these problems can be mitigated by utilizing small-scale laboratory equipment to create a smaller noodle sheet (Kovacs et al. 2003). Creating smaller samples for processing is possible, but in some cases where many experiments are run, the time to mix and sheet new samples is not practical. A convenient way to obtain many small samples for testing new processing methods would be to create a single noodle sheet and cut samples from it as needed. The drawback to this approach is the possibility of changes in textural properties of the noodle sheet with resting time. Literature on the subject of changes in textural properties of Asian noodles with dough resting time is minimal. Changes in cooked noodle texture related to dough resting time have only been examined by Kruger et al. (1994) for long periods of time (every hour for 24 hours) to represent consumer consumption of raw noodles. However, with the long intervals between evaluation of cooked noodle texture, subtle changes that may occur in the first few hours after preparation cannot be inferred. In addition, long periods of dough resting are not likely to be encountered when noodles are to be further processed (dried or fried for instant products). Information on textural changes due to dough resting may be of use to other researchers to set minimum or maximum dough resting time before noodles are further processed.

There is also a question about the need to process noodles in saturated steam before superheated steam processing. To produce an instant product, commercial instant noodles are steamed before frying or air drying. This saturated steam processing helps to gelatinize starch and may have an effect on the textural characteristics of the final product. Processing in superheated steam is effective at gelatinizing starches, as the product has sufficient moisture and the temperatures are high enough to allow for gelatinization (Cenkowski and Sosulski 1997; Taechapairoj et al. 2004). By not pre-steaming the noodles in saturated steam, the drying kinetics of the noodles will be easier to ascertain. The effect of pre-steaming of superheated steam processed noodles and the affects on starch gelatinization and textural characteristics need to be determined.

Therefore, the objectives of this research were two-fold: (1) to determine if the textural properties of alkaline Asian noodles processed with superheated steam change in relation to the amount of time (dough resting time) that passes between the preparation of the dough sheet and processing and (2) to verify if alkaline Asian noodles need to be processed with saturated steam to increase gelatinization in the final product before further processing in superheated steam, and determine the effects of saturated steam treatment on textural properties.

METHODS and MATERIALS

Flour

Raw noodles were prepared from flour milled from the Canada Western Hard White (CWHW) wheat class (cultivar Snowbird). The wheat was milled at Canadian International Grains Institute (CIGI) in Winnipeg, Manitoba, Canada, following standard procedures for the production of straight grade (75.2% extraction) noodle flour (Dexter and Tipples 1987). The flour had a protein content of 13.3% (14.1% moisture content, wet basis) and was used in the preparation of raw alkaline noodles.

Noodle preparation

A laboratory noodle sheeter constructed in the Department of Biosystems Engineering at the University of Manitoba based on a design by Kovacs et al. (2003) was used to create noodle sheets that were then cut into strands to produce the raw noodles for experimentation (Fig. 1). The laboratory noodle sheeter has a 75 mm wide by 180 mm diameter stainless steel roll powered by a 186 W (¼ HP) DC gear motor.

A noodle sheet was prepared from raw dough following a similar procedure as described by Kovacs et al. (2003). In short, the noodle dough was mixed as a 100:34:1:1 ratio of flour, distilled water, alkaline salts (*Kansui*) (9:1 ratio of sodium and potassium carbonate), and table salt. An aqueous salt solution was prepared by combining 50 mL of solution containing 2.56 g sodium carbonate and 0.29 g of potassium carbonate with 50 mL of solution containing 2.85 g sodium chloride. A mixer (Kitchen-Aid, St Joseph, MI) with a flat beater was used to mix 120 g of flour with 41 mL of the aqueous salt solution for 5 min, forming a crumbly dough mixture of approximately 33% wb (wet basis) final moisture. The dough mixture was passed through the rollers of the

