Potential of bacteriocins produced by probiotic bacteria isolated from tiger shrimp and prawns as antibacterial to *Vibrio, Pseudomonas, and Aeromonas* species on fish [version 1; peer review: 2 approved, 1 approved with reservations, 1 not approved]

Feli Feliatra¹, Zainal Abidin Muchlisin², Hiwan Yuda Teruna³, Widya Rahmi Utamy³, Nursyirwani Nursyirwani¹, Andi Dahliaty³

¹Marine Microbiology Laboratory, Department of Marine Science, Fisheries and Marine Sciences Faculty, University of Riau, Riau, Indonesia
²Department of Aquaculture, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh, Indonesia
³Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Riau, Riau, Indonesia

Abstract

**Backgrounds:** Bacteriocin has been used widely in industry as a biopreservative agent. The objective of the present study was to investigate the potency of Bacteriocin isolated from tiger prawn *Penaeus monodon* and freshwater shrimp *Macrobrachium rosenbergii* as an anti-bacterial on fish.

**Methods:** A total of ten candidates of probiotic bacteria consisted of five isolates from tiger shrimps (H1, H2, H3, H4, H5) and five isolates from freshwater prawns (W1, W2, W3, W4, W5) were evaluated. Bacteriocin was produced by centrifugation at a speed of 150 rpm and at 37 °C for 24 hours. The bacteriocin extract was purified by adding sulphate ammonium salt ([(NH₄)₂SO₄] at 80% of the saturation level. Bacteriocin activity was determined using a diffusion method against pathogenic bacteria *Vibrio alginolyticus*, *Aeromonas hydrophila*, and *Pseudomonas stutzeri*. Bacteriocins were analyzed using High Performance Liquid Chromatography (HPLC) and Fourier Transform Infra-Red (FTIR). The data were subjected to analysis of variance (ANOVA) and followed with Duncans multiple range test.

**Results:** Bacteriocins produced by bacteria isolate H4 from tiger prawn indicated the highest bacteriocin activity against *Pseudomonas stutzeri* at the diameter of inhibition zone of 887.10 ± 409.24 mm²/mL. While isolate W2 from freshwater shrimp indicated inhibition zone of 1466.96 ± 127.62 mm².

---

**Open Peer Review**

**Reviewer Status**

<table>
<thead>
<tr>
<th>Invited Reviewers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazel Monica Matias-Perala</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Tun Hussein Onn University of Malaysia (UTHM), Batu Pahat, Malaysia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sriram Seshadri</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Nirma University, Ahmedabad, India</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tati Nurhayati</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Bogor Agricultural University, Bogor, Indonesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eddy Afrianto</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Padjadjaran University, Jatinangor, Indonesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Any reports and responses or comments on the article can be found at the end of the article.
Both bacteriocins were purified by chromatography column using Sephadex LH-20.

Conclusions: This finding showed that bacterial isolates H4 and W2 have the potential to produce bacteriocins which inhibit the pathogenic bacteria. FTIR analysis showed an amide group at wave number 1652 cm\(^{-1}\) contained in the bacteriocins of isolates H4 and W2.

Keywords
potency, bacteriocin, probiotic, tiger shrimp, prawn, antibacterial, pathogen

Corresponding author: Zainal Abidin Muchlisin (muchlisinza@unsyiah.ac.id)

Author roles: Feliatra F: Conceptualization, Data Curation, Funding Acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – Original Draft Preparation; Muchlisin ZA: Formal Analysis, Methodology, Resources, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; Teruna HY: Data Curation, Investigation, Project Administration, Software, Validation; Utamy WR: Data Curation, Formal Analysis, Investigation, Project Administration, Resources, Software, Validation, Visualization; Nursyirwani N: Formal Analysis, Investigation, Methodology, Project Administration, Visualization; Danliaty A: Data Curation, Investigation, Project Administration, Resources, Software, Validation, Visualization

Competing interests: No competing interests were disclosed.

Grant information: This study was supported by the Ministry of Research, Technology and Higher Education (Ristekdikti) of the Republic of Indonesia Grant No. 486/UN.19.5.1.3/PP/2017. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright: © 2018 Feliatra F et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Data associated with the article are available under the terms of the Creative Commons Zero "No rights reserved" data waiver (CC0 1.0 Public domain dedication).

How to cite this article: Feliatra F, Muchlisin ZA, Teruna HY et al. Potential of bacteriocins produced by probiotic bacteria isolated from tiger shrimp and prawns as antibacterial to Vibrio, Pseudomonas, and Aeromonas species on fish [version 1; peer review: 2 approved, 1 approved with reservations, 1 not approved] F1000Research 2018, 7:415 https://doi.org/10.12688/f1000research.13958.1
**Introduction**

Probiotics are beneficial microbes for living organisms and, in certain quantities, have a positive impact on health\(^3\). Probiotic bacteria play a vital role in suppressing the growth of pathogenic microbial populations. Probiotic bacteria including lactic acid bacteria have an ability to produce several antimicrobial compounds such as lactic acid, diacetyl, hydrogen peroxide, carbon dioxide and bacteriocins\(^4\).

Bacteriocins are antimicrobial peptides which act as antibacterial compounds against bacterial pathogens\(^5\). Bacteriocins can inhibit Gram positive and Gram negative bacteria such as *Salmonella* species (sp.), *Escherichia coli*, *Vibrio* sp., *Shigella* sp., *Aeromonas* sp. and *Pseudomonas* sp\(^6\). Bacteriocins have an important role against microbes as a bactericidal as they are resistant to heat and maintain activity in an acidic environment, and low temperature during storage does not affect bacteriocin activity\(^1\). Bacteriocins can be damaged by degradation from proteolytic enzymes\(^7\).

