Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

A model for *N*-to-*C* direction in prebiotic peptide synthesis

Li Zhang, [a] Min Zhang, [a] Xiaofan Guo, [a] Dingwei Gan, [b] Yong Ye, [d] Yufen Zhao, [ac] and Jianxi Ying*[a]

a L. Zhang, M. Zhang, X.F. Guo, Prof. Y.F. Zhao, Prof. J.X. Ying
Institute of Drug Discovery Technology
Ningbo University
No.818 Fenghua Road, Ningbo, Zhejiang, China 315211
E-mail: yingjianxi@nbu.edu.cn

b Dr.D.W. Gan
School of Electrical Engineering,
Xi'an Jiaotong University
No.28 Xianning West Road, Xi'an, Shaanxi 710049, P.R. China
E-Mail: Dingwei.Gan@stu.xjtu.edu.cn

c Prof. Y.F. Zhao
College of Chemistry and Chemical Engineering
Xiamen University
No. 422, Siming South Road, Xiamen, Fujian, China

d Prof. Y.Ye
College of Chemistry
Zhengzhou University
Zhengzhou 450001, China

* Corresponding authors: yingjianxi@nbu.edu.cn (Jianxi Ying)

Content

1. Materials and Methods

1.1 Materials

Glu-NH_2, Ser-NH_2, Met-NH_2, Asp-NH_2, Tyr-NH_2 were obtained from Shanghai Macklin Biochemical Co., Ltd. (China). Ala-NH_2, Val-NH_2, Leu-NH_2, Pro-NH_2, Phe-NH_2 were purchased from Energy Chemical (China).Ac-Ala-NH_2 was purchased from Shanghai yuanye Bio-Technology Co., Ltd (China). Ac-Gly-NH_2 was purchased from Meryer (Shanghai) Chemical Technology Co., Ltd. (China). Arg-NH_2, His-NH_2 were obtained from Leyan (China). Lys-NH_2, Thr-NH_2, Trp-NH_2 were obtained from BIDE PHARMATECH CO., LTD. (China). Ile-NH_2 was purchased from Shanghai Titan Scientific Co., Ltd. (China). Ultrapure water (18.2 MΩ cm) from a Milli-Q water purification system (Millipore, Bedford, MA) was used to prepare solutions and the mobile phase.

1.2 Polymerization process

Two-component system reaction: 0.1 M Ac-AA^1-NH_2 and 0.1 M AA^2-NH_2 were dissolved in 1mL deionized water, mixed evenly, and adjusted to neutral solution with 0.5 M NaOH. The reactants were placed in a centrifuge tube and reacted at 80 ° C for 24 hours. After complete drying, 0.1mL deionized water was added to fully dissolve the reactants, and continued drying at 80℃ for 24 hours.

One-pot mixing system reaction: 0.1 M Ac-AA^1-NH_2 and 15 kinds of AA-NH_2 with a total concentration of 0.1 M were mixed in 1mL deionized water, and after mixing evenly, 0.5 M NaOH was used to adjust the solution to be neutral. The reactants were placed in a centrifuge tube and reacted at 80 ° C for 24 hours. After complete drying,

0.1mL deionized water was added to fully dissolve the reactants, and continued drying at 80℃ for 24 hours.

1.3 Calculation of conversion efficiency of Ac-AA-NH_2.

The method for calculating conversion efficiency as follows: Conversion Efficiency (Ac-AA-NH_2) = [The reduction amount of Ac-AA-NH_2 in the reaction group] / [Amount of Ac-AA-NH_2 in the raw material group]. We divided the reactions into a raw material group and a reaction group. The raw material group consisted of Ac-Ala-NH_2, while the reaction group was split into two subgroups: Ac-Ala-NH_2+Gly-NH_2 and Ac-Ala-NH_2+His-NH_2. All three groups received their Ac-Ala-NH_2 from the same parent solution. After undergoing two dry-wet cycles, the pH of all three groups (Ac-Ala-NH_2, Ac-Ala-NH_2+Gly-NH_2, and Ac-Ala-NH_2+His-NH_2) was uniformly adjusted to 7. Upon completion of the reactions, the peak area of Ac-Ala-NH_2 was extracted in the mass spectrum.

1.4 Analysis Methods (HPLC-MS)

The MS was performed in positive mode on a Thermo Scientific TM Q Exactive PlusTM system. MS instrument parameters were set as follows: The capillary voltage was 3800 V, the atomizer pressure was 2 bar, the dry gas was 3 L•min^{-1} and the dry temperature was 320 °C. Mass spectra were registered in the scan range from m/z = 50 to 500. For ESI-MS, approximately 1/10 of the LC eluent was introduced through a splitting T valve. For HPLC-MS online detection of reaction products, we set up the divert valve of the MS instrument as: This valve can be used to switch HPLC flows directly to the MS when the divert valve was located at the source. HPLC was performed on Thermo Scientific TM Q Exactive PlusTM system and fitted with a Luna-C18 column, 5 μm, 4.6 mm × 250 mm column. The column temperature was kept at room temperature. A binary mobile phase (solvent C: acetonitrile; solvent D: water with 0.1% formic acid) was used with the flow rate at 1 mL•min^{-1}. The linear gradient elution program was as follows: 0∼4 min, 5% C; 4∼19 min, 5%–70% C; 19∼21 min,

70% C; 21～22 min, 70% -5% C; 22～30 min, 5% C. The detection wavelength was 210 nm and the sample size was 3 μL. For the on-line detection of reaction products by HPLC-MS, a shunt T-valve was used to cleverly switch the eluent of higher performance liquid chromatography to achieve on-line desalination detection. The specific setting is :0-1 min, the shunt valve will switch the HPLC eluent to the waste liquid; After 1 minute, the diverter valve switches the HPLC eluent to MS.

2. Supplementary Figures

2.1 The Fourier transform infrared spectroscopy (FTIR).

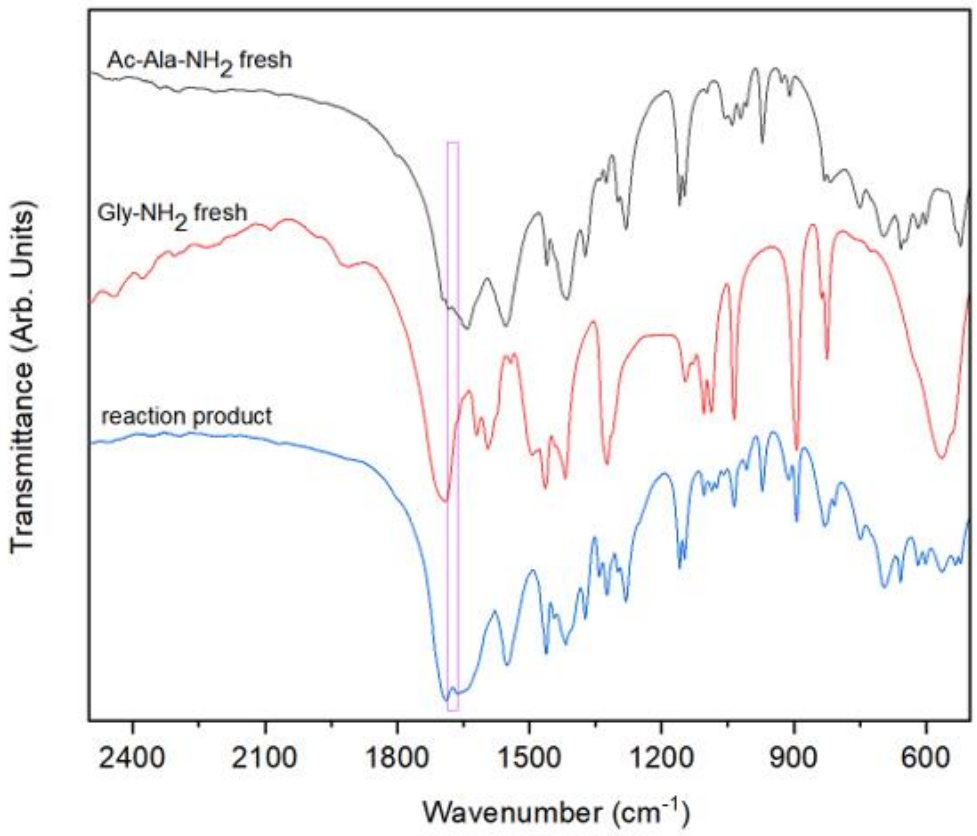

Fig. S1 The Fourier transform infrared spectroscopy (FTIR) reveals changes in the band at 1620–1700 cm^{-1}, which are associated with amide I vibrations (mainly CO group stretching mode). Fresh represents raw materials that have not undergone chemical reactions.

2.2 The polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Gly-NH_2 resulted in the formation of the highest pentapeptide N-Ac-Ala-Gly_4-OH.

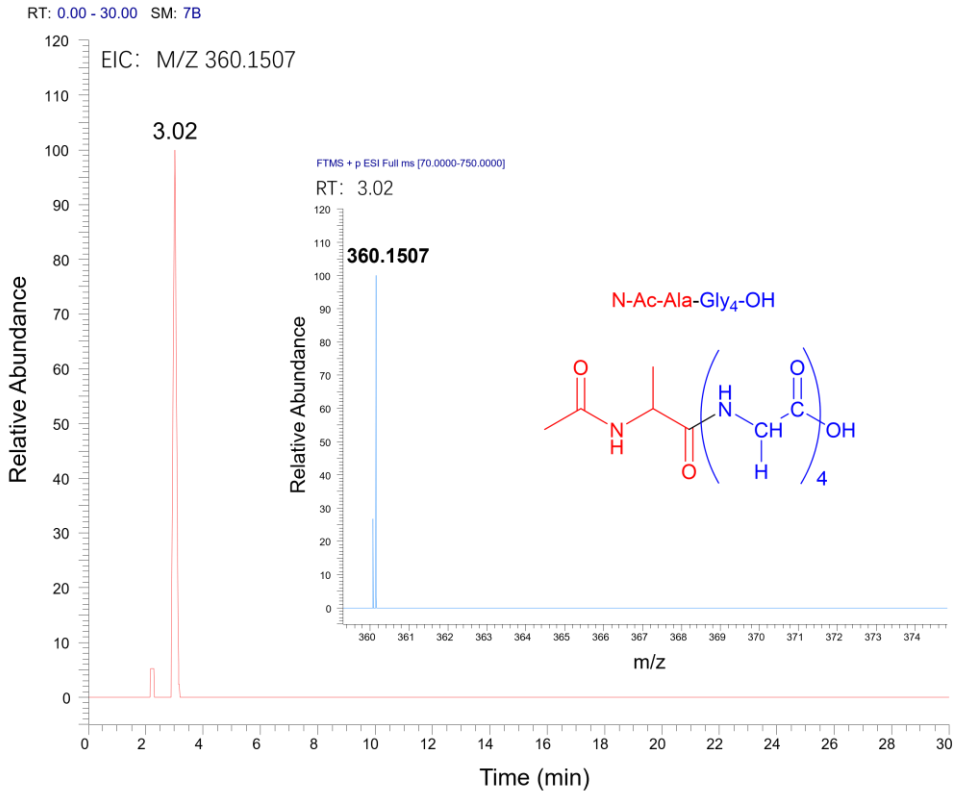

Fig. S2 The polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Gly-NH_2 resulted in the formation of the highest pentapeptide N-Ac-Ala-Gly_4-OH. The mass charge ratio of N-Ac-Ala-Gly_4-OH tetrapeptide is m/z=360.1507, and the peak occurs at 3.02 min retention time.

2.3 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Gly-NH_2.（Figs. S3-S15）

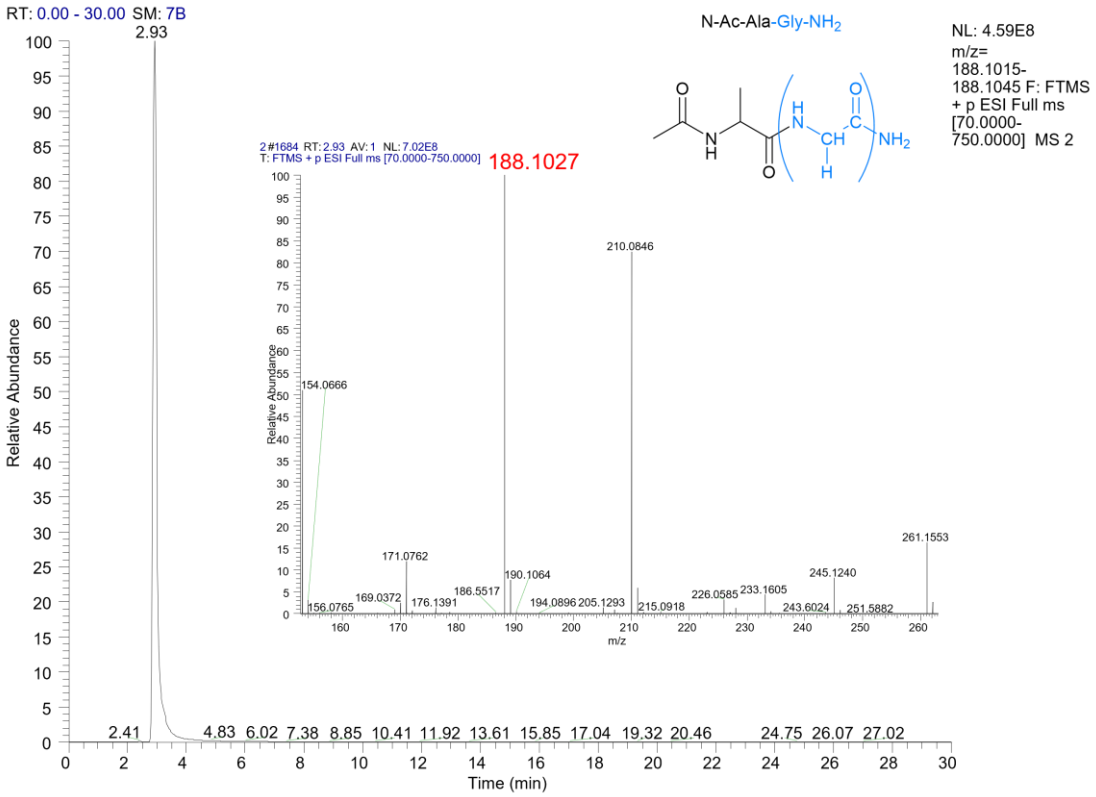

Fig. S3 Extraction ion chromatography-mass spectrometry of the product. The EIC of m/z 188.1027 was analyzed, and its EIC corresponded to the dimer N-Ac-Ala-Gly- NH_2 with a retention time of 2.93 min.

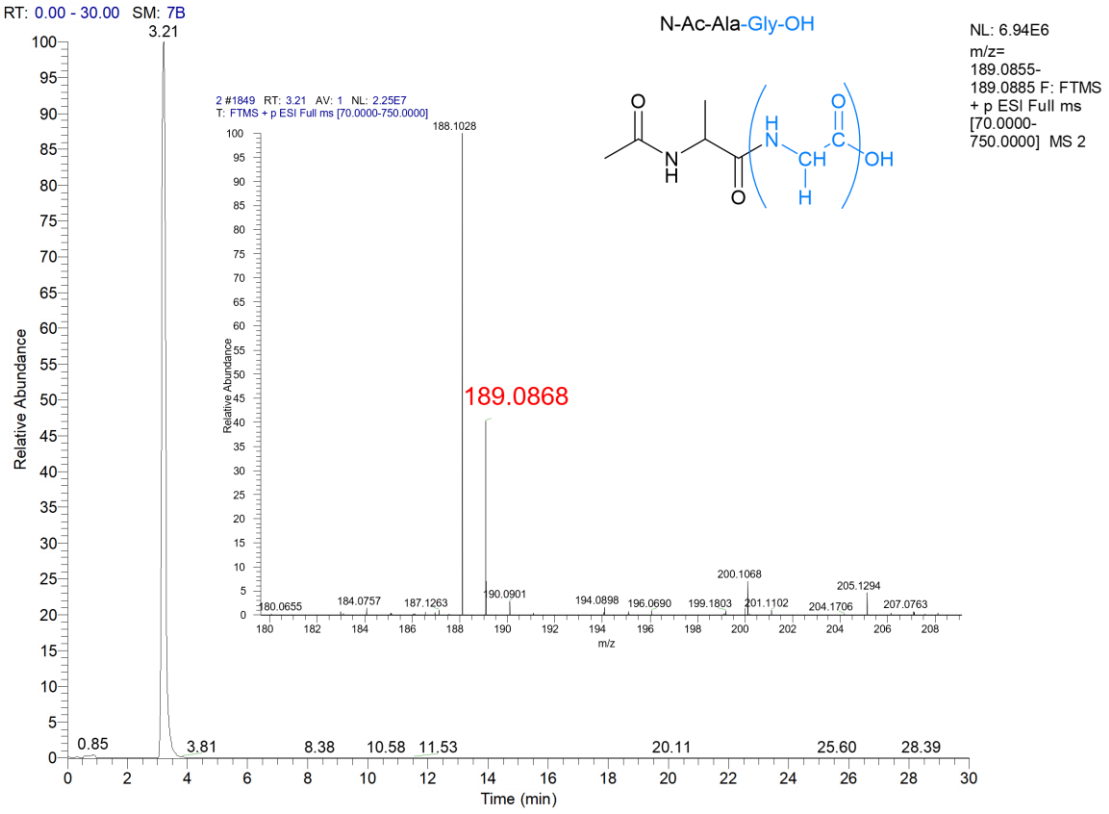

Fig. S4 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 189.0868 was analyzed and its EIC corresponded to the dipeptide N- Ac-Ala-Gly-OH with a retention time of 3.21 min.

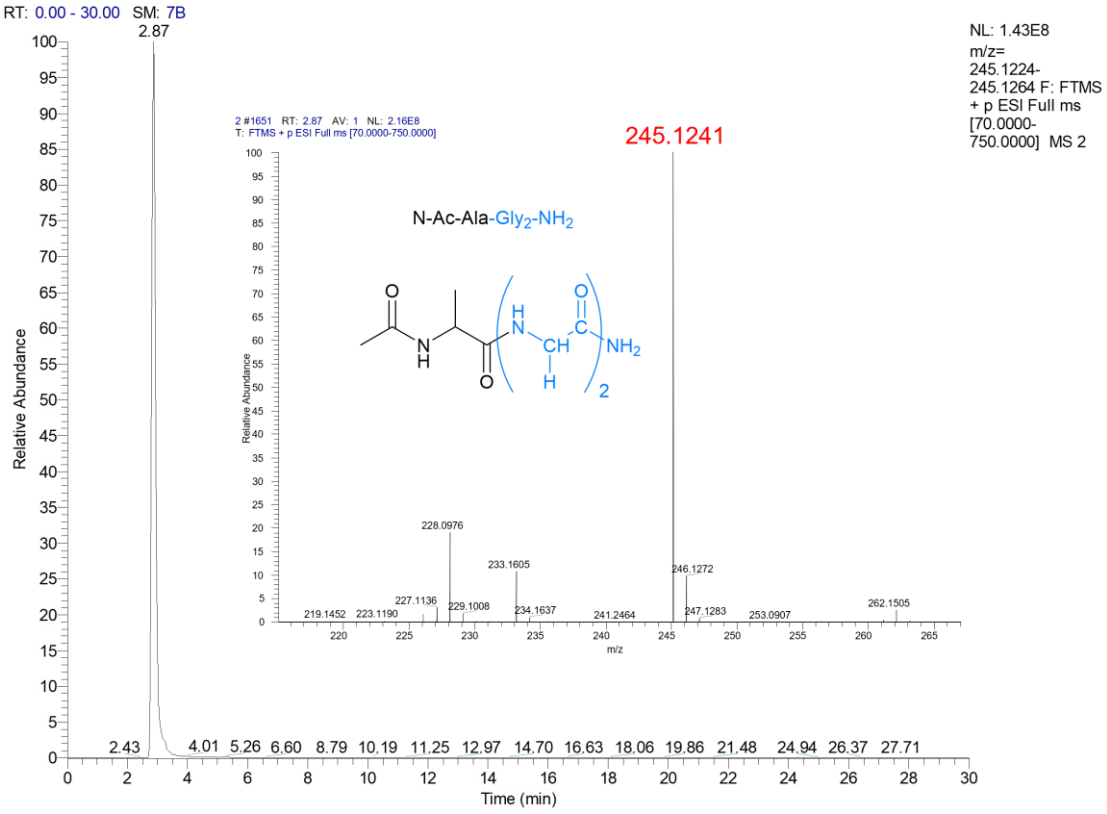

Fig. S5 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 245.12418 was analyzed, and its EIC corresponds to the trimer N-Ac-Ala-Gly_2-NH_2 with a retention time of 2.87 min.

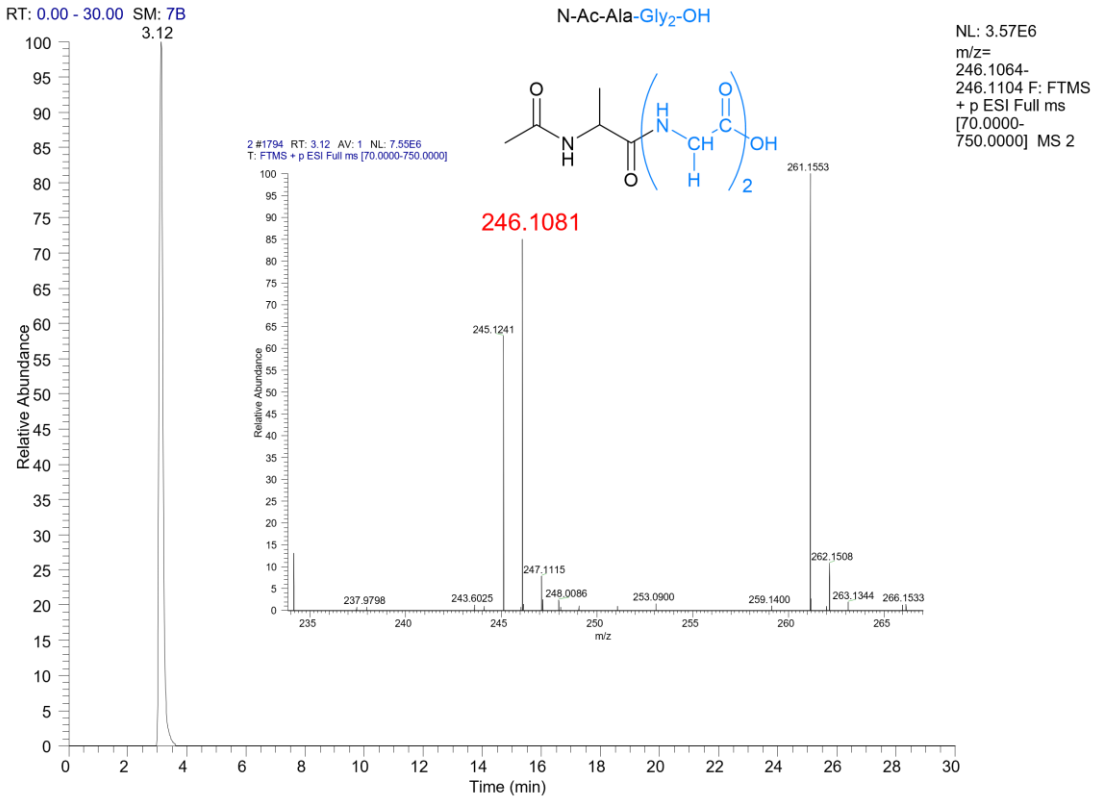

Fig. S6 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 246.1081 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Ala-Gly_2-OH with a retention time of 3.12 min.

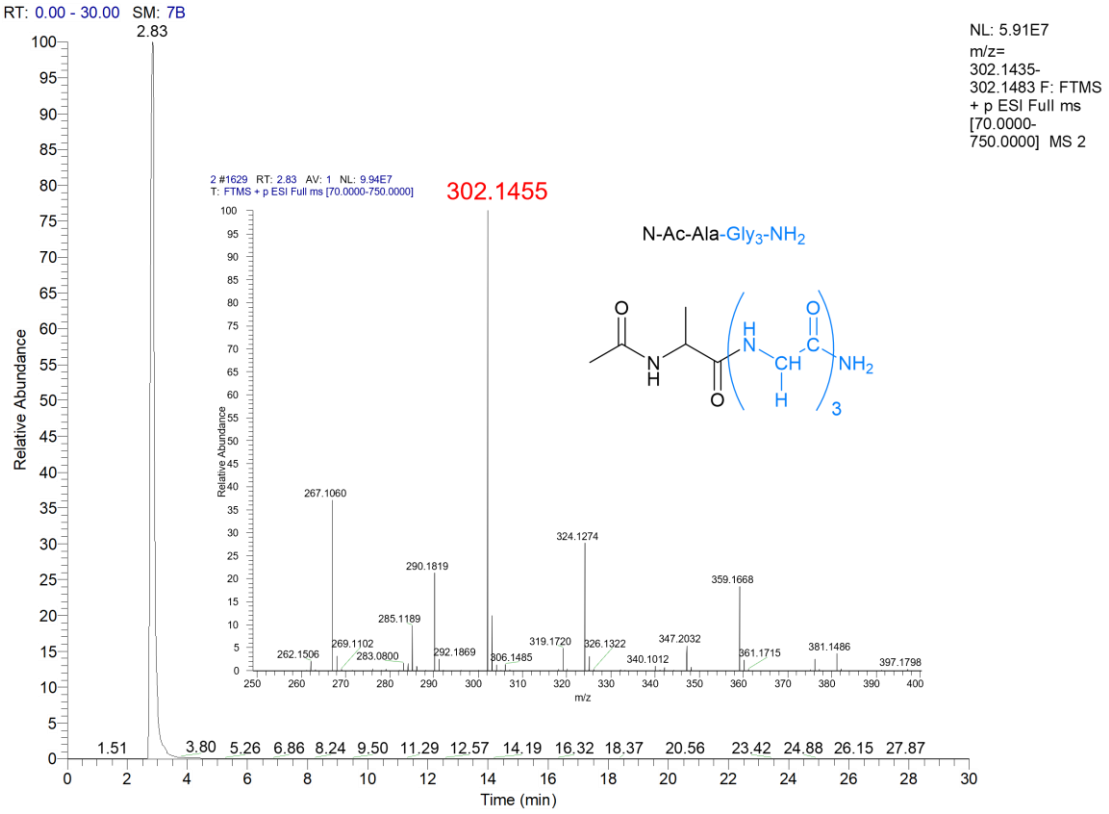

Fig. S7 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 302.1455 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Gly_3-NH_2 with a retention time of 2.83 min.

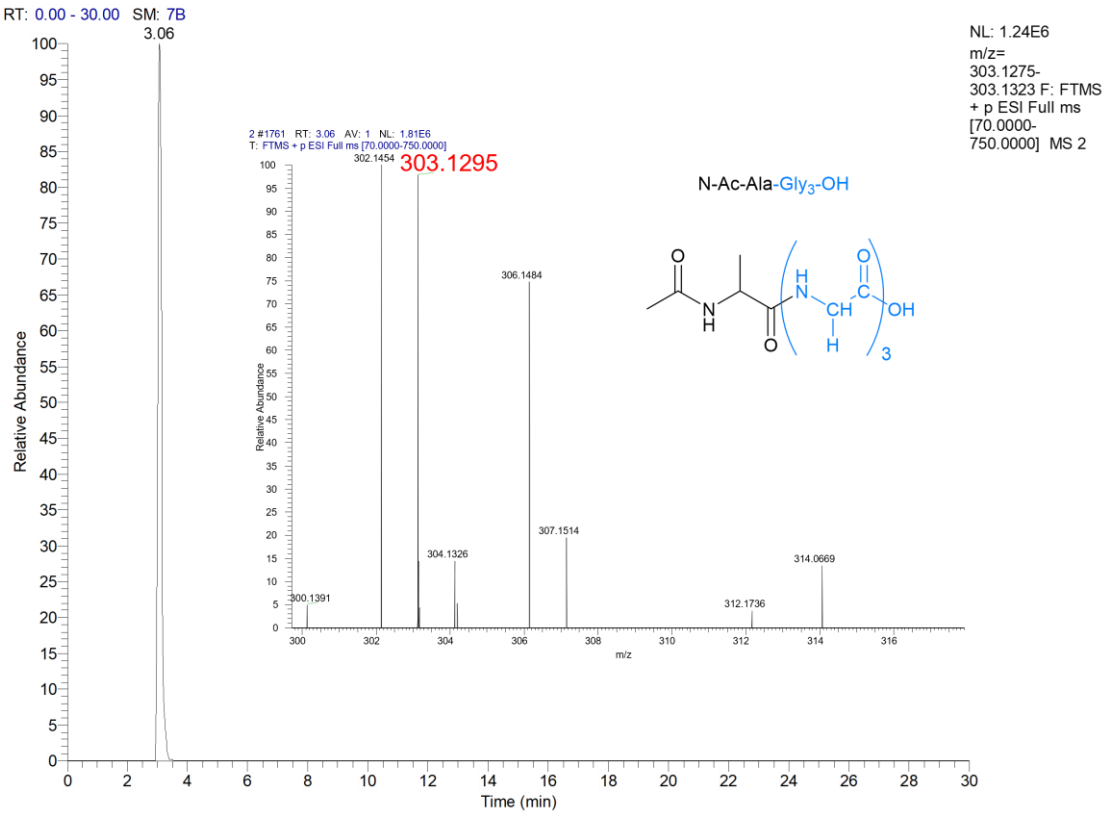

Fig. S8 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 303.1295 was analyzed and its EIC corresponded to the tetrapeptide N-Ac-Ala-Gly_3-OH with a retention time of 3.06 min.

