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Original Paper

Study on Removal Methods of Heavy Metals from Marine Freshwater Products

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Abstract

Nowadays, Marine rivers are seriously polluted, and heavy metals such as arsenic, cadmium, mercury, lead, chromium and copper are absorbed by Marine freshwater organisms, seriously endangering human health. After boiling Marine river products such as scallop skirt into a concentrated liquid and adding sodium carbonate Na_2CO_3, most heavy metals will precipitate under strong alkaline conditions and be removed by filtration. But it doesn't work on tin Sn. Adding calcium hydroxide $Ca(OH)_2$, the heavy metal forms a precipitate under strong alkaline conditions. It's filtered out. Citric acid or calcium citrate are strong chelating agents that can form chelating precipitates with heavy metals and be removed by filtration. The combination of the above two is better. Filtration loss can be reduced if hydrolysis is performed first!

Keywords

Marine science, seafood juice, scallops, alkali, calcium hydroxide, sodium carbonate

1. Introduction

The world pollution is more and more serious, since China's reform and opening up 40 years of rapid economic development pollution even more serious! Marine rivers are polluted, and heavy metals such as arsenic, cadmium, mercury, lead, chromium and copper are absorbed by Marine freshwater organisms. Cadmium is easily enriched in crustaceans, kelp, seaweed and nori, which seriously endangers human health.

According to Guangdong-domestic and international reports: Pearl River estuary oyster copper 100 times over the standard. According to Zhihu.com, the pass rate of sea crabs sampled by the state is only 20%. According to our detection: Shandong Laizhou scallop skirt cadmium content reached 15-34 times of the standard. Arsenic levels in laver in Lianyungang, Jiangsu province, were 20 times higher

than the legal limit. Lianyungang, a large laver processing business owner unexpectedly did not know that laver also test heavy metals. Such a serious problem has not yet attracted enough attention from the relevant departments!

2. Materials, Equipment and Methods

Boil the skirt of Laizhou scallop into concentrated liquid, precipitate and filter. Detection results (mg/kg): 1# Cd=1.4, 2# Cd=2.7, 3# Cd=4.4, 4# Cd=7.3 and 5# Cd=17. Both exceed national standards. Methods of removing heavy metals are now investigated using 3# and 5# samples (Figures 1 and 2).

2.1 Devices

2.1.1 The precipitation method, precipitation-chelation method and chelation-precipitation method use a 5L triangular cone bottle and 1500w temperature control furnace.

2.1.2 Hydrolyzation-chelation-precipitation method requires hydrolysis equipment.

2.1.2.1 Reflux hydrolysis. With a 5L triangular cone bottle, plus a rubber plug, plug in the condensation tube, and connect the tap water to cool the hydrolyzed steam, so as not to burn the hydrolysate dry. It was heated in a temperature controlled electric furnace and hydrolyzed at 100^0C at one atmospheric pressure (1kg pressure) for 12 hours. Take care to regulate the temperature to prevent excessive boiling and dry the hydrolysate liquid.

2.1.2.2 Reactor hydrolysis.

Use 304 stainless steel reactor, volume according to need. With an anchor mixer. Run the mixer for 10 minutes at regular intervals at 40 RPM. Be careful not to fill the reactor too full, 70% can be. Hydrolysis at 2kg pressure, 112-118^0C for 12 hours. Be careful not to heat too much to avoid a burnt taste.

2.2 Citric Acid Hydrolysis

The above hydrolyzed raw materials are heated and hydrolyzed with citric acid and appropriate amount of water calculated by the following formula.

2.2.1 The amount of citric acid hydrolysis can be calculated by the "double Chen hydrolysis formula": from Chen Junhao and Chen Guiqing. Study on Crystal Structure and Application of Pearl and shellfish [M]; December 2018, Jinan University Press, P.143.

$M_{\text{Hydrolytic acid}}$=(molecular weight of hydrolytic acid/14.0067) × raw protein content × 16%×***CC***÷Y

Citric acid is a ternary acid Y=3.

$M_{\text{Citric acid}}$=(192.125÷14.0067) × (weight of raw material × protein content of the raw material) × 16% × ***CC*** ÷ 3

=Weight of raw material × protein content of raw material × ***CC*** × 0.7315=weight of raw material × nitrogen content of raw material × 6.25 × ***CC*** × 0.7315..... (1).

