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Technology Optimization for the Production of Meat Paste with Lithium

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ABSTRACT

This article was aimed to develop a technology for the production of paste from poultry meat enriched with lithium. As a result of the experiment, the optimal mode for cutting minced meat for paste was determined, which provides high organoleptic, physicochemical characteristics and low microbial contamination of the product. Fortification of food raw materials (poultry meat) with an important essential element (lithium) has a greater effect at the stage of raising birds, adding it to their diet. In preclinical studies, the safety of the use of poultry paste enriched with lithium has been proven. The resulting recipe for the production of paste from poultry meat enriched with lithium can be recommended for use in the food industry.

Key words: *Meat paste, Lithium, Supplement, Selenium, Enriched meat*

INTRODUCTION

In the modern food industry, the enrichment of meat products with important micronutrients can be carried out through a sequence of individual links in a single trophological chain "from field to counter" [1, 2]. Valuable feed additives are introduced into the ration of animals, which in the future will provide meat with necessary microelements. This method eliminates the risk of an overdose of nutrients and increases their digestibility. In this regard, the use of organic forms of essential elements in the composition of animal feed is one of the safest and most inexpensive methods of obtaining enriched meat raw materials.

Of particular interest is the study of the possibility of modifying the chemical composition of poultry meat due to its enrichment with such an important source of essential elements as lithium. This implies the inclusion of a feed additive with lithium in the diet of broiler chickens, which provides vital enrichment with this element. The need for lithium is due to many reasons.

So, at the present, due to an increase in the volume of mental work and a sedentary lifestyle, the human diet is characterized by an unbalanced diet with an insufficient content of essential micronutrients [3, 4]. The problem of insufficient intake of essential macro-and micronutrients into the human body is becoming widespread and covers various groups of the population in many regions of the world [5].

The most promising and expedient solution to this problem is the enrichment of consumer products [6-8]. The optimal solution to this problem is the systematic use of specialized food products enriched with the necessary micronutrients in quantities of the physiological needs of a person. Numerous studies have proven the unique effect of bioconversion of inorganic forms of microelement salts into bioavailable organic salts. It is important to note that this process can only occur in animals. Bioconversion of modified feed allows obtaining meat raw materials of increased biological value. The presence in food of trace elements in biotic doses actively affects the course of metabolic and other biochemical processes in the human body [9-11]. Examples of products fortified with micronutrients with proven beneficial biological and high consumer properties are widely known. Sinyukova studied the enrichment of poultry products with iodine. The results obtained by the author indicate a direct correlation between the level of introduced iodine with feed and the content of a trace element in the body of laying hens. At the same time, "even though the concentration of iodine in the feed increases 22.5 times compared to its actual content in the compound feed, its increase in the thyroid gland occurs 1.2 times, in the liver, it increases 1.8 times, in the blood - 1.9 times, in the spleen - 1.7 times, and in the muscles - 1.6 times" [12]. According to Gorlov *et al*. (2019), the optimization of diets of small ruminants for zinc, iodine, and selenium by enriching the diets with special feed additives had a positive effect not only on the productivity of animals but also contributed to the production of mutton for further production of functional meat products. The authors experimentally substantiated the positive effect of the developed lamb snacks, enriched with iodine, selenium, and zinc, on metabolic processes in the body of experimental animals. This confirms the expediency of their use in the correction of protein, carbohydrate, fat, and mineral metabolism. These microelements that make up this product have high bioavailability, which helps to normalize the physiological functions of the body in case of nutritional deficiency [13]. The body's need for lithium has been proven by numerous studies, however, dietary supplements available on the market contain different amounts of salts of this essential trace element, the bioavailability of such products for the body in the presented forms has not been proven. Often, such additives can contain high concentrations of trace elements and especially ultra-trace elements due to the complexity of microdosing during production and mixing. In this regard, certain advantages are possessed by bioavailable forms of trace elements, which the body receives naturally from food. Zarse *et al*. argue that long-term intake of low doses of lithium into the human body can have a rejuvenating effect on the body and reduce mortality in representatives of various living organisms, including humans [14].