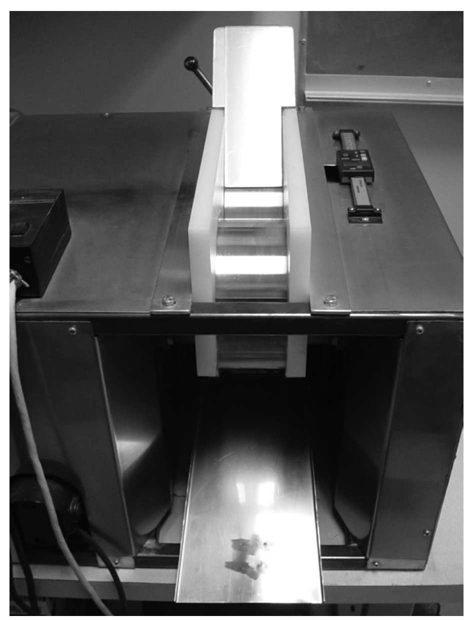

Fig. 1. Laboratory noodle sheeter (75 mm wide rolls).

laboratory dough sheeting machine with an initial gap of 5 mm at 2 3/4 rpm to create a thick dough sheet. The sheet was then folded in half lengthwise and passed through the rollers with a gap of 4 mm, replicating the commercial laminating process. The sheet was then passed through the rollers two more times with the roller gaps set to 4 and 3 mm with each pass, respectively. The roller speed was then increased to 4 1/3 rpm and the sheet was passed through four more times while the roller gaps were reduced to 2, 1.5, 1.2, and 1 mm with each pass. The resulting sheet, 1.95 ± 0.16 mm thick (due to expansion) was cut into noodle strands 1.60 ± 0.04 mm wide with a pasta cutter (Shule Pasta Machine, Changzhou Shule Kitchen Utensils Co., Ltd., Jiangsu China) with the edge noodles discarded. The cut noodles were wrapped in wax paper and stored in plastic bags to prevent moisture loss. The initial moisture content of the noodles was determined in triplicate following the AACC Approved Method 44-15A (AACC 2000).

Superheated steam system

A superheated steam processing system (Fig. 2) developed in the Department of Biosystems Engineering at the University of Manitoba, based on the system used by Tang and Cenkowski (2000), but further updated and improved by Gervais et al. (2004), was used to simultaneously dehydrate and cook the raw noodles to produce an instant product. Saturated steam at 0.41 MPa and 145°C is produced by the steam generator (1). A globe valve (2) prevents steam from entering the system until warm-up is complete. When the steam passes through the steam pressure regulator (4), its pressure drops to 0.13 MPa, and superheated steam is generated. The pressure regulator ensures a steady flow of steam through the pipelines and the drying chamber (11). The flow rate is adjusted by the gate valve (5) and a vortex meter (7), pressure transducer (8), and a thermoelectric probe (9) relays information to a flow computer (Compart DXF 351 Flow Computer, Endress Hauser GmbH, Weil am Rhein, Germany) that amalgamates the individual readings to accurately provide a flow measurement for the superheated steam. Between the two valves is the vacuum breaker (3), which is required in the superheated steam system because of air drawn into the system after it is shut down. Breaking vacuum conditions is necessary to allow for the proper flow of steam in the system during operation. Without the vacuum breaker, the flow of steam through the pipes may be prevented. After passing though the superheater (6), where its temperature is adjusted to the desired level, the steam goes through the drying chamber (11) or is sent back to the water tank (14) during warm up or sample loading by controlling the three-way actuated valve (10). A sparge tube (15) safely exhausts the steam in the water tank during warm up or loading and a flat-plate counter-current heat exchanger (MPN5X12-8, Wolseley, York, PA) (12) condenses the steam after it exits the drying chamber. Water is recycled back to the boiler with the use of a 250 W (1/3 HP) impeller type pump (16). Throughout the system there are check valves (13) that ensure unidirectional flow of the steam or water.

Processing conditions

Noodles were processed at a temperature of 120°C, a steam velocity of 1.0 m/s, and a processing time of 8 min. The noodles were processed at intervals of 20 min starting from the time the noodle sheet was prepared for a total of 200 min of resting time. Approximately 28 noodles, 30 to 40 mm long, were placed in the sample tray, taking care to prevent noodles from touching each other, as this could affect drying. After processing in superheated steam, the samples were placed in a sealed plastic bag and stored in a freezer until the texture profile analysis (TPA) was conducted. Three trials were run at each time interval.