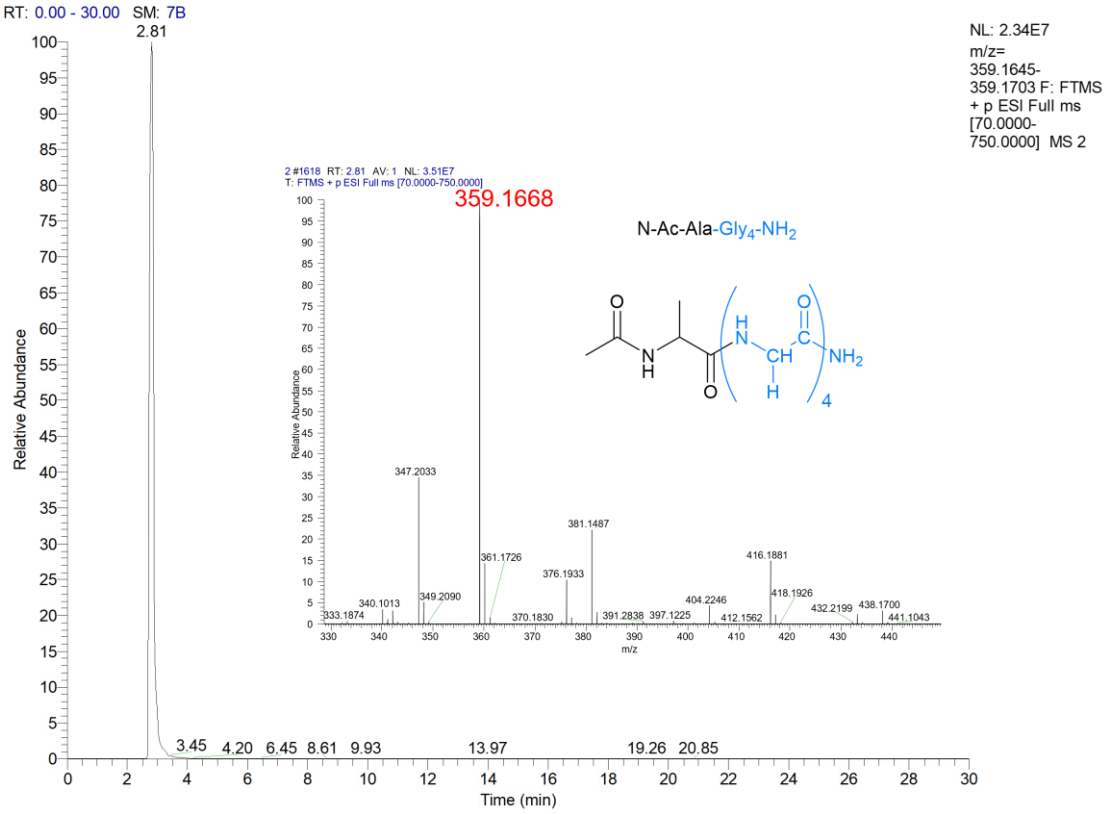

Fig. S9 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 359.1668 was analyzed, and its EIC corresponded to the pentamer N-Ac-Ala-Gly_4-NH_2 with a retention time of 2.81 min.

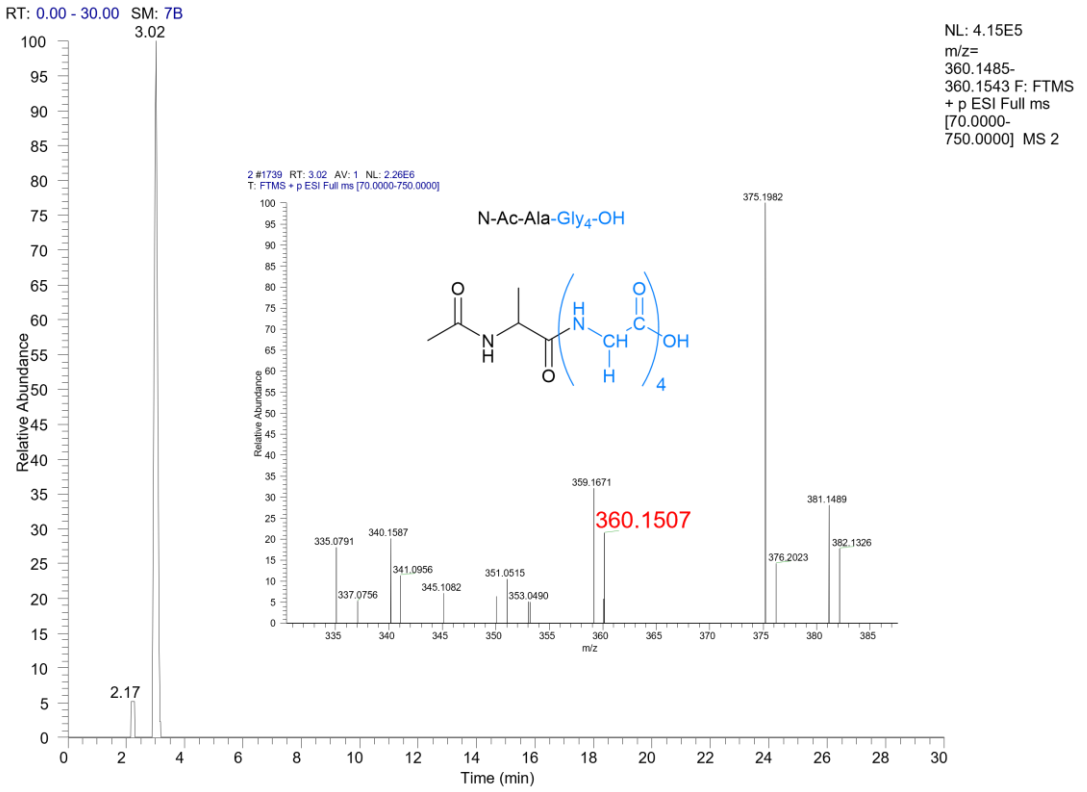

Fig. S10 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 360.1507 was analyzed and its EIC corresponded to pentapeptide N-Ac-Ala-Gly_4-OH with a retention time of 3.02 min.

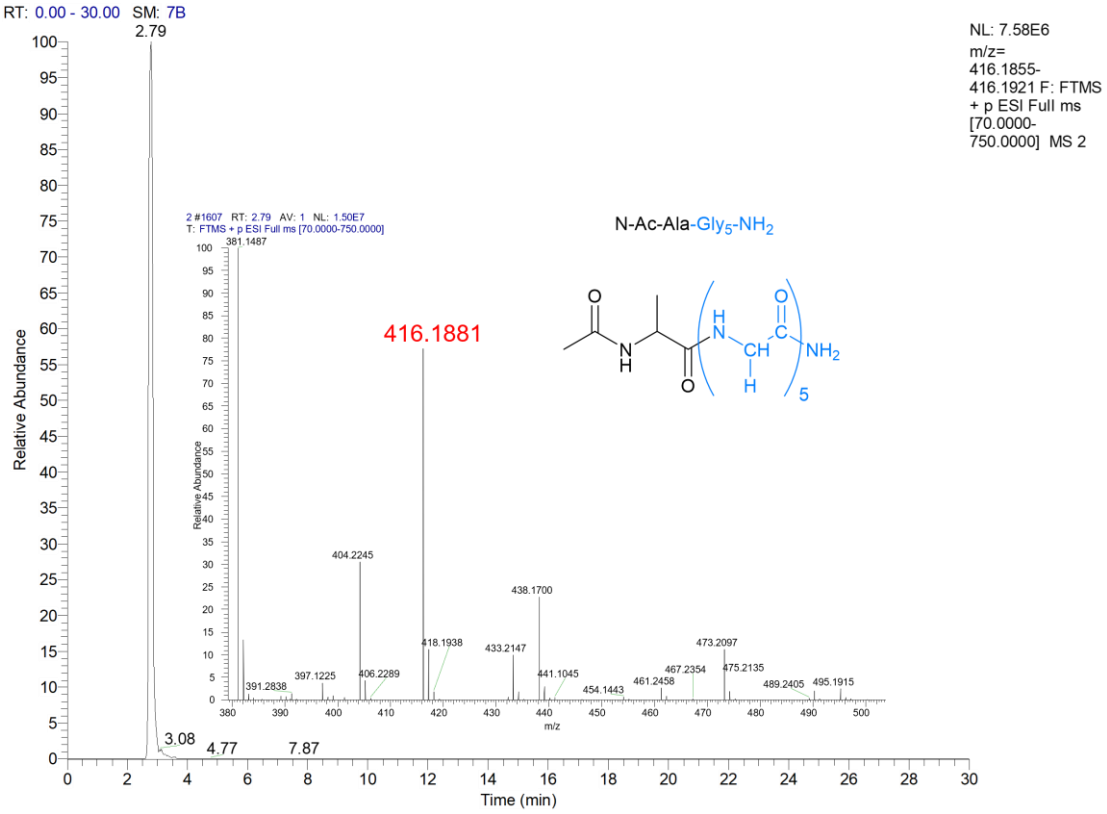

Fig. S11 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 416.1881 was analyzed and its EIC corresponded to the hexamer N-Ac-Ala-Gly_5-NH_2 with a retention time of 2.79 min.

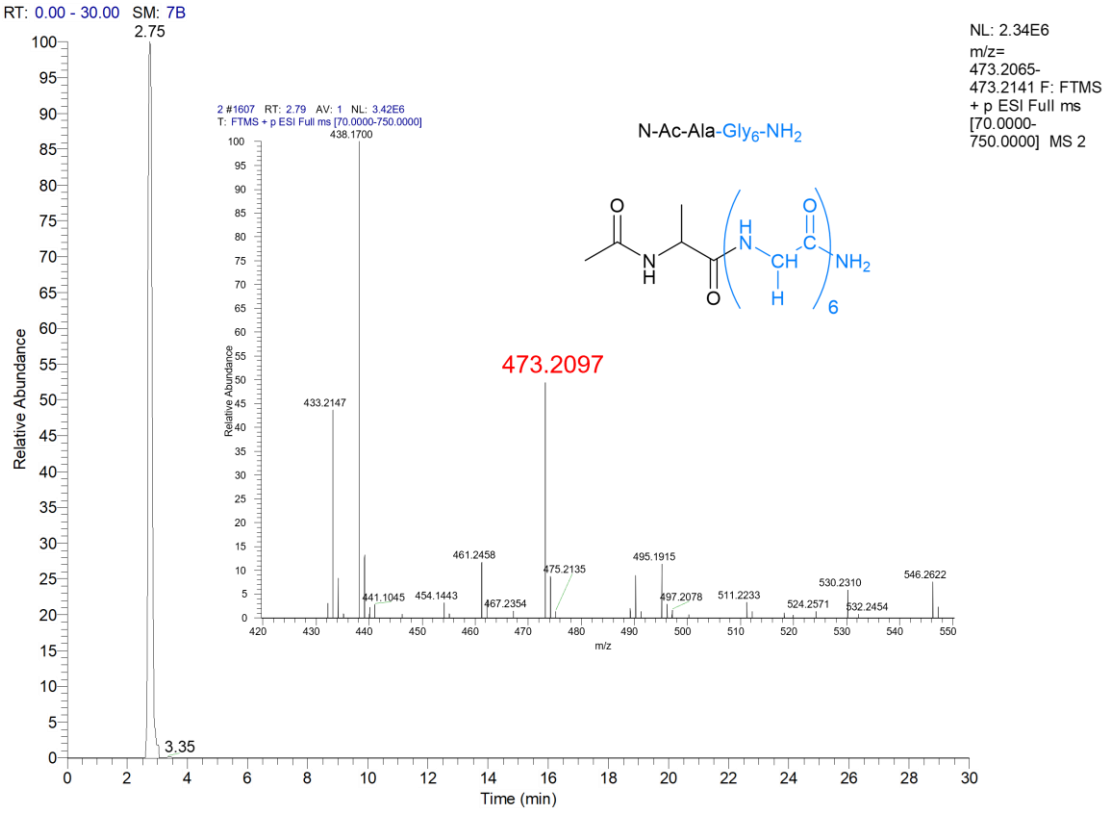

Fig. S12 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 473.2097 was analyzed and its EIC corresponded to the heptamer N-Ac-Ala-Gly_6-NH_2 with a retention time of 2.75 min.

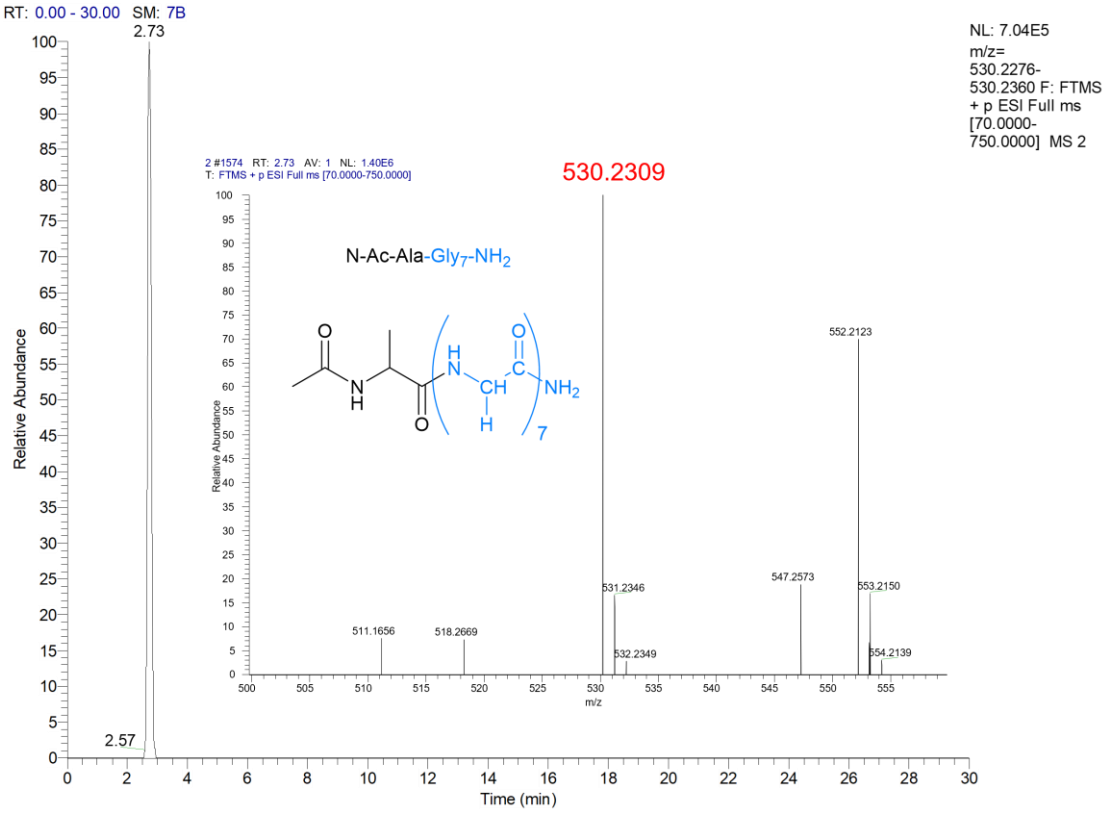

Fig. S13 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 530.2309 was analyzed and its EIC corresponded to the octamer N-Ac-Ala-Gly_7-NH_2 with a retention time of 2.73 min.

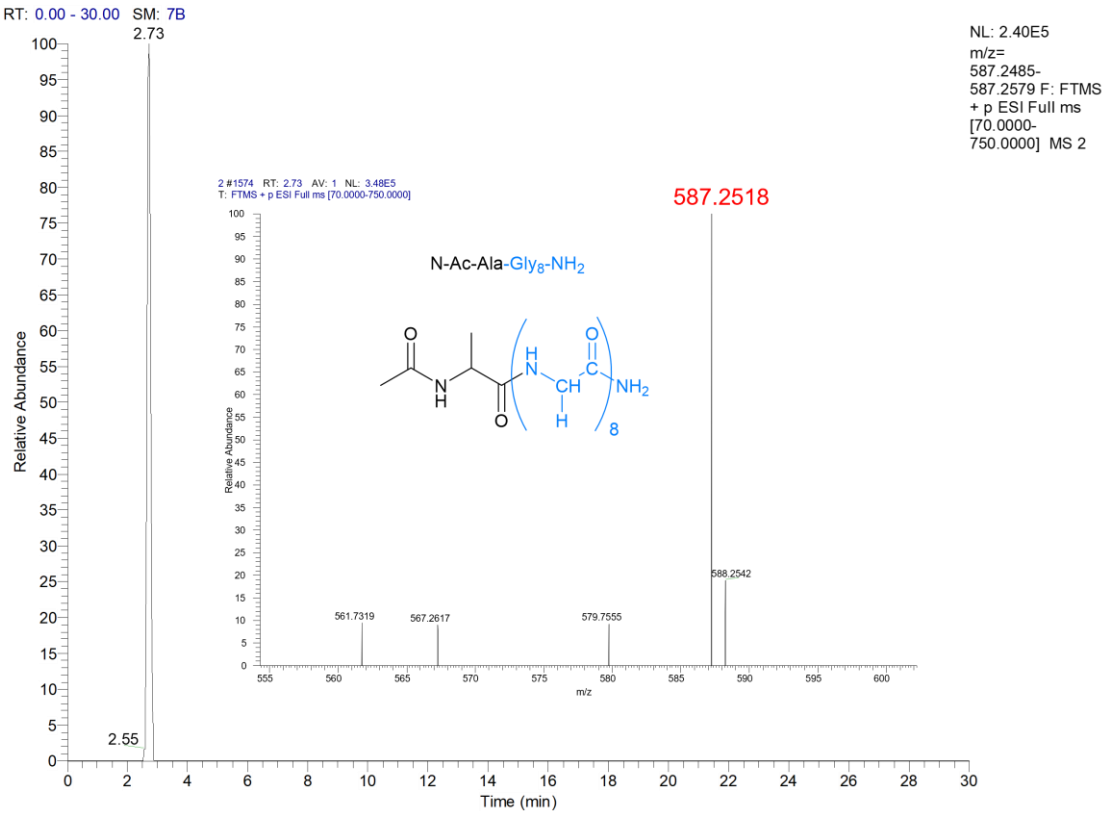

Fig. S14 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 587.2518 was analyzed, and its EIC corresponds to the unimer N-Ac-Ala-Gly_8-NH_2 with a retention time of 2.73 min.

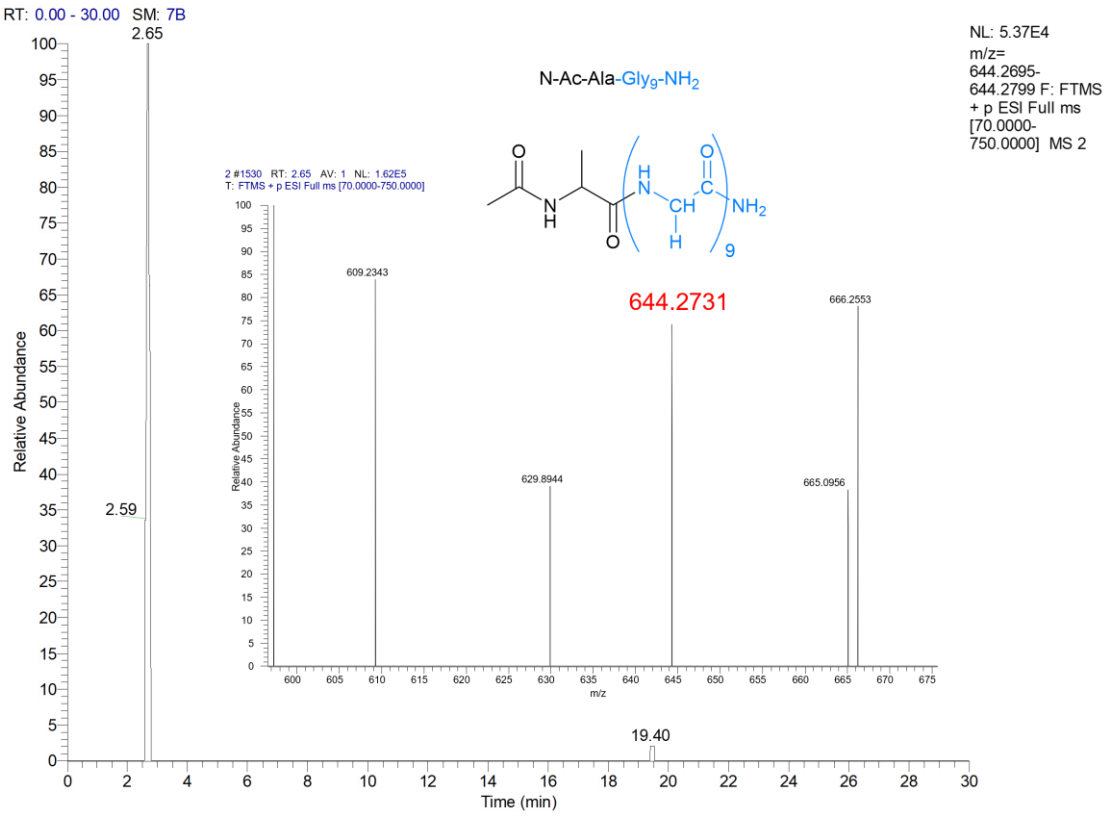

Fig. S15 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 644.2731 was analyzed and its EIC corresponded to the decamer N-Ac-Ala-Gly_9-NH_2 with a retention time of 2.65 min.

2.4 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Glu-NH_2.（Figs. S16-S20）

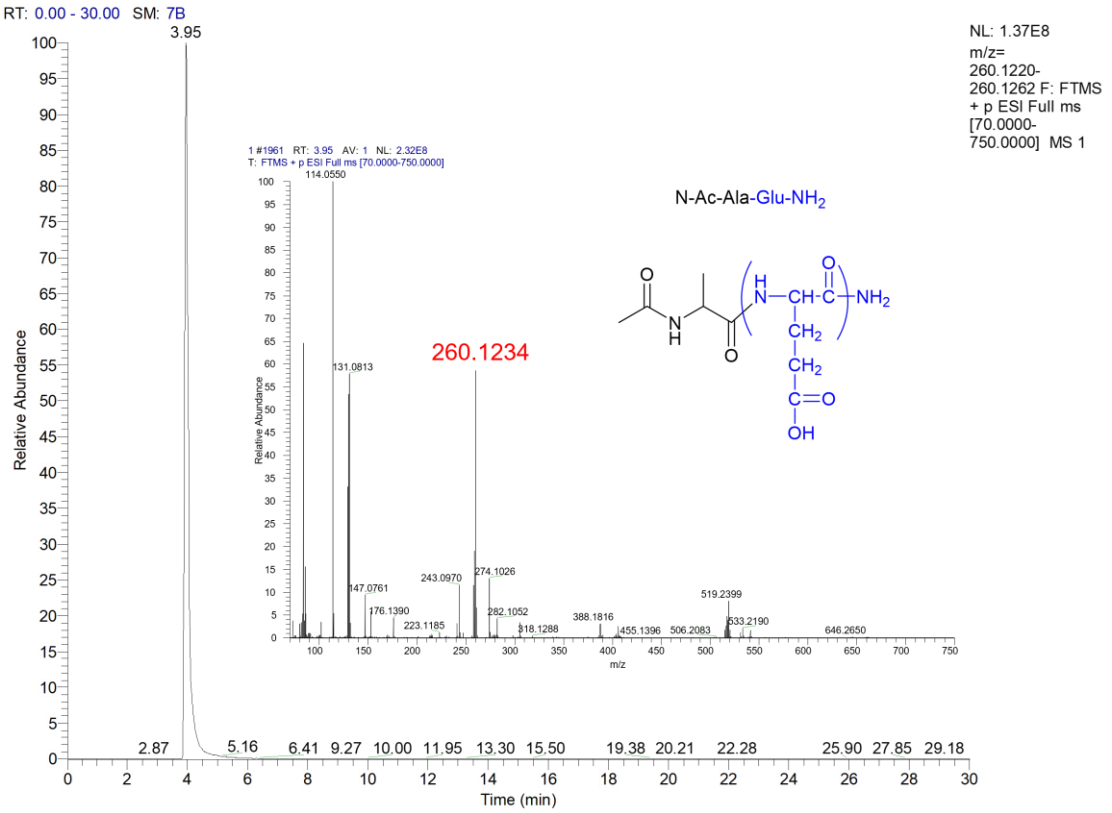

Fig. S16 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z 260.1234 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Glu-NH_2 with a retention time of 3.95 min.

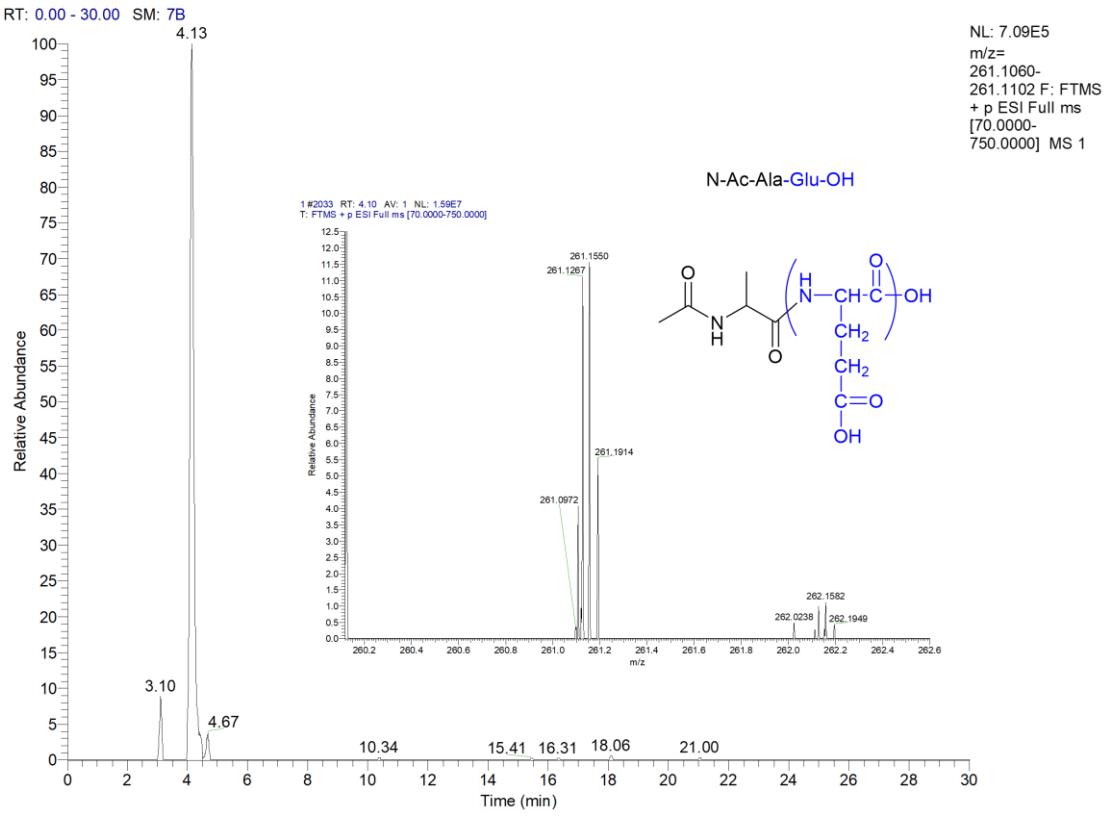

Fig. S17 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 261.1550 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Ala-Glu-OH with a retention time of 4.13 min.