Lately the use of bacteriocins has become of interest due to their potential use as a preservative in the food industry, especially in fermented foods. Nisin, for example, is one of the bacteriocins produced by lactic acid bacteria of *Lactococcus lactis* that has been known and recognized as safe to use, and can degrade pathogenic and spoilage microbes. Therefore, it could improve the quality and shelf life of food products\(^8\). This study examines extracts of bacteriocins produced by probiotic bacteria isolated from tiger shrimp and prawn which have an ability to inhibit pathogenic bacteria. The findings in this study will help researchers to inform fish farmers in preparing food for fish and shrimp populations in order to prevent pathogens, improve food efficiency and to increases the animals’ immune system.

**Methods**

**Sample collection**

A total of ten isolates of probiotic bacteria were collected, consisting of five isolates from tiger shrimp and five isolates from prawn\(^7\), which were from the collection of the Marine Microbiology Laboratory of the Faculty of Fisheries, University of Riau, Indonesia. ID numbers for each isolates are (GenBank): H1: KY995544, H2: KY995545, H3: KY995546, H4: KY995547, H5: KY995548, W1: KY995549, W2: KY995550, W3: KY995551, W4: KY995552 and W5: KY995553. This study was conducted from April-September 2016. Pathogenic gram-negative bacteria, *Vibrio alginolyticus* was obtained from Brackish water Research Institute in Jepara, Indonesia, while *Aeromonas hydrophila* and *Pseudomonas stutzeri* were purchased from Quarantine Centre in Pekanbaru, Indonesia.

The Nutrient Agar (NA; Merck, Kenilworth, NJ, USA, Cat. No. 1.05450.0500), Nutrient Broth (NB; Thermo Scientific Oxoid, Waltham, MA, USA, Cat.No.CM0001), Thiosulfate Citrate Bile Sucrose (TCBS; Merck, Cat.No.1.10263.0500), Trypticase Soy Agar, (TSA;Merck, Cat.No. 1.05458.0500), Trypticase Soy Broth (TSB, Merck, Cat.No. 1.05459.0500) were used in this study.

Glycerol, glasswool, paper disc 6mm (Macharey-Nagel, Düren, Germany, MN827/ATD), gel filtration chromatography using Sephadex LH-20 (Sigma-Aldrich, St-Louis, MO, USA - Offer sigma-GE17-0090-01), methanol and other chemicals were used in accordance with the laboratory procedures.

**Refreshment of probiotic bacteria**

Probiotic bacteria can grow in acidic conditions so each process was performed in physiological acidic pH solutions. In this study, probiotic bacteria were grown at pH 4. The probiotic bacteria was cultured in the following manner: a tube filled with the 500μL physiological solution of pH 4 was inoculated with probiotic bacteria aseptically at concentration of 10\(^8\) cfu/mL. The mixture was homogenized and left to stand for 5 minutes. One loop full of the mixture was streaked on NA media. Media containing the bacteria were incubated at 37 °C for ± 24 hours.

**Production of bacteriocins**

Liquid medium, nutrient broth of 300 mL volume was used for the production of bacteriocins\(^9\). The Medium was sterilized in an autoclave at a pressure of 15 psi, at 121°C for 15 minutes. After one day at room temperature, the medium was inoculated with 5% of probiotic bacteria that had previously been incubated overnight at the optical density (OD) at 600nm ~ 0.1 (v/v) which was equivalent to 10\(^7\) CFU/mL (OD measured with Thermo Scientific GENESYS 10S Uv-Visible)\(^3\). The inoculated media was then fermented in a shaking incubator at a speed of 150 rpm for ± 24 hours at 37 °C. After incubation, the fermented medium was cooled in a refrigerator at 5–10°C for ± one hour. The crude bacteriocin extract from the medium by centrifugation (Hitachi, Tokyo, Japan – CS150FNX) at 10,000 rpm for 10 min at 4°C. The supernatant was then separated by filtration through glasswool. The cell-free supernatant (extracted bacteriocins) produced, was tested for activity against pathogenic bacteria by using a disc diffusion method. Some of the supernatants was precipitated by the addition of 80% salt ammonium sulfate [(NH4)\(_2\)SO\(_4\)], and then was tested for activity in the same manner, and finally was analyzed by using High-performance liquid chromatography (HPLC).

**Purification of bacteriocins**

Bacteriocin was precipitated from the crude extract by the addition of 80% salt ammonium sulfate [(NH4)\(_2\)SO\(_4\)], and then was tested for activity in the same manner, and was stored in a freezer (-20 °C).