Add the same amount of water, heat to hydrolysis. M stands for weight. Select ***CC*** refer to Table 1.

2.2.2 Neutralization of food-grade hydrated lime.

From the inorganic chemistry textbook.

M calcium hydroxide=(222.284÷384.251) × M citric acid=0.5785×M citric acid... The essay

In order to prevent residual calcium hydrogen citrate $CaH(C_6H_5O_7)$ and calcium hydrogen citrate $CaH_4(C_6H_5O_7)_2$ from being converted into calcium citrate $Ca_3(C_6H_5O_7)_2$ precipitation, and to completely remove heavy metals, so that the hydrolysate reaches PH12-13, the addition of hydrated lime requires an increase of 5% of the original amount. Since the saturated solubility of hydrated lime $Ca(0H)_2$ at 20^0C is 0.16(g/100g), PH12-13 is reached at this time. Excess lime can be precipitated and filtered out, and the saturated solubility of lime in the solution of 0.16g/100g will not affect the subsequent treatment.

2.2.3 After 5 hours of precipitation, filter.

2.2.4 Expected production V (volume).

From Chen Junhao, Chen Guiqing. Crystal structure and application of pearls and shellfish [M]. December 2018, Jinan University Press, P.147.

Product volume V(mL)=raw material weight (g) × protein content of the raw material %×16%×γ ÷ Amino nitrogen of the product (g/mL)..... (3)

2.2.5 Extraction rate γ: reactor hydrolysis γ=50% ~ 70%, reflux hydrolysis temperature is greatly affected by temperature, worse in winter, γ=30% ~ 50%.

The hydrolysis capacity of citric acid is weaker than that of hydrochloric acid, and it is more suitable for hydrolysis of seafood with protein content below 30%.

3. Experimental Methods

3.1 Precipitation Method

3.1.1 After adding sodium carbonate Na_2CO_3 to seafood liquid, most heavy metals will precipitate under strong alkaline conditions, such as $CaHAsO_4{\cdot}H_2O$, $CaCrO_4$, $CdCO_3$, Hg_2CO_3, $PbCO_3$, $ZnCO_3$, $NiCO_3$, $CuCO_3$, and then filter out. But it doesn't work on tin Sn.

3.1.2 After adding hydrated lime $Ca(OH)_2$ to seafood liquid, all heavy metals will precipitate under strong alkaline conditions, such as:

$Ca_5(AsO_4)_3{\cdot}OH$, $Ca_4(OH)_2(AsO_4)_2$, $Cd(OH)_2$, $Cd(OH)_3$, $Cr(OH)_2$, $Cr(OH)_3$, $Cu(OH)_2$, $Hg_2(OH)_2$, $Ni(OH)_2$, CA5 $(ASO_4)_3{\cdot}$ OH, CA_4 $(OH)_2(AsO4)_2$, CD (OH)2, Cr(OH)3, Cu(OH)2, HG2 (OH)2, Ni(OH)2, Pb(OH)2, Pb(OH)4, Sn(OH)2, Sn(OH)4, Zn(OH)2. Filter out.

3.2 Precipitation-chelation

After the removal of heavy metals, the seafood juice is strongly alkaline, not delicious, and cannot measure amino acids, and must be adjusted to weak acidity. The use of hydrated lime precipitates, which must be regulated with citric acid, forms calcium citrate and heavy metal precipitates, which are filtered out. This is precipitation-chelation, not precipitation anymore.

3.3 Chelation-precipitation Method

Citric acid is a strong chelating agent, able to chelate heavy metals. Calcium citrate and heavy metal precipitates are formed by adding hydrated lime, and heavy metals are removed by filtering and discarding residue after a long time precipitation.

3.4 Hydrolyzation-chelation-precipitation Method

Protein is a large molecule, filtration loss. First, the protein is hydrolyzed into soluble amino acids with citric acid, and the hydrated lime is added to form calcium citrate and heavy metal precipitates, which are filtered and removed to reduce losses.

4. Experimental Results

4.1 Precipitation Method

Sodium carbonate is not a base, classified as salt, called alkaline substances, alkaline weak.