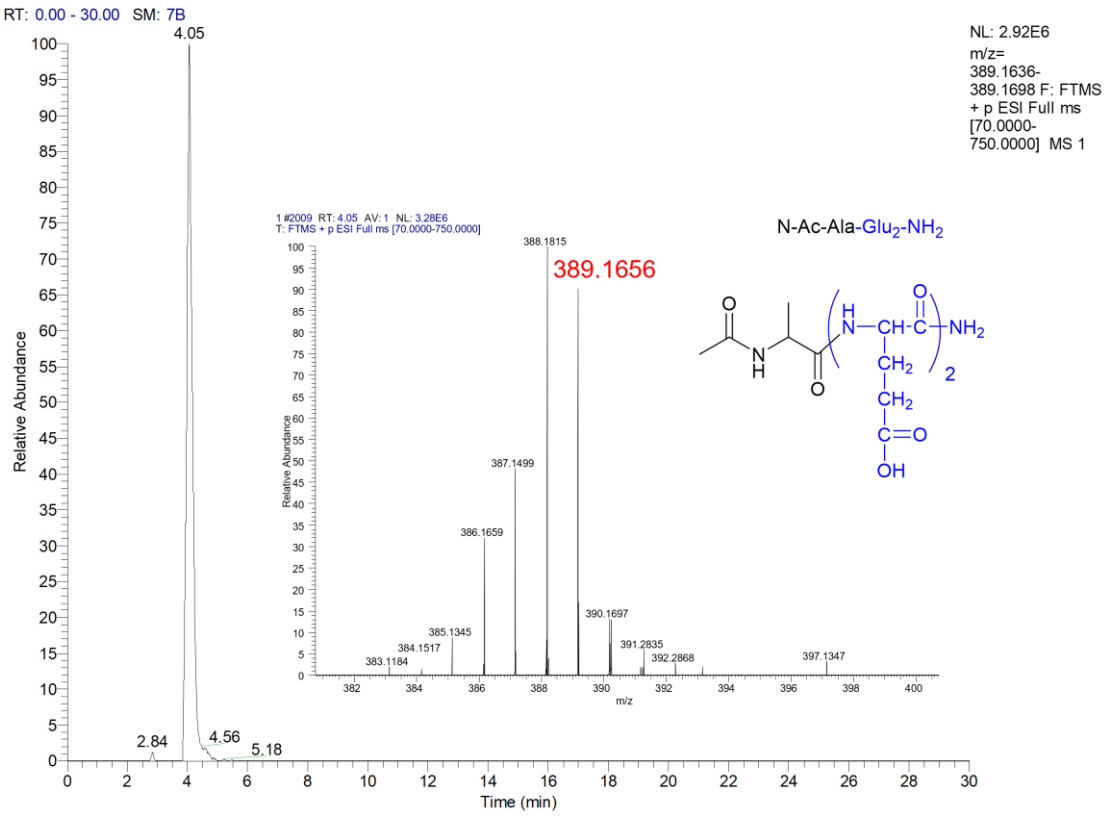

Fig. S18 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 389.1656 was analyzed, and its EIC corresponds to the trimer N-Ac-Ala-Glu_2-NH_2 with a retention time of 4.05 min.

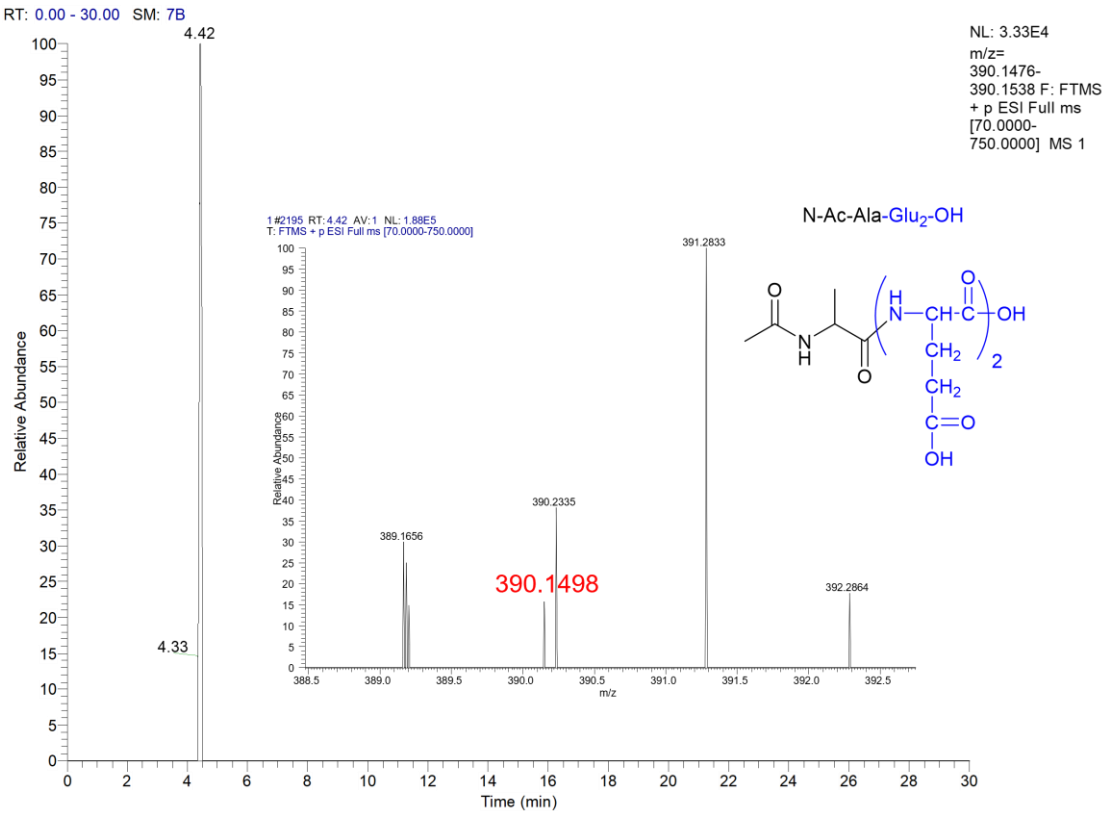

Fig. S19 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 390.1498 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Ala-Glu_2-OH with a retention time of 4.42 min.

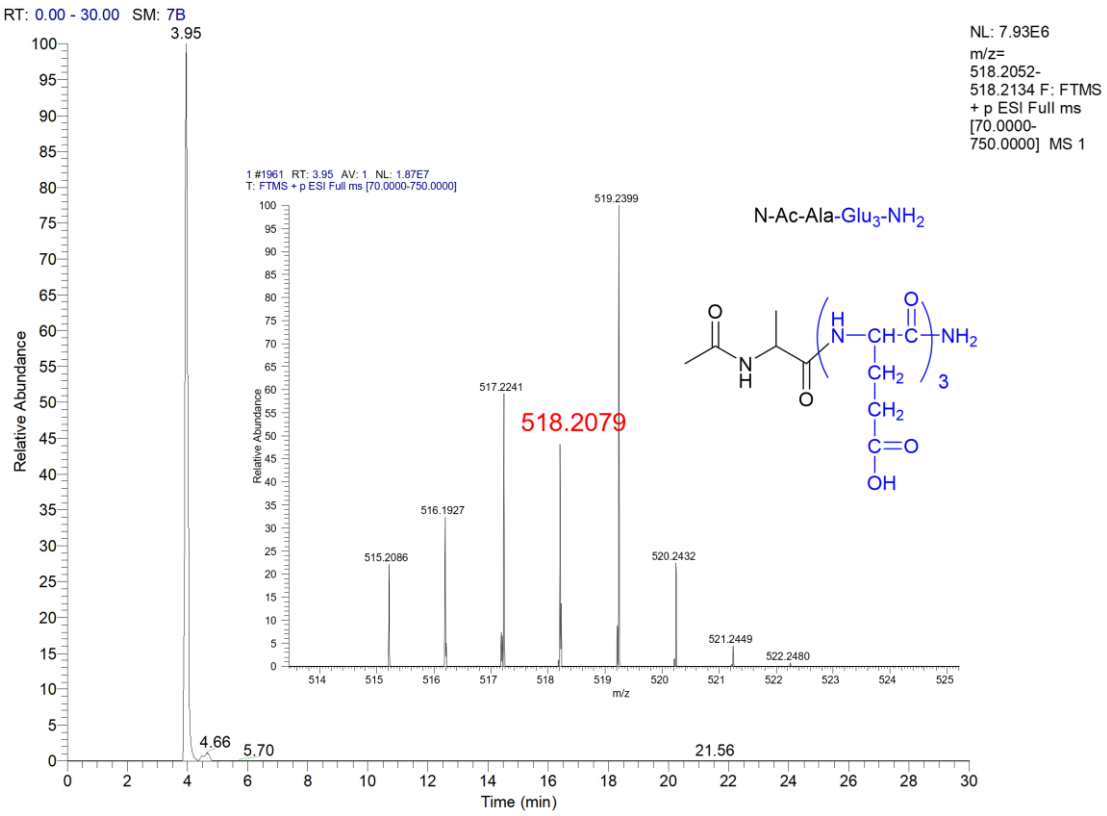

Fig. S20 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 518.2079 was analyzed, and its EIC corresponded to the tetramer N-Ac-Ala-Glu_3-NH_2 with a retention time of 3.95 min.

2.5 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Ser-NH_2.（Figs. S21-S26）

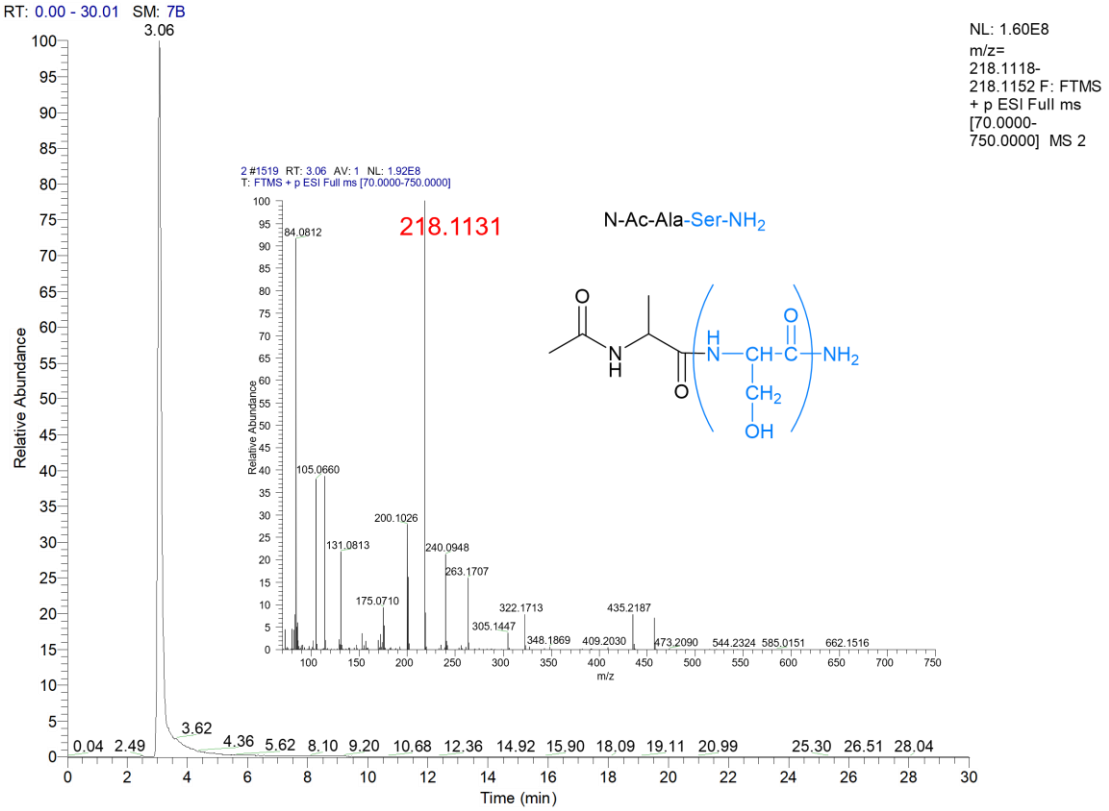

Fig. S21 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 218.1131 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Ser-NH_2 with a retention time of 3.06 min.

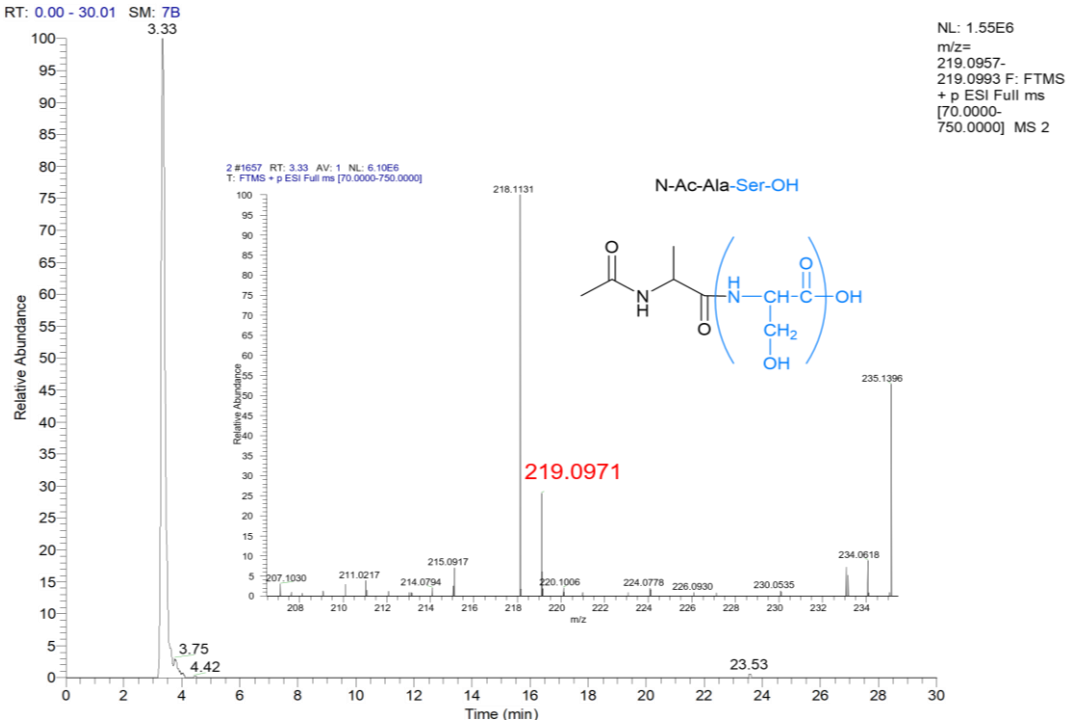

Fig. S22 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 219.0971 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Ser-OH with a retention time of 3.33 min.

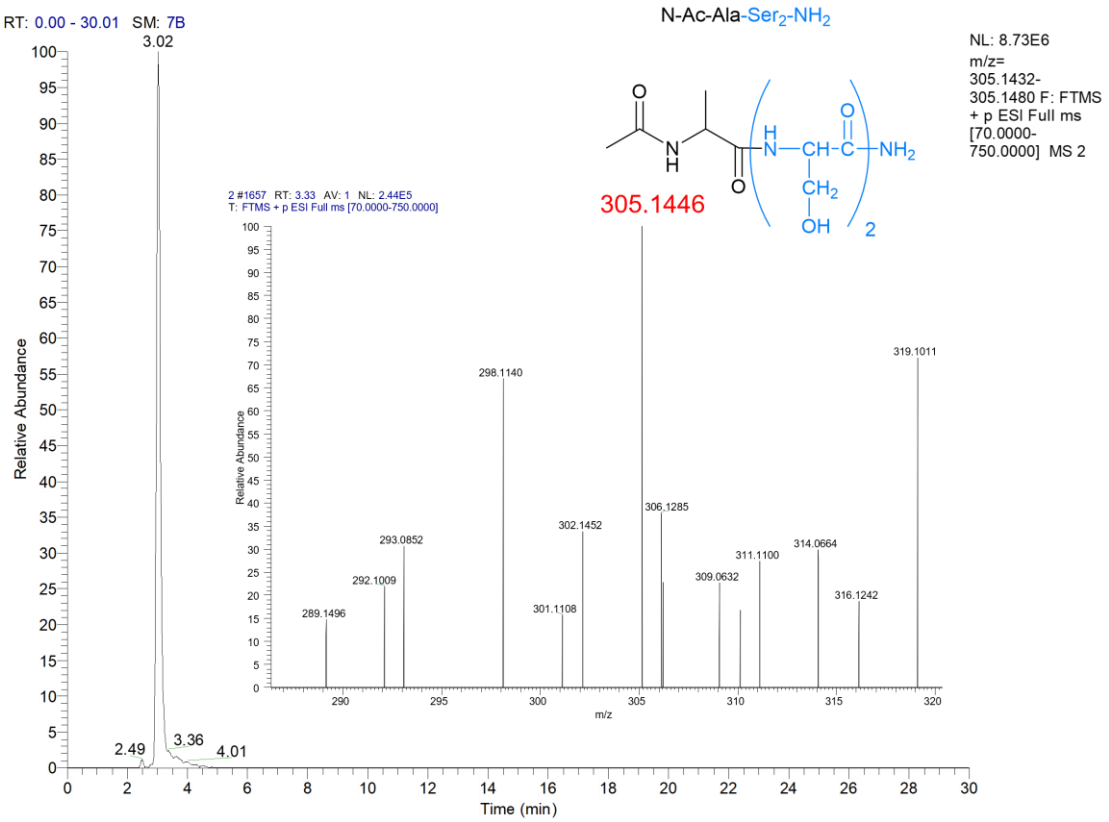

Fig. S23 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 305.1446 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Ser_2-NH_2 with a retention time of 3.02 min.

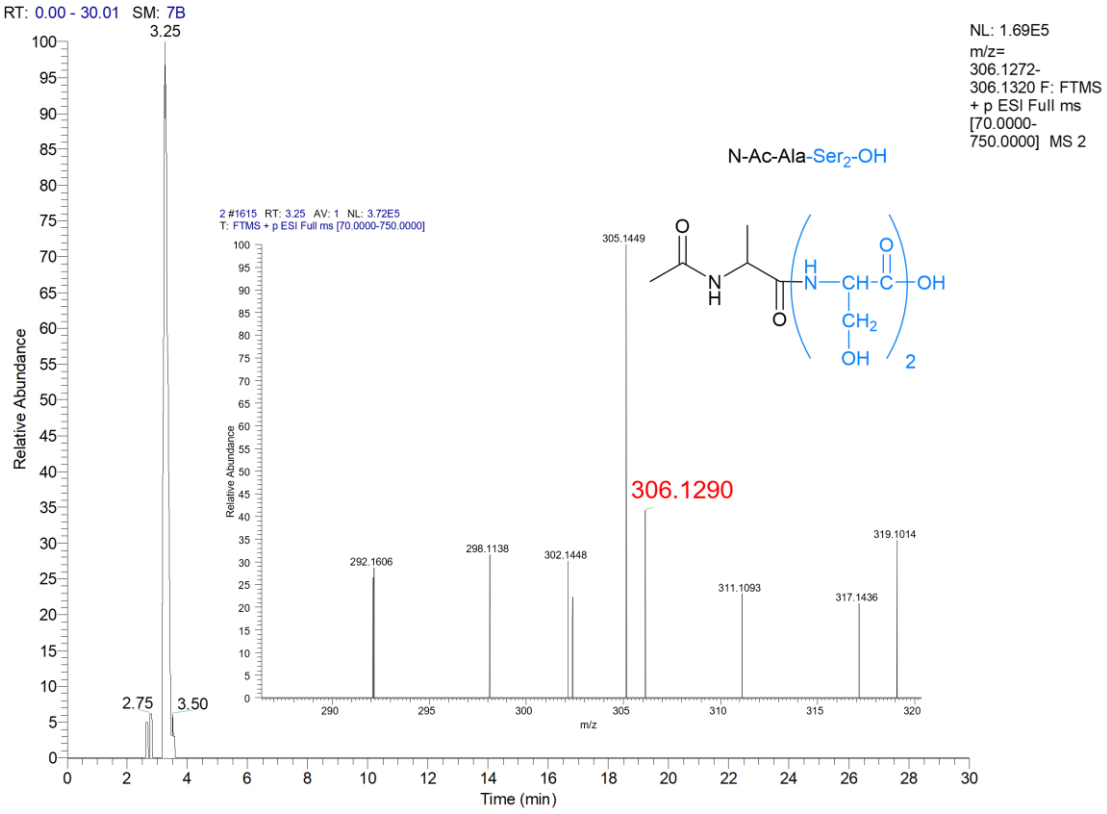

Fig. S24 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 306.1290 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Ser$_2$-OH with a retention time of 3.25 min.

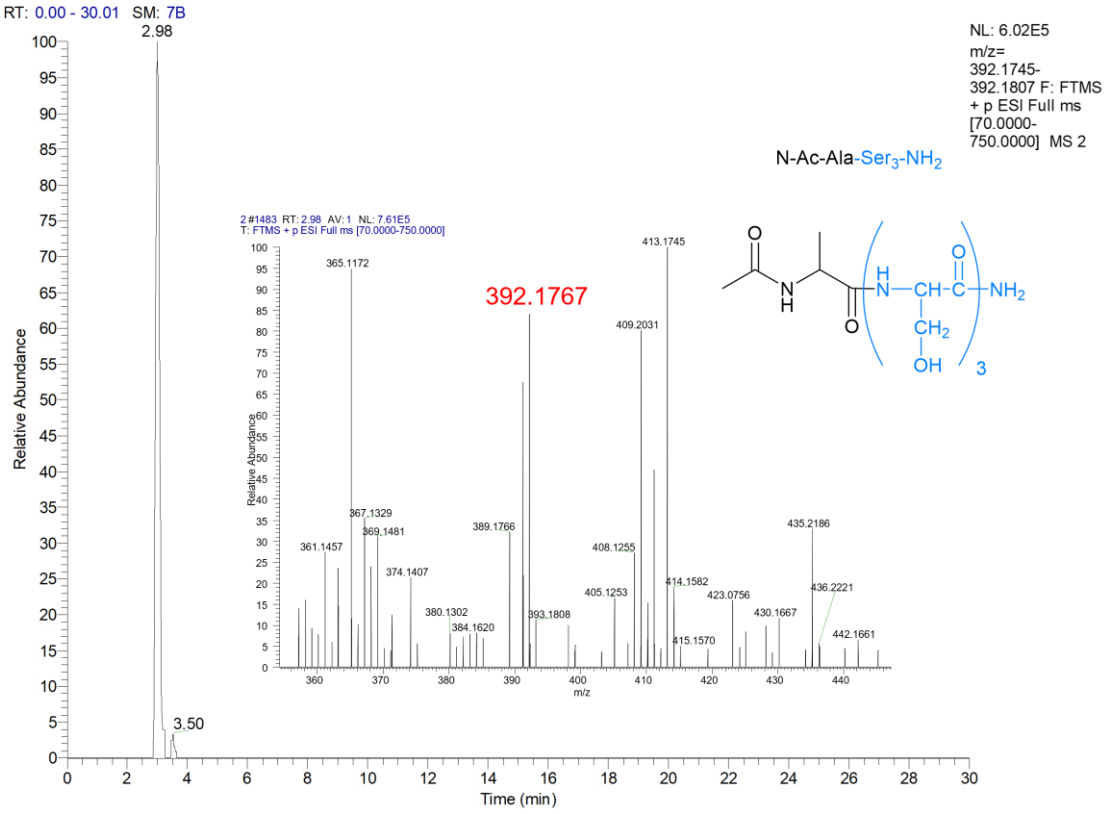

Fig. S25 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 392.1767 was analyzed and its EIC corresponded to the tetracer N-Ac-Ala-Ser_3-NH_2 with a retention time of 2.98 min.

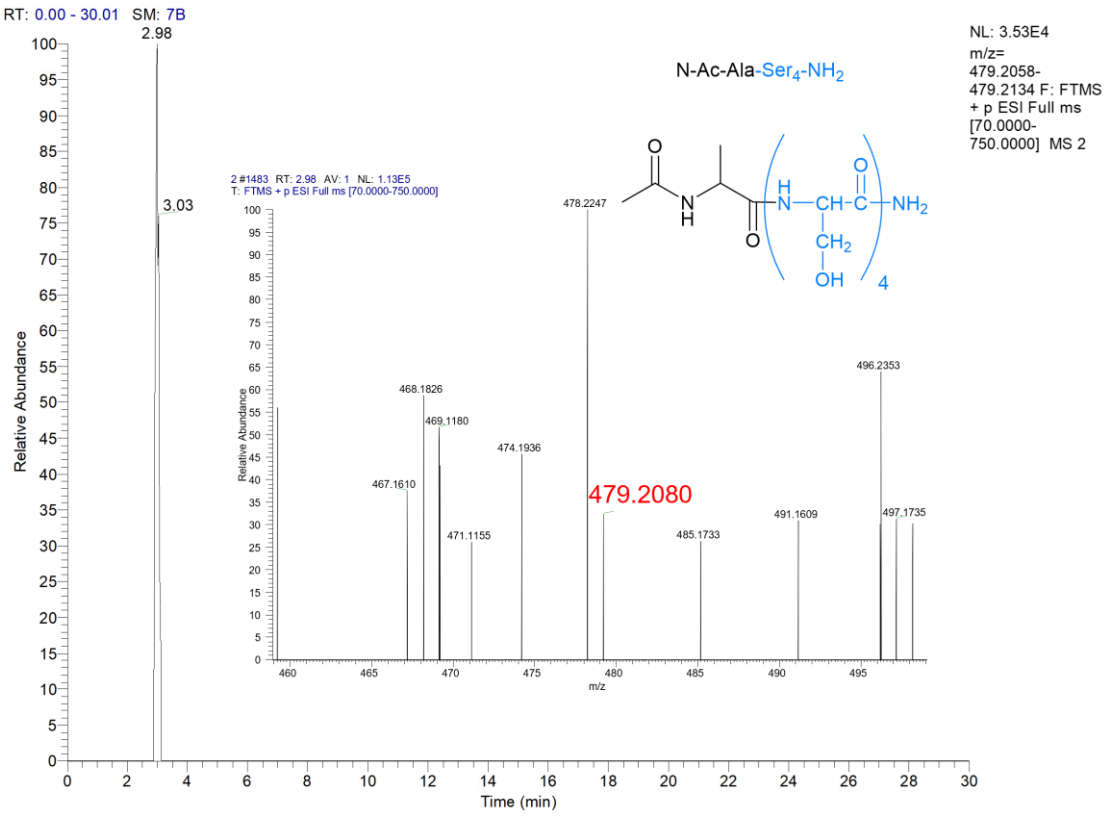

Fig. S26 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 479.2080 was analyzed and its EIC corresponded to the pentamer N-Ac-Ala-Ser_4-NH_2 with a retention time of 2.98 min.