**Bacteriocin activity test**

Bacteriocin activity was tested by the diffusion agar method by using a paper disc of 6 mm pore size against pathogenic bacteria *V. alginolyticus*, *A. halophyla*, and *P. stutzeri*. One mL of
each of pathogen inoculum (OD 600nm ~ 0.1, which is equivalent to 10^7 CFU/mL) was inoculated into a test tube containing 15 mL of NA medium and was then vortexed. The inoculated medium was poured into a Petri dish and was allowed to solidify. A total of 50 mL of bacteriocins (bacteriocin extract both before and after precipitation) was dropped on paper discs and was allowed to dry. Amoxsan® 30μg from local pharmacy in Pekanbaru Indonesia was used as positive control and sterile liquid medium as the negative control. The dried paper discs were placed on pathogenic-inoculated NA media. After incubation for ± 24 hours, the bacteriocin activities were indicated by clear zone formed around the discs. The diameter of the clear zones was measured by using calipers. Inhibitory activity against pathogenic bacteria of extracellular fluid was calculated as AU (Activity Unit). One AU/mL was the area of inhibition zone per unit volume of bacteriocinsamples tested (mm²/ml). Bacteriocin activity can be calculated using the following equation:

Bacteriocin Activity (mm²/mL) = \( \frac{Lz - Lc}{V} \)

Where:
- \( Lz \) = diameter of clear zone area (mm²/ml)
- \( Lc \) = Disc diameter (mm²/ml)
- \( V \) = Sample Volume (mL)

**Gel filtration chromatography**

Gel filtration or gel permeation is a protein separation technique based on molecular size. This technique used a column measuring 2.5 × 50 cm (Sephadex LH-20) as steady phase and methanol as mobile phase. A total of 9 g Sephadex LH-20 was weighed and then was added to 50 mL of methanol. The mixture was stirred gently until dissolved. The dissolved Sephadex was poured into the column until the marked limit. The eluent was collected in a beaker containing a mixture of Sephadex, it was then poured into the column until Sephadex expanded and solidified for 20 minutes. Afterward, the bacteriocin was inserted into the column through the column wall carefully and waited until the sample penetrated through pores of the gel Sephadex LH-20 pores. The eluate was then collected in a marked vial as the first fraction, and the next eluent was collected in vials containing 20 drops until final-clear eluent reached. Small molecules will enter the pores of the gel Sephadex and move slowly, while the large molecules will move faster because it cannot enter and retaining the gel. Thus, the large molecules will emerge as the initial component. Products of each of separated bacteriocin fractions were finally analyzed by using FTIR spectroscopy.

**HPLC (high-performance liquid chromatography) analysis**

Bacteriocins produced after precipitation in ammonium sulphate was then analyzed using HPLC. A spectrophotometer ultraviolet (UV) detector (Thermo Scientific Genesys 10S) was used for the analysis of bacteriocins at a wavelength of 210 nm and 250 nm. Wavelength selection was based on preliminary measurement using UV spectrophotometer in The Research Laboratory of Enzymes, Fermentation, and Biomolecular, following the research performed by Masuda et al. The analysis used Shimadzu HPLC system of UFLC Shim Pack C18 series with column size of 4.6 mm × 250 mm (Shimadzu, Kyoto, Japan).

**Statistical analysis**

The data were subjected to one-way analysis of Variance (ANOVA) followed by Duncan multiple range test at significance levels of 95%. The analysis was performed using a SPSS ver.20 software.

**Results**

**Bacteriocins activities**

Inhibitory activity of bacteriocins was expressed as the inhibition zone per unit volume of samples tested (mm²/mL). Table 1 shows the activity of bacteriocins extract of tiger shrimp against pathogenic bacteria *V. alginolyticus*, *A. hydrophila* and *P. stutzeri*. Statistical analysis indicated that the activity was not significantly different (P>0.05), the highest activity was indicated by bacteria isolate H1 against *V. alginolyticus*. However, the activity was not significantly different (P>0.05) from isolates H2 and H5, which was 674.65 mm²/mL, but it was

<table>
<thead>
<tr>
<th>Probiotics</th>
<th>Activities of bacteriocin crude extract (mm²/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>V. alginolyticus</em></td>
</tr>
<tr>
<td>H1</td>
<td>(674.65±369.34)ab</td>
</tr>
<tr>
<td>H2</td>
<td>(409.38±56.01)bc</td>
</tr>
<tr>
<td>H3</td>
<td>(244.66±175.62)c</td>
</tr>
<tr>
<td>H4</td>
<td>(117.00±66.13)c</td>
</tr>
<tr>
<td>H5</td>
<td>(329.93±98.57)c</td>
</tr>
</tbody>
</table>

Note: H = Bacterial Code. Superscript of the same letters indicates no significant differences in the level of 5%. Values were average of triplicate samples ± standard deviation.
Bacteriocin activities of bacterial isolates from prawns against all pathogens (*V. alginolyticus*, *A. hydrophila*, and *P. stutzeri*) were not significantly different (P>0.05). The highest activity was produced by isolate W2 against *P. stutzeri*, and the highest inhibitory activity was 1466.96 mm²/mL which was significantly (P>0.05) different from other four bacteria isolates (Table 4). Overall, the activity of bacteriocin precipitated in ammonium sulphate ([NH4]2SO4) was higher than bacteriocin before precipitation in ammonium sulphate.

A quantity of 270 mL of bacteriocin-crude extract was obtained after centrifugation, and then it was precipitated with ammonium sulphate salt ([NH4]2SO4). In the deposition process at salt saturation level of 80%, a total of 139.32 g of salt ammonium sulphate ([NH4] 2SO4) was added to the crude extract of bacteriocins. The precipitated bacteriocin was added with buffer in order to reach a volume of 3,375 mL bacteriocins.