It should be noted that according to the latest studies, the effects of prolonged exposure to 10 mg/kg of lithium chloride during low-intensity exercise on endurance in obese rats, lithium increases exercise performance and increases the expression of the BDNF gene, a neuroprotective factor in the hippocampus of obese mice. Treatment with lithium alone suppressed the activity of the GSK3 beta gene, which is a positive sign and can be used for the prevention of neurodegenerative diseases [15].

The Mc Coll *et al*. found that, at clinically relevant concentrations, lithium increased survival by 46% throughout life during normal aging. Life expectancy is increased by a new mechanism with altered expression of genes encoding functions associated with nucleosomes. It has been experimentally proven that lithium directly regulates survival by modulating histone methylation and chromatin structure [16].

It should be noted that numerous studies by Rahimi (2014), Boyko (2015), Hajek (2016) have shown that lithium has a multifaceted positive effect on the central nervous system. In particular, it has neuroprotective effects and stimulates the development of a nerve cell through several signaling transduction pathways [17-19]. Abdel-Maksoud (2009) found that lithium is effective in both chronic and episodic forms of cluster headache [20]. Leeds (2014) found that lithium reduces the level of neurological death, microglial activation, improving cognitive abilities and memory by maintaining the integrity of the blood-brain barrier and reducing the level of neurological defects and psychotic disorders [21]. Schrauzer (2002), Gallichio (2011) scientifically proved that a vital dose of ionized lithium for an adult weighing 70 kg is 1 mg/day. This dose provides important processes of neurogenesis, as well as protects neurons from toxic substances and affects the activity of stem cells at the level of nerve tissue and bone marrow [22, 23]. Zamani (2009) showed that maintenance therapy with lithium salts can preserve or increase bone mass. Empirical evidence also supports lower rates of bone destruction in those receiving lithium [24]. Silva (2007) found that the therapeutic efficacy of lithium as a mood stabilizer is precisely related to the stimulation of vascular endothelial growth factor, which is also associated with resistance to stress in humans and animals [25]. Angelucci (2003) concluded that neurotrophic factors play a role in the development of depression and are closely related to the mechanism of action of lithium [26].

It should be added that lithium has a significant immunoregulatory effect by increasing the production of proinflammatory cytokines (IFNgamma, TNFalpha, and IL-8) and negative immunoregulatory cytokines or proteins interleukins-10 and interleukins -1RA [27]. Under certain experimental conditions, lithium also exhibits pro-inflammatory properties due to the induction of interleukins-4, the synthesis of interleukins-6, and other pro-inflammatory cytokines.

Currently, the positive effect of lithium on the immune system is unambiguous [28]. Amsterdam (1996) proved the activity of lithium against the herpes simplex virus. He added that, given long-term intake of lithium, it can be effective in suppressing recurrent herpes infections [29]. Zarse (2011) found that long-term intake of low doses of lithium can be effective against aging and reduce mortality in humans and animals of different species at different stages of evolution [30].

Thus, nowadays the scientific challenge is to produce a lithium-fortified product. In this article, meat paste can be a perspective food product. Scientific researches have found that the use of enriched meat in the production of paste is an alternative to the traditional use of these meat products. Researchers have created a new product with physicochemical characteristics that meet the recommendations of the scientific community on proper nutrition [31].

There are many works on enriching meat paste with micronutrients. Thus, researchers de Carli *et al*. have proven that the addition of coenzyme Q10 and ascorbic acid to a chicken liver paste recipe prevents oxidative spoilage. After adding antioxidants to pasteurized paste, the color and smell improved and the taste deteriorated [32]. Srebernich (2017) considered paste as foods that play a positive role in the prevention of iron deficiency anemia. This meat product makes it possible to obtain iron in an accessible organic form at the same time as other components that are significant for the body in a normal diet [33].

Due to this, the research aims to optimize the technology for the production of poultry meat paste, enriched with lithium.

MATERIALS AND METHODS

The experimental work was carried out to optimize the technology for the production of poultry paste. The recipe for enriched meat paste includes (in kg / 100 kg of the main raw material): mechanically deboned broiler chicken (meat of the 2nd experimental group) – 60, by-products – 29, butter – 9, potato starch or wheat flour – 2; additives and materials, g / 100 kg of the main unsalted raw materials: table salt – 2000, black pepper – 100, allspice ground – 100, granulated sugar – 150.