4.1.1 Scallop solution 100ml+ 7% sodium carbonate + 18ml water, dissolved by stirring, pH≈9. Precipitate for 48 hours and filter. Test results are shown in Figure 3, Cd=0.89.

4.1.2 Scallop liquid 250ml+ 10% sodium carbonate + 25ml water, stir to dissolve, pH>9. Precipitate for 72 hours and filter. Test results are shown in Figure 4, Cd=0.71.

4.1.3 Scallop liquid 250ml+ sodium carbonate 15%+ water 38ml, dissolved by stirring, pH≈10. Precipitate for 72 hours and filter. Test results are shown in Figure 5, Cd=0.72.

* Using more than 9% sodium carbonate does not improve results. All Cd>0.5, not up to standard.

4.2 Precipitation-chelation Method

4.2.1 Scallop liquid 300ml+ 2% hydrated lime, stir to dissolve, PH=12. Precipitate for 24 hours, add citric acid to PH=8. Chelate, precipitate for 36 hours, filter. Test results are shown in Figure 6, Cd=0.39.

4.2.2 Scallop liquid 350ml+ hydrated lime 2.5%, stir to dissolve, PH=12. Precipitate for 24 hours, add citric acid to PH=8. Chelate, precipitate for 36 hours, filter. Test results are shown in Figure 7, Cd=0.34.

4.3 Chelation-precipitation Method

4.3.1 Scallop liquid 560ml+ 6% citric acid, stir to dissolve, pH=3. Reaction for 12 hours, add hydrated lime to pH=12. Precipitate for 12 hours and filter. The test results are shown in Figure 8, Cd=0.21.

4.3.2 Scallop liquid 560ml+ 6% citric acid, stir to dissolve, pH=3. Reaction for 12 hours, add hydrated lime to pH=12. Precipitate for 48 hours and filter. Test results are shown in FIG. 9, Cd=0.21. 12 hours of precipitation is enough.

4.3.3 Scallop solution 100ml+ citric acid 6%, stir to dissolve, pH=3. Reaction for 12 hours, add hydrated lime to pH=12. Precipitate for 14 hours. The filtering methods are as follows:

4.3.3.1 Filter paper filtering. Test results are shown in FIG. 10, Cd=0.44.

4.3.3.2 1 micron filter filter. Test are shown in FIG.11, Cd=0.4.

4.3.3.3 0.5 micron filter Filter. Test results are shown in FIG. 12, Cd=0.28.

4.4 Hydrolyzation-Chelation-precipitation Method

4.4.1 Scallop liquid 2120ml+ citric acid 426.5g+ water 1600ml. Hydrolysis for 12 hours, hydrated lime neutralization and other treatment after precipitation for 12 hours, filtration. Test results as shown in FIG. 13, Cd<0.02, As1.2, Pb0.0600, Hg<0.05, Cr0.21, Cu<0.05; Precipitate for 48 hours and filter. Test results are shown in Figure 14, As 0.60; Precipitate for 60 hours and filter. Test results as shown in FIG.15, As 0.48, inorganic arsenic 0.15, Cd 0.0040.

4.4.2 Scallop liquid 1695ml+ citric acid 337.3g+ water 1600ml. Hydrolysis for 12 hours, hydrated lime neutralization and other treatment after precipitation for 24 hours, filtration. Test results as shown in FIG. 16, Cd 0.020, inorganic arsenic 0.15.

4.4.3 Scallop liquid 1680 ml+ citric acid 330g+ water 1600ml. Hydrolysis for 12 hours, hydrated lime neutralization and other treatment after precipitation for 3 hours, filtration. Test results as shown in FIG. 17, Cd0.079, inorganic As was not detected, Pb 0.0370, Hg was not detected, Cr 0.42. Precipitate for 6 hours and filter. Test results as shown in FIG. 18, Cd 0.078, inorganic As was not detected, Pb was not detected, Hg was not detected, Cr0.42. Precipitate for 9 hours and filter. Test results as shown in FIG. 19, Cd0.077, inorganic As was not detected, Pb 0.0284, Hg was not detected, Cr 0.33. Precipitate for 12 hours and filter. Test results as shown in FIG. 20, Cd 0.072, inorganic arsenic As 0.041, Pb 0.0373, Hg 0.011, Cr 0.43. 3 hours of precipitation is enough.