**HPLC analysis.** High-Performance Liquid Chromatography (HPLC) is a chromatographic method that uses a reversed-phase system as its working system. This method was used to determine the purity level of a compound to be analyzed. Bacteriocins of tiger shrimp and prawns with high bacteriocin-activity values (H4 and W2), were then analyzed by HPLC as shown in Figure 1 and Figure 2. The figures showed that bacteriocin produced by each of probiotic bacteria was not a pure product indicated by the number of chromatogram peaks.

**Gel filtration chromatography**

Bacteriocins as a group of proteins, were separated by column chromatography on Sephadex LH-20 using methanol. The resulted eluate was initially appeared light brown in color in the column, and was collected in a vial which was then marked as fraction 1. After that, as the sample was in the middle of the column, the next eluate was collected as fraction 2, and followed by collecting every 20 drop samples until the sample appeared faded, and finally clear in vial 25. This indicates that the protein samples in the column Sephadex LH-20 have been

<table>
<thead>
<tr>
<th>Probiotics</th>
<th>Bacteriocins Activities (mm²/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>V. alginolyticus</em></td>
</tr>
<tr>
<td>H1</td>
<td>(321.47±80.75)³abc</td>
</tr>
<tr>
<td>H2</td>
<td>(854.07±55.25)a</td>
</tr>
<tr>
<td>H3</td>
<td>(896.50±375.14)a</td>
</tr>
<tr>
<td>H4</td>
<td>(610.28±257.32)abc</td>
</tr>
<tr>
<td>H5</td>
<td>(702.26±156.45)abc</td>
</tr>
</tbody>
</table>

Note: H = Bacterial Code. Superscript of the same letters indicates no significant differences in the level of 5%. Values were average of triplicate samples ± standard deviation.
Figure 1. Chromatogram bacteriocins H4 of probiotic bacteria isolated from black tiger shrimp.

Figure 2. Chromatogram of bacteriocins W2 from probiotic bacteria isolated from prawns.
completely eluted by methanol. The eluate of 25 fractions was allowed to evaporate at room temperature to remove the solvent. The solids obtained were observed to look like thin films in some of the fractions. Five fractions contained thin films of 25 fractions produced, those were fractions 6, 9, 14, 18 and 25, which were then analyzed using FTIR spectroscopy to observe the functional groups containing the fraction.

**FTIR analysis**

Fourier Transform Infra-Red (FTIR) was used to find out bonding vibration and functional groups contained by bacteriocins. FTIR analysis results from one of the bacteriocins produced by bacteria H4 are shown in Figure 3. The spectrum figure shows the comparison of fractions that produced films (fractions 6, 9, 14, 18 and 25) as the separation products of bacteriocins H4 using gel filtration column, and after being precipitated in ammonium sulphate [(NH4)2SO4]. Each fraction showed absorption bands at similar wave numbers.

The infrared spectrum of bacteriocins for fraction 6 shows absorption at wave numbers (cm-1) of 978, 1340, 1355, 1648, 2831, 2921, 3420 and 3595. Fraction 9 shows absorption at wave numbers (cm-1) of 977, 1089, 1339, 1363, 1404, 1457, 1647, 3239, and 3587. Fraction 14 showed absorption at wave numbers (cm-1) of 978, 1097, 1312, 1363, 1405, 1457, 1647, 2836, and 3502. Fraction 18 shows absorption at wave numbers (cm-1) of 988, 1334, 1358, 1400, 1460, 1649, 2835, 2954, 3415 and 3588. Finally, fraction 25 shows absorption at wave numbers (cm-1) of 971, 1082, 1312, 1339, 1355, 1416, 1457, 1647, 2834, 2988, 3336, 3443 and 3593. Meanwhile, bacteriocins precipitated by salts of ammonium sulphate [(NH4)2SO4] shows an absorption band at wave number (cm-1) 979, 1339, 1355, 1418, 1456, 3336, 3445, and 3592.

**Figure 3.** FTIR spectrum bacteriocin H4 precipitated in ammonium sulfate [(NH4)2SO4] in comparation to the purification product of bacteriocins of some fractions (fraction 6, 9, 14, 18 and 25).
**Discussion**

Bacteriocins are secondary metabolites in the form of proteins that act as antimicrobial compounds. The activity of bacteriocin-crude extracts of bacteria from tiger shrimp before precipitation in ammonium sulphate \([(NH_4)_2SO_4]\] was as presented in Table 1, and after precipitation with the same salt was shown in Table 2. Protein precipitation using 80% ammonium sulphate salt was a partial protein purification technique (partial purification) that is frequently applied as it has high solubility and is easy to obtain. Bacteriocins can be concentrated through the application of methods of salting out using ammonium sulfate as a natural protein\(^1\). Salting out is a mechanism of protein precipitation as a result of reduction in solvent molecules required to dissolve the protein. This occurs due to the increase of salt concentration which can decrease protein solubility. When ammonium sulphate is added to the protein solution, the salt ions of ammonium sulphate will attract water molecules away from protein. This is due to the competition between the binding of ions of ammonium sulphate and water which causes the protein precipitates\(^2\).

Bacteriocin inhibitory activity against bacterial indicators was indicated as AU (Activity unit). One AU/mL was inhibition area per unit volume of bacteriocin samples tested (mm\(^2\)/mL).

The method used was similar to the antibacterial assay method using agar diffusion method and three Gram-negative bacteria as pathogenic indicators (V.alginolyticus, A. hydrophila, and P. stutzeri).