The technology of pastes includes salting meat in pieces up to 0.5 kg and offal of broiler chickens. A concentrated solution of common salt is preliminarily prepared at the rate of 100 liters of cold drinking water, 35-40 kg of salt is taken and mixed, then the solution is settled, filtered, and cooled to temperatures from 0 to 4 °C. The amount of brine added to raw meat (100 kg) is 7 liters. Then the raw material is mixed with brine for 3-6 minutes in mixers, kept in a container for 48-50 hours at a temperature from 0 to 4 °C. The next step is the cutting of the main raw materials and the addition of recipe components and ice during the cutting process. The total cutting time is 14-20 minutes. Ice is introduced twice: 50% (or 15% by weight of raw meat) at the initial stage of cutting and after 8-10 minutes of cutting, so that the temperature of the meat system does not exceed 15 °C.

To select the optimal cutting mode, the technical parameters were compared in three different modes:

Mode 1: cutting 10-12 minutes, adding ice, knife speed 2000-2200 rpm, bowl speed 9-12 rpm, ice filling, cutting 6-8 minutes, ice filling, knife speed 2000-2200 rpm, bowl speed 9-12 rpm;

Mode 2: chopping 8-10 minutes, adding ice, knife speed 2200-2400 rpm, bowl speed 12-14 rpm, chopping 4-6 minutes, adding ice, knife speed 2200-2400 rpm, bowl revolutions 12-14 rpm;

Mode 3: chopping 6-8 minutes, adding ice, knife speed 2400-2600 rpm, bowl speed 14-16 rpm, chopping 2-4 minutes, adding ice, knife speed 2400-2600 rpm, bowl speed 14-16 rpm.

To determine the optimal influence of technological parameters (the frequency of rotation of the cutter knives and the duration of the mixing process) on the quality indicators of the paste after production, mathematical planning of the experiment was carried out.

Studies have made it possible to determine the range of variation of the input components: the frequency of rotation of the cutter knives (X) in the range from 2000 rpm to 2600 rpm (the frequency of rotation of the bowl from 9 rpm to 16 rpm) and the duration of the process (Y) within from 6 minutes to 12 minutes. Kuttering was carried out on an industrial apparatus ROBON COUPE R 300. The output parameter of the experiment was the quantitative content of QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms) in the paste, CFU / g, characterized by the index (Z) and further evaluation of the physical and organoleptic properties of the paste.

It should be taken into account the results of the experiment planning matrix **(Table 1)**. The implementation of the two-factor experiment plan and statistical data processing allowed for a graphical presentation. It adequately describes the dependence of the content in the paste QMAFAnM (Z) on the frequency of rotation of the cutter knives (bowl) (X) and the duration of the process (Y):

Table 1. Matrix for planning a two-factor experiment with the combined effect of the frequency of rotation of the cutter knives (bowl) and the time of the mixing process

factor	factor designation	variation levels		
		-1	0	+1
Rotation frequency of knives (bowl), rpm	X	2000 (9)	2300 (13)	2600 (16)
Mixing duration, min	Y	12	9	6

