微生物学报 *Acta Microbiologica Sinica*
49(5):609 – 616;4 May 2009
ISSN 0001 – 6209;CN 11 – 1995/Q
http://journals.im.ac.cn/actamicrocn

Paracin 1.7, a bacteriocin produced by *Lactobacillus paracasei* HD1.7 isolated from Chinese cabbage sauerkraut, a traditional Chinese fermented vegetable food

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Abstract: [**Objects**] To purify and characterize bacteriocin produced by *L. paracasei* HD1.7. [**Methods**] Paracin 1.7 was purified by chromatography and its molecular weight was measured by using sodium dodecyl sulfate -polyacrylamide gel electrophoresis (SDS-PAGE). Antibacterial activity was measured by using the agar-well diffusion method. [**Results**] The bacterial strain for the fermentation was identified as *Lactobacillus* subsp. *paracasei*. Paracin 1.7 had the activity of inhibiting the growth of other bacteria. Maximum production of Paracin 1.7 was in the stationary phase. Paracin 1.7 can be well purified with Cation exchange chromatography, Sephedex (G50, G25, G10) gel chromatography and high performance liquid chromatography (HPLC) on C18 column and its determined molecular weight was about 11 kDa by Tricine-SDS-PAGE. Paracin 1.7 shows a broad spectrum of activities against various strains in the genera of *Proteus*, *Bacillus*, *Enterobacter*, *Staphylococcus*, *Escherichia*, *Lactobacillus*, *Micrococus*, *Pseudomonas*, *Salmonella* and *Saccharomyces*, some of which belong to food borne pathogenic bacteria. Although Paracin 1.7 displayed stability toward heat and acidic pH, it was sensitive to several proteolytic enzymes. The inhibitory activities remain well after stored at 4℃ for 4 months; the inhibitory activity declined only 4.19%. [**Conclusion**] Paracin 1.7 can be a potential food preservative on the basis of its antibacterial characters.

Keywords: *Lactobacillus paracasei* HD1.7; Paracin 1.7; sauerkraut; bacteriocin; purification
CLC number: Q935 **Document code**: A **Article ID**: 0001-6209(2009)05-0609-08

Many bacteria can produce bacteriocins, which are bacterial peptides or proteins with antibacterial activity against bacterial strains closely related to the producing bacteria. In particular, bacteriocins from lactic acid bacteria (LAB) have attracted great interest because of their potential uses as non-toxic and safe additives for food and feed preservation. According to their physico-chemical, biological, genetic characteristics[1], compositions, sizes, heat-stabilities, modes of action, types of export mechanism and activity spectra[2], the LAB bacteriocins have been classified into different groups and the class Ⅱ (small, heat stable and two-component) is the most abundant and best studied.

Cabbage sauerkraut is one of the traditional fermentation foods in Northeastern China, produced through fermentation by lactic acid bacteria on which Chinese cabbage. Most of the bacteriocins were produced by *Lactobacillus paracasei* from raw milk[3], cheese[4] and cereal based drinks[5]. Caridi (2002)[6] reported two strains of *L. paracasei* subsp. paracasei isolated from artisanal Caprino d'Aspromonte cheese, made from raw goats' milk. These strains exhibited antimicrobial ability against *Candida* genus[4]. The molecular weight of bacteriocins varied with different *L. paracasei* strains, e.g., strain M3 produced a 43 kDa bacteriocin[4] and strain BUGBUK2-16 produced a 7 kDa bacteriocin[7]. However, little is known about bacteriocin produced by *L. paracasei* subsp. *paracasei* from cabbage sauerkraut. This work reports the

Supported by The Foundation of Key Program of Heilongjiang (GB05 B401); Outstanding Teacher Funds of Heilongjiang Province, China (1055G034); The Project-sponsored by SRF for ROCS, SEM; The Natural Science Foundation of Heilongjiang Province, China (C200505);
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Received: 21 November 2008 /Revised: 21 February 2009

characterization of a proteinaceous bacteriocin from another *L. paracasei* strain HD1.7, which was isolated from the fermentation broth of Chinese cabbage sauerkraut.

