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Enhancing Meat Paste Production: Lithium-Based Technology Optimization

Miftakhutdinova Elena[1], Tikhonov Sergey[2], Diachkova Anna[2,3]*, Miftakhutdinov Alevtin[1], Tikhonova Natalya[2], Tretyakova Irina[1], Brashko Ivan[2], Pestova Inga[4], Saifulmuliukov Ernest[1], Nogovitsina Elena[1]

[1]South Ural State Agrarian University, Troitsk, Chelyabinsk region, Russia.
[2]Ural State University of Economics, Ekaterinburg, Russia.
[3]Ural Federal University named after the first president of Russia B.N. Eltsin, Ekaterinburg, Russia.
[4]Perm Institute (branch) of Plekhanov Russian University of Economics, Gagarina, 57 Perm, Russia.

***E-mail** ✉ avdb@yandex.ru

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ABSTRACT

This paper aimed to create a method for turning fowl flesh that has been enhanced with lithium into a paste. The research achieved the best method for chopping minced meat for paste, which provides excellent organoleptic and physicochemical properties and low microbiological contamination. The process of rearing birds and supplementing their diet with fortified food raw materials (poultry meat) with a crucial element (lithium) has a bigger impact. The safety of using poultry paste enhanced with lithium has been established in preclinical research. For usage in the food business, the resulting recipe for making a paste from bird flesh enhanced with lithium can be suggested.

Keywords: Lithium, Meat paste, Selenium, Supplement, Enriched meat

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Introduction

A series of separate links in a single trophological chain "from field to counter" can be used in the modern food business to enhance meat products with significant micronutrients [1, 2]. Animal rations now contain valuable feed additives that will eventually supply flesh with the microelements it needs. This technique improves the nutrients' digestion and removes the possibility of an overabundance. In this sense, one of the safest and least expensive ways to produce enriched meat raw materials is to incorporate organic forms of important nutrients into animal feed. The investigation of the potential to alter the chemical makeup of poultry meat by enriching it with such a significant source of vital elements as lithium is of particular interest. This suggests adding a lithium-containing feed additive to grill hens' diets, which gives them essential enrichment with this element. Lithium is required for a variety of reasons.

Therefore, the diet of humans is currently characterized by an inappropriate diet with an inadequate content of important micronutrients because of an increase in mental workload and a sedentary lifestyle [3, 4]. The issue of inadequate consumption of vital micro and macro-nutrients by the human body is expanding and affects numerous demographic groups in many parts of the world [5].

Enhancing consumer products is the most promising and practical way to address this issue [6-8]. The systematic utilization of specialized food products enhanced with the required micronutrients in values of a person's physiological requirements is the best way to address this issue. The unique effect of bioconverting inorganic forms of microelement salts into accessible organic salts has been demonstrated by numerous research. It is crucial to remember that only animals are capable of this process. Modified feed can be bioconverted to provide meat raw materials with higher biological value. Trace elements in biotic amounts in food have an active effect on the processes of metabolic and other biochemical in the human body [9-11]. It is common knowledge that products enriched with micronutrients have great consumer qualities and verified biological benefits. Sinyukova investigated adding iodine to poultry products. The author's findings show a clear relationship between the amount of iodine added to feed and the trace element composition of laying hens' bodies. Simultaneously, "even though the iodine concentration in the feed enhances 22.5 times compared to its actual value in the compound feed, it increases 1.2 times in the thyroid gland, 1.8 times in the liver, 1.9 times in the blood, 1.7 times in the spleen, and 1.6 times in the muscles" [12]. Gorlov *et al*. [13] claim that optimizing small ruminant diets for selenium, iodine, and zinc by supplementing the diets with particular feed additives improved animal productivity and helped produce mutton for use in the manufacturing of other functional meat products. The beneficial impact of the produced lamb snacks, which are enhanced with zinc, selenium, and iodine on the metabolic processes in the bodies of experimental animals was experimentally confirmed by the authors. This demonstrates how quickly they can be used to correct the metabolism of minerals, fats, proteins, and carbohydrates. In the event of a nutritional deficit, the high bioavailability of the microelements that comprise this product aids in restoring the body's physiological processes [13]. Numerous studies have demonstrated that the body needs lithium, but the bioavailability of dietary supplements that are currently on the market in their current forms has not been established. These supplements include varying levels of salts of this vital trace element. These additives frequently contain large amounts of trace elements, particularly ultra-trace elements, because of the difficulty of microdosing during mixing and manufacture. In this sense, accessible forms of trace elements—which the body naturally obtains from food—have significant advantages. According to Zarse *et al*. [14], consuming small amounts of lithium over an extended period can revitalize the body and lower mortality in a variety of living things, including people.