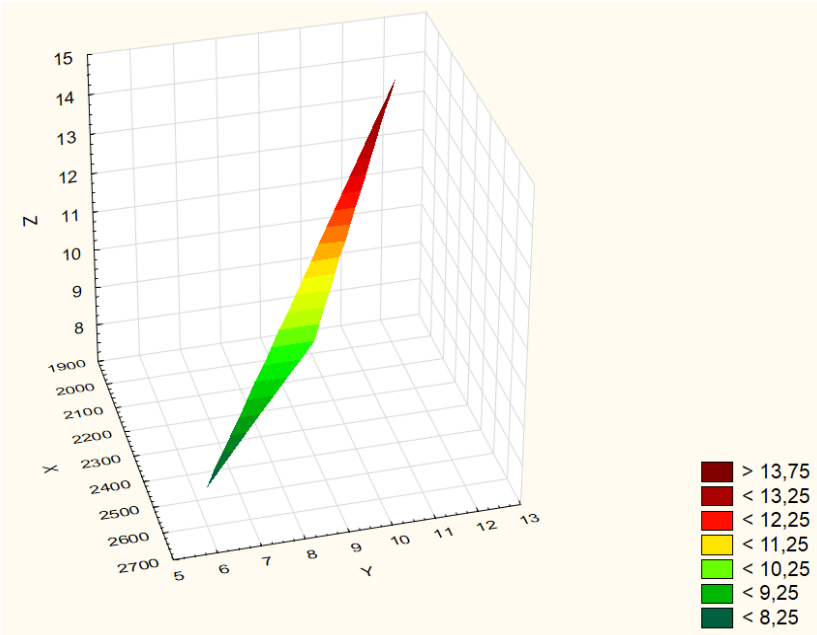

Figure 1. The Response Surface in the Study of the Dependence of the Value of the Indicator (Z), CFU / g on the Rotation Frequency (X), rpm and the Duration of the Process (Y), min

Analysis of the response surface **(Figure 1)** shows that the smallest number of mesophilic aerobic and facultatively anaerobic microorganisms (Z < 8) in the paste samples is observed at the rotation frequency of the knives (bowl) more than 2500 rpm (15 rpm) and the duration of cutting less than 7 minutes. A further increase in the frequency of rotation of the working organs of the cutter, as shown by studies, leads to a deterioration in the viscoplastic properties and organoleptic characteristics of the finished paste.

Thus, technological mode 3 is rational with the recommended speed of the knives (bowl) 2500-2600 rpm (15-16 rpm) and the duration of 6-7 minutes.

Further, the technology involves cooling the paste, packing it into metal cans, approved for use in the prescribed manner and rolled up on a vacuum seaming machine, sterilized in an autoclave for 45 minutes at a temperature of 105-135 °C at a pressure of 0.19-0.25 MPa, cool.

Preclinical trials

As a model, male Wistar rats weighing 200-250 g were used, a total of 30 animals, 10 in each of the three groups. All studies were carried out following the rules and regulations governing research on laboratory animals. The animals were kept in a vivarium under the same conditions, in cages, 5 animals each. The animals were fed daily with compound feed at the rate of 30-35 g per head, additionally, minced meat was introduced into the diet at the rate of 1 g per 1 head per day, which corresponds to 4-5 g per 1 kg of body weight. This dosage corresponds to the norms of consumption of meat products for humans, according to the normative.

At the first stage (for 14 days) all rats were accustomed to a new diet with the introduction of meat paste prepared without the use of raw materials enriched with lithium. At the second stage (28 days long) experimental studies were carried out according to the above scheme.

RESULTS AND DISCUSSION

As a result of the experiment to optimize the technology of meat paste enriched with lithium, the organoleptic characteristics of the paste were measured **(Table 2)**.

Table 2. Organoleptic Characteristics of the Paste

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
Appearance	Metal Cans with a Clean and Dry Surface, without Damage		
Consistency	Gentle Smearing		
Sectional view	Homogeneous, Evenly Mixed Mass		
Smell and Taste	Pleasant to the Taste, Typical for this type of product, with a Spice Aroma		

In appearance, all the studied samples of paste represent a homogeneous finely groundmass with a delicate, smearing consistency, pleasant to the taste, typical for such products, with a spice aroma. From the data in the Table, it follows that the samples of pastes produced with different modes of cutting, in terms of organoleptic indicators, corresponded to the regulatory requirements. A study of the physical and chemical parameters of the paste is presented in **Table 3**.

Table 3. Physicochemical Indicators of the Quality of the Paste

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
Protein, %	14,8 ± 0,1	14,6 ± 0,1	14,7 ± 0,1
Fat, %	11,3 ± 0,2	11,4 ± 0,1	11,4 ± 0,2
Lithium, mg/100 g	0,28 ± 0,1	0,27 ± 0,2	0,28 ± 0,1
Sodium Chloride, %	1,21 ± 0,01	1,20 ± 0,01	1,20 ± 0,01

According to the data from **Table 3**, the content of protein, fat, and sodium chloride in all studied samples of paste do not differ significantly. The mass fraction of protein is in the range of 14.6-14.8%, fat 11.3-11.4%, and table salt 1.20-1.21%, which meets the regulatory requirements.