1 MATERIALS AND METHODS

1.1 Bacterial strain and medium

L. paracasei strain HD 1.7 was isolated from the fermentation broth of Chinese sauerkraut in Fengyuan Food Factory of Heilongjiang province, China. It was identified as *L. paracasei*. subsp. *paracasei* by sugar fermentation tests using an API 50 CHL identification kit (API system, BioMérieux, Marcy 1 'Etoile, France) and the sequence of its partial 16S rRNA gene was analyzed. The API LAB Plus computer-aided identification program version 4.0 (BioMérieux, France) was used to analyze the carbohydrate fermentation profiles obtained with the identification strips. Strain HD1.7 was grown in MRS broth(composition of the used medium in g/L: peptone -10; meat extract -10; yeast extract-5; D(+) glucose-20; K_2HPO_4-2; Na_2SO_3-0.1; sodium acetate-5; ammonium hydrogen citrate-2; $MgSO_4$-0.2; $MnSO_4$-0.05; Tween 80-1 mL) or MRS agar and incubated at 30℃. *Bacillus subtilis* ACCC 11061 was used as the indicator strain in the bacteriocin assay. They were stored in LB broth containing 20% (v/v) glycerol at −80℃.

1.2 Bacteriocin activity assay

Bacteriocin screening was performed by using the agar-well diffusion method, described by Schillinger and Lücke (1989)[8]. To eliminate the antimicrobial effect of lactic acid, the pH of the supernatants was adjusted to 5.5 with 1M NaOH, and the activity was expressed in AU/mL. Titers were defined as the reciprocal of the highest dilution that inhibited the growth of the indicator strain. The result of the bacteriocin activity was presented in arbitrary units per milliliter (AU/mL).

1.3 Bacteriocin production

Sterile modified MRS broth (soytone peptone instead of the standard peptone component) was inoculated with 1% (v/v) of an HD1.7 culture and incubated at 30℃ with an agitation speed of 180 r/min. Samples were taken every 4h to determine the optical density of the culture at 600nm, the antimicrobial activity (AU/mL) of the bacteriocin produced, and the pH of the supernatant.

1.4 Purification of bacteriocin

Bacteriocin was purified by CM Sepharose Fast Flow, Sephadex and HPLC. Cell free supernatant of the strain HD 1.7 (30 mL) was loaded at a flow rate of 3 mL/min onto a CM Sepharose Fast Flow cation-exchange column (16 mm × 200 mm) equilibrated with 0.05 mol/L ammonium acetate buffer (pH 6.0). The elution was conducted with a stepwise gradient from 0.05 to 1.0 mol/L ammonium acetate at a flow rate of 1mL/min and detected with a UV detector at 254 nm. Fractions were collected to test the antimicrobial activity. The active fractions (Fraction I) obtained by cation-exchange chromatography were combined, concentrated and applied on a Sephadex column (1000 mm × 10 mm) self packed with G50, G25 and G10 packing materials respectively, to further fractionate the active fraction. The columns were equilibrated with 0.05 mol/L ammonium acetate (pH 6.0) at a flow rate of 0.8 mL/min and detected with a UV detector at 254 nm. The active fractions were concentrated by vacuum evaporation. Activity test was performed using the agar-well diffusion method as described above in section 1.2.

Concentrated active fractions separated by Sephadex G10 chromatography were further purified using a Waters HPLC system (Waters 510 HPLC pump, Waters TM 996 Photodiode Array Detector). The column was a Delta-Pak TM 300 nm C18 column (5 μm, 3.9 mm × 150 mm) and the flow rate was 0.8 mL/min. Elution was performed by applying a gradient from 100% buffer A (5%, v/v, acetonitrile / distilled water) to 100% buffer B (80%, v/v, acetonitrile / distilled water) in 30 min.

1.5 Determination of antimicrobial spectrum

Fraction I was used to determine the antimicrobial spectrum. HD 1.7 was grown in MRS broth for 24h at 30℃ with an agitation speed of 180 r/min. The spectra of these samples were tested against a wide range of indicator strains, such as Gram positive and Gram negative bacteria, yeast and LAB. All of the bacteria were grown in LB broth at 37℃ for 24 h. Yeast was grown in PDA broth at 30℃ for 48 h. Minimal inhibitory concentrations (MICs) of bacteriocin (Fraction I) were determined using standard microdilution method[10-11]. Briefly, indicator strains (1×10^6 CFU/mL) were incubated in LB broth or YPD broth containing serial

diluted Fraction I (50 uL). The MIC was defined as the lowest concentration of bacteriocin that visibly inhibited bacterial or yeast growth after incubation at 37℃ or 30℃ for 16 – 24 h. Each assay was performed three times.