The bacteriocins-crude extract before being precipitated in ammonium sulphate showed inhibitory activity against three different indicators. The activity of bacteriocin-crude extract of bacterial isolate H4 from tiger shrimp was the highest (Table 1) against V. alginolyticus (117.00 ± 66.13 mm\(^2\)/mL), A. hydrophila (319.91 ± 101.03 mm\(^2\)/mL and P. stutzeri (178.79 ± 61.84 mm\(^2\)/mL). After precipitation in ammonium sulphate, bacteriocin-activities (Table 2) increased against V. alginolyticus (610.28 ± 257.32 mm\(^2\)/mL), A. hydrophila (872.93 ± 170.02 mm\(^2\)/mL), and P. stutzeri (887.10 ± 169.08 mm\(^2\)/mL). The H4 isolate showed the greatest inhibitory activity due to its high inhibitory activity against the three bacterial indicators. The better the bacteria inhibit pathogenic bacteria, the better the ability to produce bacteriocins.

Activities of the bacteriocins-crude extract of bacteria from prawns before and after the salt precipitation in ammonium sulphate were were shown in Table 3 and Table 4, respectively. Similar to the inhibitory activity of probiotics bacteria from tiger

---

**Table 3. Activities of bacteriocins-crude extract of probiotic bacteria isolated from prawns before precipitation in ammonium sulphate ([NH4] 2SO4).**

<table>
<thead>
<tr>
<th>Probiotics</th>
<th>Activity of crude extract bacteriocins(mm^2/mL)</th>
<th>V. alginolyticus</th>
<th>A. hydrophila</th>
<th>P. stutzeri</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>(310.69±223.32)bc</td>
<td>(238.41±197.97)ab</td>
<td>(314.35±238.86)ab</td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>(345.90±306.16)bc</td>
<td>(455.02±169.59)a</td>
<td>(412.73±209.53)a</td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>(343.00±158.96)ab</td>
<td>(279.41±112.59)ab</td>
<td>(342.36±257.02)ab</td>
<td></td>
</tr>
<tr>
<td>W4</td>
<td>(645.76±315.20)ab</td>
<td>(746.95±227.01)a</td>
<td>(92.21±59.37)ab</td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>(293.20±197.16)bc</td>
<td>(625.10±296.59)a</td>
<td>(346.00±81.58)ab</td>
<td></td>
</tr>
</tbody>
</table>

Note: W = Bacterial Code. Superscript of the same letters indicates no significant differences in the level of 5%. Values were average of triplicate samples ± standard deviation.

**Table 4. Bacteriocins activities of probiotic bacteria isolated from prawns after precipitation in ammonium sulphate ([NH4] 2SO4).**

<table>
<thead>
<tr>
<th>Probiotics</th>
<th>Bacteriocins activities(mm^2/mL)</th>
<th>V. alginolyticus</th>
<th>A. hydrophila</th>
<th>P. stutzeri</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>(581.03±425.55)ab</td>
<td>(490.88±400.68)bc</td>
<td>(770.87±570.42)d</td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>(1043.2±357.10)a</td>
<td>(1113.9±423.02)a</td>
<td>(1466.96±127.62)a</td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>(607.73±13.94)ab</td>
<td>(531.90±179.18)bc</td>
<td>(461.59±341.75)c</td>
<td></td>
</tr>
<tr>
<td>W4</td>
<td>(367.01±86.39)bc</td>
<td>(917.90±186.53)ab</td>
<td>(238.42±35.42)bc</td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>(706.18±365.07)bc</td>
<td>(666.49±268.47)ab</td>
<td>(888.76±360.27)bc</td>
<td></td>
</tr>
</tbody>
</table>

Note: W Bacterial Code. Superscript of the same letters indicates no significant differences in the level of 5%. Values were average of triplicate samples ± standard deviation.
shrimp, all probiotic bacteria from prawns produced bacteriocins which indicated the active role in inhibiting pathogenic bacteria.

The average activity of bacteriocins-crude extract from bacteria W2 before salt-precipitation in ammonium sulphate (Table 4) against V. alginolyticus, A. hydrophila and P. stutzeri were 345.907 ± 306.160 mm²/mL, 455.022 ± 169.591 mm²/mL and 412.735 ± 209.537 mm²/mL, respectively. After the salt-precipitation in ammonium sulfate, the bacteriocin activities increase against V. alginolyticus, A. hydrophila and P. stutzeri, which were 1043.228 ± 357.102 mm²/mL, 1113.914 ± 423.026 mm²/mL and 1466, 127.626 ± 962 mm²/mL, respectively. Activities of bacteriocins produced by bacteria W2 demonstrated the greatest potential to inhibit all three pathogenic indicator bacteria. Ponce et al.,17 found that bacteriocins of Lactococcus lactis have inhibitory activity against L. monocytogenes which was 83.33 mm²/mL. This value was lower than the bacteriocin activity of bacteria W2 (1043.228 mm²/mL) against V. alginolyticus. This is likely due to the inhibition ability of bacteria W2 being closely related to the bacterial cell growth. The better the cell growth, the number of cells increases, and this will further increase the production of bacteriocins.

Antimicrobial compounds such as bacteriocins are proteins produced as secondary metabolites. The production of secondary metabolites is encoded by DNA-containing genes. Formation of secondary metabolites was affected by several conditions, among which are limitations of available nutrients in the media, the addition of inducer compounds and decrease in the growth rate6.