The impacts of prolonged exposure to lithium chloride 10 mg/kg during low-intensity exercise on endurance in obese rats should be mentioned. Recent research indicates that lithium improves exercise performance and enhances the BDNF gene expression, a neuroprotective factor in obese mice's hippocampal region. The GSK3 beta gene's activity was lowered by lithium treatment alone, which is encouraging and may help avoid neurodegenerative illnesses [15].

According to McColl *et al*. [16], lithium improved survival by 46% during normal aging at clinically relevant dosages. A novel method that involves changed expression of genes encoding nucleosome-related functions extends life expectancy. Lithium directly controls survival by altering chromatin structure and histone methylation, as demonstrated by experiments [16].

Several studies by Rahimi [17], Boyko *et al*. [18], and Hajek and Weiner [19] have demonstrated that lithium has a variety of beneficial effects on the central nervous system. Specifically, it increases nerve cell proliferation via many signaling transduction pathways and has neuroprotective effects [17-19]. Lithium is useful for both chronic and episodic types of cluster headaches, according to Abdel-Maksoud *et al*. [20]. Leeds [21] discovered that lithium preserves the blood-brain barrier integrity, lowers the level of psychotic disorders and neurological defects, and improves cognitive function and memory by lowering the level of neurological death and microglial activation. According to scientific research, an adult weighing 70 kg needs 1 mg of ionized lithium each day [22, 23]. Important neurogenesis activities are provided by this dosage, which also shields neurons from harmful substances and influences bone marrow and nerve tissue stem cell activity [22, 23]. Lithium salt maintenance therapy has been demonstrated by Zamani *et al*. [24] to protect or increase bone mass. Additionally, empirical data indicates that those taking lithium have reduced rates of bone loss. Silva *et al*. [25] discovered that the vascular endothelial growth factor stimulation, which is likewise linked to stress resistance in both humans and animals, is directly related to the therapeutic impact of lithium as a mood stabilizer. According to Angelucci *et al*. [26], neurotrophic factors are strongly linked to the mechanism of action of lithium and contribute to the development of depression.

Furthermore, lithium stimulates the production of negative immunoregulatory proteins or cytokines, such as interleukins-1RA and interleukins-10, and proinflammatory cytokines, such as IFNgamma, TNFalpha, and IL-8, which have strong immunoregulatory effect [27]. Lithium also has pro-inflammatory qualities in specific experimental settings because it stimulates the production of interleukins-4, interleukins-6, and other pro-inflammatory cytokines.

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experimental settings because it stimulates the production of interleukins-4, interleukins-6, and other pro-inflammatory cytokines [14, 28, 29].

Therefore, nowadays the scientific issue is to produce a lithium-fortified product. In current research, meat paste can be a prospective food product. Scientific specialists have reported that the enriched meat in paste production is an alternative to the traditional utilization of these meat products. Specialists have created a new product with physicochemical specifications that meet the scientific community's recommendations on proper nutrition [30].

Numerous studies have been conducted on adding micronutrients to meat paste. Therefore, it has been demonstrated by researchers de Carli *et al*. that oxidative spoiling can be avoided by adding ascorbic acid and coenzyme Q10 to a chicken liver paste recipe. Pasteurized paste's color, smell, and taste all improved once antioxidants were added [31]. According to Srebernich [32], the paste is one food that can help avoid iron-deficient anemia. In addition to other elements that are important for the body in a typical diet, this meat product allows for the acquisition of iron in an easily accessible organic form [32].

Therefore, the goal of the research is to improve the technique for making poultry meat paste that is enhanced 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 2^{nd} 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), and 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 2000-2600 rpm (the frequency of rotation of the bowl from 9-16 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 impact of the frequency of the cutter knives (bowl) rotation and the mixing process time

Factor	Factor designation	Variation levels		
		-1	**0**	**+1**
Rotation frequency of knives (bowl), rpm	X	2000 (9)	2300 (13)	2600 (16)
Duration of mixing, min	Y	12	9	6