1.6 Effect of proteolytic enzyme, pH and temperature on bacteriocin stability

The effect of various proteolytic enzymes on bacteriocin activity was determined by incubating 100 μL of Fraction I with 20 μL of the following enzyme solutions at a final concentration of 1 mg/mL: proteinase K (pH7.0, 37℃, Sigma), trypsin from bovine pancreas (pH8.0, 25℃, Merck); papain (pH6.0, 37℃, Sigma), pepsin (pH3.0, 37℃, Merck). The effect of the proteases was defined under the conditions optimal for each enzyme (pH and temperature). After 2 h incubation at each optimal temperature, enzyme reaction was terminated by boiling at 100℃ for 3 min.

After adjusted to pH 5.5, the residual bacteriocin activity was assayed against *B. sublitis* ACCC 11061 in the presence of negative controls (e. g., untreated samples). The effects of different pH on bacteriocin activity were determined by adjusting the pH of the Fraction I to 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0 using 1 M NaOH or 1 M HCl. Incubation was done at room temperature for 2 h, and the residual activity was assayed against *B. sublitis* ACCC 11061 by the agar-well diffusion method. The effect of temperature was determined by heating Fraction I at 30℃, 50℃, 60℃, 80℃, 100℃ for 30 min, respectively, and at 121℃ for 15 min[12,5]. The residual activity was assayed against *B. sublitis* ACCC 11061 by the agar-well diffusion method.

1.7 Tricine-SDS-PAGE

In order to determine the molecular mass, purified bacteriocin of HD1.7 was subjected to Tricine-SDS-PAGE, according to the method of Schägger (1987)[13]. Electrophoresis was conducted at a constant current (60mA in stacking gel and 100 mA in separating gel). A 5 μL aliquot of bacteriocin sample was mixed with a 5 μL two-fold concentrated sample buffer and heated at 100℃ for 3 – 5 min. Protein was stained with Comomassie brilliant blue R-250.

1.8 Mode of action

100 uL of Fraction I (123.3162 AU/mL) was added to LB broth of the indicator strain *B. sublitis* ACCC 11061 in early logarithmic phase and then incubated at 37℃ with an agitation speed of 180 r/min. Samples were determined at a 2 h interval to monitor bacterial growth at 600 nm. *B. sublitis* ACCC 11061 grown without Fraction I was used as a control[14 – 15].

1.9 Storage stability

Fraction I was stored at 4℃ for 1, 2, 3 and 4 months, and its residual antibacterial activity was determined against *B. sublitis* ACCC 11061 using the agar-well diffusion method.

2 RESULTS

2.1 Bacteriocin production

Cell growth, pH fluctuation and bacteriocin production of HD1.7 were examined at 30℃. Maximum production of the bacteriocin was achieved in the stationary phase, and the production declined slightly in the late stationary phase (Fig.1). The pH of the growth medium remained constant throughout the bacteriocin production period.

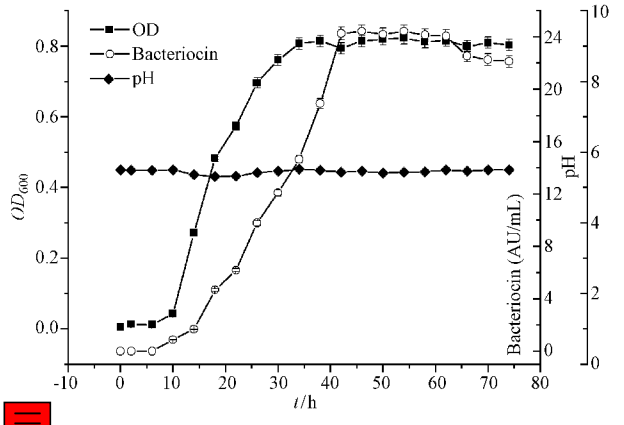

Fig. 1 Production of bacteriocin (○). Changes in optical density (■) and pH (◆) have also been plotted.