4.4.4 Scallop liquid 2100ml+ citric acid 499g+ water 1200ml. Hydrolysis for 12 hours, hydrated lime neutralization and other treatment after precipitation for 12 hours, filtration. Test results as shown in Figure 21, Cr 830.93μg/L, Cu 116.44μg/L, inorganic arsenic 0.36mg/Kg, Cd0.86μg/L, Hg 0.34μg/L, Pb 8.93μg/L.

4.4.5 Experimental laver. Total amino acid 32.5%. Test results as shown in Figure 22, total arsenic 20, total mercury 0.010, cadmium 0.77, chromium 0.93, copper 13.5, lead 0.508.

4.4.6 Laver seasoning liquid. 180g dried laver + 258g citric acid + 1600ml water. CC=7, hydrolysis 12 hours, hydrated lime neutralization and other treatment after precipitation 12 hours, Test results as shown in FIG. 23 shows lead < 0.05, total arsenic 0.38, total mercury < 0.05, cadmium < 0.02, chromium < 0.1, copper < 0.5.

4.4.7 Nori 84g+ Citric acid 159.8g+1680ml water. CC=8. Hydrolysis for 12 hours, hydrated lime neutralization and other treatment after precipitation for 12 hours, filtration. Test results as shown in Figure 24, Cr 92.16μg/L, Cu 130.92μg/L, inorganic arsenic 0.46mg/Kg, Cd 21μg/L, Hg 0.12μg/L, Pb 4.34μg/L.

5. Conclusion

1) It is not possible to remove heavy metals by simple precipitation method, because it is strongly alkaline and must be adjusted to weak acidity to make food, which is no longer a precipitation method.

2) Precipitation-chelation or chelation-precipitation method is feasible to remove heavy metals, the latter effect is better!

3) Hydrolyzation-chelation-precipitation method is the most effective method to remove heavy metals, with less filtration loss, and can directly produce amino acids to make seafood condiments and complex seasonings.

The book is illustrated

National standard for heavy metals in seafood condiments						
Unit mg/kg	Inorganic As	Cd	Orgenic Hg	Pb	Cr	Cu
Fish seasoning	⩽0.1	⩽0.1	----	⩽0.5	----	----
Other condiments	⩽0.5	⩽0.5*	----	----	----	----
Oyster sauce	----	----	⩽0.5	⩽1.0	----	----

* No National standard, refer to inorganic As.

Table 1. 3# Scallop liquid

鉴科检测 Janko Testing Service

第 3 页 共 4 页

报告编号： JATF20061749a 检测报告

检测项目	分析结果	检测依据
	山东莱州扇贝汁（2）	
镉(mg/kg)	4.4	GB 5009.15-2014
无机砷(mg/kg)	0.27	GB 5009.11-2014 第二篇第一法
铅(mg/kg)	未检出（<0.04）	GB 5009.12-2017 第一法
总汞(mg/kg)	未检出（<0.01）	GB 5009.17-2014 第一篇第一法
铬(mg/kg)	0.11	GB 5009.123-2014

Table 2. 5# Scallop liquid

检 验 检 测 结 果

报告编号：WF02021047384 检 测 结 果 日期：2021年04月29日

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.89	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

Table 3. 7% of edible alkali, precipitated 48 hours

检 验 检 测 结 果

报告编号：WF0210501084 共2页 第2页

序号	检验项目	检测方法	单位	检测结果
1	镉	GB 5009.15-2014	mg/kg	0.71

Table 4. 10% of edible alkali, precipitated 72 hours

检 验 检 测 结 果

报告编号：WF0210501101 共2页 第2页

序号	检验项目	检测方法	单位	检测结果
1	镉	GB 5009.15-2014	mg/kg	0.72

Table 5. Edible alkali 15%, precipitation 72 hours

汇标检测

检验检测报告

报告编号：WF02020100666 日期：2020年10月16日

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.39	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

Table 6. Hydrated lime 2%+ citric acid, precipitation 36 hours

汇标检测

检验检测报告

报告编号：WF02020100659 日期：2020年10月16日

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.34	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