An experiment was conducted in the same manner as the time effect trial, except that after the noodles were arranged in the sample tray, they were immediately placed into a food steamer (Salton, Lake Forest, IL) for 120 s. The food steamer was preheated prior to use to ensure samples were subjected equally to the pretreatment. After 120 s, the noodles were removed from the steamer and immediately placed into the superheated steam system. They were then processed under the same conditions as in the time effect trial.

Quality evaluation

Noodles were added to boiling water and cooked for the optimum period, as determined by the loss of the visible

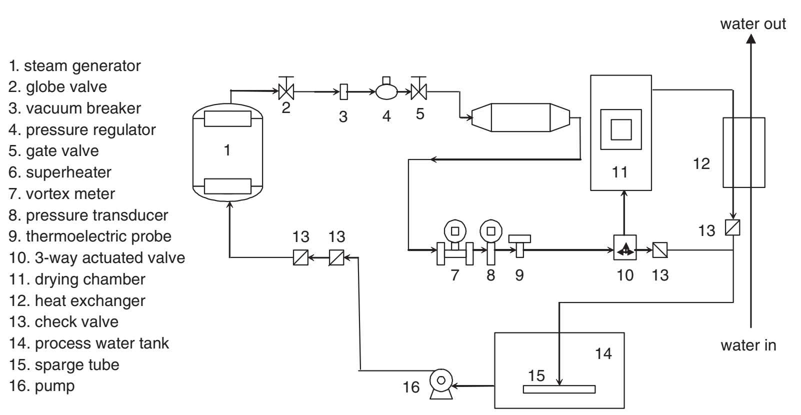

Fig. 2. Schematic of the superheated steam processing system.

noodle core when squeezed between two plexiglass plates. The cooked noodles were cooled in running tap water for 1 min and excess water was drained away. The drained noodles were stored in a sealed plastic bag at room temperature for 10 min before initiating the textural tests. Each textural test was performed at fixed 5-min intervals to produce three replicates. A texture analyzer (TA.XT2i, Texture Technology Co., Hamilton, MA) was used to conduct a double compression texture profile analysis (TPA) that simulated the first and second bite of a noodle on cooked noodle samples. Tests were conducted with an attachment having a width of 9 mm, the compression speed was 0.4 mm/s and the compression depth was 1 mm, approximately one half of the thickness of the noodles (the noodles were approximated as square after cooking). Three noodles were placed on the textural analyzer perpendicular to the probe and touching one another to ensure that test results would be less affected by variances in individual noodle dimensions. The resulting TPA curves were analysed using Texture Expert software (Ver. 1.22) and values for hardness, adhesiveness, springiness, chewiness, and resilience were obtained.

Thermal analysis of the characteristics of starch was conducted using a DSC 7 (PerkinElmer, Norwalk, CT) connected to a thermal analysis controller (TAC 7/DX, PerkinElmer, Norwalk, CT), which was controlled by a computer running Pyris software (V8.0, PerkinElmer, Norwalk, CT). Differential scanning calorimeter (DSC) analyses were performed on flour, raw noodles dough, and on the dehydrated instant noodles at a ramp rate of 10°C/min using nitrogen as the purge gas. Approximately 5 to 12 mg of powdered noodles were placed into 60 μL stainless steel pans and reverse osmosis water was added with a 25 μL syringe (Microliter #702, Hamilton Co., Reno, NV) to bring the moisture content to 60% (wb) to enable the complete gelatinization of any starch (Cenkowski and Sosulski 1997). The onset temperature, peak temperature, and enthalpies (ΔH) of the amylopectin and amylose-lipid complex in the superheated steam dried noodles were determined from the resulting energy-temperature curves.