2.2 Bacteriocin purification

After 48 h fermentation, *L. paracasei* 1.7 culture was centrifuged and the supernatant containing bacteriocin was submitted to caiton-exchange chromatography at pH6.0 on a CM-Sepharose Fast Flow column. After chromatography, one peak named Fraction I (Fig. 2A) was eluted and showed antimicrobial activity against *B. sublitis* ACCC 11061 (Fig.3).

Fraction I samples from several rounds of cation-exchange chromatography were combined, concentrated by lyophilization and then further resolved on Sephedex G50, G25, G10 columns and HPLC. Elution was

performed at a flow rate of 0.8 mL/min. One fraction (P1) (Fig. 2B) was separated and showed antimicrobial activity after chromatography with G50 column, but the peak acreage was a little large, indicating ineffective separation. The active fractions (P1) were further collected and concentrated and applied to Sephedex G25 and G10 columns. Two (P2, P3) (Fig. 2C) and three (P4, P5, P6) (Fig. 2D) fractions were eluted from G25 and G10, respectively. Only P2 and P4 showed antimicrobial activities. P4 was collected and further analyzed on reverse phase HPLC. One peak (P7) (Fig. 2E) was eluted at 15-16 min and showed antimicrobial activity. The Fraction I obtained by CM-Sephorase Fast Flow cation exchange chromatography showed an activity of 125.8948 AU/mL, and a special activity of 608 AU/mg (Table 1). Tricine-SDS-PAGE of P7 revealed one protein band after coomassie blue staining. The protein was named Paracin 1.7 according to its producing strain. The molecular weight was approximately 11 kDa (Fig. 4).

Table 1 Purification of Paracin 1.7

Purification stage	Volume (mL)	Total protein (mg/mL)	Total activity (AU/mL)	Special activity (AU/mg)	Purification fold
Cell culture supernatant	35	0.108	40	370	1
Fraction I	3	0.207	125.8948	608	1.64

Fraction I, cation exchange chromatography products.