The amount of lithium is 0.27-0.28 mg / 100 g **(Table 3)**, which allows the new product to be classified as an enriched paste. Studies of the microbiological parameters of pastes (sterilized canned food) after production and storage for 21 months have been carried out following normative. The determination of the shelf life of canned products is carried out according to the time of the last checkpoint, at which the stability of all indicators was confirmed, reduced by a factor of 1.15 taking into account the reserve ratio. The microbiology indicators of the meat product after production are presented in **Table 4**.

Table 4. Microbiological Parameters of the Paste after Production

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
QMAFAnM, CFU/g no more than	14	10	8
Coliform Bacteria, not Allowed	Not Selected	Not Selected	Not Selected
Clostridium Perfringens not Allowed	Not Selected	Not Selected	Not Selected
S. Aureus (in 0,1 g)	Not Selected	Not Selected	Not selected

It was found that all investigated microbiological indicators meet the requirements. It should be noted that the number of mesophilic aerobic and facultative anaerobic microorganisms in the paste samples during production in the second and third modes is lower by 28.2 and 42.9% lower in the control samples. The shelf life of the paste was determined by the time of the last control point (24 months), in which the stability of all indicators was confirmed, reduced taking into account the reserve ratio by 1.15 times. Microbiological parameters of the meat product after 12 and 22 months of storage are presented in **Tables 5 and 6**, respectively.

Table 5. Microbiological Parameters of Paste after 12 Months of Storage

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
QMAFAnM, CFU/g no more than	48	29	27
Coliform Bacteria, not Allowed	Not Selected	Not Selected	Not Selected
Clostridium Perfringens not Allowed	Not Selected	Not Selected	Not Selected
S. Aureus (in 0,1 g)	Not Selected	Not Selected	Not Selected

Table 6. Microbiological Parameters of Paste after 22 Months of Storage

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
QMAFAnM, CFU/g no more than	76	43	38
Coliform Bacteria, not Allowed	Not Selected	Not Selected	Not Selected
Clostridium Perfringens not Allowed	Not Selected	Not Selected	Not Selected
S. Aureus (in 0,1 g)	Not Selected	Not Selected	Not Selected

All investigated organoleptic and physicochemical indicators during storage for 22 months met the regulatory requirements. As a result of organoleptic, physicochemical, and microbiological studies, it has been established that the optimal shelf life period is 18 months. Storage conditions are temperature from 0 to 20 °C and relative humidity not more than 75%. The regulated indicators for the investigated product are determined and presented in **Table 7**.

Table 7. Regulated Indicators of the Quality of Meat Pastes

Parameter	Characteristic / Norm
Appearance	Metal Cans with a Clean and Dry Surface, without Damage
Consistency	Gentle Smearing
Sectional View	Homogeneous, Evenly Mixed Mass
Taste and Smell	Pleasant to the Taste, Typical for This Type of Product, with a Spice Aroma
Protein, %, not less than	14,0
Fat, %, not more than	15,0
Lithium, mg/100 g	0,3–0,4
Sodium Chloride, %, not more than	1,3

Preclinical trials of paste on rats led to the following conclusions. Throughout the experiment, the safety of animals was 100%. The eating ability of meat paste was complete. Observations at the first stage did not reveal any deviations from normal behavior, the processes of urination and defecation were within the physiological norm. The bodyweight of the rats corresponded to the normative values and did not differ statistically in different groups. Visible mucous membranes, and hair within the physiological norm was seen.

At the second stage of the research, no deviations from the normal course of physiological processes and external manifestations of intoxication or the development of pathological processes were found. Bodyweight corresponded to the normative values and did not have group differences. The hematological parameters of rats, reflecting the general condition of the body after 28 days of using the paste are presented in **Table 8**.