2.6 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Val-NH_2.（Figs. S27-S30）

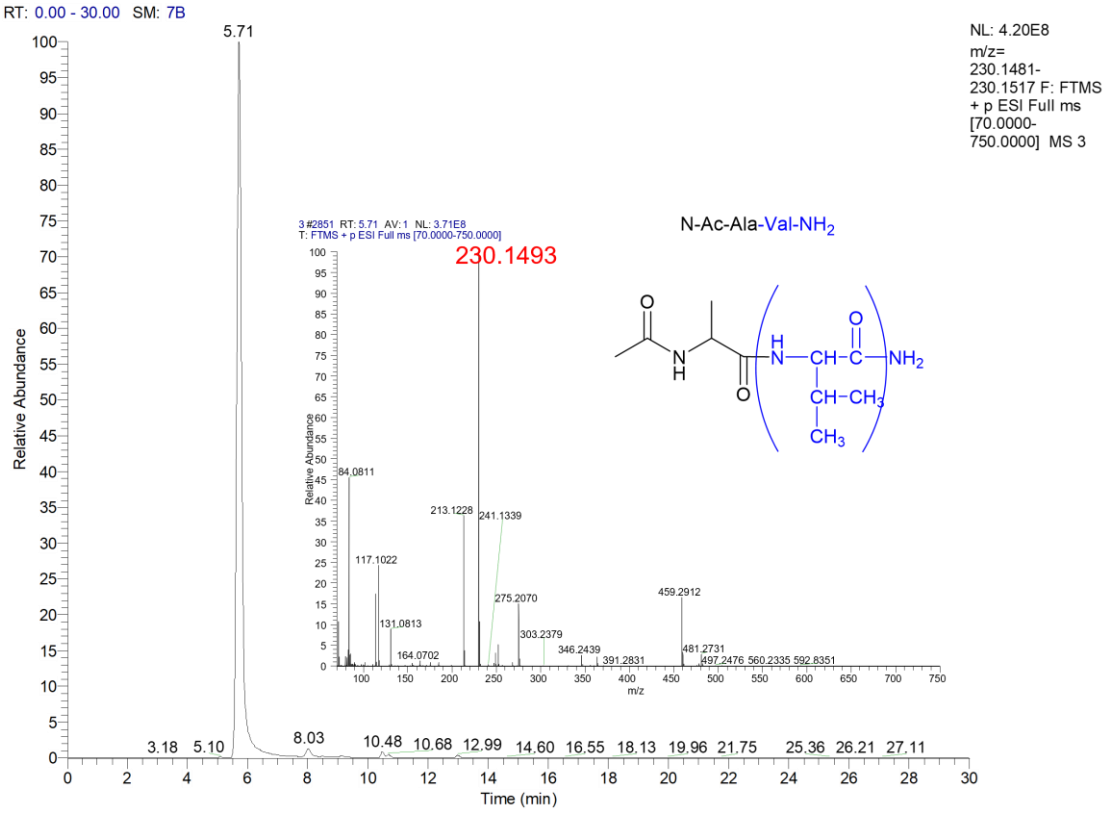

Fig. S27 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 230.1493 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Val-NH_2 with a retention time of 5.71 min.

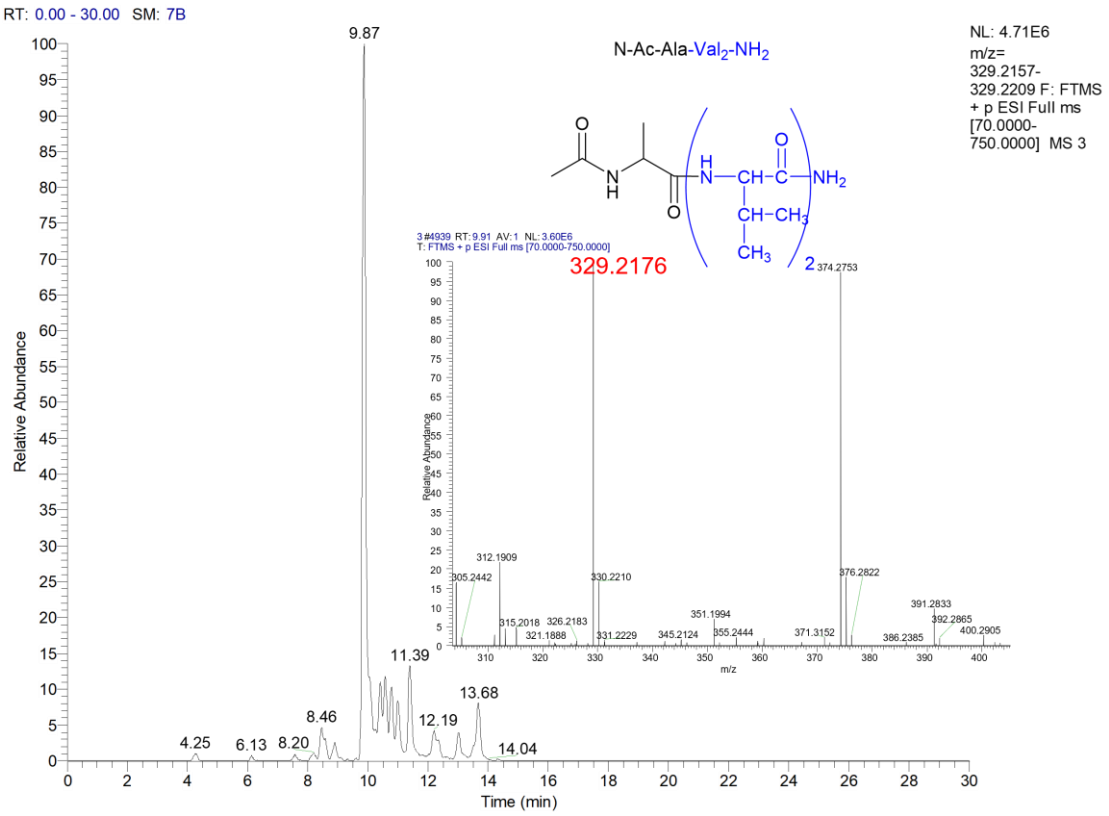

Fig. S28 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 329.2176 was analyzed and the EIC corresponds to the trimer N-Ac-Ala-Val_2-NH_2 with a retention time of 9.87 min.

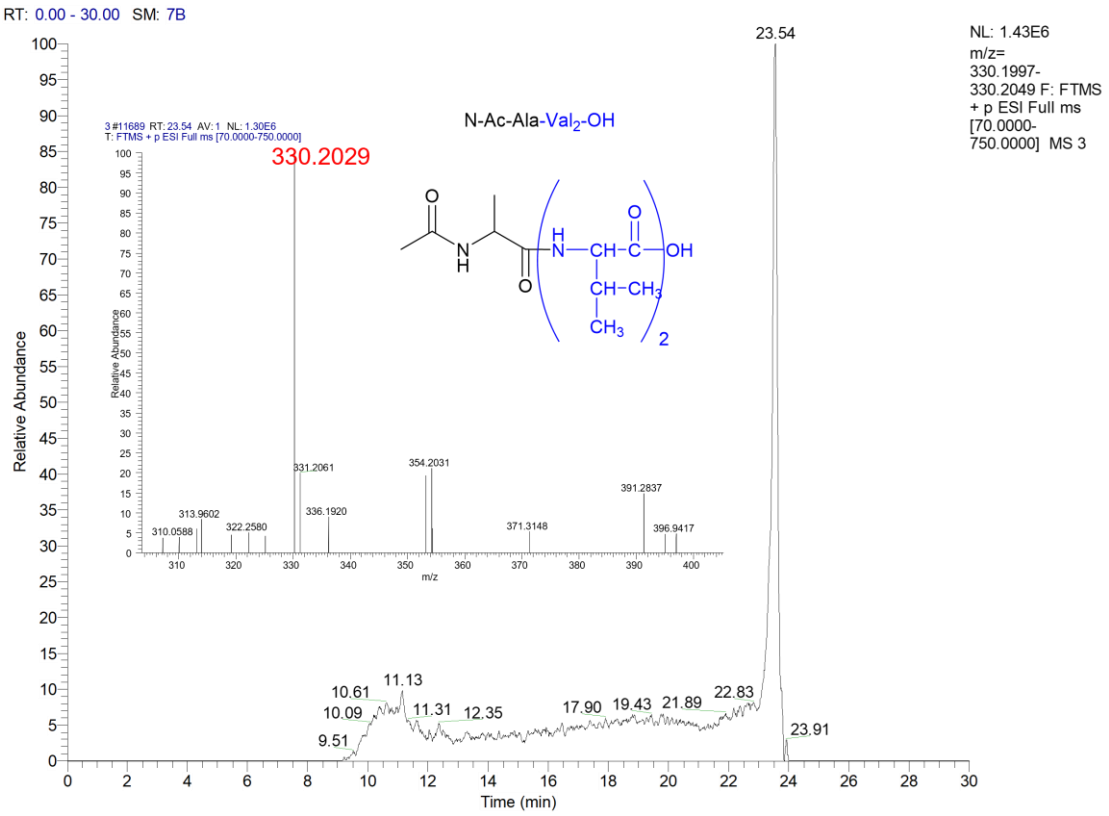

Fig. S29 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 330.2029 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Val_2-OH with a retention time of 23.54 min.

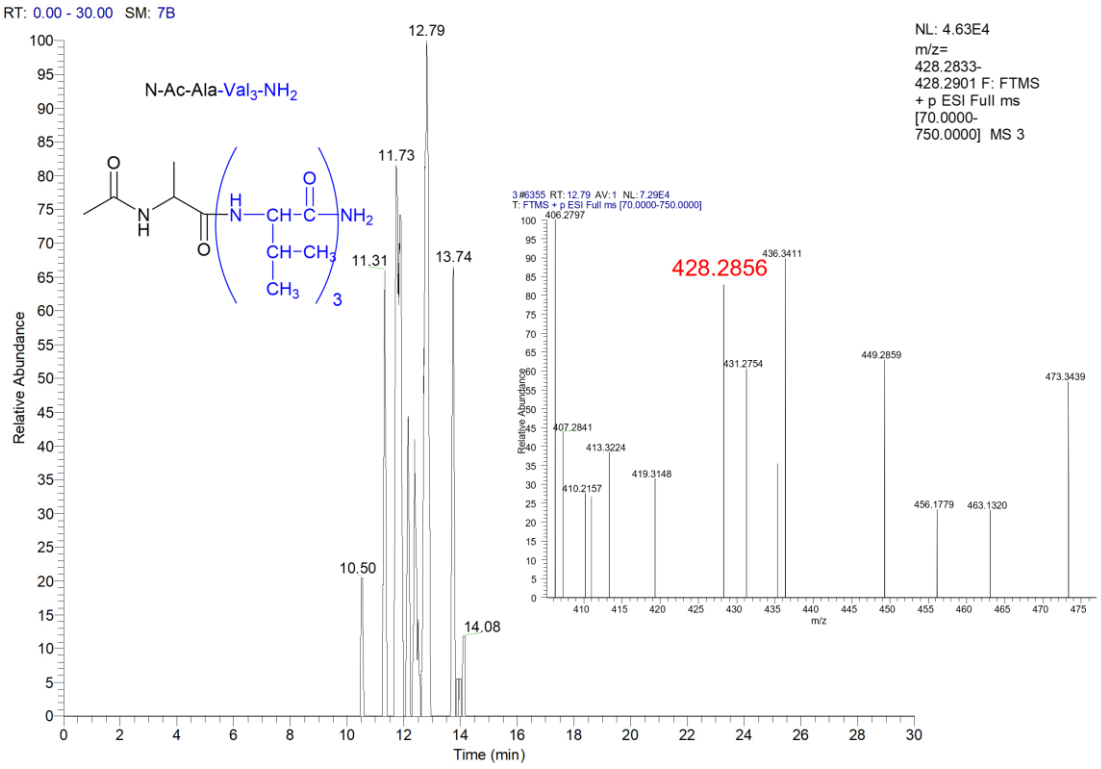

Fig. S30 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 428.2856 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Val_3-NH_2 with a retention time of 12.79 min.

2.7 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Arg-NH_2.（Figs. S31-S32）

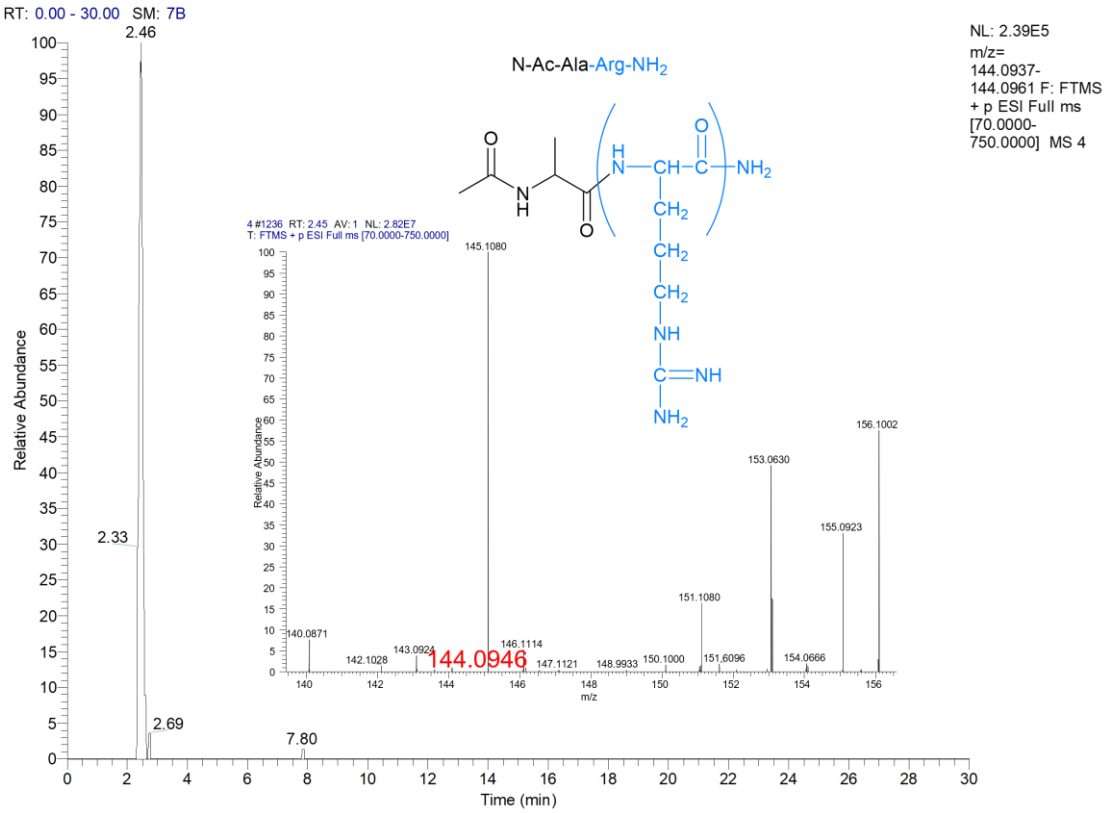

Fig. S31 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 144.0946 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Arg-NH_2 with a retention time of 2.46 min.

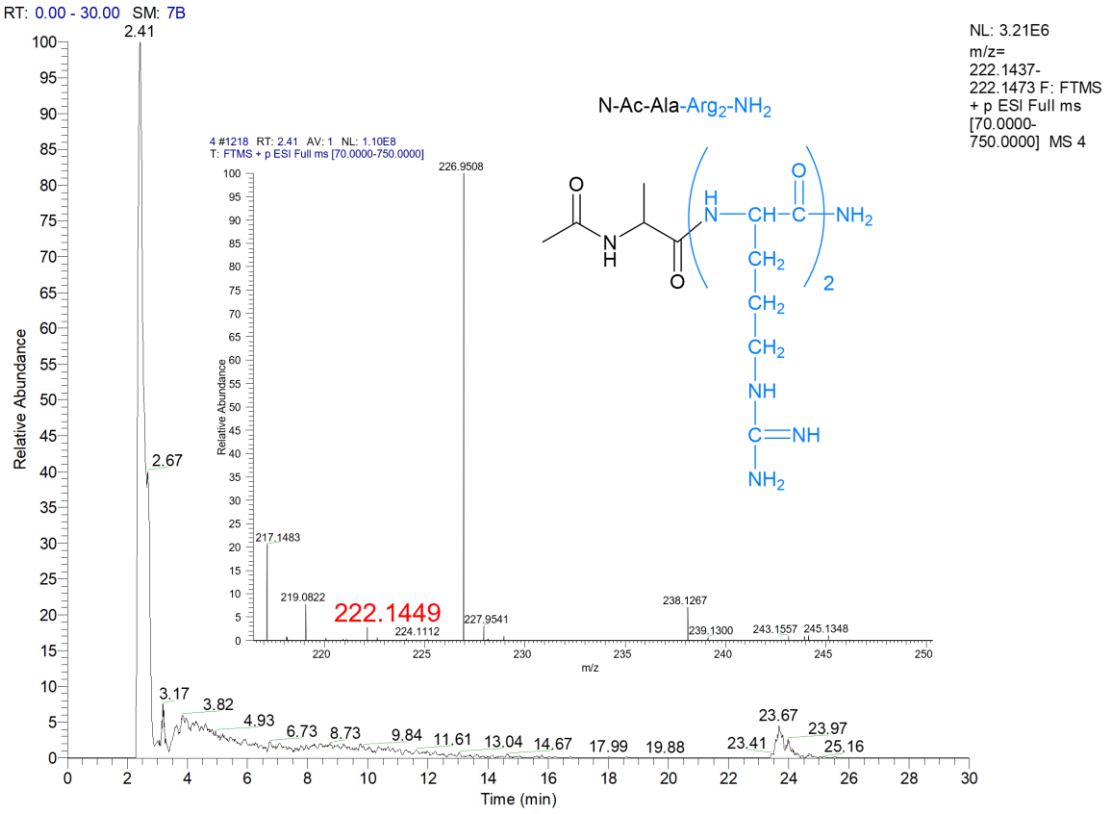

Fig. S32 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 222.1449 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Arg_2-NH_2 with a retention time of 2.41 min.

2.8 Oligomer produced by the polymerization of 0.1M Ac-Ala-NH_2 and 0.1M Lys-NH_2. （Figs. S33-S36）

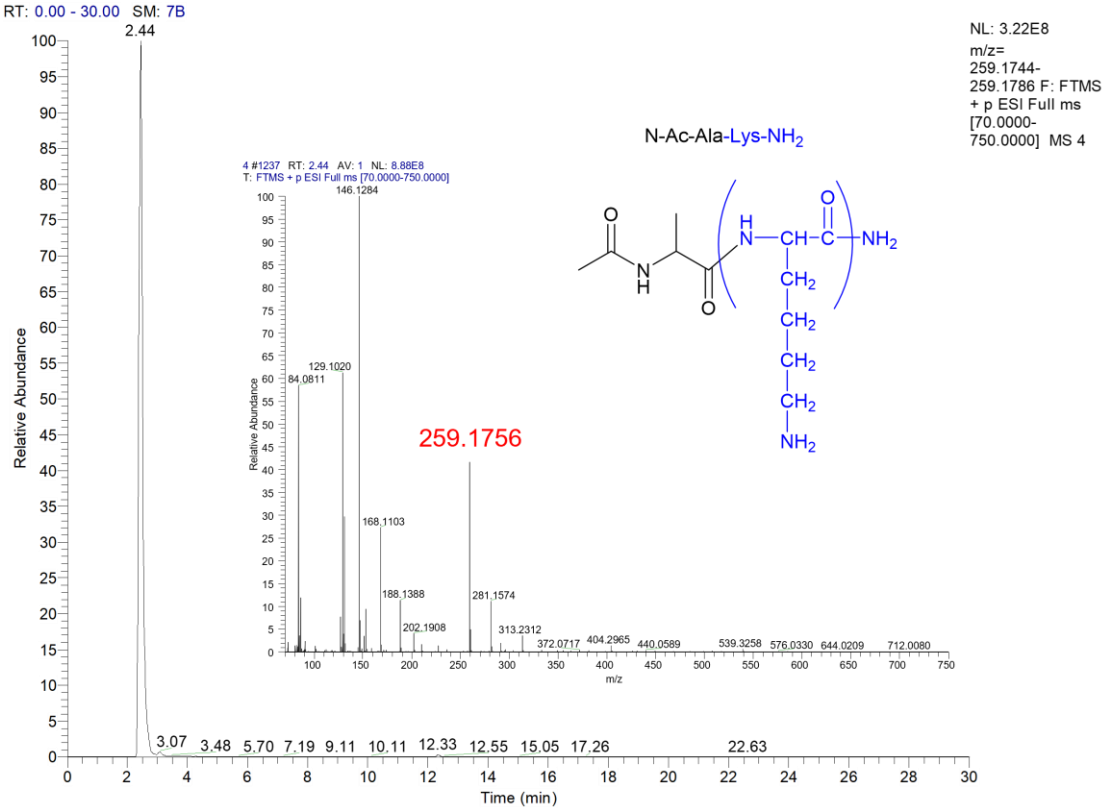

Fig. S33 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 259.1756 was analyzed, and its EIC corresponds to the dimer N-Ac-Ala-Lys-NH_2 with a retention time of 2.44 min.

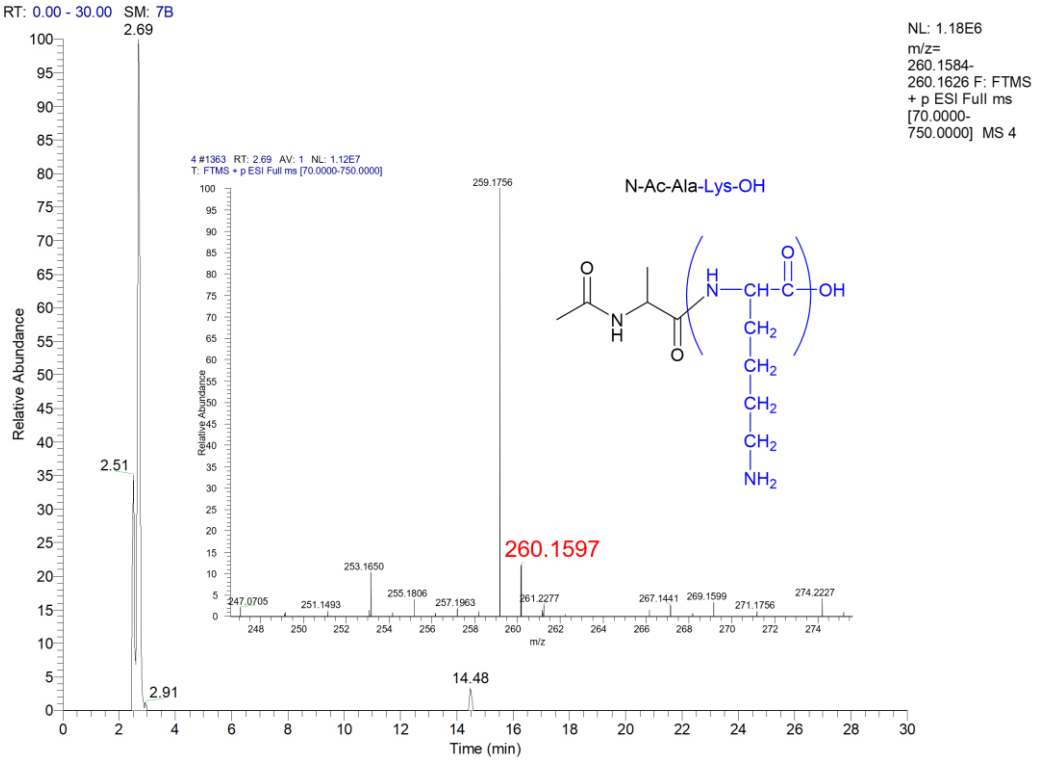

Fig. S34 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 260.1597 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Lys-OH with a retention time of 2.69 min.

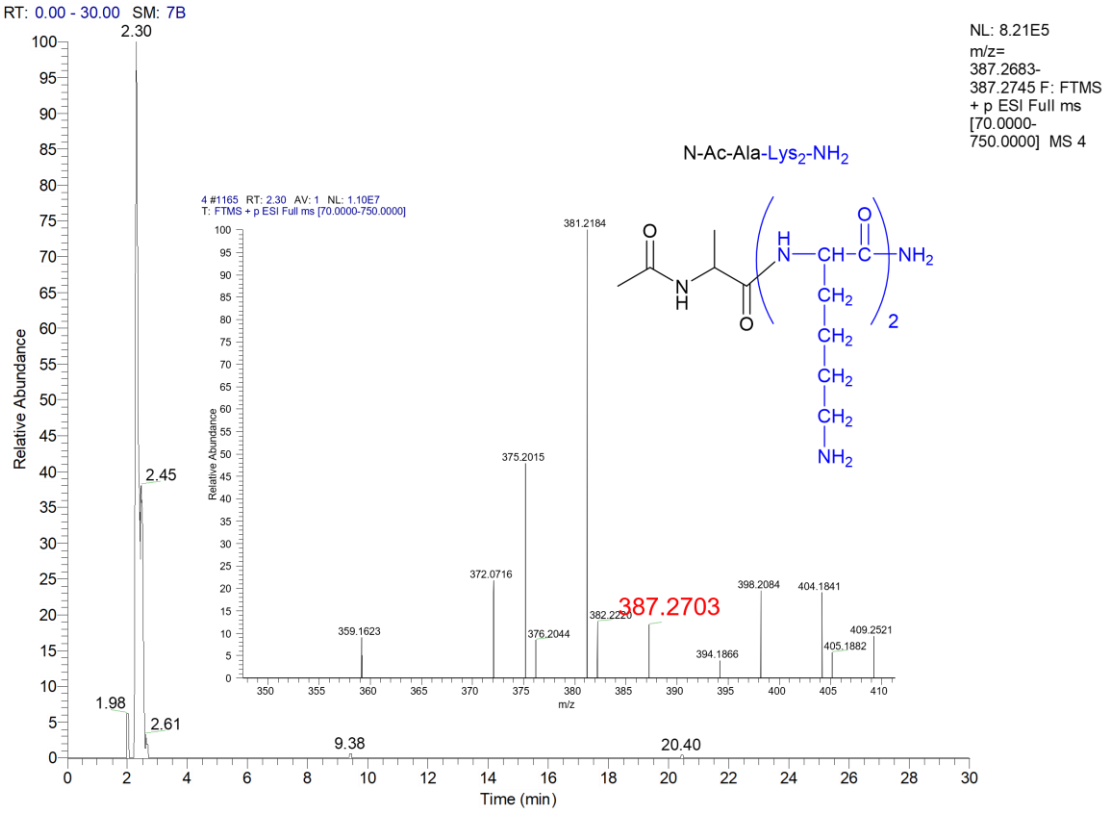

Fig. S35 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 387.2703 has been analyzed and its EIC corresponds to the trimer N-Ac-Ala-Lys_2-NH_2 with a retention time of 2.30 min.

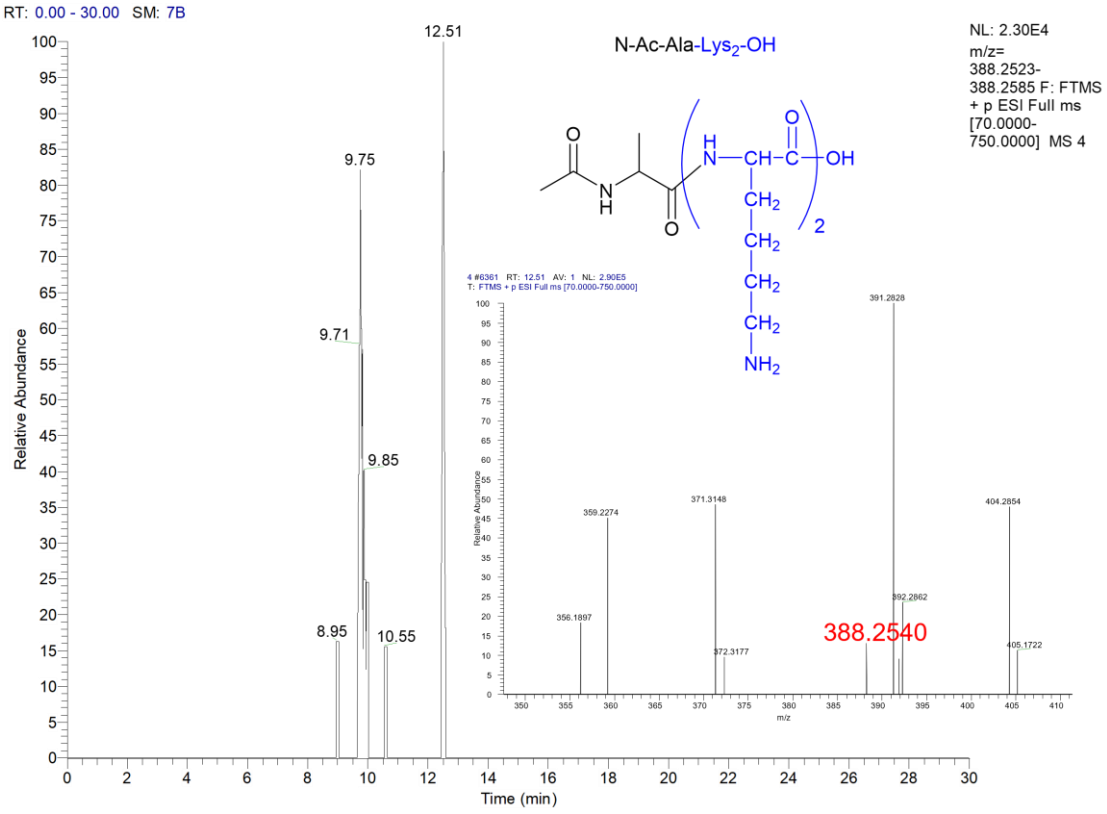

Fig. S36 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 388.2540 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Lys_2-OH with a retention time of 12.51 min.