Comparing the activity of bacteriocins produced by both bacteria (H5 and W2), probiotic bacteria W2 from prawns had the highest activity against the three bacterial indicators. The significant difference (P > 0.05) in the inhibition of the three bacterial indicators showed that the active protein compounds (bacteriocins) were also different6. The sensitivity of bacteria to bacteriocins is determined by the specific characteristics possessed by each bacteria. Thus, inhibition mechanism of bacteriocins against indicator bacteria depends on the specific receptors possessed by the bacteria.

The high inhibitory activity caused by bacteriocin produced by, H5 is closely related to the bacterial indicators which belong to Gram-negative bacteria as shown in Table 5. Bacteriocins produced by Gram-positive bacteria have low inhibitory activity, or none at all, against Gram-negative bacteria20. For example, the activity generated by Lactobacillus lactis against E. coli is very low21. Bacteriocins can inhibit or kill pathogenic bacteria when the bacteria have a close relationship6. Such as bacteriocins produced by Lactobacillus sp. SCG 1223 has a high inhibitory activity against L. monocytogenes (1648.500 mm²/mL)22. High activity was also obtained from bacteriocins produced by Lactobacillus lactis against Bacillus subtilis, Bacillus megaterium, Bacillus cereus, Staphylococcus aureus and Enterococcus faecalis23.

Bacteriocins analysis was performed by HPLC system after purification with salt ammonium sulfate [[(NH4)2SO4]. This analysis used a wavelength of 210 nm and 250 nm because, at these wavelengths, bacteriocins produced by Lactococcus mesenteroides show high purity24. The mobile phase was used was methanol while the steady phase was silica gel. Bacteriocins analysis results were shown as in Figure 1 and Figure 2. Bacteriocins produced by all the probiotic bacteria after analysis cannot be considered as the pure product because many peaks appear in the chromatogram analysis. This proves that the new protein sample was just partially purified using ammonium sulfate [(NH4)2SO4]. Bacteriocins were protein compounds that the separation should be done with a variety of purification methods as has been done by Smaoui et al.,25 bacteriocins with code BacTN635 initially purified by ammonium sulfate [(NH4)2SO4], followed by gel filtration chromatography, HPLC, and SDS-PAGE electrophoresis. Nisin isolated from Lactococcus lactis was also purified by various purification methods, which was initially precipitated with ammonium sulphate salt [(NH4)2SO4], and was continued by purification using various chromatographic methods20-24. Nissin was the first type bacteriocin allowed as biopreservation on food5.

Bacteriocins were produced by probiotic bacteria H4 from tiger shrimp and probiotic bacteria W2 from prawns which were purified by gel filtration chromatography using Sephadex LH-20. The results of the sample separation were characterized by FTIR spectroscopy to identify functional groups contained in the functional group of the bacteriocins based on the literature of various types of bacteriocins by Sakhamuri et al.,21 Sel Vendran and Babu23 as shown in Table 6.

The infrared spectrum of bacteriocins H4 at wave numbers (cm-1) of 971, 977, 978, 979, and 988 indicated the presence of bending vibration of amide group (O= oxygen, C= carbon, N= nitrogen), while the wave numbers (cm-1) of 1082, 1089 and 1079 indicated a bond phoshodiester (P = O), and the wave number (cm-1) of 1647, 1648, 1649 and 1652 indicated a stretching vibration of carbonyl (C = O, amide I). The infrared spectrum bacteriocins obtained relate to specific functional groups of nisin which was similar to that reported by Sakhamuri et al.24. The wave numbers (cm-1) 3336, 3415, 3420, 3443, and 3445

<table>
<thead>
<tr>
<th>Code isolates of tiger shrimp</th>
<th>Gram</th>
<th>Code isolates of tiger shrimp</th>
<th>Gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>(+)</td>
<td>W1</td>
<td>(+)</td>
</tr>
<tr>
<td>H2</td>
<td>(-)</td>
<td>W2</td>
<td>(-)</td>
</tr>
<tr>
<td>H3</td>
<td>(-)</td>
<td>W3</td>
<td>(-)</td>
</tr>
<tr>
<td>H4</td>
<td>(-)</td>
<td>W4</td>
<td>(-)</td>
</tr>
<tr>
<td>H5</td>
<td>(+)</td>
<td>W5</td>
<td>(+)</td>
</tr>
</tbody>
</table>
Table 6. FTIR characteristic wave numbers of different types of bacteriocins by Sakhamuri et al.,24, Selvendran and Babu25.

<table>
<thead>
<tr>
<th>Phase Number</th>
<th>Functional groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>976</td>
<td>OCN</td>
</tr>
<tr>
<td></td>
<td>vibration buckling</td>
</tr>
<tr>
<td>1079</td>
<td>P=O</td>
</tr>
<tr>
<td></td>
<td>Fosfodiester</td>
</tr>
<tr>
<td>1180-1360</td>
<td>C-N</td>
</tr>
<tr>
<td></td>
<td>peptide bond</td>
</tr>
<tr>
<td>1650</td>
<td>C=O</td>
</tr>
<tr>
<td></td>
<td>carbonyl stretching vibration</td>
</tr>
<tr>
<td>3336</td>
<td>N-H</td>
</tr>
<tr>
<td>3500</td>
<td>OH</td>
</tr>
</tbody>
</table>

indicated the presence of N-H stretching vibration. Bacteriocins produced was the result of probiotic bacteria isolated from black tiger shrimp and prawns, one of which has 99% homologous with the bacteria Bacillus sp.26.