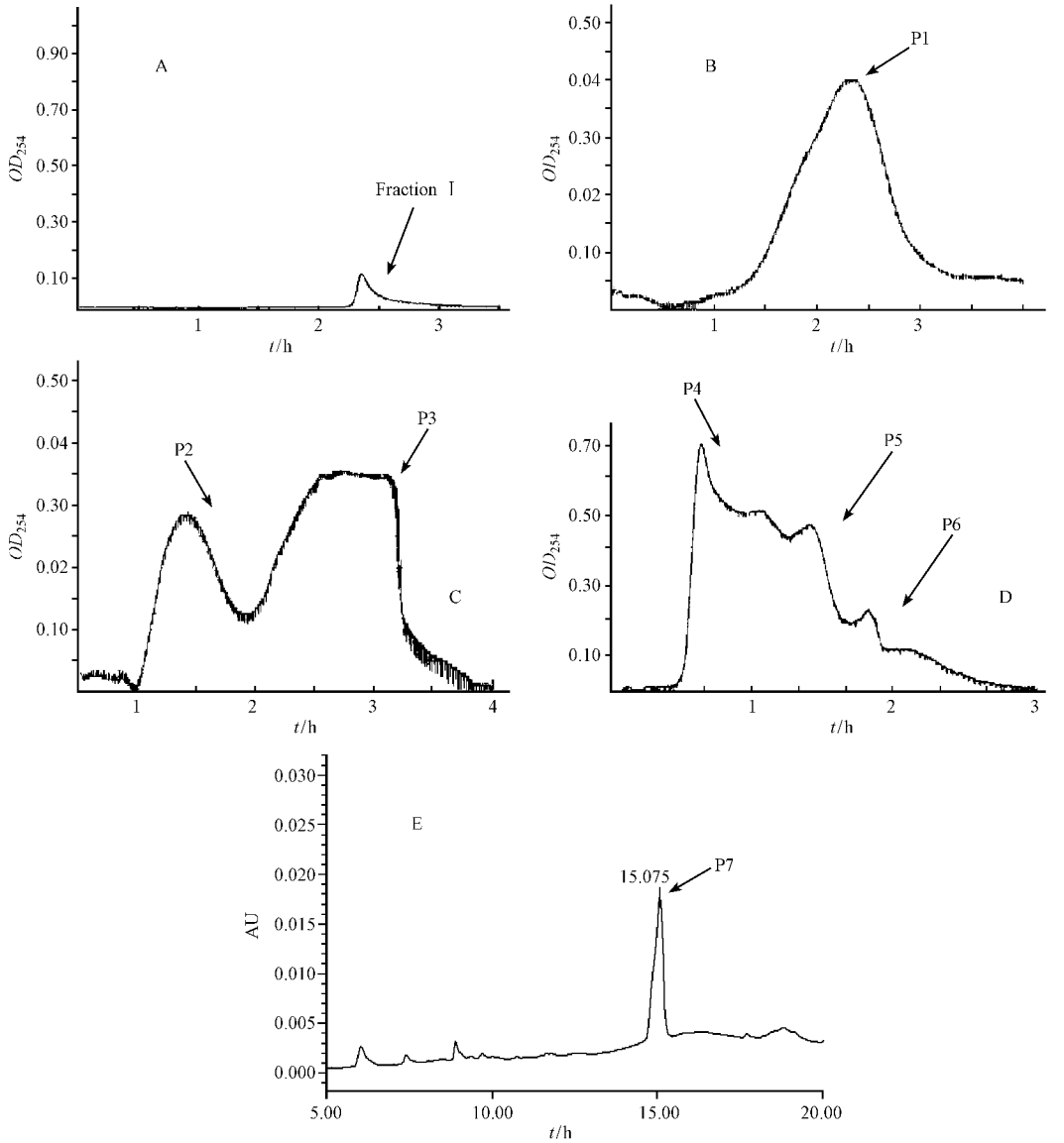

Fig. 2 Chromatography analysis of bacteriocin produced by *L. paracasei* HD1.7. (A) CM-sephorase Fast Flow and the Fraction I active fraction was indicated by an arrow; (B) Sephedex G50 showed the P1 active fraction; (C) Sephedex G25 showed two fractions P2 (the active fraction) and P3; (D) Sephedex G10 showed three fractions and only P4 was active; (E) P7 separated by HPLC showed the purified bacteriocin.

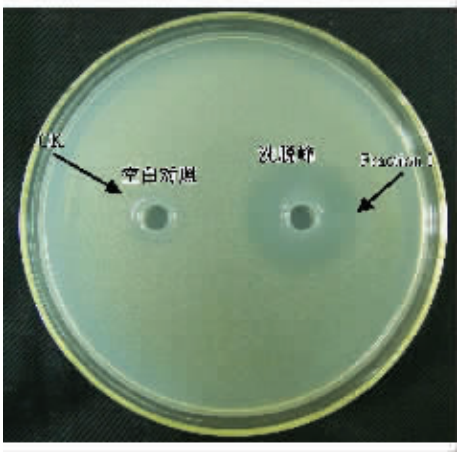

Fig. 3 Fraction I showed antimicrobial activity against *B. sublitis* ACCC 11061.

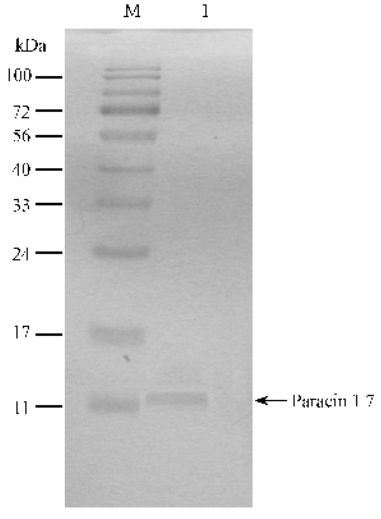

Fig. 4 Tricine-SDS-PAGE of purified bacteriocin. M. DNA marker; 1. purified Paracin 1.7.

2.3 Spectrum of inhibitory activity

The bacteriocin produced by HD1.7 showed a broad spectrum of activity against different strains, including Gram positive, Gram negative and yeast strains in the genera of *Proteus*, *Bacillus*, *Enterobacter*, *Staphylococcus*, *Escherichia*, *Lactobacillus*, *Micrococcus*, *Pseudomonas*, *Salmonella*, *Saccharomyces*, especially *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, *Bacillus subtilis*, *Bacillus megaterium*, *Proteus Vulgaris Houser*, which were food borne pathogenic bacteria.

Paracin 1.7 also inhibited some pathogens such as *Salmonella typhimurium* and *Pseudomonas aeruginosa*, and inhibited the closely related bacteria *Lactococcus* and *Lactobacillus*. Yeast *saccharomyces cerevisiae* was also inhibited by this bacteriocin. The MICs of the bacteriocin against each indicator strain was shown in Table 2.