Table 8. Hematological Parameters of Rats during the Experiment

Parameter	Normative	1st Group	2nd Group	3rd Group
White blood Cells (WBCs), x109/l	6,6-12,6	8,6±0,9	8,8±0,9	8,7±0,8
Lymphocytes, %	57,5-83,6	71,4±4,8	72,7±5,9	69,3±5,1
Monocytes, %	0,6-2,9	1,12±0,3	1,51±0,2	1,41±0,3
The Relative Content of Granulocytes, %	20,0-28,0	22,7±4,4	24,4±3,9	24,1±5,1
Red Blood Cells (RBCs), x1012/l	6,76-9,75	8,2±0,6	8,9±0,7	9,1±0,7
Hemoglobine, g/l	115-161	141,4±7,8	139,1±6,7	145,6±5,8
Platelets, x109/l	631-719	710,4±41,4	704,4±52,7	708,6±41,8
Proportion l/l, Units	-	0,32±0,09	0,33±0,08	0,35±0,08

From the data of **Table 3**, it is seen that hematological parameters indicate the absence of deviations from the standard values and correspond to those of healthy animals. The intergroup differences were not pronounced, which indicates the absence of any toxic effects of the lithium-containing paste. The ratio of granulocytes to lymphocytes, a marker of the development of adaptive reactions, has no statistically pronounced deviations and corresponds to the normal course of physiological processes without signs of the development of stress or other pronounced adaptive reactions. The biochemical parameters of the blood of rats, reflecting the main indicators of metabolic processes in the body after 28 days of eating the paste, are presented in **Table 9**.

Table 9. Blood Test

Parameter	Normative	1st Group	2nd Group	3rd Group
Crude Protein, g/L	50,0-80,0	65,1±5,2	66,7±6,8	67,1±5,7
Glucose (Fasting), mmol/L	7,77-12,21	7,7±0,8	7,4±0,7	7,5±0,9
T. bili, mmol/L	0-8,5	2,5±0,2	2,4±0,2	2,4±0,2
Creatinine, mmol/L	9,0-70,0	61,4±5,7	63,7±5,7	59,6±5,1
Urea, mmol/L	4,28-8,57	7,4±0,5	7,1±0,7	7,6±0,8
AST, IU/L	20,0-100,0	84,4±2,7	85,4±5,8	84,6±4,9
ALT, IU/L	10,0-80,0	39,4±4,7	38,1±3,8	39,7±3,2
ALP, IU/L	70,0-450,0	205,4±25,4	208,4±24,7	207,9±31,1
Cholesterol, mmol/L	0,51-2,85	1,96±0,13	1,88±0,13	1,76±0,09
Triglycerides, mmol/L	0,56-2,23	1,51±0,10	1,42±0,14	1,38±0,12

It has been established that biochemical blood parameters correspond to the normal course of physiological processes in the body. The use of a paste enriched with lithium does not have a visible effect on the main indicators of homeostasis, protein, carbohydrate, and fat metabolism without signs of deviations from normal values. The activity of the enzymes AST and ALT correspond to healthy animals and indicate the absence of pathologies of the liver and heart. The consumption of paste by rats did not have a pronounced effect on the level of triglycerides but had a statistically significant effect on the level of cholesterol. In the rats of the third group, which were treated with meat paste, enriched lithium, the cholesterol level was 8.6% lower than the control values, the statistical significance of the differences was at the average level $p = 0.024$.

For rats that were injected with lithium in the form of citrate, a similar effect was noted in the form of a decrease in cholesterol levels by 6.0%, however, the differences in indicators were not significant.

So, introducing the meat paste into the diet of rats does not hurt the main indicators of homeostasis, protein-carbohydrate, and fat metabolism in the subjects, $p = 0.382$.

CONCLUSION

Therefore, as a result of the study on optimization of the technology of poultry meat paste enriched with lithium, the following conclusions were made:

- Enrichment of food raw materials (poultry meat) with an important microelement (lithium) has a greater effect at the stage of raising chicken when adding it to their diet
- The following technology for the production of poultry meat paste is recommended: cutting 6-8 minutes, adding ice, knife speed 2400-2600 rpm, bowl speed 14-16 rpm, cutting 2-4 minutes, ice filling, knife speed 2400-2600 rpm, bowl revolutions 14-16 rpm,
- the introduction of meat paste made based on lithium-enriched meat into the diet of rats does not have a negative effect on the main indicators of homeostasis, protein-carbohydrate, and fat metabolism in the subjects
- the resulting recipe for the production of paste from poultry meat enriched with lithium can be recommended for implementation in the food industry.

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