2.9 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Leu-NH_2.（Figs. S37-S39）

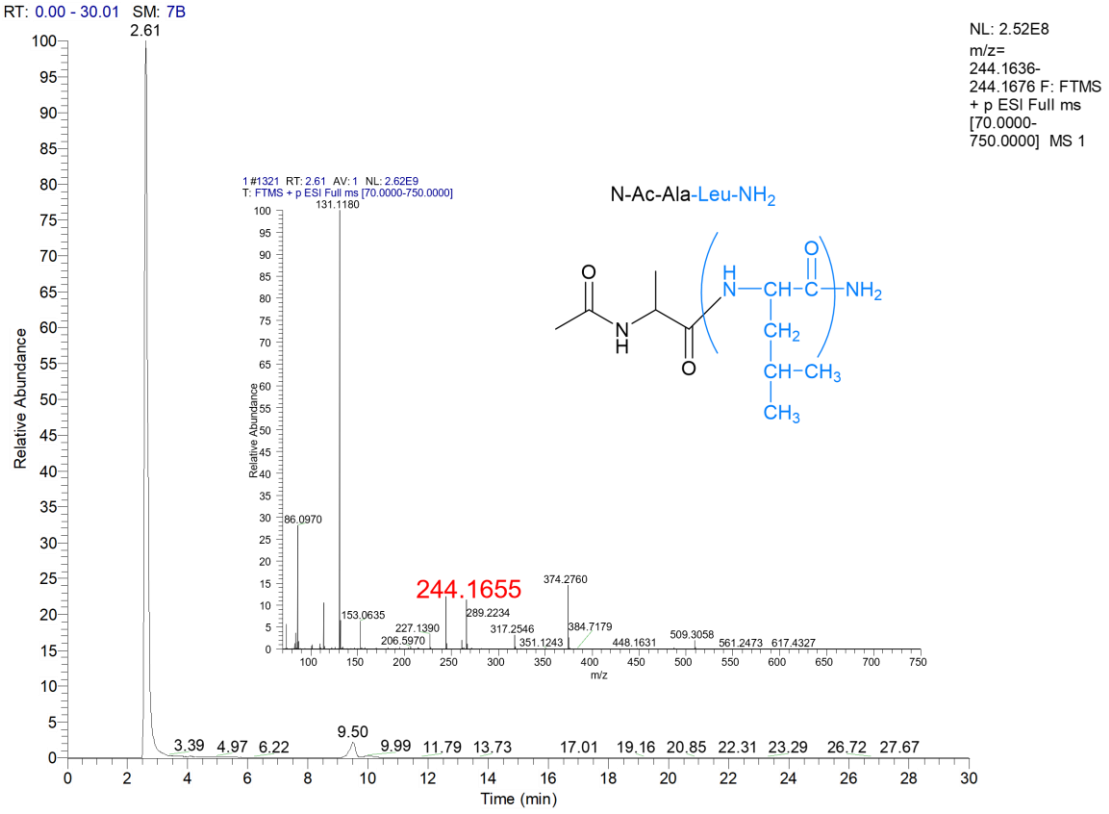

Fig. S37 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 244.1655 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Leu-NH_2 with a retention time of 2.61 min.

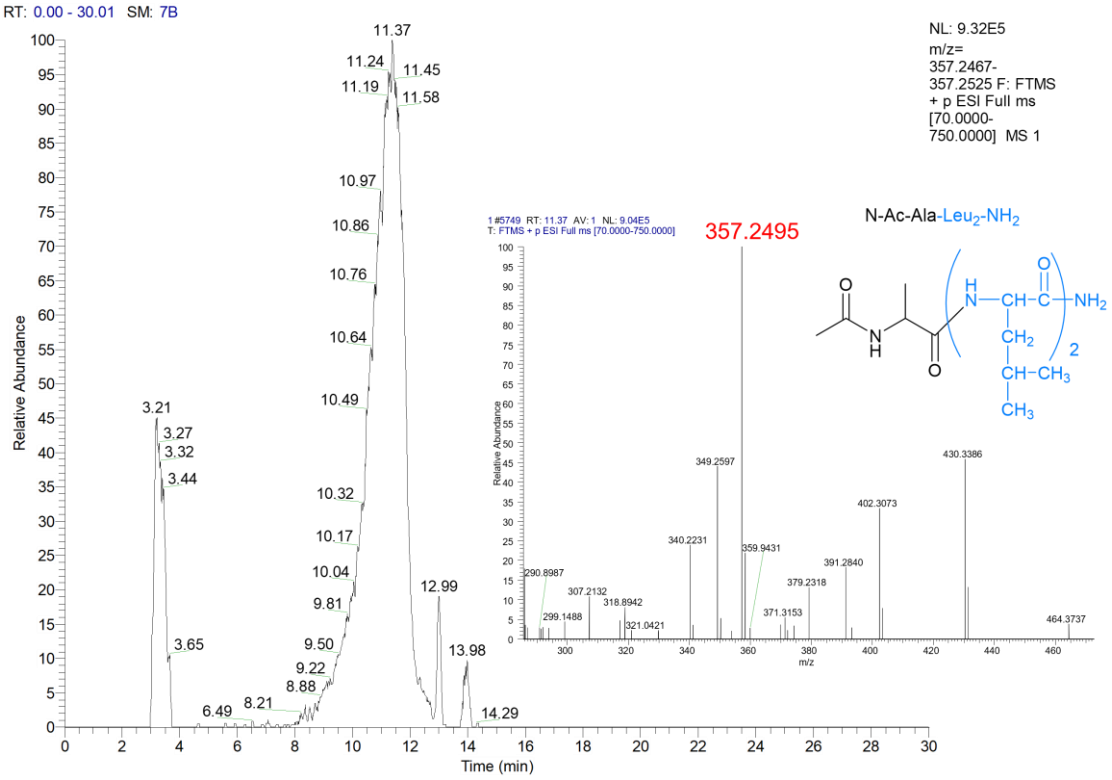

Fig. S38 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 357.2495 was analyzed and its EIC corresponds to the trimer N-Ac-Ala-Leu_2-NH_2 with a retention time of 11.37 min.

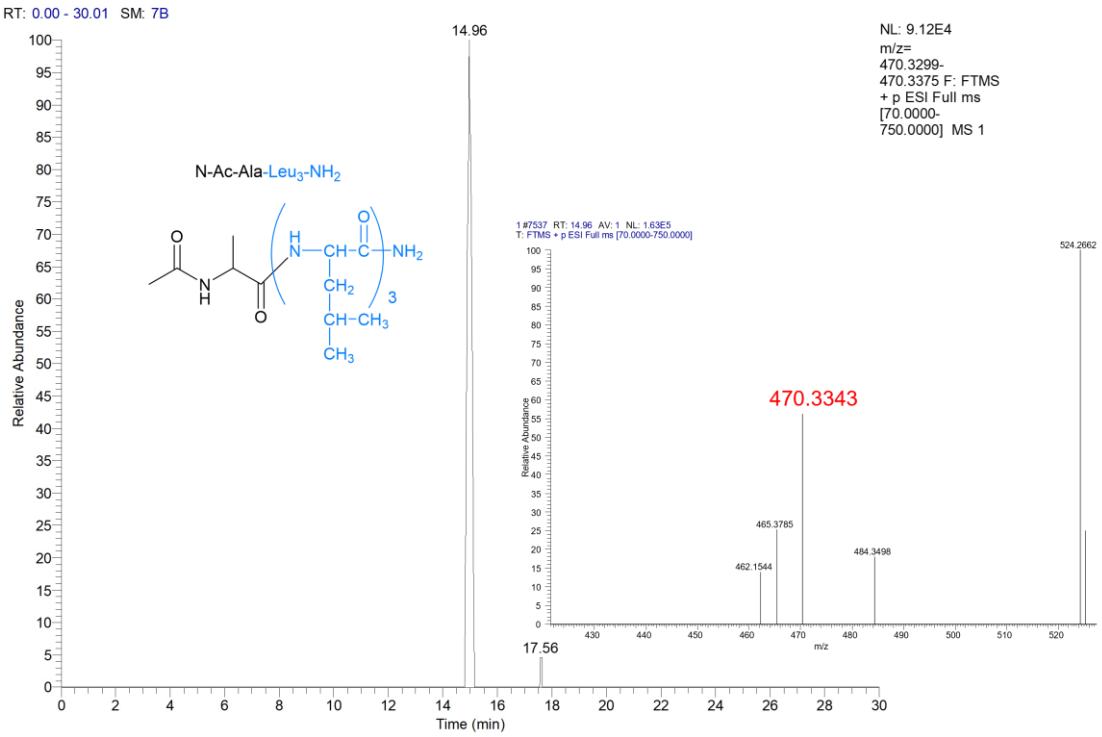

Fig. S39 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 470.3343 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Leu$_3$-NH$_2$ with a retention time of 14.96 min.

2.10 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Pro-NH_2.（Figs. S40-S43）

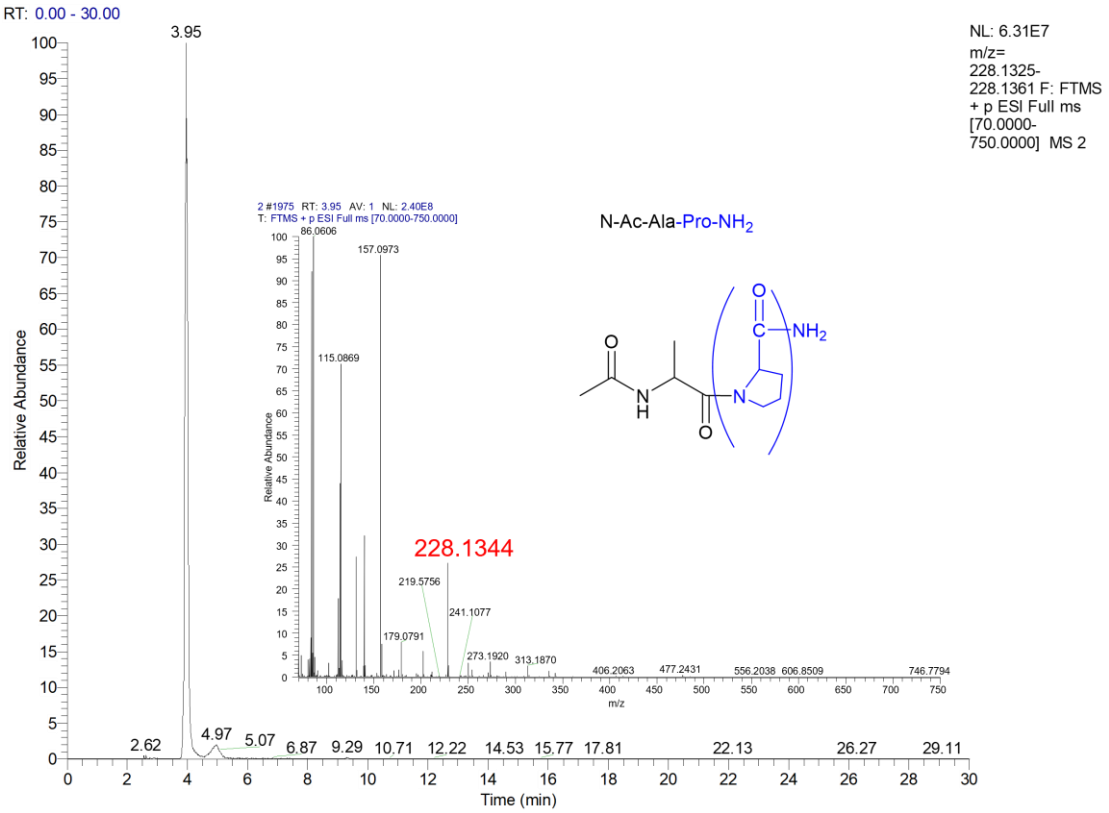

Fig. S40 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 228.1344 was analyzed and its EIC corresponds to the dimer N-Ac-Ala-Pro-NH_2 with a retention time of 3.95 min.

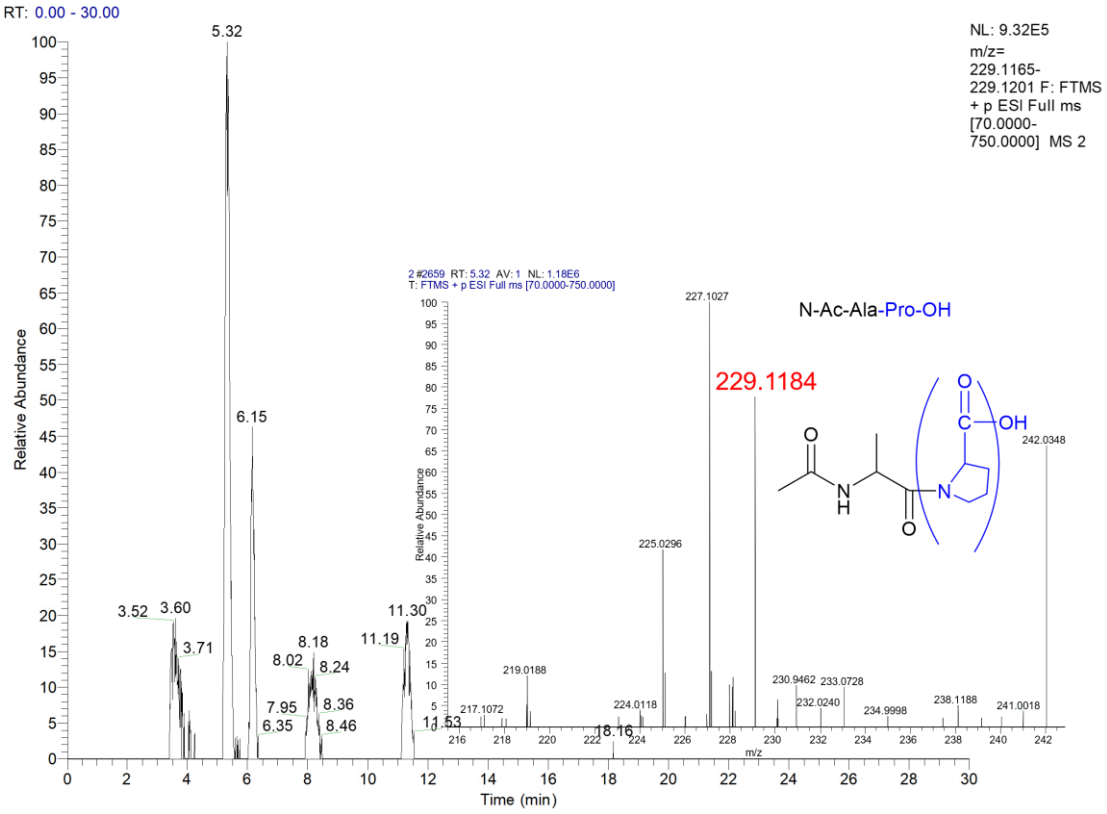

Fig. S41 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 229.1184 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Ala-Pro-OH with a retention time of 5.32 min.

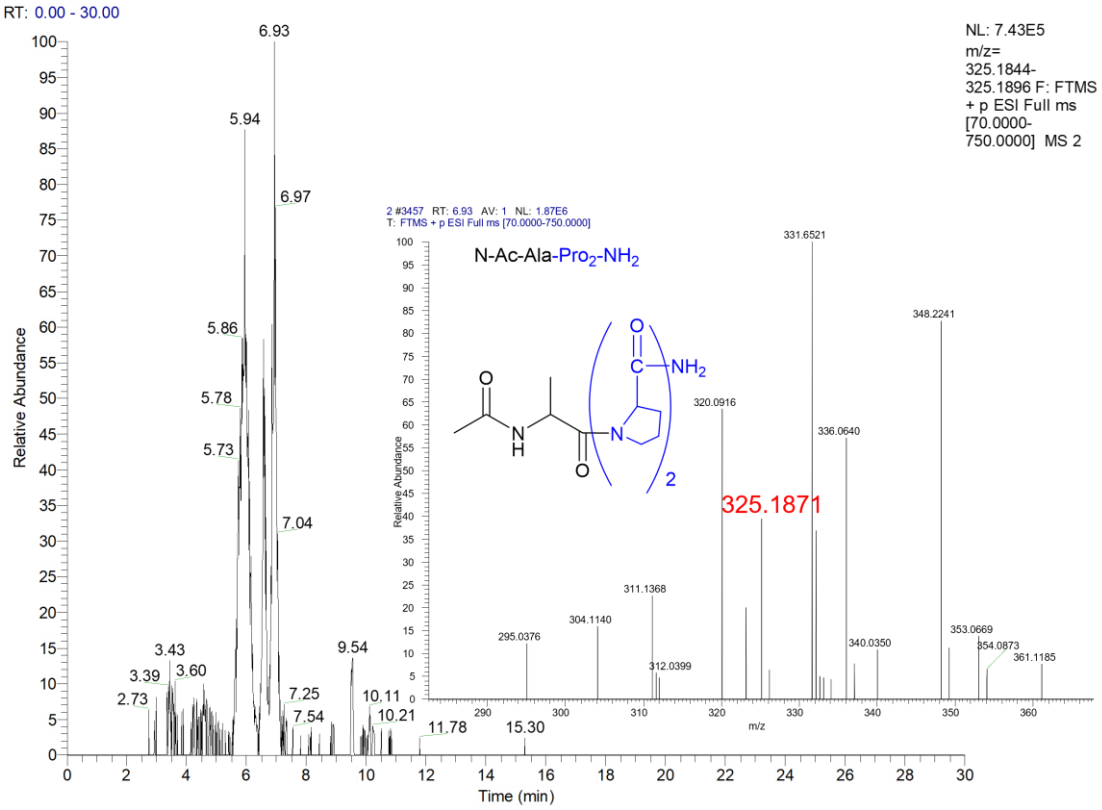

Fig. S42 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 325.1871 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Pro_2-NH_2 with a retention time of 6.93 min.

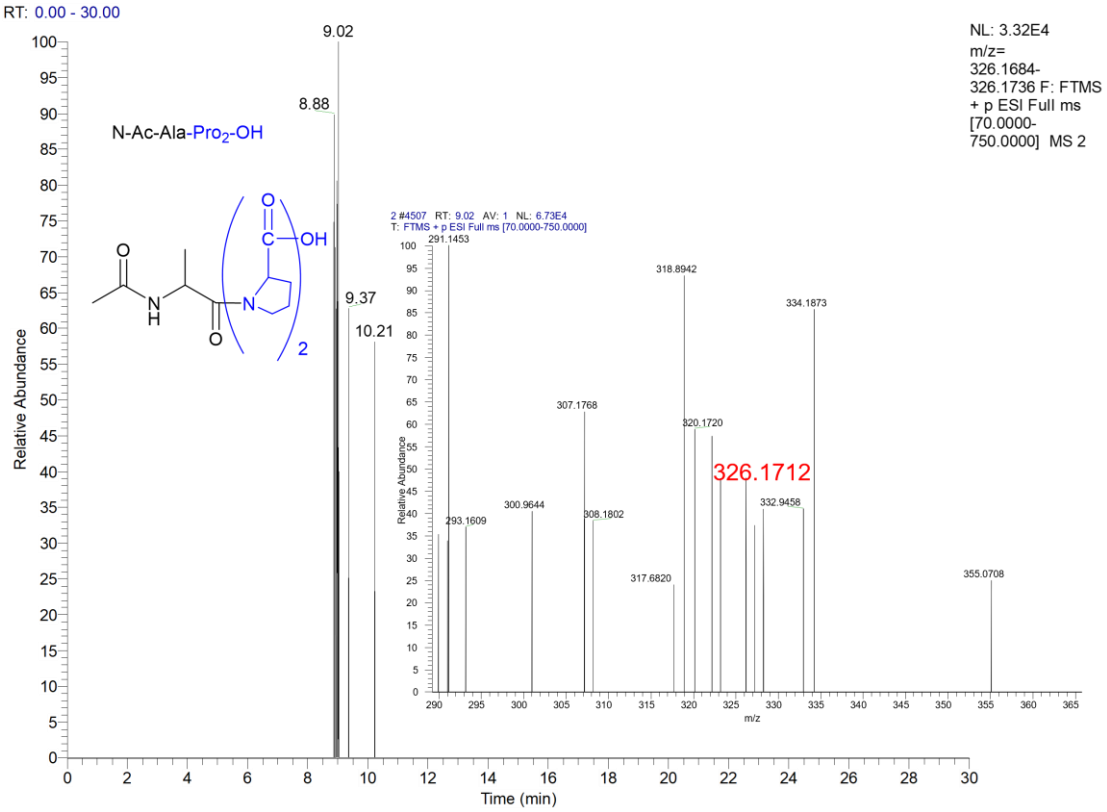

Fig. S43 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z326.1712 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Ala-Pro$_2$-OH with a retention time of 9.02 min.

2.11 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Phe-NH_2.（Figs. S44-S48）

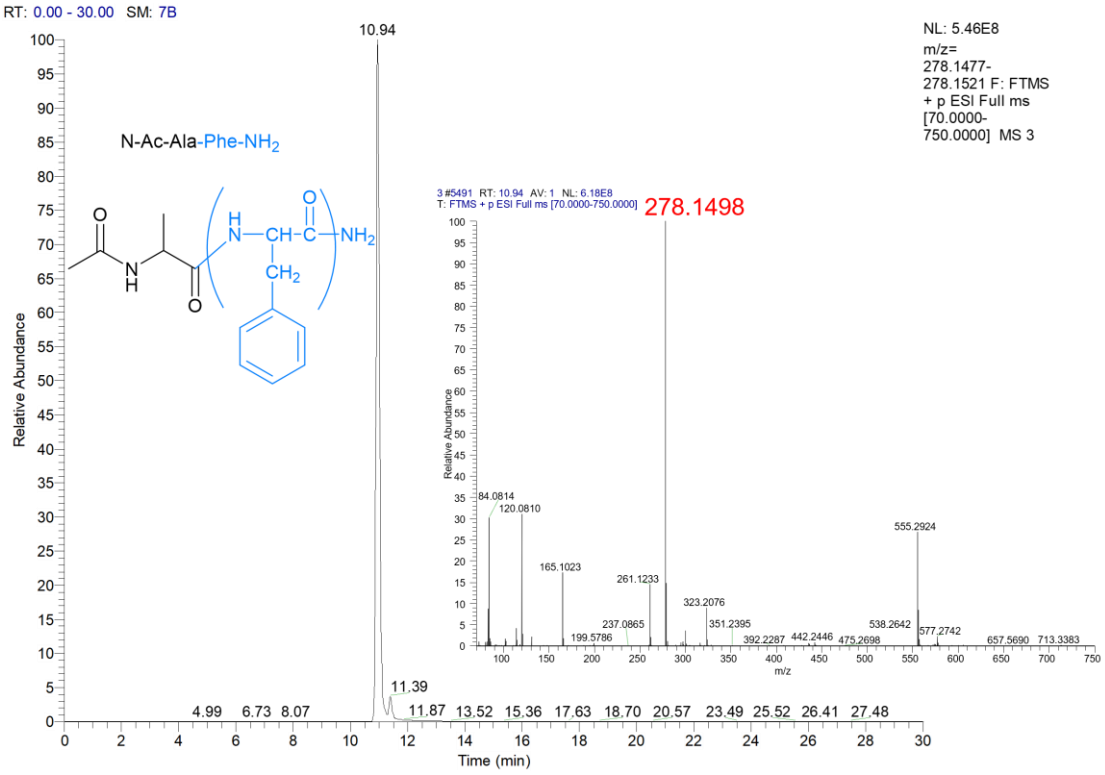

Fig. S44 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 278.1498 was analyzed, and its EIC corresponds to the dimer N-AC-Ala-Phe-NH_2 with a retention time of 10.94 min.

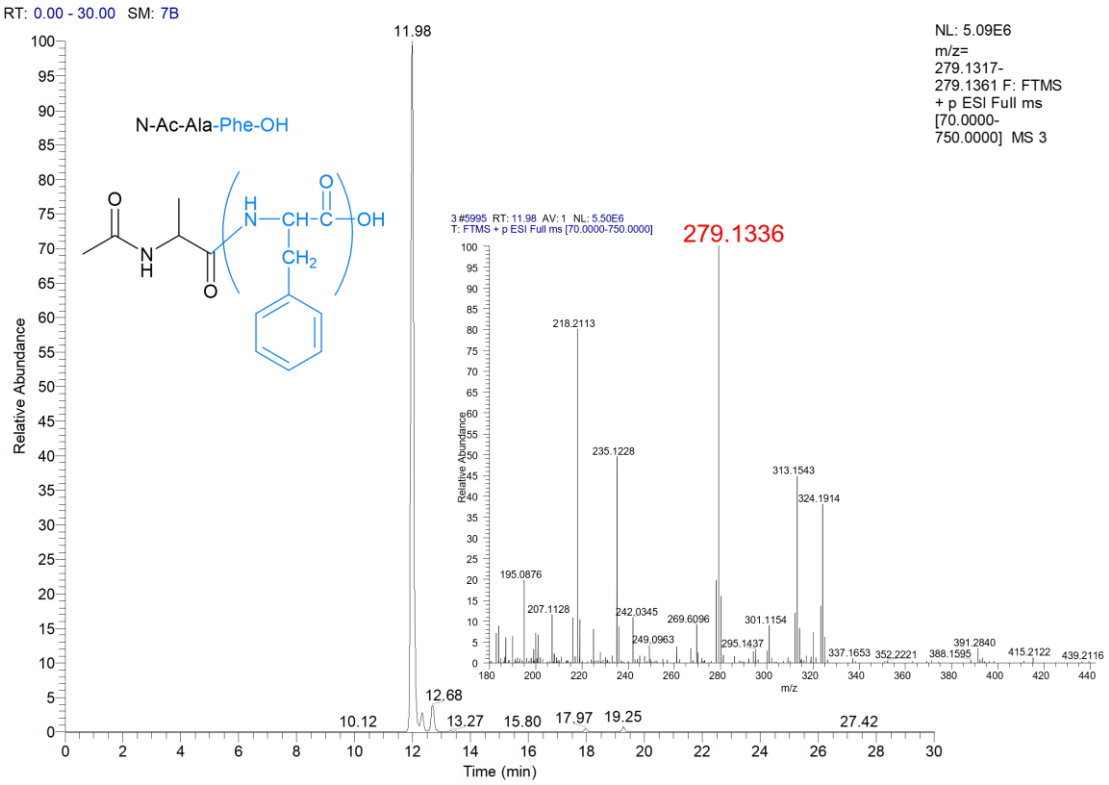

Fig. S45 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 279.1336 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Phe-OH with a retention time of 11.98 min.