2.4 Effect of pH, heat, proteolytic enzymes on bacteriocin stability

Bacteriocin was found to be active from pH 3.0 to 5.5. The antimicrobial activity declined at pH 6.0, 6.5 and 7.0. There was no activity at pH 8.0 (Table 3). The activity of bacteriocin produced by HD1.7 was completely inactivated or partially inactivated by treatment of proteolytic enzymes, such as trypsin from bovine panereas (completely inactivated), pepsin, papain and protecases K (partially inactivated) (Table 4).

Table 2 Antimicrobial spectrum of Paracin 1.7

Indicator strains	The inhibitory diameters of Fraction I(mm)	Minimal inhibitory concentrations of Fraction I(AU/mL)
Bacillus laterosporus AS 1.864	22.82 ± 0.02	62.9463 ± 0.8300
Bacillus megaterium ACCC 10008	22.58 ± 0.01	31.4731 ± 0.7621
Bacillus Cereus (our strain collection)	36.40 ± 0.01	31.4731 ± 0.5842
Bacillus pumilus CMCC(B) 63202	26.80 ± 0.07	52.4552 ± 1.5696
Bacillus licheniformis AS 1.807	30.44 ± 0.05	41.9642 ± 1.1418
Bacillus thuringiensis ACCC 10068	30.78 ± 0.07	41.9642 ± 1.3506
Bacillus subtilis ACCC 11061	32.96 ± 0.08	62.9463 ± 1.7315
Lactobacillus plantarum AS 1.557	30.40 ± 0.01	31.4731 ± 0.5536
Lactobacillus acidophilus IFFI 06005	26.86 ± 0.01	62.9463 ± 0.4790
Lactobacillus brevis IFFI 06004	28.96 ± 0.01	54.4542 ± 0.2859
Lactococcus lactis (our strain collection)	No inhibition	No inhibition
Micrococcus luteus ACCC 11001	25.96 ± 0.01	52.4552 ± 0.3593
Staphylococcus aureus AS 1.801	25.28 ± 0.01	41.9642 ± 0.7610
Enterobacter aerogenes CMCC(B) 45103	29.16 ± 0.01	52.4552 ± 0.3442
Escherichia coli CICIM B0123	36.44 ± 0.01	52.4552 ± 0.3579
Proteus vulgaris ACCC 1100	29.00 ± 0.01	52.4552 ± 0.5907
Pseudomonas aeruginosa AS 1.250	41.92 ± 0.04	41.9642 ± 0.3945
Salmonella typhimurium AS 1.1174	33.52 ± 0.02	31.4731 ± 0.8037
Saccharomyces cerevisiae W5 (our strain collection)	41.52 ± 0.01	62.9463 ± 0.3984

Notes: ACCC, Agricultural Culture Collection of China; AS, Institute of Microbiology, Chinese Academy of Scince; IFFI, Industry Food Fermentation Institute; CMCC, China Center of Medical Culture Collection; CICIM: Culture and Information Centre of Industrial Microorganisms of China Universities.

These data supported the nature of the antimicrobial activity of bacteriocin. The bacteriocin also displayed stability toward heat treatment (Table 5). The inhibitory activity could be detected from 4℃ to 100℃ for 30min, even at 121℃ for 15min, although the inhibitory activity declined with the increase of temperature.

Table 3 pH affecting the antimicrobial activity of the Paracin 1.7

pH	Inhibition activity
3.0	+ + +
3.5	+ + +
4.0	+ + + +
4.5	+ + +
5.0	+ +
5.5	+ +
6.0	+
6.5	+
7.0	+
8.0	–

Note: Inhibition zone (mm): + + + +, 36-45mm; + + +, 26 – 35 mm; + +, 16 – 25 mm; +, 10 – 15 mm; –, no inhibition.

Table 4 Proteolytic enzymes affecting the antimicrobial activity of the Paracin 1.7

proteolytic enzymes	residual bacteriocin activity
negative control	+
trypsin from bovine panereas (pH8.0, 25℃, Merck)	–
Pepsin (pH3.0, 37℃, Merck)	+ –
Papain (pH 6.0, 37℃, Sigma)	+ –
protecases K (pH 7.0, 37℃, Sigma)	+ –

Note: Inhibition zone (mm): +, 10 – 15 mm; + –, 1 – 9 mm; –, no inhibition.