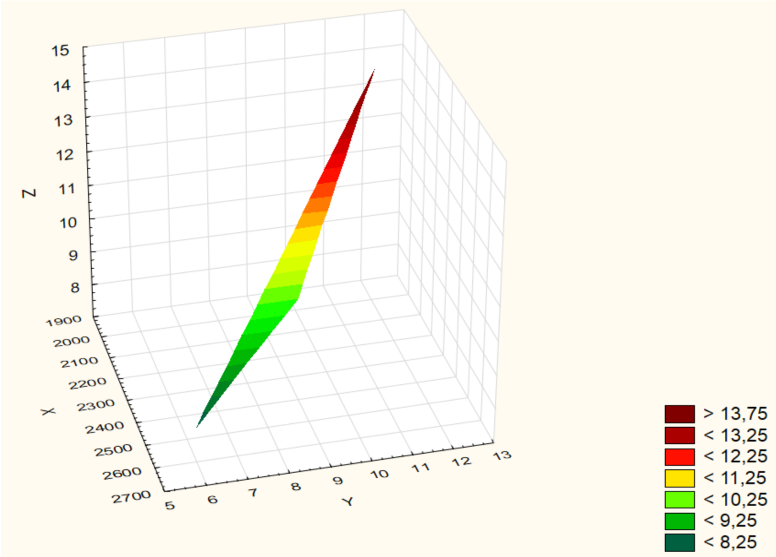

Figure 1. The response surface in the research of the value dependence of the indicator (Z), CFU / g on the frequency of rotation (X), rpm, and the process duration (Y), min

The response surface analysis **(Figure 1)** reveals that the smallest number of facultatively anaerobic and mesophilic aerobic microorganisms (Z < 8) in the paste samples is seen when the knives (bowl) rotate at a frequency greater than 2500 rpm (15 rpm) and cutting for less than 7 minutes. Because of this, the study attempts to improve the technique for making poultry meat paste that is enhanced with lithium. Studies have demonstrated that a further increase in the cutter's working organ rotation frequency results in a decline in the final paste's viscoplastic qualities and organoleptic traits. Therefore, technological mode 3 is rational with the suggested speed of the knives (bowl) 2500-2600 rpm (15-16 rpm) and the 6-7 minutes duration.

Additionally, the process entails cooling the past, putting it into metal cans that have been certified for utilization in the specified manner, rolling it up on a vacuum seaming machine, and sterilizing it in an autoclave for 45 minutes at 105–135 °C and 0.19–0.25 MPa of pressure. Finally, it is allowed to cool.

Preclinical trials

Male Wistar rats weighing between 200 g and 250 g were used as the model; there were 30 animals in all, 10 in each of the three groups. Every study was conducted following the laws and guidelines controlling laboratory animal research. Five animals each were housed in cages in a vivarium with identical settings. Compound feed was given to the animals every day at a rate of 30-35 g per head. In addition, 1 g of minced meat per head per day—or 4-5 g per kilogram of body weight—was added to the diet. According to the normative, this dosage is in line with the standards for human consumption of animal products.

All rats were acclimated to a new diet during the first phase (14 days), which involved the introduction of beef paste made without the utilization of raw materials enhanced with lithium. According to the aforesaid plan, experimental research was conducted in the second stage, which lasted for 28 days.

Results and Discussion

As a finding of the experiment to optimize the meat paste technology enriched with lithium, the organoleptic specifications of the paste were determined **(Table 2)**.

Table 2. Organoleptic specifications of the paste

Parameter	Characteristics		
	Mode 1	Mode 2	Mode 3
Appearance	Metal cans with a dry and clean surface, without damage		
Consistency	Gentle smearing		
Sectional view	Homogeneous, evenly mixed mass		
Taste and smell	Pleasant to the taste, typical for this product type, with a spice aroma		

All of the examined paste samples have a uniformly finely powdered bulk, a delicate, smeared consistency, a flavourful flavor that is typical of these items, and a spice scent. Based on the information in the table, it can be concluded that the paste samples made using various cutting techniques met the regulatory standards in terms of organoleptic indicators. **Table 3** presents an analysis of the paste's chemical and physical characteristics.

Table 3. Physicochemical indicators of the paste quality

Parameter	Specifications		
	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

Table 3 shows that there are no appreciable differences in the amounts of sodium chloride, fat, and protein in any of the paste samples under study. Protein's mass fraction falls between 14.6% and 14.8%, fat's between 11.3 and 11.4%, and table salt's between 1.20% and 1.21%, all of which satisfy regulatory standards.

With a lithium content of 0.27–0.28 mg/100 g **(Table 3)**, the new product can be categorized as an enriched paste. Following conventional procedures, studies of the microbiological characteristics of pastes (sterilized canned food) have been conducted following manufacturing and storage for 21 months. When calculating the shelf life of canned goods, the time of the last checkpoint, when all indicators were stable, is subtracted by 1.15 to account for the reserve ratio. **Table 4** displays the meat product's post-production microbiological indications.

Table 4. Microbiological specifications of the paste after production

Parameter	Specifications		
	Mode 1	Mode 2	Mode 3
QMAFAnM, CFU/g no more than	14	10	8
Coliform bacteria, are not allowed	Not selected	Not selected	Not selected
Clostridium perfringens not allowed	Not selected	Not selected	Not selected
Staphylococcus Aureus (in 0,1 g)	Not selected	Not selected	Not selected

It was discovered that every microbiological indication that was examined complied with the standards. It is noteworthy that the quantity of facultative anaerobic and mesophilic aerobic bacteria in the paste samples produced in the second and third modes is 42.9% and 28.2% lower in the control samples, respectively. Taking into account the reserve ratio, the paste's shelf life was shortened by 1.15 times by the time of the final control point, which was 24 months ago, during which the stability of all indicators was verified. Following 12 and 22 months of storage, the meat product's microbiological parameters are shown in **Tables 5 and 6**, respectively.