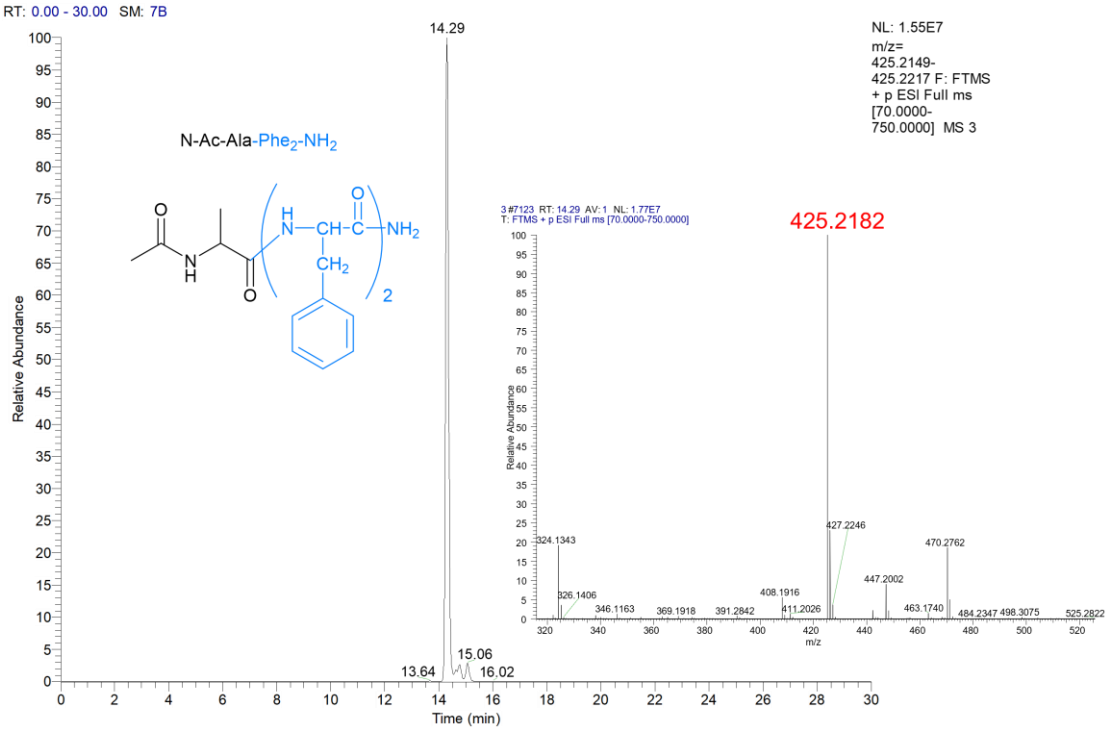

Fig. S46 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 425.2182 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Phe_2-NH_2 with a retention time of 14.29 min.

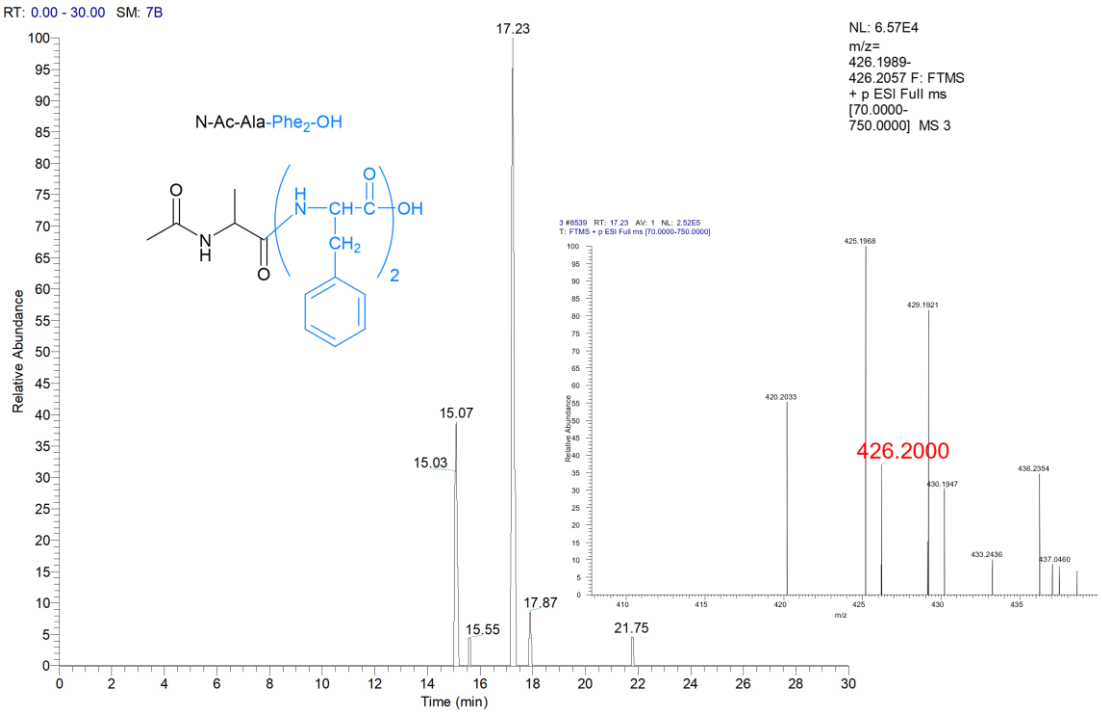

Fig. S47 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 426.2000 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Phe$_2$-OH with a retention time of 17.23 min.

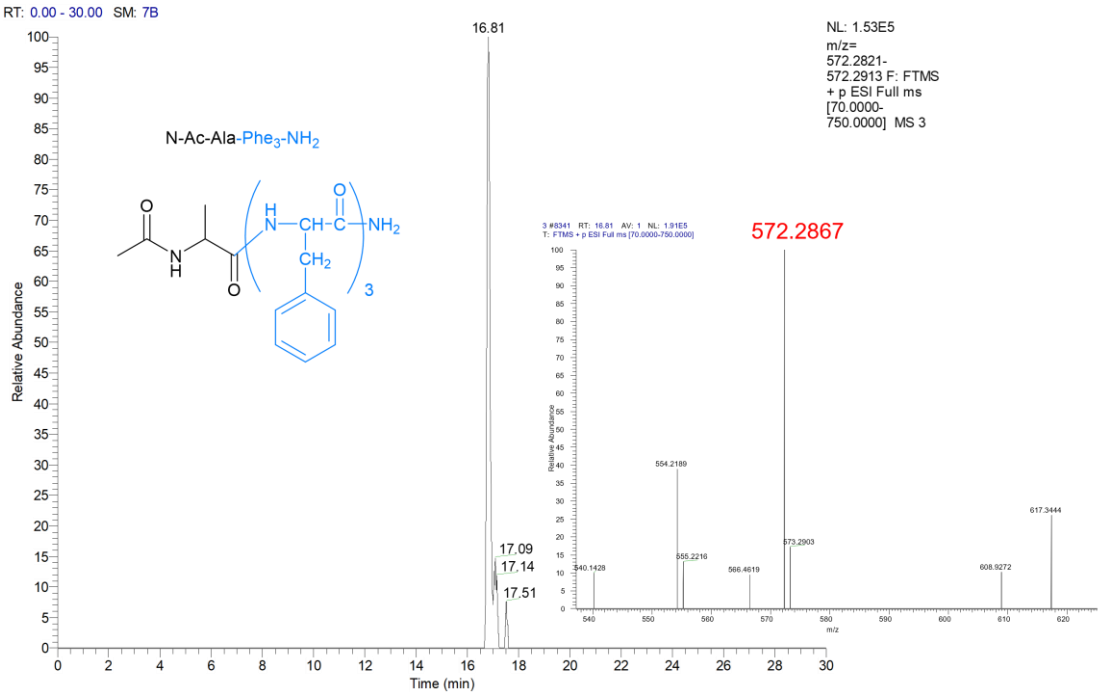

Fig. S48 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z572.2867 was analyzed, and its EIC corresponded to the tetramer N-Ac-Ala-Phe$_3$-NH$_2$ with a retention time of 16.81 min.

2.12 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Ile-NH_2.（Figs. S49-S51）

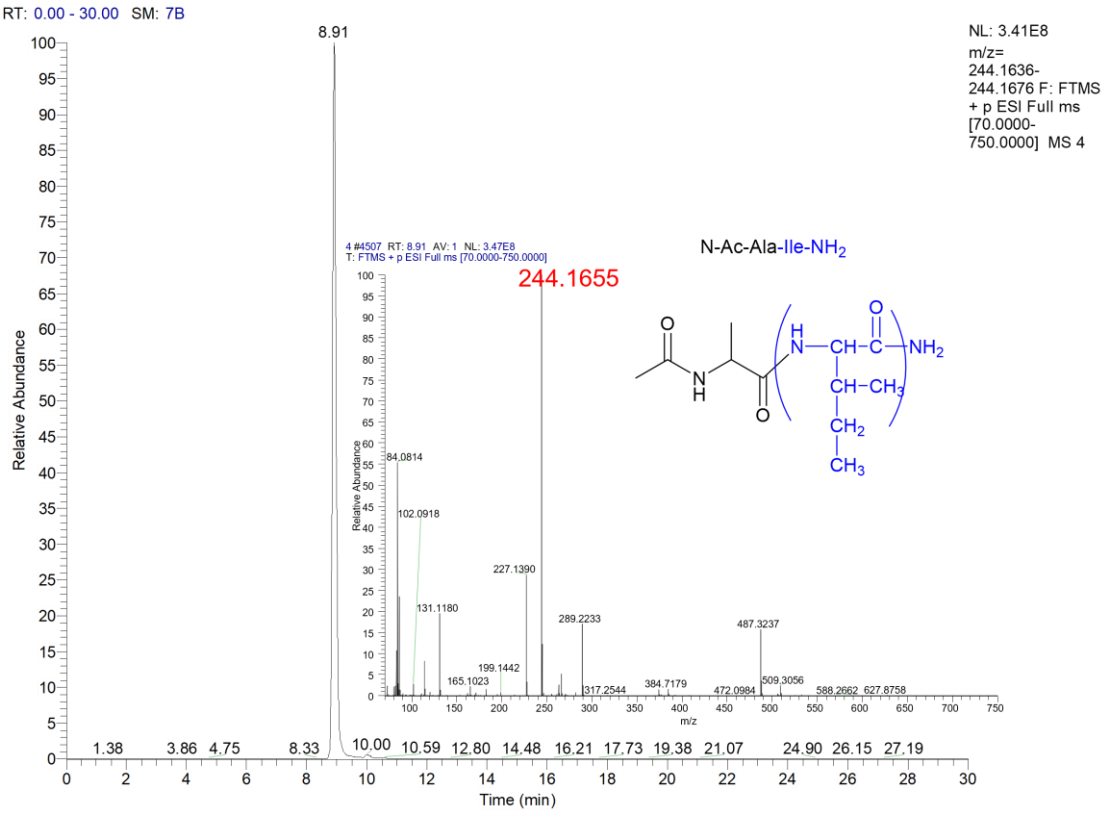

Fig. S49 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 244.1655 was analyzed, and its EIC corresponded to the dimer N-Ac-Ala-Ile-NH_2 with a retention time of 8.91 min.

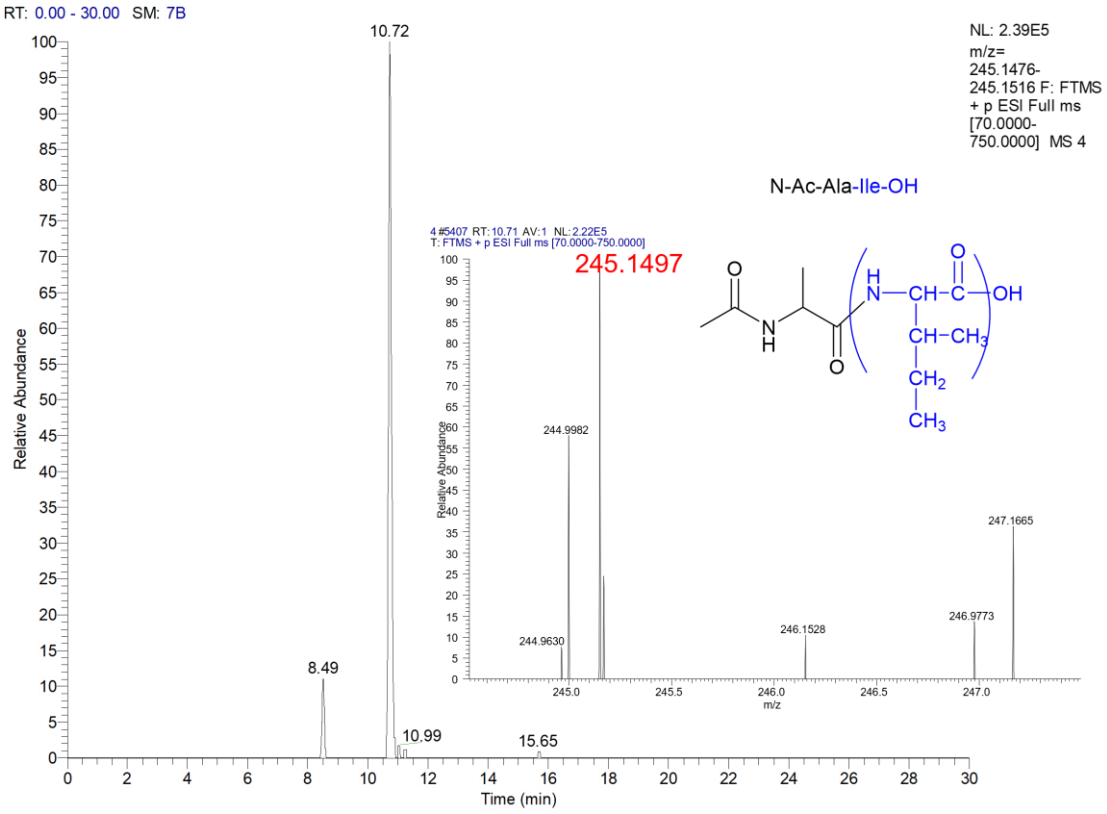

Fig. S50 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 245.1497 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Ala-Ile-OH with a retention time of 10.72 min.

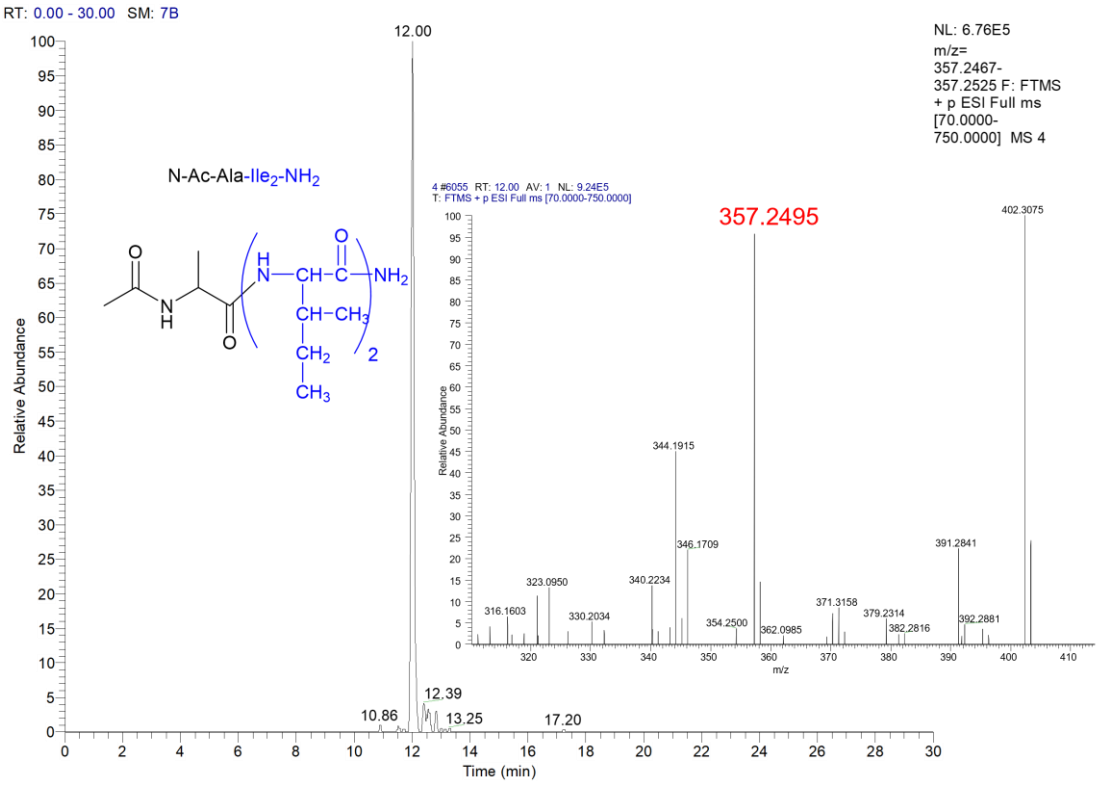

Fig. S51 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 357.2495 was analyzed and its EIC corresponds to the trimer N-Ac-Ala-Ile_2-NH_2 with a retention time of 12.00 min.

2.13 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Met-NH_2.（Figs. S52-S58）

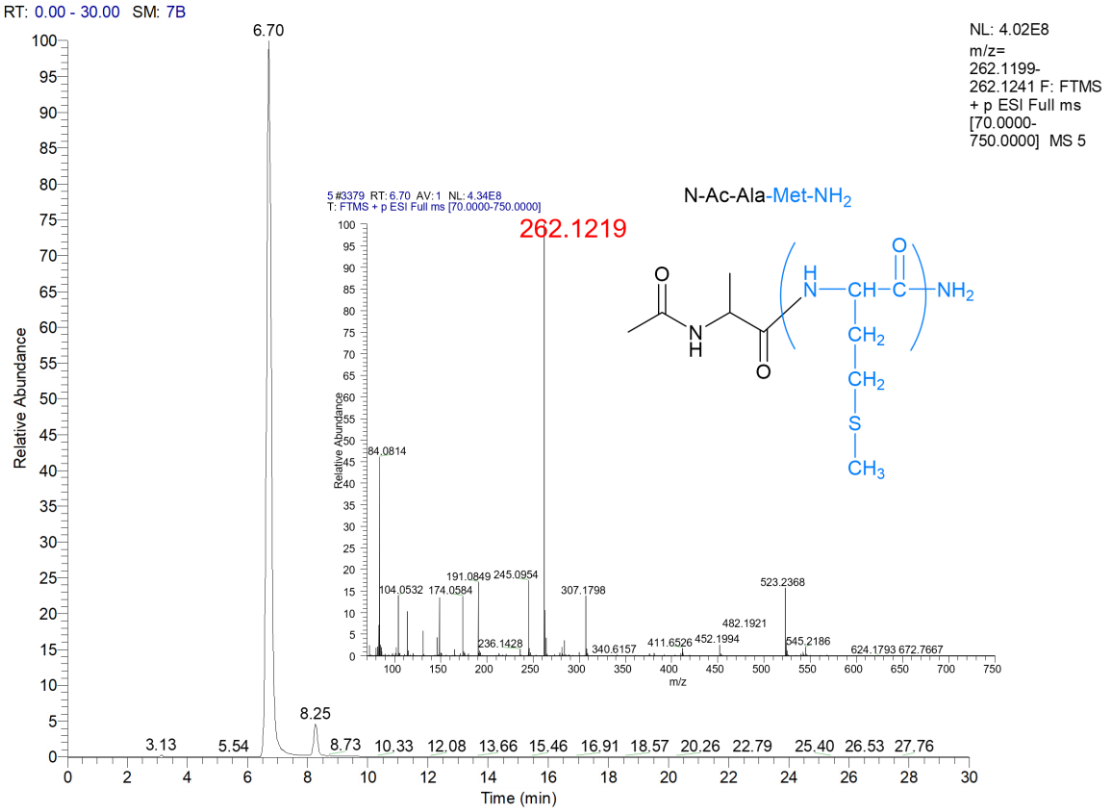

Fig. S52 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z262.1219 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Met-NH_2 with a retention time of 6.70 min.

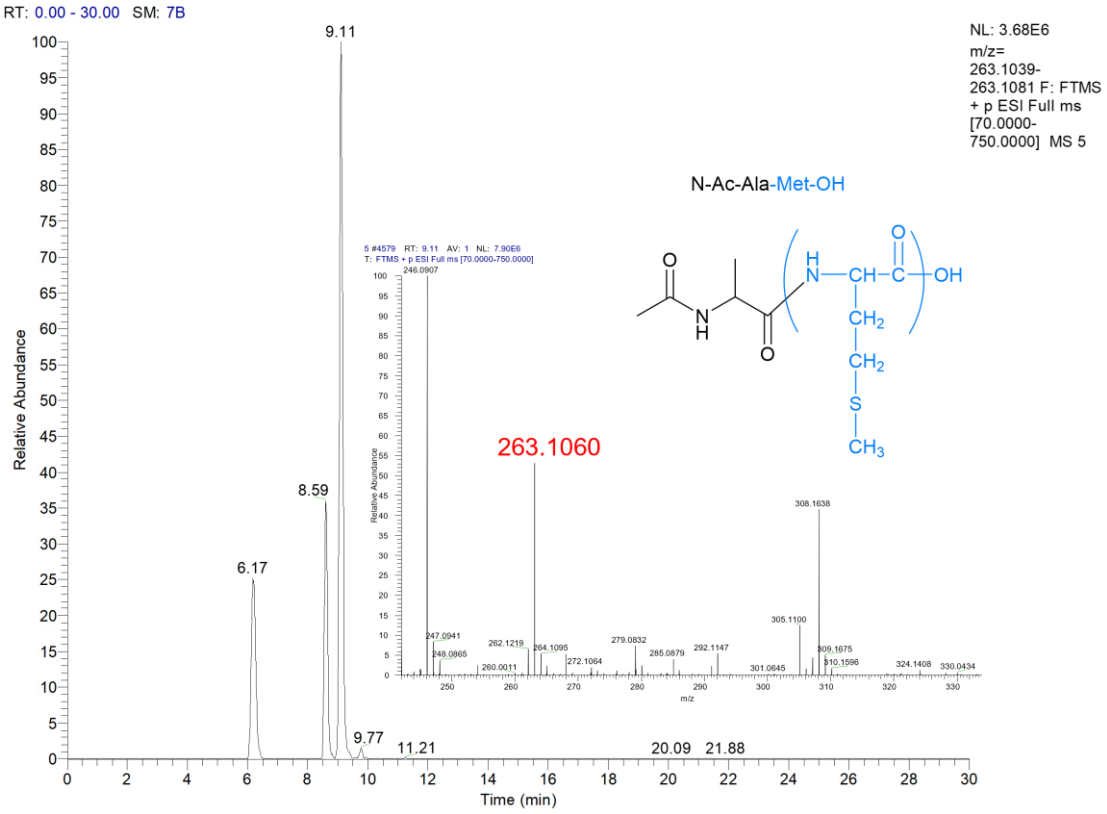

Fig. S53 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 263.1060 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Met-OH with a retention time of 9.11 min.

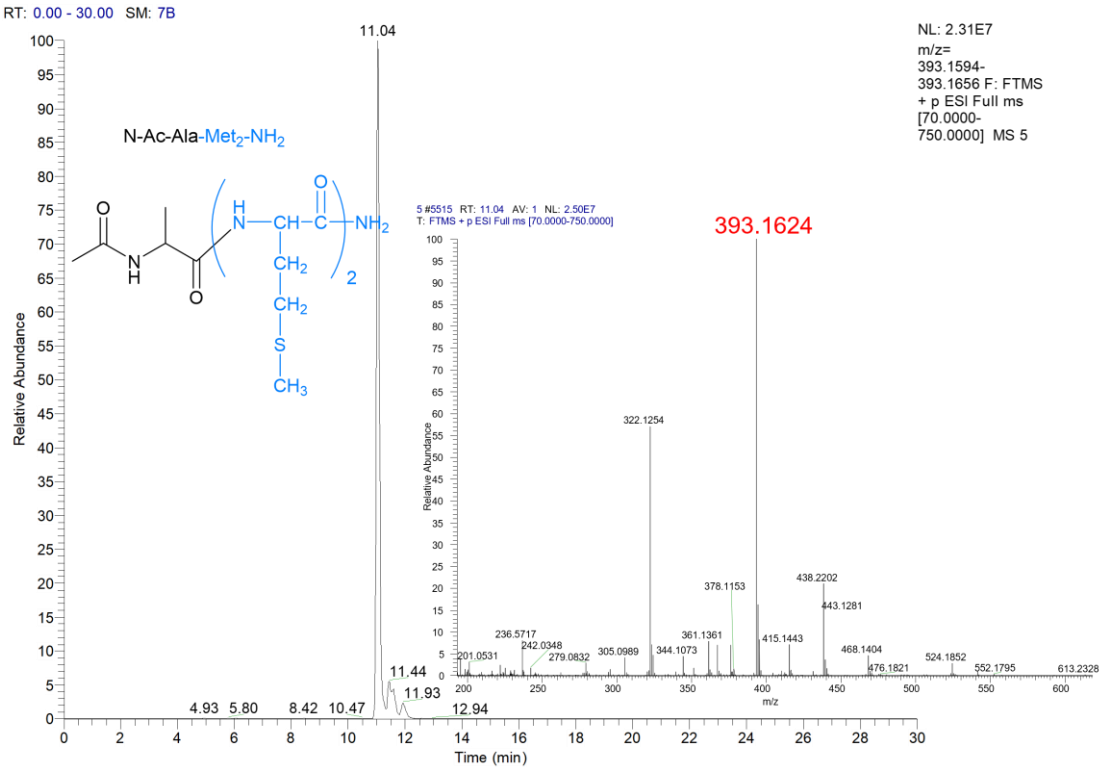

Fig. S54 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 393.1624 was analyzed, and its EIC corresponds to the trimer N-Ac-Ala-Met_2-NH_2 with a retention time of 11.04 min.

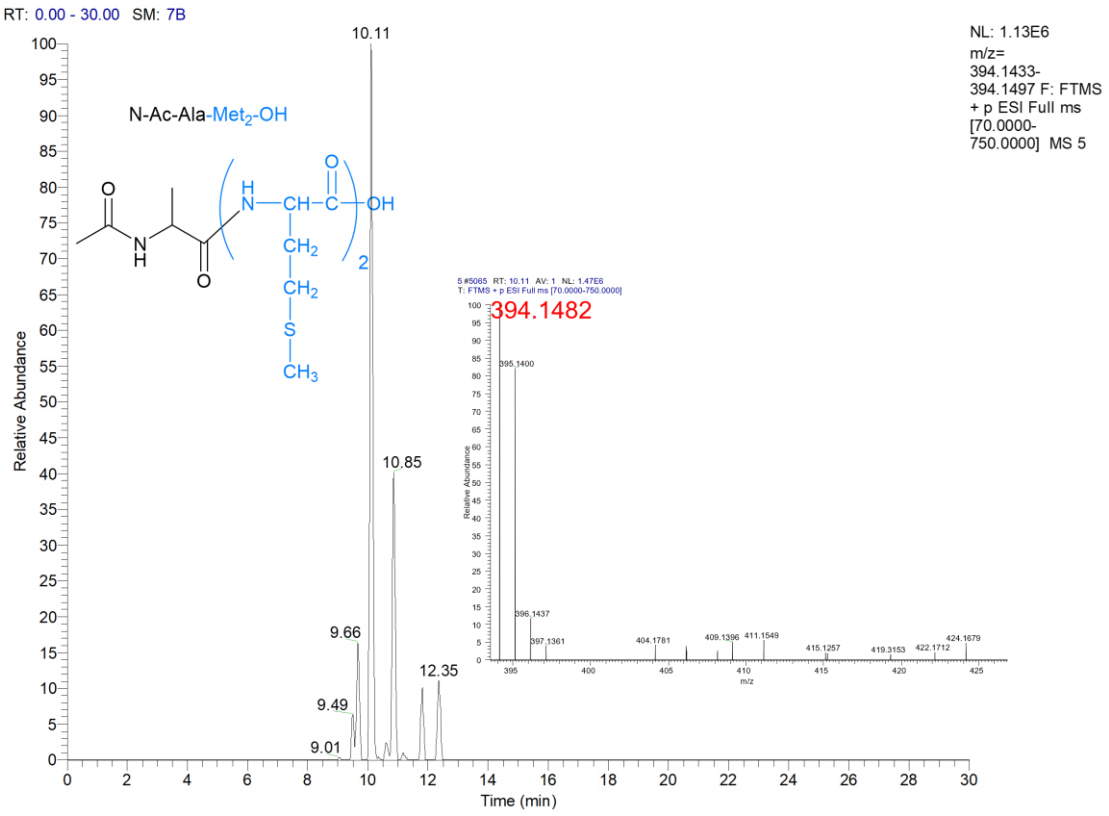

Fig. S55 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 394.1482 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Met_2-OH with a retention time of 10.11 min.