Table 5 Temperature affecting the antimicrobial activity of the Paracin 1.7

Temperature (℃)	Treatment Time(min)	Residual inhibitory activity (AU/mL)	Declined inhibitory acticity (%)
4	30	151.6849 ± 0.4512	0
30	30	137.7640 ± 0.3899	9.18
50	30	112.6606 ± 0.5754	25.73
60	30	95.8584 ± 0.1245	36.80
80	30	88.7874 ± 0.9851	41.47
100	30	80.6978 ± 0.6678	46.80
121	15	76.4957 ± 0.2124	49.57

2.5 Mode of antimicrobial action

Addition of the Fraction I to early logarithmic phase cells of *B. sublitis* ACCC 11061 resulted in significant growth inhibition, followed by complete inhibition for the rest 20 h (Fig. 5). When transferring the agar with the antimicrobial activity to LB broth and incubating at 37℃ for 24 h, the optical density reached to 1.624 at 600 nm. This result suggested that the growth of *B. sublitis* ACCC 11061 could only be inhibited by Paracin 1.7 and the antimicrobial action was bacteriostatic function.

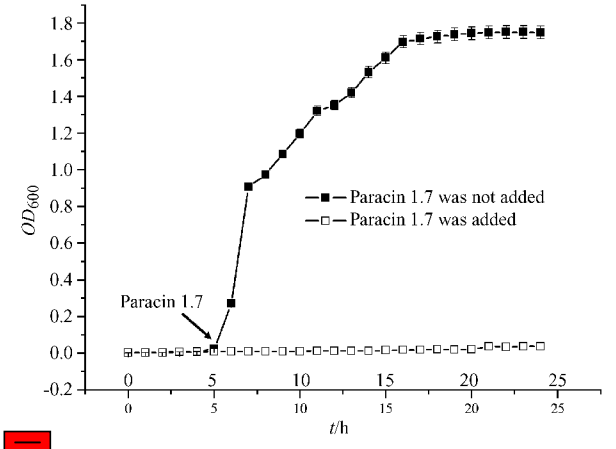

Fig. 5 Effect of bacteriocins Paracin 1.7 on the growth of *B. sublitis* ACCC 11061. Arrow indicated the point at which the bacteriocin was added.

2.6 Storage Stability

Paracin 1.7 maintained its stability after a long period of storage (Table 6). After storage at 4℃ for 4 months, the inhibitory activity declined only 4.19%. This property highlighted the potential of using it as effective food preservatives for long term food storage.

Table 6 Storage period of Paracin 1.7

Storage time (Month)	Residual inhibitory activity (AU/mL)	Declined inhibitory acticity (%)
Fresh sample	123.3162 ± 0.5523	–
1	122.3038 ± 0.5896	0.82
2	120.4759 ± 0.9845	2.30
3	119.2697 ± 0.8871	3.28
4	118.1517 ± 0.6556	4.19

3 DISCCUSION

Paracin 1.7 was shown to be the fermentation product of *L. paracasei*. subsp. *paracasei*. The strain was recently isolated from Chinese sauerkraut fermentation broth in Fengyuan Food Factory of Heilongjiang province, China. In batch culture, bacteriocin Paracin 1.7 could be detected during logarithmic phase and stationary phase, indicating that the peptide is a bacterial metabolite. Similar results were reported for plantaricin Y[16], bacteriocins produced by *P. acidilactici*[17], *L. paracasei* subsp. *paracasei* M3[4] and serial bacteriocins ST194BZ (*L. plantarum*), ST242BZ (*L. paracasei*), ST284BZ (*L. paracasei*), ST414BZ (*L. plantarum*), ST461BZ (*L. rhamonsus*), ST462BZ (*L. rhamonsus*), ST664BZ (*L.*

plantarum) and ST712BZ (*L. pentosus*)[6]. Extended growth does not necessarily lead to higher bacteriocin activity. The activity remained at 2 AU/mL, suggesting stable production of Paracin 1.7. However, a decrease in activity after logarithmic growth has been observed for lactacin B, mesenterocin 5, helveticin J, enterocin 1146[18-21]. In many of these cases, loss of activity was due to proteolytic degradation, protein aggregation, adsorption to cell surfaces and feedback regulation[22].