Table 5. Microbiological specifications of the 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, are not allowed	Not selected	Not selected	Not selected

Clostridium perfringens not allowed	Not selected	Not selected	Not selected
Staphylococcus Aureus (in 0,1 g)	Not selected	Not selected	Not selected

Table 6. Microbiological specifications of the 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, are not allowed	Not selected	Not selected	Not selected
Clostridium perfringens not allowed	Not selected	Not selected	Not selected
Staphylococcus Aureus (in 0,1 g)	Not selected	Not selected	Not selected

During the 22-month storage period, every examined organoleptic and physicochemical indicator complied with the regulations. Microbiological, physicochemical, and organoleptic investigations have determined that 18 months is the ideal shelf life. Temperatures between 0 °C and 20 °C and relative humidity levels below 75% are ideal for storage. **Table 7** displays the regulatory indications for the product under investigation.

Table 7. Regulated indicators of the meat paste quality

Parameter	Specification / Norm
Appearance	Metal cans with a dry and clean 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

The following findings were reached after preclinical tests of paste on rats. The animals were completely safe during the trial. Meat paste had full eating potential. The first stage's observations showed no departures from typical behavior, and the physiological norms for urination and defecation were met. Rats' body weights did not statistically differ across groups and were in line with normative levels. Hair and mucous membranes were visible within the physiological range.

There were no outward signs of drunkenness or the emergence of pathological processes at the second stage of the study, nor were there any abnormalities from the typical progression of physiological processes. Bodyweight did not differ by group and was in line with the normative norms. **Table 8** displays the rats' hematological markers, which indicate the overall health of the body following 28 days of paste use.

Table 8. Hematological specifications of rats during the experiment

Parameter	**Normative**	**1st Group**	**2nd Group**	**3rd Group**
White blood cells (WBCs) (x 109/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) (x 1012/l)	6.76-9.75	8.2 ± 0.6	8.9 ± 0.7	9.1 ± 0.7
Hemoglobin (g/l)	115-161	141.4 ± 7.8	139.1 ± 6.7	145.6 ± 5.8
Platelets (x 109/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

It is evident from **Table 3** data that hematological parameters show no departures from the norm and match those of animals in good health. The lack of significant intergroup differences suggests that the lithium-containing paste had no harmful consequences. A measure of the emergence of adaptation reactions, the ratio of granulocytes to lymphocytes, does not exhibit statistically significant variations and is consistent with the typical progression of physiological processes devoid of indications of the emergence of stress or other prominent adaptive reactions. The biochemical specifications of the rat's blood, reflecting the principal indicators of metabolic processes in the body after 28 days of eating the paste, are provided in **Table 9**.

Table 9. Test of blood

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

Biochemical blood parameters have been shown to correlate with the body's normal physiological activities. There is no discernible impact of using a paste enhanced with lithium on the primary markers of homeostasis, protein, carbohydrate, and fat metabolism, and there are no indications of departures from normal levels. The AST and ALT enzymes' activity is consistent with healthy animals and shows that there are no liver or cardiac diseases present. Rats' ingestion of paste had a statistically significant impact on their cholesterol levels but no discernible influence on their triglyceride levels. Rats in the third group, which received enriched lithium and meat paste, had cholesterol levels that were 8.6% lower than the values of control; the differences were statistically significant at the average level ($P = 0.024$).

For rats injected with lithium in the citrate form, a similar impact was observed in the decreased form in cholesterol levels by 6.0%, but the differences in indicators were not remarkable.

Thus, the introduction of meat paste into the rat's diet did not hurt the principal indicators of protein-carbohydrate, homeostasis, and fat metabolism in the subjects ($P = 0.382$).

Conclusion

- Thus, the following findings were drawn from the study on the technological optimization of poultry meat paste enhanced with lithium:
- It is advised to use the following method to produce poultry meat paste because enriching food raw materials (poultry meat) with a crucial microelement (lithium) has a bigger impact on the chickens throughout the rearing stage: bowl speed 14-16 rpm, knife speed 2400-2600 rpm, ice filling, cutting 6-8 minutes, adding ice, bowl revolutions 14-16 rpm, cutting 2-4 minutes.
- The primary markers of fat metabolism, protein-carbohydrate, and homeostasis in rats do not suffer when meat paste made from lithium-enriched poultry is added to their diet; the resulting recipe for making a paste from poultry meat enriched with lithium can be suggested for utilization in the food industry.

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