Table 7 Hydrated lime 2.5%+ citric acid, precipitated for 36hours

鉴科检测 Janko Testing Service

第 3 页 共 3 页

报告编号： JATF20092727-01 检测报告

检测项目	分析结果	检测依据
	扇贝汁 5（整合、沉淀、过滤 12 小时）	
镉(mg/kg)	0.21	GB 5009.15-2014

Table 8 Citric acid 6%+ hydrated lime, precipitated for 12hours

鉴科检测 Janko Testing Service

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报告编号： JATF20092727-03 检测报告

检测项目	分析结果	检测依据
	扇贝汁 5（整合、沉淀、48 小时）	
镉(mg/kg)	0.21	GB 5009.15-2014

报告编号：WFO2020112323 检 测 结 果 日期：2020年11月17日

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.44	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

Table 9. 6% citric acid + hydrated lime, precipitated for 48hours

Table 10. 6% citric acid + hydrated lime, precipitated for 14hours

报告编号：WFO2020112321 检 测 结 果 日期：2020年11月17日

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.40	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

报告编号：WFO2020112324 日期：2020年11月17日

检 测 结 果

序号	检测项目	检测结果	结果单位	检测方法
1	镉	0.28	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定

Table 11. Citric acid 6% + hydrated lime, precipitated for 14 hours

Table 12. Citric acid 6% + hydrated lime, precipitated for 14 hours,

1 filter membrane filtrationr

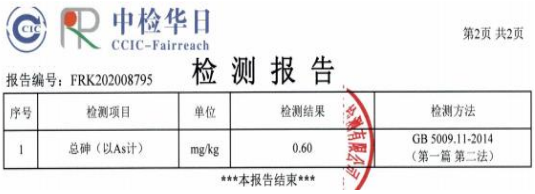
0.5 filter membrane filtrationr

中检华日 CCIC-Fairreach

第2页 共3页

报告编号：FRK202007351 检 测 报 告

序号	检测项目	单位	检测结果	检测方法
1	镉（以Cd计）	mg/kg	<0.02	GB 5009.15-2014
2	总砷（以As计）	mg/kg	1.2	GB 5009.11-2014（第一篇 第二法）
3	铅（以Pb计）	mg/kg	0.0600	GB 5009.12-2017（第二法）
4	总汞（以Hg计）	mg/kg	<0.05	GB 5009.17-2014（第一篇 第一法）
5	铬（以Cr计）	mg/kg	0.21	GB 5009.123-2014
6	铜（以Cu计）	mg/kg	<0.5	GB 5009.13-2017（第二法）



中检华日 CCIC-Fairreach

第2页 共2页

报告编号：FRK202008795 检 测 报 告

序号	检测项目	单位	检测结果	检测方法
1	总砷（以As计）	mg/kg	0.60	GB 5009.11-2014（第一篇 第二法）

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Table 13. Scallop hydrolyzed juice , precipitated for 12hours

Table 14. Scallop hydrolyzed juice , precipitated for 48hours

鉴科检测 Janko Testing Service

第 3 页 共 3 页

报告编号： JATF20071801 检测报告

检测项目	分析结果	检测依据
	山东莱州扇贝汁（去除重金属沉淀 60 小时）	
总砷(mg/kg)	0.48	GB 5009.11-2014 第一篇第二法
无机砷(mg/kg)	0.15	GB 5009.11-2014 第二篇第一法
镉(mg/kg)	0.0040	GB 5009.15-2014

报告编号： JATF20071870 第 3 页 共 3 页

检测项目	分析结果	检测依据
	山东莱州扇贝汁（2）（去除重金属沉淀 24 小时）	
镉(mg/kg)	0.020	GB 5009.15-2014
无机砷(mg/kg)	0.15	GB 5009.11-2014 第二篇第一法

Table 15. Scallop hydrolyzed juice, precipitated for 60hours

Table 16. Scallop hydrolyzed juice, precipitated for 24hours

检 测 结 果

报告编号：WFQ2020074324

序号	检测项目	检测结果	检出限	结果单位	检测方法
1	镉	0.079	0.001	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定
2	无机砷	未检出	0.03	mg/kg	GB 5009.11-2014 食品安全国家标准 食品中总砷及无机砷的测定 第二篇 第一法 液相色谱-原子荧光光谱法（LC-AFS）法
3	铅	0.0370	0.02	mg/kg	GB 5009.12-2017 食品安全国家标准 食品中铅的测定 第一法 石墨炉原子吸收光谱法
4	总汞	未检出	0.003	mg/kg	GB 5009.17-2014 食品安全国家标准 食品中总汞及有机汞的测定 第一篇 第一法 原子荧光光谱分析法
5	铬	0.42	0.01	mg/kg	GB 5009.123-2014 食品安全国家标准 食品中铬的测定 石墨炉原子吸收光谱法