Conclusions
Bacteriocins had been explored from probiotic bacteria isolated from black tiger shrimp and prawns. The bacteriocins show potential as anti-pathogens in shrimp culture or in fish farming. Bacteriocins of from H4 isolate from tiger shrimp and bacteriocins of W2 isolate from prawns were two antimicrobial compounds which had the greatest inhibitory activity against all three pathogens, Vibrio alginolyticus, Aeromonas hydrophila and Pseudomonas stutzeri. HPLC analysis of the bacteriocins produced by 18 of probiotic bacteria did not show a high degree of purity. FTIR analysis of the purified products of H4 bacteriocins showed an amide bond at a wavelength of 1652 cm⁻¹ which indicated that the compound was a protein. Bacteriocins

Data availability
Dataset 1: Word document containing the following data tables: 10.5256/f1000research.13958.d198458

Crude extract of bacteriocins of probiotic bacteria isolated from black tiger shrimp before being precipitated in ammonium sulphate [(NH4)2SO4].

The activities of bacteriocins-crude extract of probiotic bacteria isolated from black tiger shrimp after precipitation in ammonium sulphate [(NH4)2SO4].

The activities of bacteriocins-crude extract of probiotic bacteria isolated from prawns before precipitation in ammonium sulphate [(NH4)2SO4].

Dataset 2: The bacteriocins activities of probiotic bacteria isolated from prawns after precipitation in ammonium sulphate [(NH4)2SO4]. 10.5256/f1000research.13958.d198459

Competing interests
No competing interests were disclosed.

Grant information
This study was supported by the Ministry of Research, Technology and Higher Education (Ristekdikti) of the Republic of Indonesia Grant No. 486/UN.19.5.1.3/PP/2017.

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Acknowledgements
Grateful thanks goes to the Ministry of Technology, Research and Higher Education of Indonesia who has supported this research.

References


27. **Lim ES**: Inhibitory effect of bacteriocin-producing lactic acid bacteria against histamine-forming bacteria isolated from Myeolchi-Jeot. *Fish Aquatic Sci*. 2016; 19: 42. **Publisher Full Text**


In the field of fisheries, the attack of pathogenic microbes and the use of formaldehyde are some of the main issues. The use of formalin as a food preservative has reached dangerous stage, but its more effective substitute compounds have not been successfully developed. Bacteriocin is a compound that has great potential to be developed as a prevent attacks of pathogenic bacteria and preservative inhibitor to replace formaldehyde.

Bacteriocin is a secondary metabolite product from lactic acid bacteria (BAL). These bacteria are often found in various places, including the digestive tract of fish and shrimp. There have been many efforts made to get bacteriocin-producing microbes. Increased mass production of bacteriocin is very helpful for fish cultivation activities in preventing pathogenic microbial attack and processing of fishery products as preservatives replacing formalin.

This research is the initial stage of the effort to develop bacteriocin as a deterrent to the activity of pathogenic microbes and decay. Bacterial isolates that have been found need to go through several stages in order to produce bacteriocins, including isolation processes to produce pure cultures and optimal bacteriocin separation technology from microbial culture media.

1. In the abstract several words are repeated, reducing the use efficiency of the word.

2. The reasons put forward to carry out this research are quite relevant. It is hoped that bacteriocin can be found that can overcome the problem of pathogens that attack fish and shrimp.

3. The method used has been presented in sufficient detail so as to facilitate future replication. Some parts still need to be detailed further, for example need further explanation on how to get bacteriocins using centrifugation, how many bacteriocin samples are used in the HPLC method, what and how many solvents are used?

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 20 September 2018

https://doi.org/10.5256/f1000research.15172.r38186

© 2018 Nurhayati T. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Tati Nurhayati
Department of Aquatic Product Technology, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia

The manuscript describes the isolation of bacteriocin derived from probiotic bacteria isolated from shrimp and lobster. This compound is tested against pathogenic bacteria. However, there are some improvement notes in some parts.

Abstract

1. The research objective in the abstract has not been clearly written. Are bacteriocins obtained from shrimp or from bacteria that live on shrimp?
2. There is a typo in the method section in the abstract. Bacteriocin was written 2 times.
3. In the abstract: the sentence Bacteriocin activity against is written 2 times.
4. The results of chromatographic column analysis and HPLC have not been written in the results section of the abstract.
Methodology

1. Assay of bacteriocin activity, need to be re-examined. Need to be written clearly, how many bacteriocins are inserted into each well? In order to be able to track how to calculate the inhibition per ml. Unit diameter should be mm NOT mm2.

2. In methodology purification methods, the use of ammonium sulfate, only one concentration is 80%. What is the basis? If there have been previous studies, it is necessary to mention here referring to whose research? Use of the term the purification of proteins with ammonium sulfate is inappropriate.

3. There is a discrepancy in the designation term. In the abstract, it is stated that purification is done by chromatography column. But in the methodology, protein purification is carried out with ammonium sulfate.

4. In the methodology, there is step gel filtration. What is the use of gel filtration for? For purification only, or for specific analysis. Need to write a clear title in this method.

5. In the methodology, analysis with HPLC is used to analyze what. Need to be written in the methodology.

Discussion

1. Especially for the discussion of gel filtration, only the stages of the method are explained. The method stage should be written on the methodology not in the results and discussion.

2. In sub discussion, it is better not to repeat mentioning the actual data already in the results section. In this sub-chapter, what should be written is the discussion of the data in the results section.