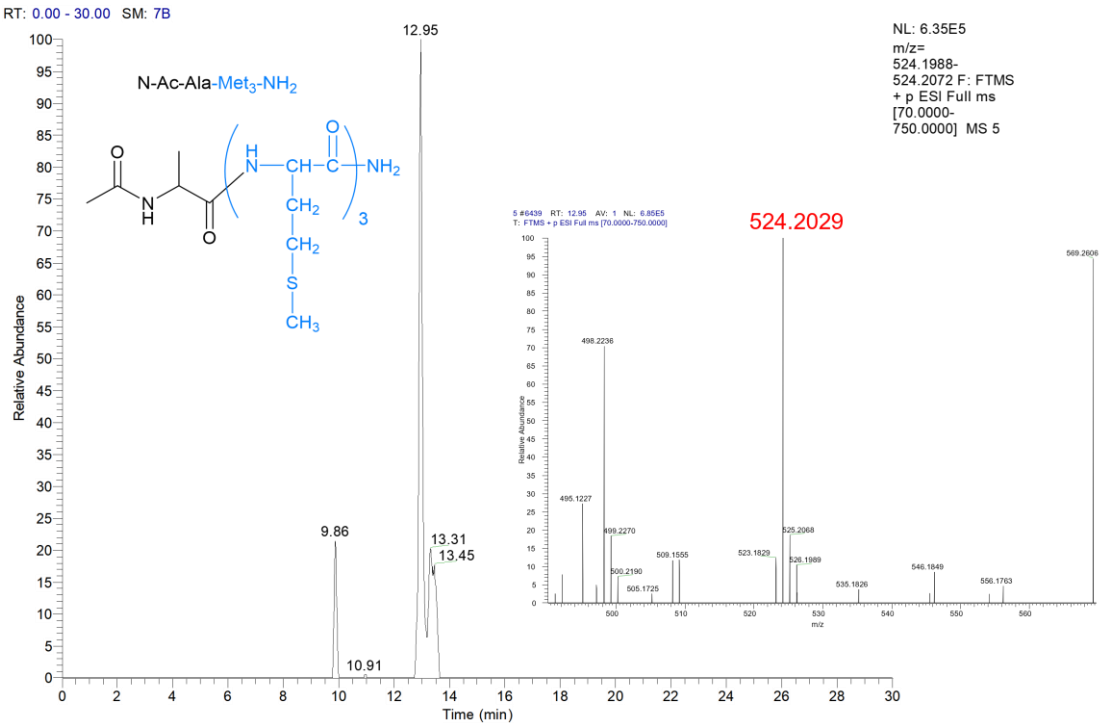

Fig. S56 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 524.2029 was analyzed, and its EIC corresponds to the tetramer N-Ac-Ala-Met_3-NH_2 with a retention time of 12.95 min.

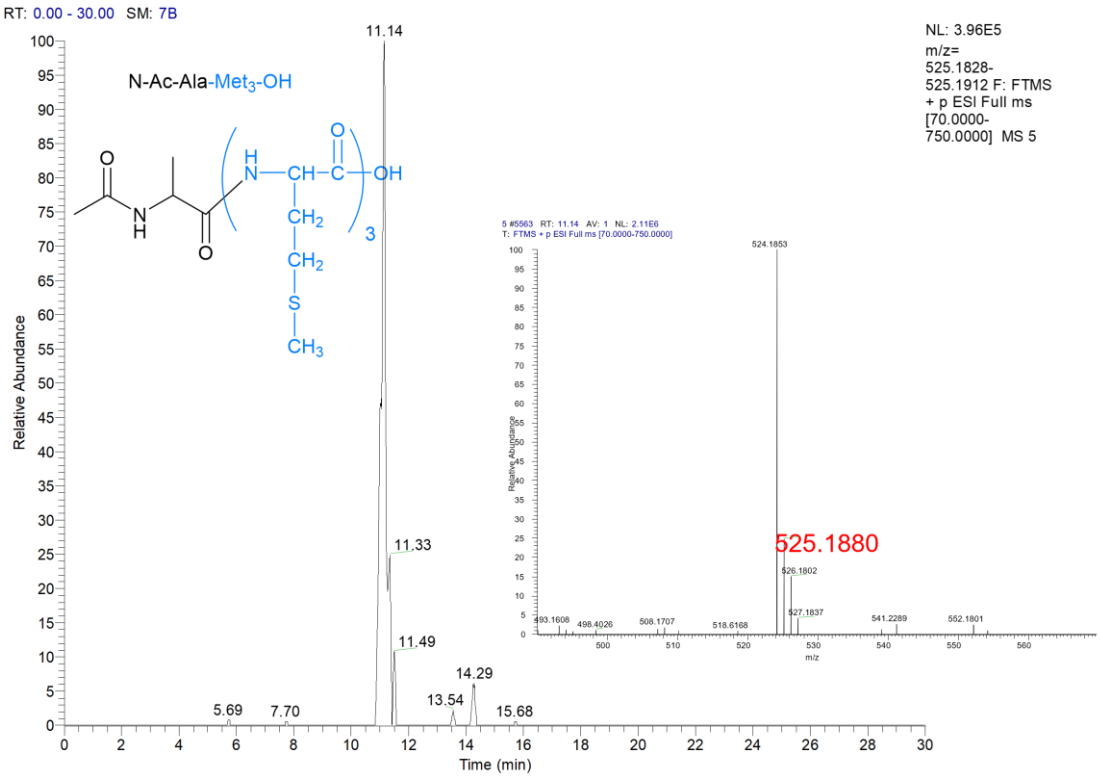

Fig. S57 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 525.1880 was analyzed and its EIC corresponded to the tetrapeptide N-Ac-Ala-Met$_3$-OH with a retention time of 11.14 min.

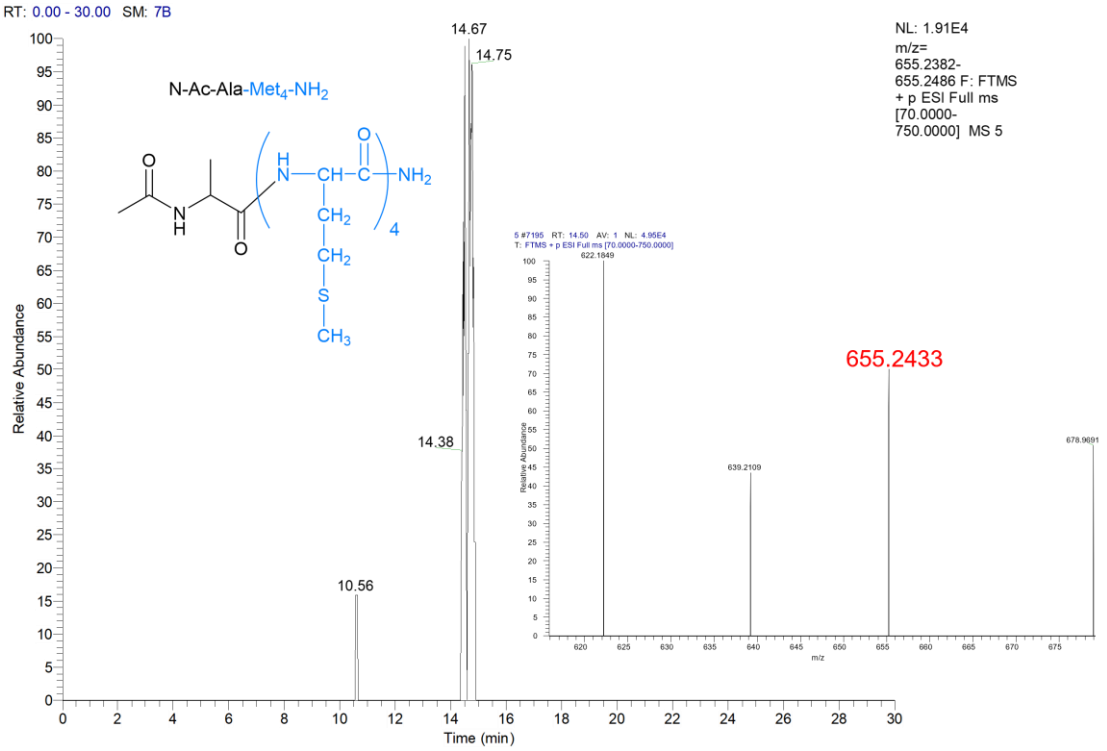

Fig. S58 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 655.2433 was analyzed, and its EIC corresponds to the pentamer N-Ac-Ala-Met_4-NH_2 with a retention time of 14.50 min.

2.14 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Thr-NH_2.（Figs. S59-S63）

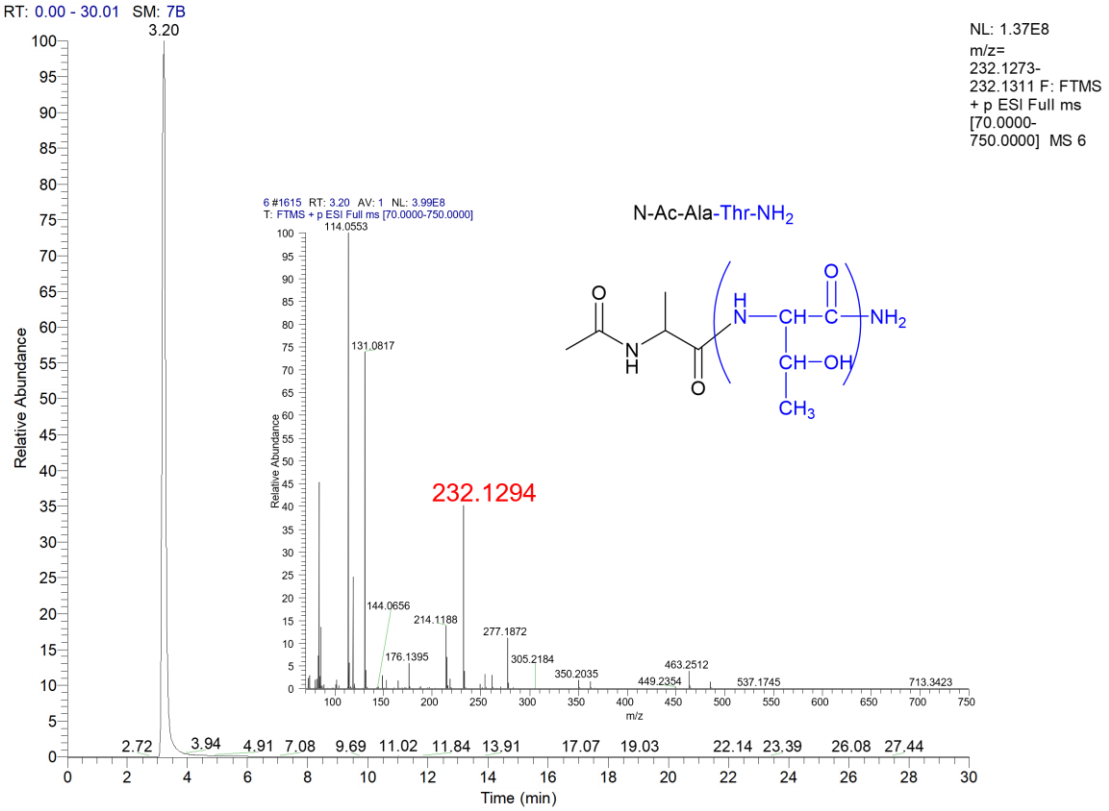

Fig. S59 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 232.1294 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Thr-NH_2 with a retention time of 3.20 min.

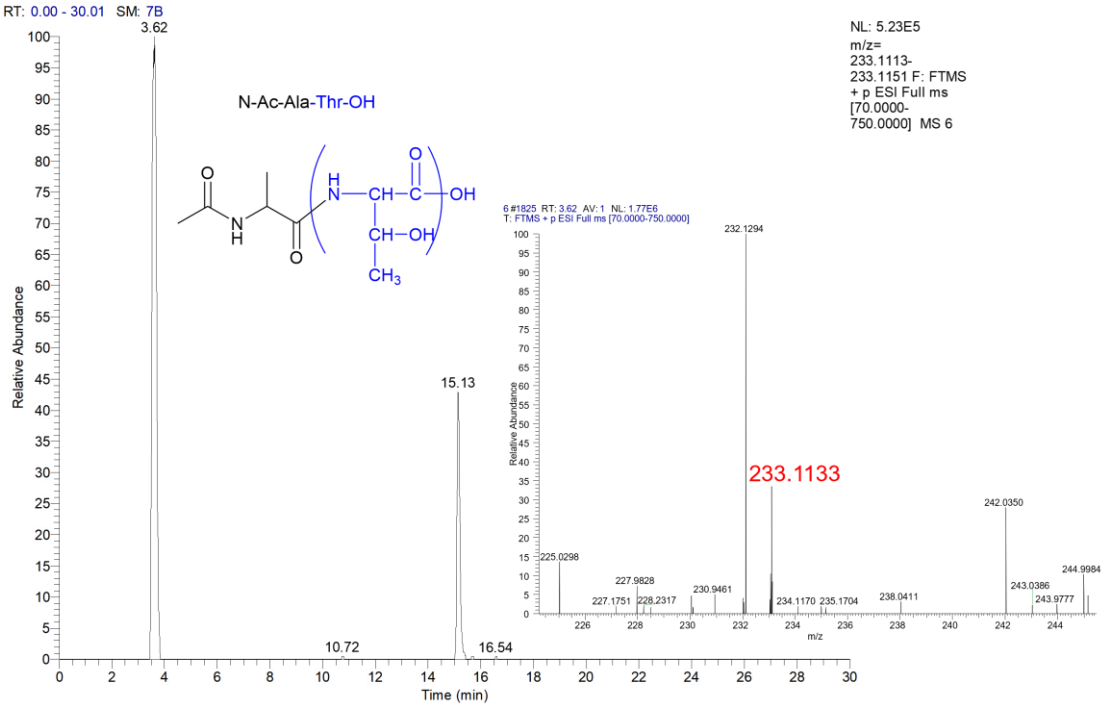

Fig. S60 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 233.1133 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Thr-OH with a retention time of 3.62 min.

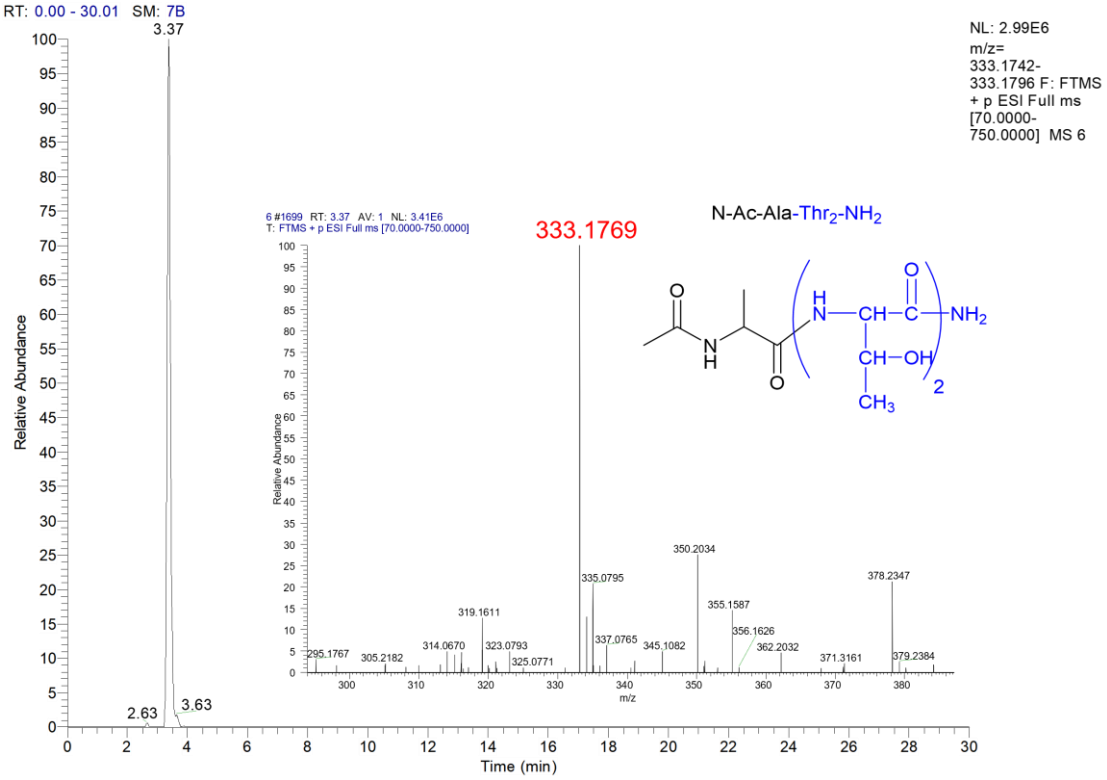

Fig. S61 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 333.1769 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Thr_2-NH_2 with a retention time of 3.37 min.

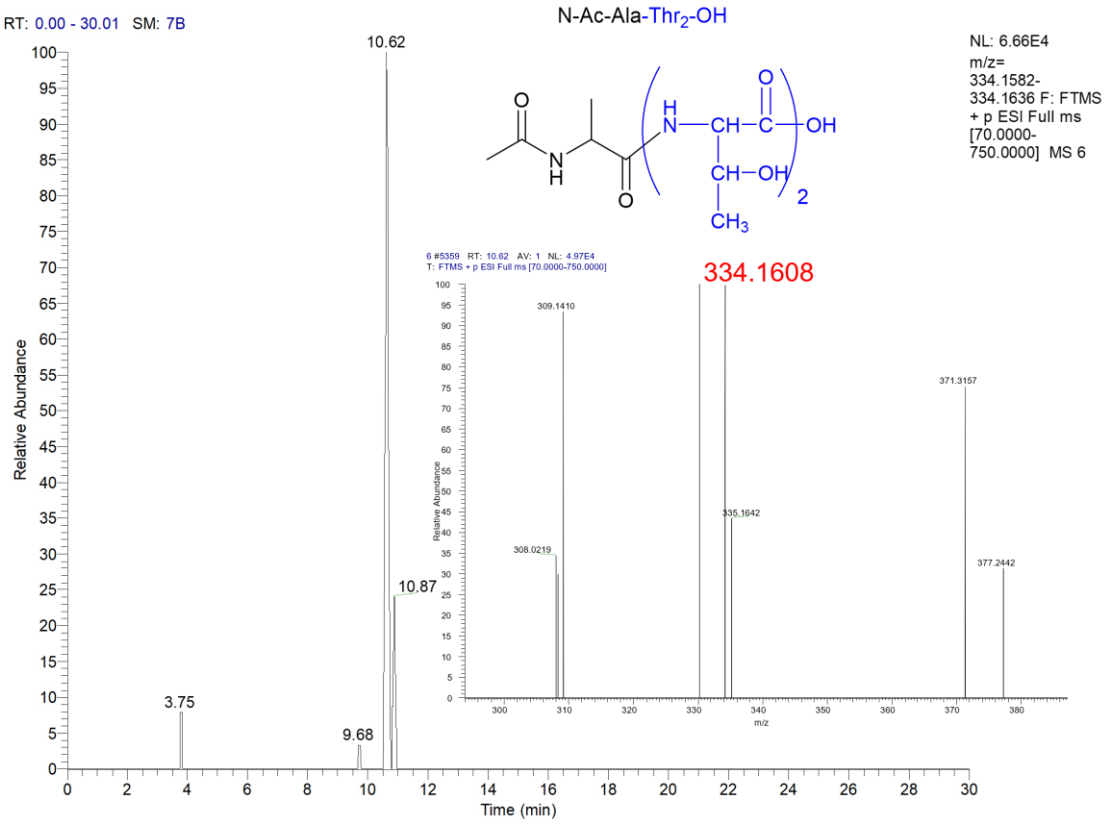

Fig. S62 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 334.1608 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Thr$_2$-OH with a retention time of 10.62 min.

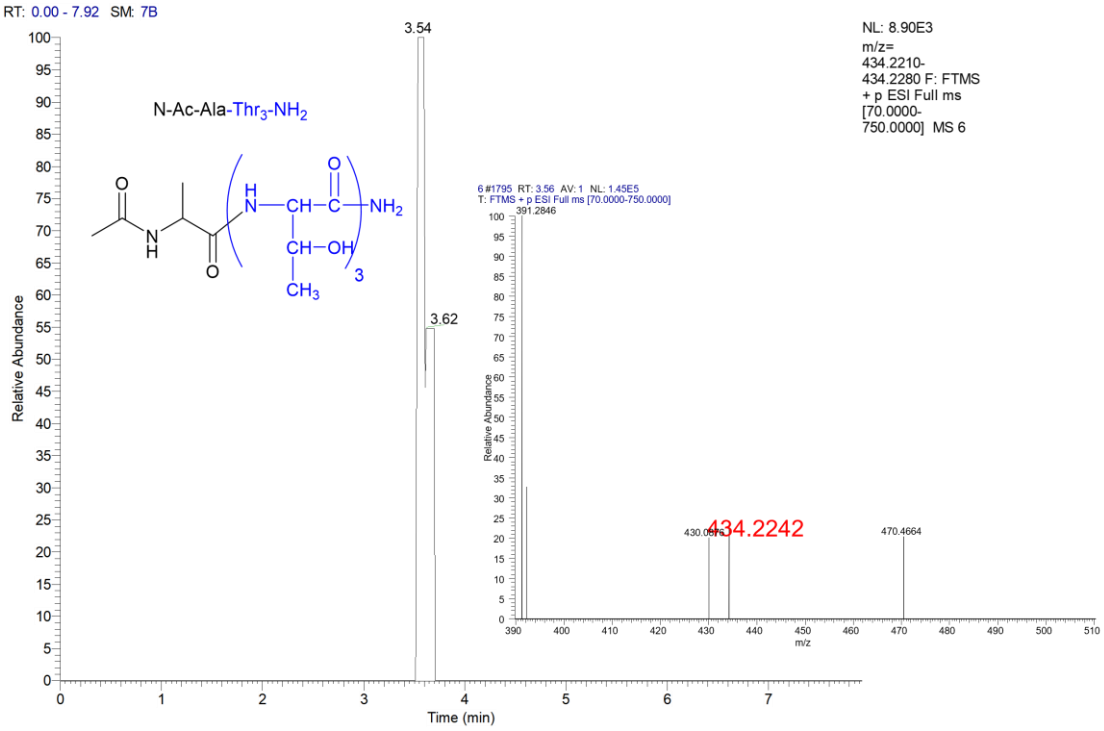

Fig. S63 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 434.2242 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Thr$_3$-NH$_2$ with a retention time of 3.55 min.

2.15 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Thr-NH_2.（Figs. S64-S68）

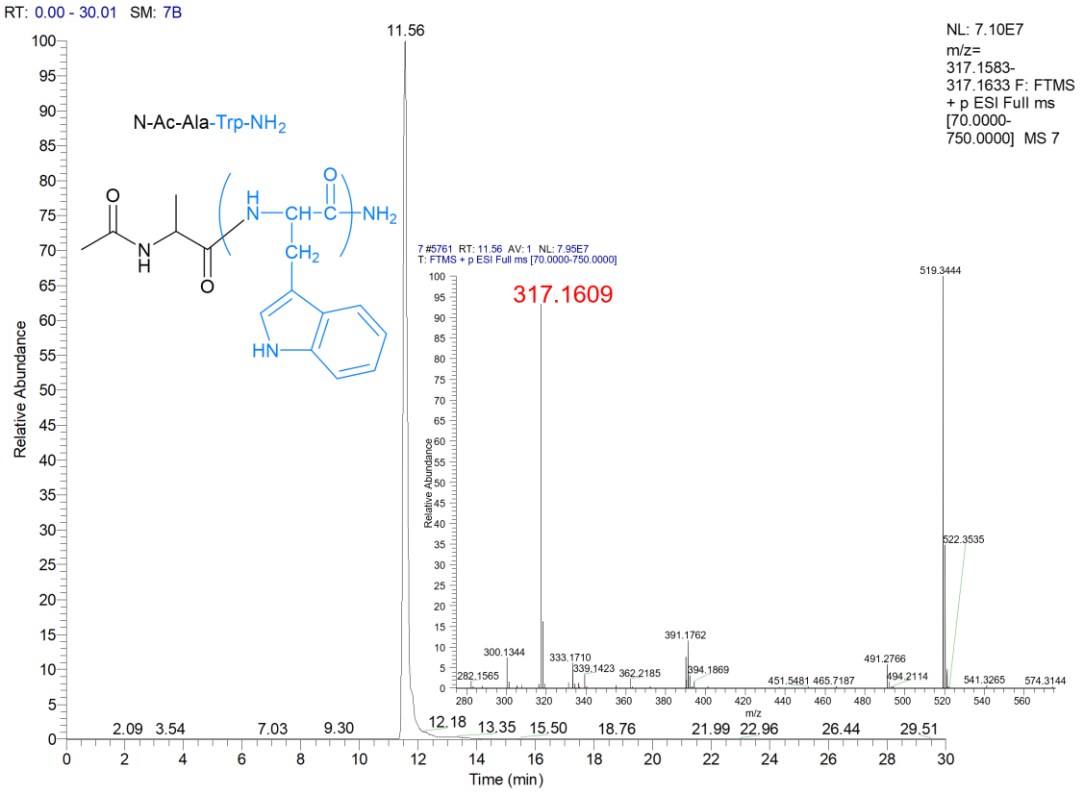

Fig. S64 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 317.1609 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Trp-NH_2 with a retention time of 11.56 min.

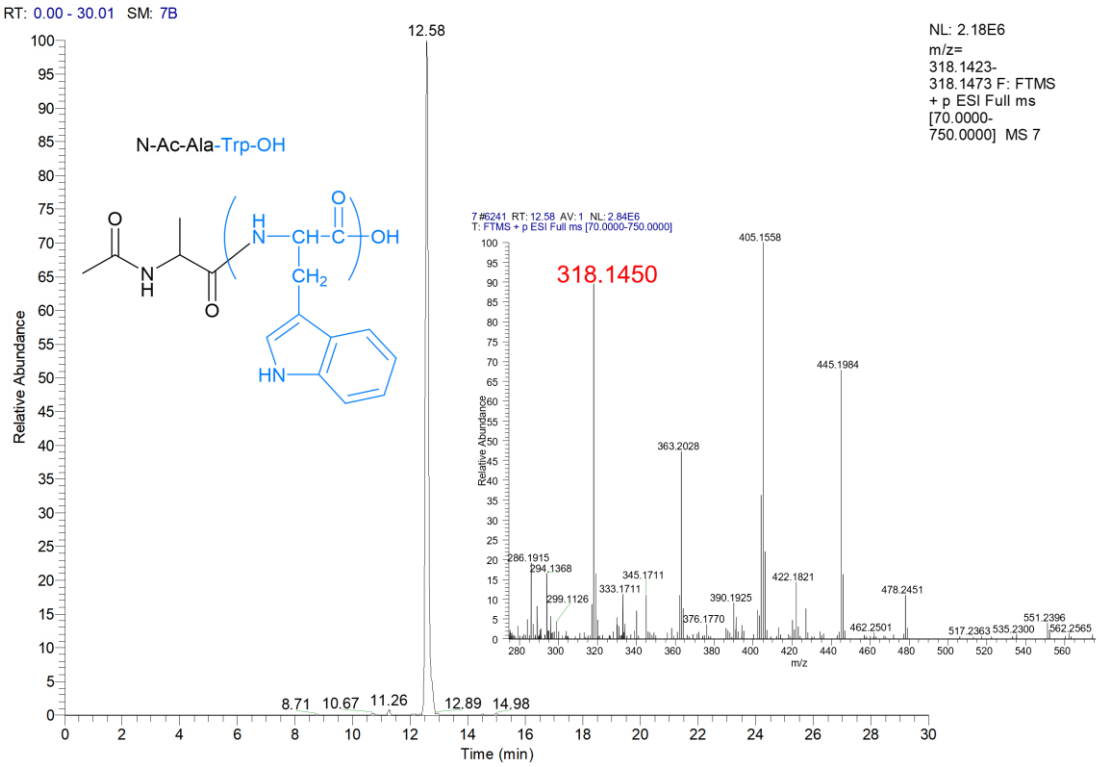

Fig. S65 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 318.1450 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-Trp-OH with a retention time of 12.58 min.