备注："未检出"表示检测结果小于检出限

Table 17. Scallop hydrolyzed juice, precipitated for 3 hours

检 测 结 果

报告编号：WFQ2020074322

序号	检测项目	检测结果	检出限	结果单位	检测方法
1	镉	0.078	0.001	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定
2	无机砷	未检出	0.03	mg/kg	GB 5009.11-2014 食品安全国家标准 食品中总砷及无机砷的测定 第二篇 第一法 液相色谱-原子荧光光谱法（LC-AFS）法
3	铅	未检出	0.02	mg/kg	GB 5009.12-2017 食品安全国家标准 食品中铅的测定 第一法 石墨炉原子吸收光谱法
4	总汞	未检出	0.003	mg/kg	GB 5009.17-2014 食品安全国家标准 食品中总汞及有机汞的测定 第一篇 第一法 原子荧光光谱分析法
5	铬	0.42	0.01	mg/kg	GB 5009.123-2014 食品安全国家标准 食品中铬的测定 石墨炉原子吸收光谱法

备注："未检出"表示检测结果小于检出限

Table 18. Scallop hydrolyzed juice, precipitated for 6 hours

检 测 结 果

报告编号：WFQ2020074328

序号	检测项目	检测结果	检出限	结果单位	检测方法
1	镉	0.077	0.001	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定
2	无机砷	未检出	0.03	mg/kg	GB 5009.11-2014 食品安全国家标准 食品中总砷及无机砷的测定 第二篇 第一法 液相色谱-原子荧光光谱法（LC-AFS）法
3	铅	0.0284	0.02	mg/kg	GB 5009.12-2017 食品安全国家标准 食品中铅的测定 第一法 石墨炉原子吸收光谱法
4	总汞	未检出	0.003	mg/kg	GB 5009.17-2014 食品安全国家标准 食品中总汞及有机汞的测定 第一篇 第一法 原子荧光光谱分析法
5	铬	0.33	0.01	mg/kg	GB 5009.123-2014 食品安全国家标准 食品中铬的测定 石墨炉原子吸收光谱法

备注："未检出"表示检测结果小于检出限

Table 19. Scallop hydrolyzed juice, precipitated for 9hours

检 测 结 果

报告编号：WFQ2020074326

序号	检测项目	检测结果	检出限	结果单位	检测方法
1	镉	0.072	0.001	mg/kg	GB 5009.15-2014 食品安全国家标准 食品中镉的测定
2	无机砷	0.041	0.003	mg/kg	GB 5009.11-2014 食品安全国家标准 食品中总砷及无机砷的测定 第二篇 第一法 液相色谱-原子荧光光谱法（LC-AFS）法
3	铅	0.0373	0.02	mg/kg	GB 5009.12-2017 食品安全国家标准 食品中铅的测定 第一法 石墨炉原子吸收光谱法
4	总汞	0.011	0.003	mg/kg	GB 5009.17-2014 食品安全国家标准 食品中总汞及有机汞的测定 第一篇 第一法 原子荧光光谱分析法
5	铬	0.43	0.01	mg/kg	GB 5009.123-2014 食品安全国家标准 食品中铬的测定 石墨炉原子吸收光谱法

Table 20. Scallop hydrolyzed juice, precipitated for 12hours

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测试结果：

报告编号：FT-20230109009-3 表 2 莱州扇贝汁重金属 6 项测试结果

样品名称	测试项目	测试结果	单位	测试仪器/方法
莱州扇贝汁	Cr	830.93	μg/L	ICP-MS
莱州扇贝汁	Cu	116.44	μg/L	ICP-MS
莱州扇贝汁	As	2571.20	μg/L	ICP-MS
莱州扇贝汁	Cd	0.86	μg/L	ICP-MS
莱州扇贝汁	Hg	0.34	μg/L	ICP-MS
莱州扇贝汁	Pb	8.93	μg/L	ICP-MS