RESULTS and DISCUSSIONS

Effect of resting time

Optimum cooking time for the control noodles (unprocessed raw noodles), superheated steam processed noodles and saturated steam pre-treated noodles were found to be 4, 5, and 4.5 min respectively. When noodles were processed in superheated steam at 120°C, a steam velocity of 1.0 m/s, and a processing time of 8 min, the textural parameters adhesiveness, springiness, and cohesiveness were not significantly affected by resting time ($p > 0.05$) (Table 1). The other textural properties showed small amounts of variability, but in most cases did not exhibit any discernable trends. In most cases, it was only a single value that influenced the results. The value for hardness at 20 min resting time was much lower than at all other resting times. When it was removed, there was no significant difference among the remaining resting times ($p > 0.05$). This in turn had an effect on the chewiness of the noodles because hardness is a factor in calculating chewiness. When chewiness at 20 min resting time was also removed, there was no significant difference ($p > 0.05$) between the remaining values. Finally, the only significantly different value for resilience occurs at a resting time of 120 min. This is probably an anomaly in the data because values after 120 min resting time are the same as those before. To eliminate any influence of resting time on the textural properties of noodles, it was decided to rest the noodle sheet for 40 min before processing samples for texture. This agrees with literature that recommends resting raw noodles for at least 40 min before processing (Hou and Kruk 1998). It is then possible to use the same noodle sheet for a total of 200 min after it is made without changes in its textural properties.

Table 1. Textural properties from TPA tests of superheated steam-processed noodles with various dough resting times before processing.

Resting Time (min)	Adhesiveness (g·s)	Springiness	Cohesiveness	Chewiness (g)	Resilience	Hardness(g)
20	-6.4^{a}	0.981^{a}	0.549^{a}	313.8^{d}	$0.495^{a,b}$	581.7^{c}
40	-5.8^{a}	0.983^{a}	0.542^{a}	$366.3^{a,b,c}$	0.503^{a}	$687.8^{a,b}$
60	-2.4^{a}	0.988^{a}	0.550^{a}	350.1^{c}	0.517^{a}	$645.2^{b,c}$
80	-5.1^{a}	0.984^{a}	0.550^{a}	$352.8^{b,c}$	0.506^{a}	$652.6^{a,b}$
100	-3.9^{a}	0.986^{a}	0.549^{a}	$369.6^{a,b,c}$	0.504^{a}	$682.8^{a,b}$
120	-6.4^{a}	0.981^{a}	0.538^{a}	$363.4^{b,c}$	0.479^{b}	$687.6^{a,b}$
140	-4.4^{a}	0.987^{a}	0.541^{a}	$382.5^{a,b}$	0.510^{a}	715.7^{a}
160	-2.3^{a}	0.981^{a}	0.556^{a}	$372.8^{a,b,c}$	$0.495^{a,b}$	$683.2^{a,b}$
180	-2.7^{a}	0.991^{a}	0.567^{a}	395.7^{a}	0.514^{a}	$709.1^{a,b}$
200	-4.4^{a}	0.982^{a}	0.549^{a}	$374.6^{a,b,c}$	0.502^{a}	$694.9^{a,b}$
LSD				31.9	0.022	68.1

Means followed by the same superscript letter are not significantly different at $\alpha = 0.05$ level
LSD = least significant difference ($\alpha = 0.05$)

Table 2. Average results of the three processing treatments.

Textural Property	Raw[a] Mean	Raw[a] Std Dev	SHP[a] Mean	SHP[a] Std Dev	PSS[b] Mean	PSS[b] Std Dev
Adhesiveness (g·s)	−17.1	1.2	−4.2	1.5	−4.2	3
Springiness	0.967	0.004	0.985	0.003	0.975	0.011
Cohesiveness	0.526	0.004	0.549	0.009	0.539	0.0065
Chewiness (g)	209.4	7.5	369.8	14.1	417.5	60.9
Resilience	0.35	0.012	0.503	0.011	0.467	0.025
Hardness (g)	411.8	18.5	684.3	23.1	746.5	66.2

[a] n = 27
[b] n = 18
SHP = superheated steam processed noodles
PSS = pre-treated with saturated steam processed noodles

Effect of pre-treatment with saturated steam

Commercial instant noodles are steamed before either frying or air drying occurs to produce an instant product. This saturated steam processing helps to gelatinize starch and may have an effect on the textural characteristics of the final product. Pre-treated with saturated steam (PSS) noodles were compared with the averages of control noodles (unprocessed raw noodles) and superheated steam processed (SHP) from the preceding section. Based on the results for raw and SHP noodles, TPA values were averaged over the last 160 min of resting time (Table 2). The effects of saturated steam pre-treatment could then be ascertained.