Paracin 1.7 showed a broad spetrum of antimicrobioal characteristics, including many Gram-positive bacteria, Gram-negative bacteria and yeast. This is consistent with what was reported by Caridi (2002)[6] and Atanassova, et al. (2003)[4]. Only a few bacteriocins produced by lactic acid bacteria had activity against Gram-negative bacteria, e.g., thermophilin 81 (4.5 kDa) produced by *Streptococcus thermophilus*, a bacteriocin produced by *L. lactis* KCA2386 (8.1 kDa), plantaricin 35d (4.5 kDa) produced by *L. plantarum*, and lacticin NK24 (between 3.0 and 3.5 kDa) produced by *L. lactis* NK24[23-26].

L. paracasei species displayed some differences in the inhibitory spectrum. The HD1.7 can inhibit the growth of several Gram-positive bacteria, Gram-negative bacteria and yeast (Table 2). In constrast, *L. paracasei* BUGBUK2-16 can't inhibit yeast[7]. *L. paracasei* M3 was able to inhibit the growth of several species of the Candida family, which indicates that the bacteriocins isolated from the *L. paracasei* are not the same[4]. This difference was also reflected by the molecular mass variations of the produced bacteriocins, e.g, 43 kDa by strain M3, 11 kDa by strain HD 1.7 and 7 kDa by strain BUGBUK2-16. It is likely that bacteriocin of different types are present in the speices of *L. paracasei*.

Similar to most bacteriocins, including those produced by the *Lactobacillus* spp. strains[27-28], Paracin 1.7 showed tolerance to high temperature and stability at pH 3.0 to 5.5. These properties highlight the potential application of the Paracin 1.7 as biopreservatives in food industry. Future research is needed to test such possibilities in making use of the current findings of this novel bacteriocin.

Acknowledgement: The authors would like to thank Professor Sixue Chen of University of Florida and Professor Zhuangwei Lou of Wyeth -Ayerst Reasearch Company for their kindly revision of the paper.

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细菌素 Paracin 1.7 的纯化与性质

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摘要:【目的】分离纯化(*Lactobacillus paracasei*)HD1.7 所产生的细菌素并分析其特性。【方法】细菌素 Paracin 1.7 的纯化采用色谱技术, 其分子量检测采用十二烷基磺酸钠 – 聚丙烯酰胺凝胶电泳(SDS-PAGE), 利用琼脂扩散法测定细菌素活力。【结果】Paracin 1.7 分离于我国传统发酵食品酸菜发酵液中, 其产生菌为副干酪乳杆菌。Paracin 1.7 可以抑制其它微生物的生长, 为细菌素。该菌在稳定期可产生大量 Paracin 1.7。经过阳离子交换层析、凝胶过滤层析以及高效液相色谱(HPLC), 对该细菌素进行了初步纯化, 并经 Tricine-SDS-PAGE 检测其分子量大约为 11 kDa。Paracin 1.7 抑菌谱较广, 其抑菌范围包括 *Proteus*, *Bacillus*, *Enterobacter*, *Staphylococcus*, *Escherichia*, *Lactobacillus*, *Micrococcus*, *Pseudomonas*, *Salmonella*, *Saccharomyces*, 其中有些为食品源致病菌。该细菌素在酸性及高温下稳定, 对几种蛋白质酶敏感。该细菌素对敏感菌株的作用方式为抑菌。在 4℃保存 4 个月后, Paracin 1.7 的抑菌活性保持稳定。【结论】基于细菌素 Paracin 1.7 的性质, 该细菌素可用作食品防腐剂。

关键词: 副干酪乳杆菌(*Lactobacillus paracasei*)HD1.7; 细菌素 Paracin 1.7; 酸菜; 细菌素; 纯化

中图分类号: Q935 **文献标识码:** A **文章编号:** 0001-6209 (2009) 05-0-0

(本文责编: 王晋芳)

基金项目: 黑龙江省科技攻关重大项目(GB05 B401); 黑龙江省骨干教师项目(1055G034); 教育部留学回国人员启动基金; 黑龙江省自然科学基金(C200505)

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收稿日期: 2008-11-21 **修回日期:** 2009-02-21