Conclusion

1. The last sentence from the conclusion is incorrect, because the researchers did not test bacteriocin activity against spoilage bacteria but against pathogenic bacteria.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

**Competing Interests:** No competing interests were disclosed.
I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 07 September 2018

https://doi.org/10.5256/f1000research.15172.r37670

© 2018 Seshadri S. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Sriram Seshadri
Institute of Science, Nirma University, Ahmedabad, India

1. Lot of words are repeating in the same sentence in the abstract.

2. How do you produce bacteriocin by centrifugation?

3. The species name of shrimp and prawn is missing in the whole test.

4. How was the isolates obtained? What was the sample used?

5. How was the health status of the shrimp and prawn confirmed?

6. Characterization of probiotic features are completely missing.

7. Have the authors confirmed whether the isolates by itself had antibacterial potentials?

8. If so, have they determined the mode of action before moving on to bacteriocin isolation and purification?

9. How do the authors justify selection of only Amoxicillin as the test antibiotics?

10. There are no citations provided for Gel filtration chromatography.

11. There is no mention of standard probiotic strain which are known to produce bacteriocins. How did the authors compare the bacteriocin production and its efficacy?

12. The chemical formula of Ammonium Sulphate is (NH₄)₂SO₄ not (NH₄)₂SO₄. It has to be rectified throughout the text.

13. Bacteriocin inhibitory activity is indicated as AU. AU does not stand for Activity Unit by Arbitrary Unit.

14. Discussion is very poorly written. It has to be re-written and there is no mention of any
papers on bacteriocins isolated from prawn/shrimps/fish sources.

References

Is the work clearly and accurately presented and does it cite the current literature?
No

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Metabolic disorder, gut microbiota, liver inflammation, probiotic characterization

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 24 April 2018

https://doi.org/10.5256/f1000research.15172.r32653

© 2018 Matias-Perala H. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
Hazel Monica Matias-Peralta
Department of Technology and Heritage, Faculty of Science, Technology and Human Development, Tun Hussein Onn University of Malaysia (UTHM), Batu Pahat, Malaysia

The manuscript contained important results from a research activity aimed to isolate potential probiotic bacteria which produce potent bacteriocin. Upon isolation of bacteriocins, they were tested for potential antibacterial activity against pathogenic bacteria, through the utilization of disc diffusion method/assay. After which, the bacteria that perform the best in the disc diffusion method was chosen (one from the tiger shrimp (H) and another one from freshwater prawn (W)) was further purified and subjected to HPLC and FTIR analysis.

○ The Introduction section clearly stated the importance of doing this research which is the utilization of bacteriocin to help in alleviating the problems of pathogens in aquaculture particularly the fish and shrimp culture. The authors also cited recent references to indicate the timeliness of this work.

○ The methods presented are clear with enough details for easy replication in the future. However, few details were left out in the HPLC analysis which has to be added to the manuscript: (Please indicate in the HPLC method the information on how much (microliter) of the bacteriocin samples were injected, what is the solvent used, how many percents of solvent are added and etc.

○ The statistical analysis is appropriate. Although it is suggested to add up which dataset were subjected to ANOVA and DMRT.

○ There are few things to clear up in the results section.

- Please check the results which the author considered "significantly different" throughout the results. Similar letters indicate no significance, therefore as an example, "ab", "bc", and "b" are not significantly different.

- Table 1, H1 - under A. hydrophila, indicate the real value (there seemed to be a problem).

- Table 3 was not cited in the text.

- Why is Table 5 not in presented in the "Results" section, but is discussed in the "Discussion" section? If the data tabulated in Table 5 is from your own research, it is more appropriate to present in the results section, rather than only cite in the Discussion section.

○ The results are considered only partially discussed in the Discussion section. Therefore it will be best to add more appropriate justifications. Following are suggested in the discussion section for improvement:

- Tables and figures should only be cited minimally in the discussion section since they have already been presented in the results section.

- Explain more the implication of increasing inhibitory activity against pathogens after precipitation in ammonium sulfate [(NH4)2SO4]. Will it help in terms of increased efficiency of bacteriocin? How about in terms of the economics?
- It will be best to expound on the result of the inhibitory activity of the bacteriocin comparing the current results to that of those previously been used. In the methodology, there was a mention of positive and negative control but the result was not used in the argument on how efficient the currently isolated and purified bacteriocin in this study.

- There should also be a clear explanation of the reason why H4 and W2 were chosen among other isolates. In here the statistical results will become handy in explaining why.

- Include more explanation on the FTIR results for the two chosen isolate which are potentially good source of potent bacteriocin. What were the implications of the FTIR results having the specific wave numbers as in the current results? Do they mean more potent? better than others?

○ As for the conclusion section: It is not advisable to cite any reference in the conclusion section since conclusion should contain the authors' own interpretation of the results collected from the study.

**Is the work clearly and accurately presented and does it cite the current literature?**
Yes

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**
Yes

**Are all the source data underlying the results available to ensure full reproducibility?**
Partly

**Are the conclusions drawn adequately supported by the results?**
Partly

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.
Reviewer Response 14 Aug 2018

Leila Ariyani Sofia, university of lambung mangkurat, Indonesia

The results of this study are needed to overcome disease attacks that often occur in aquaculture businesses in several countries with tropical climates, especially in the Asian region.

Manuscript management is complete and very good.

Therefore, it is a very worthy manuscript for indexing.

**Competing Interests:** No competing interests were disclosed.