There are many differences between the raw noodles and the processed samples, but fewer differences between the SHP and PSS noodles. Processed noodles were more firm (higher hardness), less sticky (decreased adhesiveness), more elastic (increased springiness and resilience), and would be more difficult to masticate between the teeth (increased chewiness). The increase in chewiness was mostly due to the increase in hardness as cohesiveness was similar for all three treatments. When the processed samples were compared, there was no statistical difference in the adhesiveness and springiness properties between PSS and SHP noodles ($p > 0.05$). However, hardness and chewiness were higher in the PSS noodles, while cohesiveness was lower. Measurement of noodle dimensions after superheated steam processing indicated that PSS noodles were approximately 5% smaller than SHP noodles. The increased diameter of the noodles processed using just superheated steam may have been caused by a "puffing" effect, which takes place near the beginning of processing. When the noodles are first placed in the chamber, the temperature of the noodle rises very quickly and this may cause the moisture in the noodle to flash to steam. This will create many pores of steam that will cause the noodles to puff out and create a less dense noodle. In the case of PSS noodles, moisture is absorbed very quickly near the surface of the noodle during the pretreatment, and when the sample is placed in the superheated steam chamber, the increased amount of moisture causes the noodle to dry more slowly and evenly creating a denser noodle. The increase in density could potentially cause the increase hardness and chewiness of the PSS noodles.

Starch analysis was conducted using a differential scanning calorimeter (DSC) to determine the amount of gelatinization. The degree of starch gelatinisation in instant noodles is typically 80 to 90%, depending on the product (Hatcher 2001; Hou 2001). Results showed that while starch gelatinization increased from raw to processed noodles for both starch types, differences between PSS and SHS noodles ($p < 0.05$) were only found in the

Table 3. Starch analysis of flour and noodles from three processing procedures.

Treatment	Amylopectin Onset Temperature (°C)	Amylopectin ΔH (J/g)	Amylopectin Peak Temperature (°C)	Amylose-Lipid Onset Temperature (°C)	Amylose-Lipid ΔH (J/g)	Amylose-Lipid Peak Temperature (°C)
flour	56.1 ± 0.6	6.83 ± 0.27	62.0 ± 0.4	80.8 ± 0.8	1.48 ± −0.18	92.8 ± 2.5
raw	61.0 ± 0.2	5.54 ± 0.18	67.3 ± 0.2	92.5 ± 1.0	1.01 ± 0.20	103.1 ± 1.4
SHP	75.0 ± 0.7	0.33 ± 0.02	80.9 ± 0.1	90.6 ± 1.2	0.61 ± 0.20	102.5 ± 0.2
PSS	77.5 ± 1.4	0.30 ± 0.02	81.7 ± 0.9	95.1 ± 1.4	0.50 ± 0.22	103.0 ± 0.6

Values are mean of triplicate ± standard deviation
SHP = superheated steam processed noodles
PSS = pre-treated with saturated steam processed noodles

amylopectin (Table 3). The PSS noodles had a lower enthalpy, ΔH, indicating that there was more starch gelatinization during processing. The absolute difference in enthalpies of 0.03 and 0.11 J/g for amylopectin and amylose-lipid respectively, found between SHS and PSS is extremely small. This is especially true when compared with differences of approximately 6.08 and 0.42 J/g for amylopectin and amylose-lipid, respectively, between raw and processed noodles. Results show that the combined gelatinization of amylopectin and amylose-lipid is 87% for SHS noodles and 89% for PSS, indicating that the superheated steam processing was successful in gelatinizing starch. This indicates that the pre-treatment with saturated steam for 120 s prior to superheated steam processing has only minimal effects on the total starch gelatinization in the noodles, and will likely not affect the starch properties of the final cooked product in any significant way.

CONCLUSIONS

Noodles processed in superheated steam should be rested for 40 min, after which time there are no significant changes in textural properties. No difference was found in the adhesiveness and springiness properties between saturated steam, pre-treated noodles, and superheated-steam-processed noodles. However, hardness and chewiness were higher in the saturated steam pre-treated noodles, while cohesiveness was lower. This was due to a puffing effect in noodles with no pre-treatment causing a less dense noodle that was not as hard. Pre-treatment with saturated steam for 120 s prior to superheated steam processing has only minimal effects on the total starch gelatinization in the noodles as results show that the combined gelatinization of amylopectin and amylose-lipid is only 2% greater for noodles with the saturated steam pre-treatment.

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