Table 21. Scallop hydrolyzed juice, precipitated for 12hours

中检华日 CCIC-Fairreach

报告编号：FRK202008765

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检测结果：

检 测 报 告

序号	检测项目	单位	检测结果	检测方法
1	总砷（以As计）	mg/kg	20	GB 5009.11-2014（第一篇 第二法）
2	总汞（以Hg计）	mg/kg	0.010	GB 5009.17-2014（第一篇 第一法）
3	镉（以Cd计）	mg/kg	0.77	GB 5009.15-2014
4	铬（以Cr计）	mg/kg	0.93	GB 5009.123-2014
5	铜（以Cu计）	mg/kg	13.5	GB 5009.13-2017（第二法）
6	氨基酸总量	g/100g	32.5	GB 5009.124-2016*

Table 22. Laver

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检 测 报 告

报告编号：FRK202008667

序号	检测项目	单位	检测结果	检测方法
1	铅（以Pb计）	mg/kg	<0.05	GB 5009.12-2017（第二法）
2	总砷（以As计）	mg/kg	0.38	GB 5009.11-2014（第一篇 第二法）
3	总汞（以Hg计）	mg/kg	<0.05	GB 5009.17-2014（第一篇 第一法）
4	镉（以Cd计）	mg/kg	<0.02	GB 5009.15-2014
5	铬（以Cr计）	mg/kg	<0.1	GB 5009.123-2014
6	铜（以Cu计）	mg/kg	<0.5	GB 5009.13-2017（第二法）

Table 23. Laver seasoning solution

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测试结果：

报告编号：FT-20230109009-1 表 2 连云港紫菜汁重金属 6 项测试结果

样品名称	测试项目	测试结果	单位	测试仪器/方法
连云港紫菜汁	Cr	92.16	μg/L	ICP-MS
连云港紫菜汁	Cu	130.92	μg/L	ICP-MS
连云港紫菜汁	As	1785.63	μg/L	ICP-MS
连云港紫菜汁	Cd	0.21	μg/L	ICP-MS
连云港紫菜汁	Hg	0.12	μg/L	ICP-MS
连云港紫菜汁	Pb	4.34	μg/L	ICP-MS

Table 24. New laver hydrolyzed juice

Gly 甘氨酸。Ala 丙氨酸。Val 缬氨酸。Leu 亮氨酸。Ile 异亮氨酸。Phe 苯丙氨酸。Trp 色氨酸。

Tyr 酪氨酸。Asp 天冬氨酸。His 组氨酸。Asn 天冬酰胺。Glu 谷氨酸。Lys 赖氨酸。Gln 谷氨酰胺

Met 甲硫氨酸。Arg 精氨酸。Ser 丝氨酸。Thr 苏氨酸。Cys 半胱氨酸。Pro 脯氨酸。

References

Chen Junhao, & Chen Guiqing. (2017). *Production method of amino acid liquid of Pearl oyster or ginseng of pearl oyster*. Patent No. ZL 2015 1 057130.x. Authorization date November 21, 2017.

Chen Junhao, & Chen Guiqing. (2017). *Production method of fresh scallop juice*. Patent No. ZL 2015 1 0571208.3. Authorization date November 21, 2017.

Chen Junhao, & Chen Guiqing. (2018). *Crystal Structure and application exploration of pearls and shellfish*. Jinan University Press, December 2018.

Chen Junhao, & Chen Guiqing. (2019). The Ancient Shells Were Sdudied by X-ray Diffraction and Electron probes. *Journal of Water Resources and Ocean Science*, *8*(6), 86. https://doi.org/10.11648/j.wros.20190806.11

Chen, G. Q., & Chen, J. H. (2018). *Production method of astaxanthin prawn juice*. Patent No. ZL 2015 1 0571551.8. Authorization date: January 2, 2018.

Hu Jing et al. (2017). Response Surface method optimization of removal process of cadmium from mushroom by citric acid. *Food Science*, *38*(14).

Wu Yanan et al. (2017). Effect of cadmium removal of citric acid on structure and physicochemical properties of brown rice flour. *China Journal of Grain and Oil*, *32*(8).