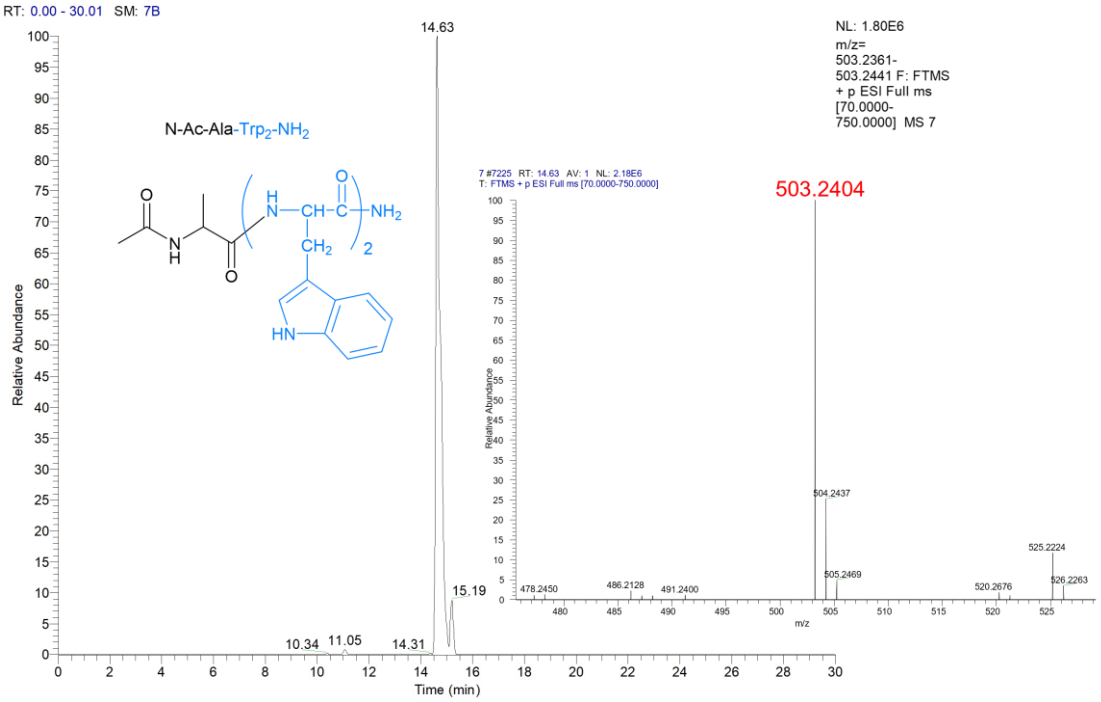

Fig. S66 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 503.2404 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Trp_2-NH_2 with a retention time of 14.63 min.

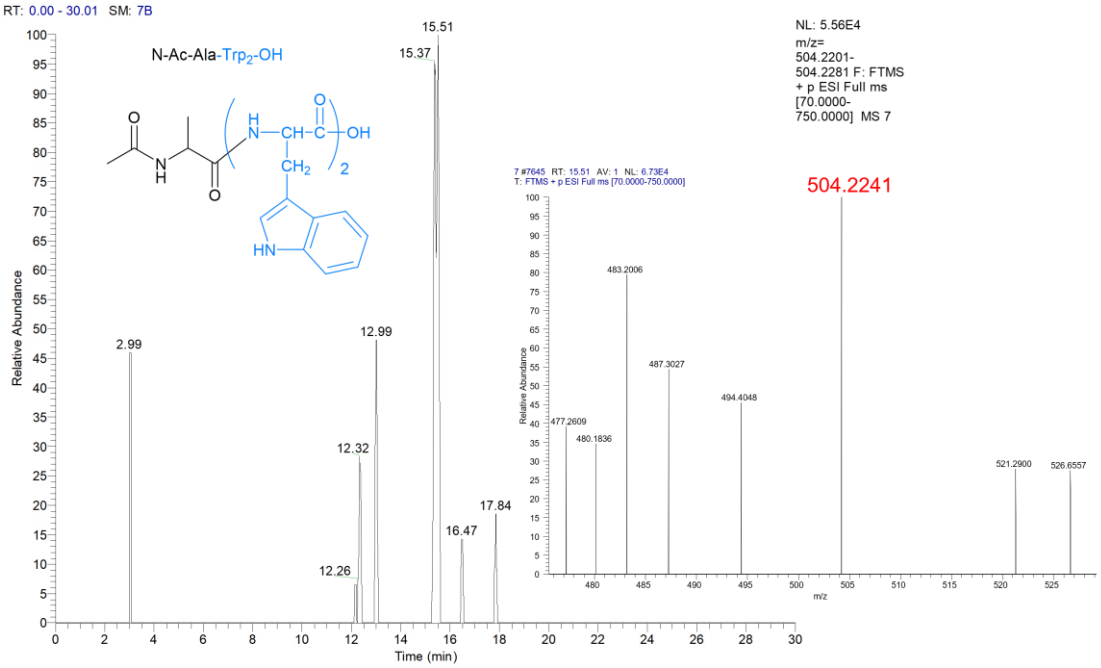

Fig. S67 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 504.2241 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-Trp$_2$-OH with a retention time of 15.51 min.

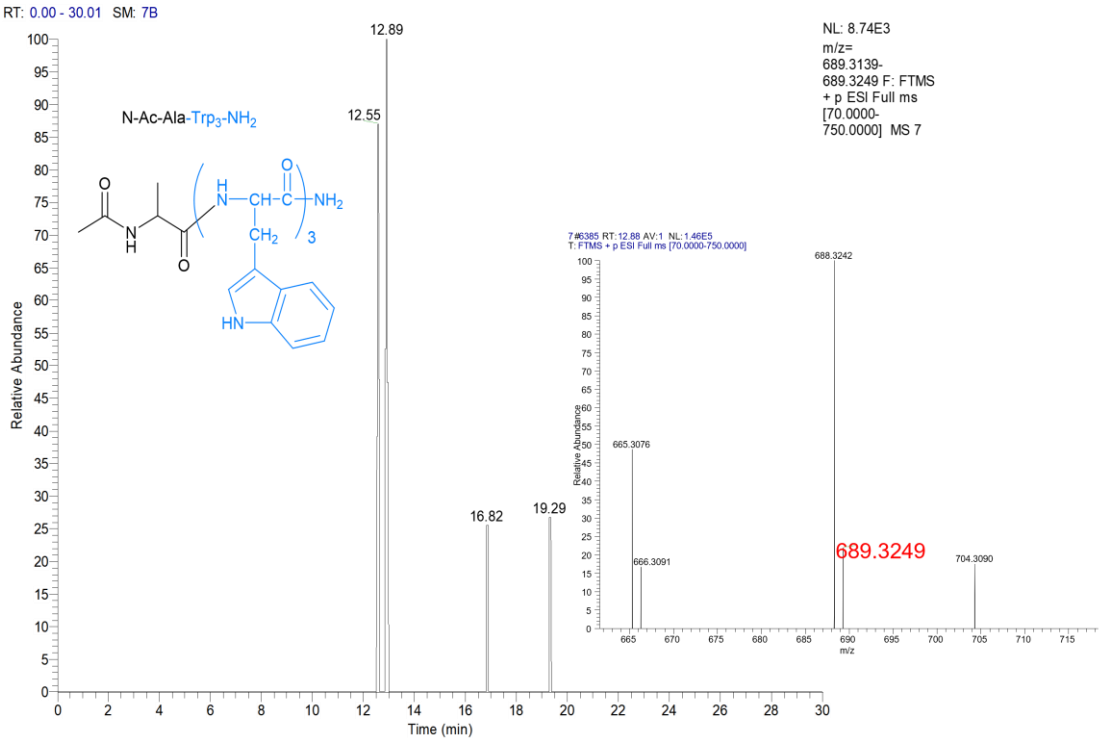

Fig. S68 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 689.3249 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Trp$_3$-NH$_2$ with a retention time of 12.89 min.

2.16 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Thr-NH_2.（Figs. S69-S72）

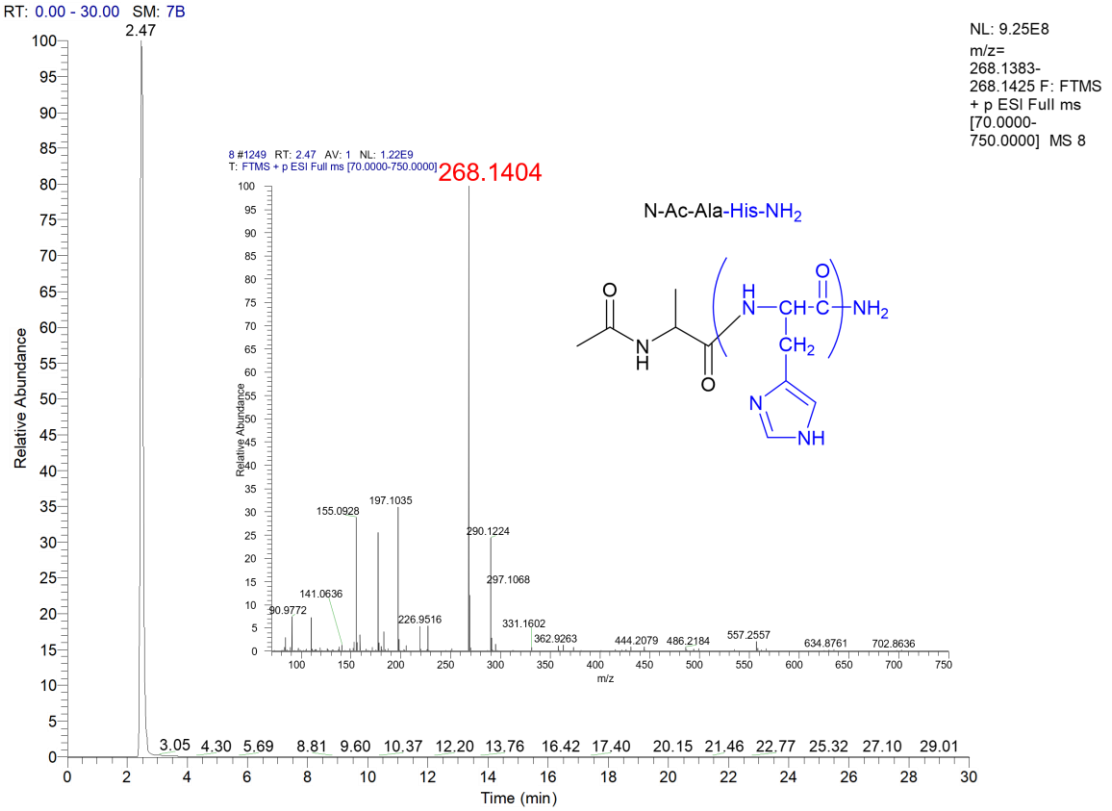

Fig. S69 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 268.1404 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-His NH2 with a retention time of 2.47 min.

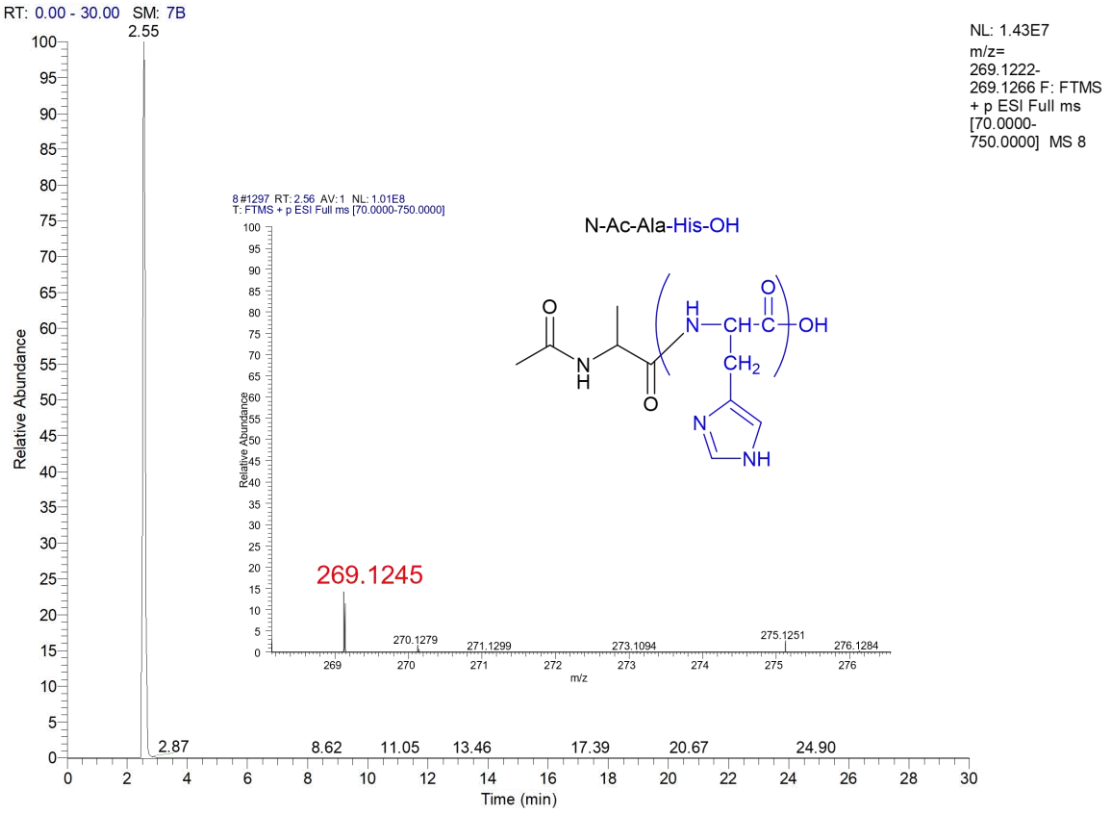

Fig. S70 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 269.1245 was analyzed and its EIC corresponded to the dipeptide N-Ac-Ala-His-OH with a retention time of 2.55 min.

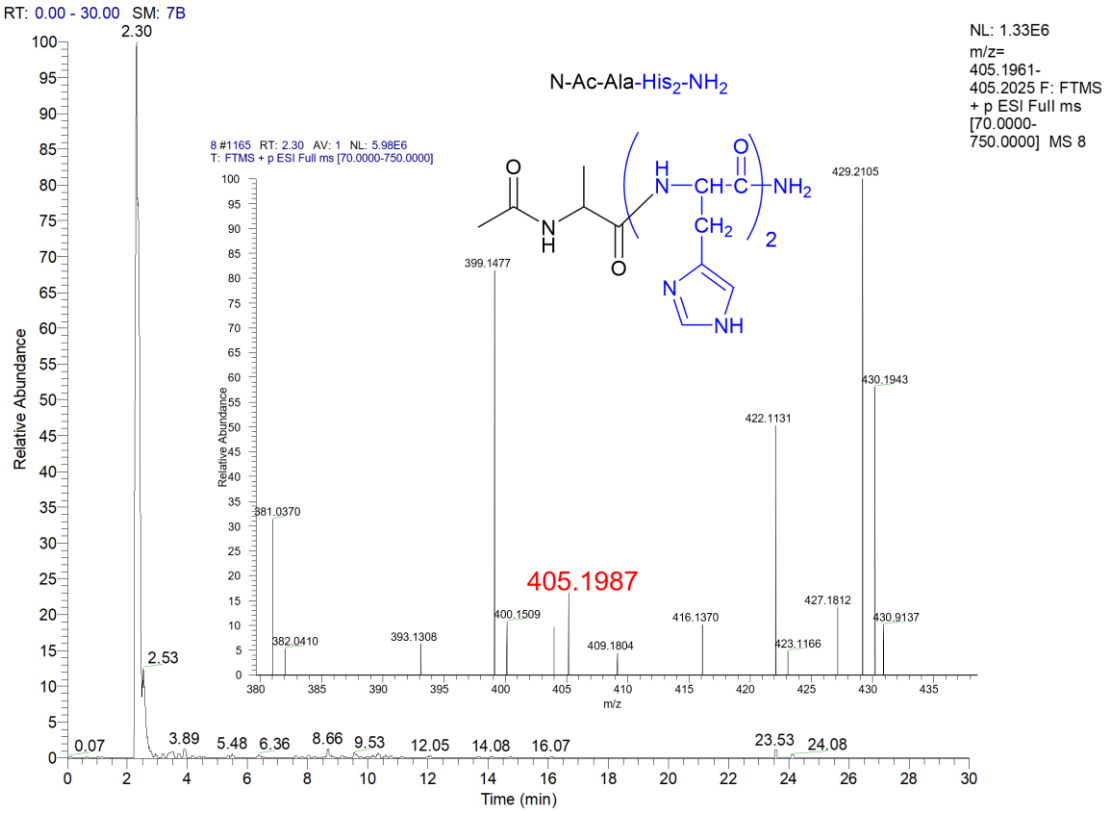

Fig. S71 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 405.1987 was analyzed, and the EIC corresponds to the trimer N-Ac-Ala-His_2-NH_2 with a retention time of 2.30 min.

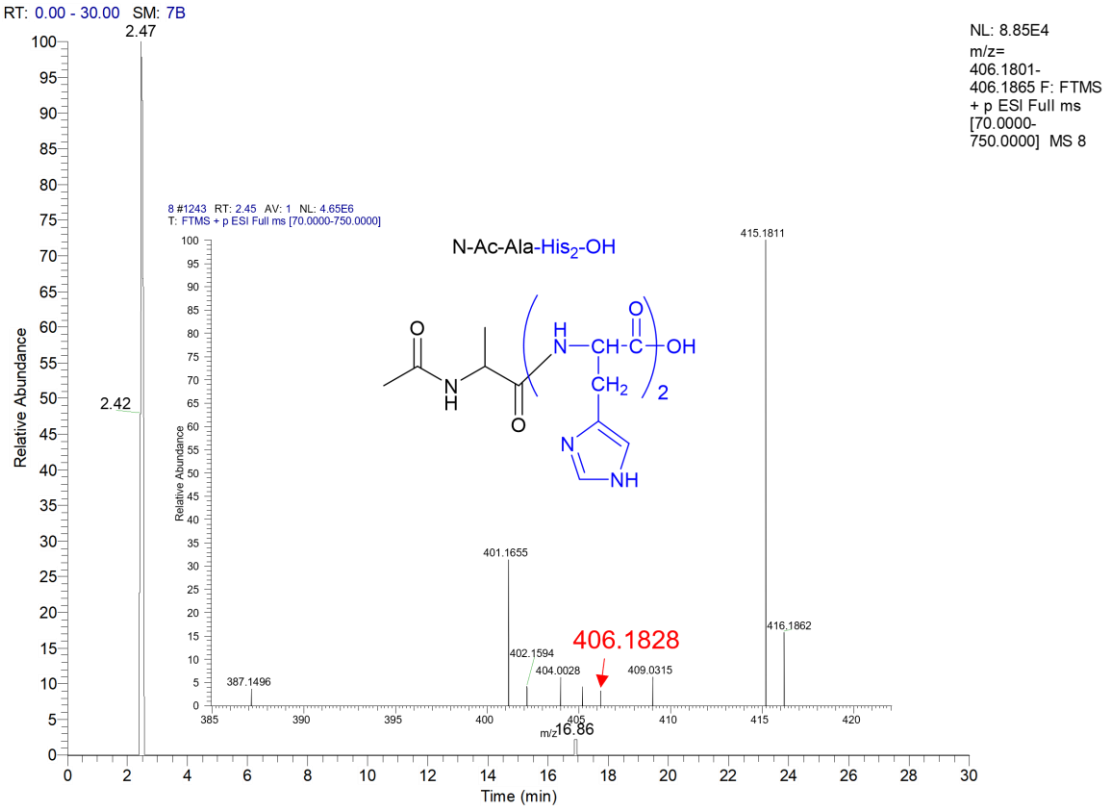

Fig. S72 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 406.1828 was analyzed and its EIC corresponded to the tripeptide N-Ac-Ala-His_2-OH with a retention time of 2.45 min.

2.17 Oligomer produced by the polymerization of 0.1 M Ac-Ala-NH_2 and 0.1 M Asp-NH_2.（Figs. S73-S78）

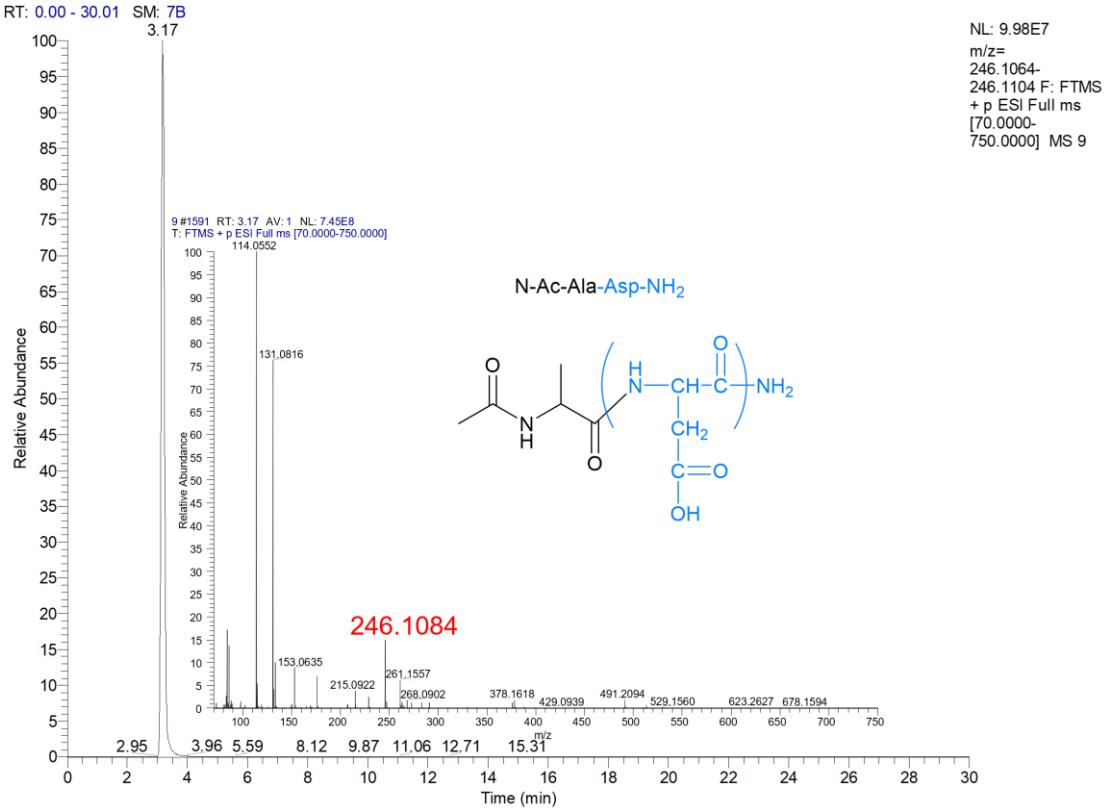

Fig. S73 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 246.1084 was analyzed, and its EIC corresponded to the dimer N-Ac-Ala-Asp-NH_2 with a retention time of 3.17 min.

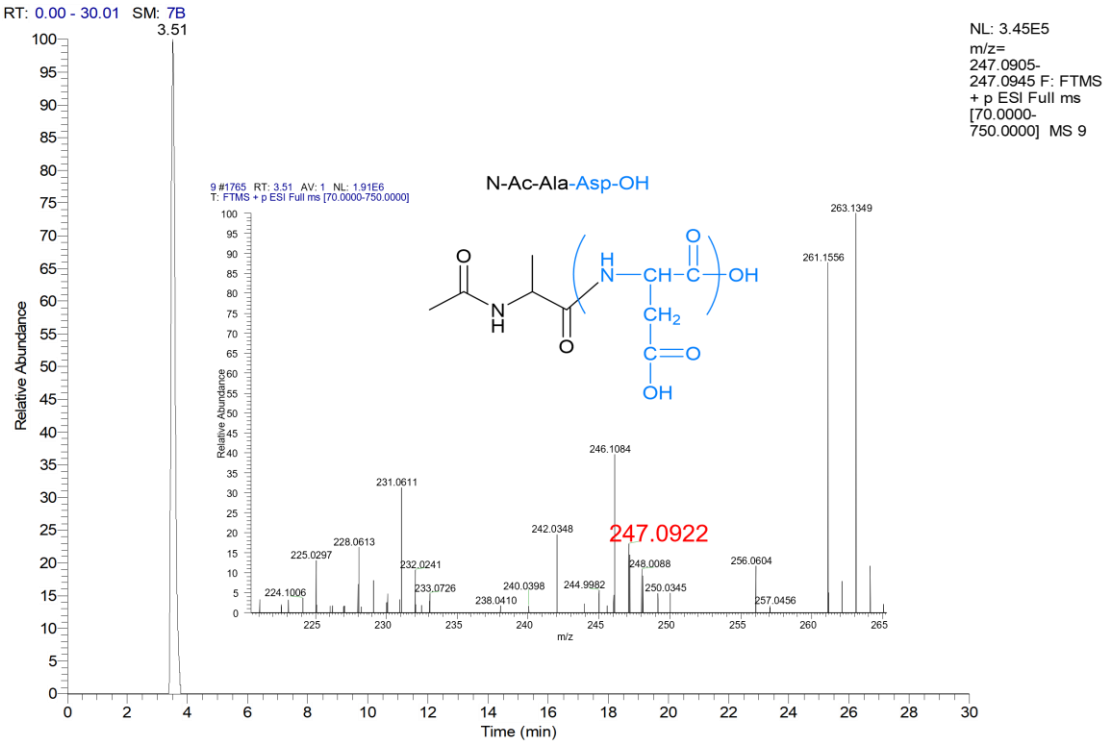

Fig. S74 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 247.0922 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Ala-Asp-OH with a retention time of 3.51 min.

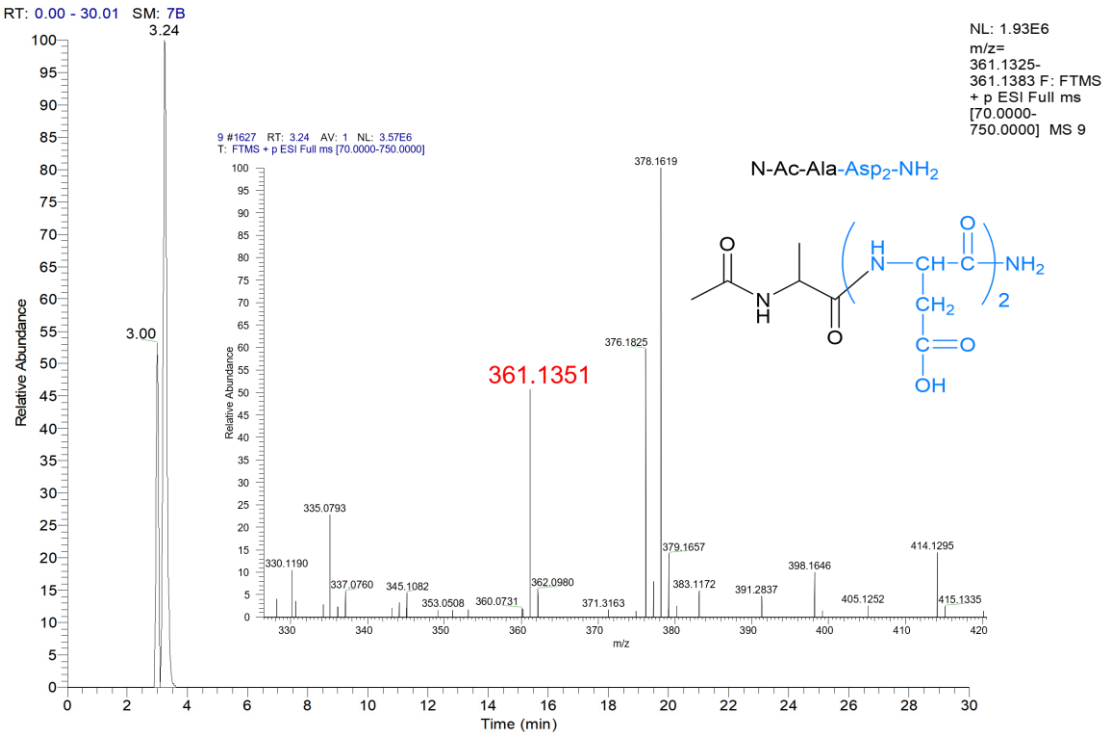

Fig. S75 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 361.1351 was analyzed, and its EIC corresponds to the trimer N-Ac-Ala-Asp_2-NH_2 with a retention time of 3.24 min.

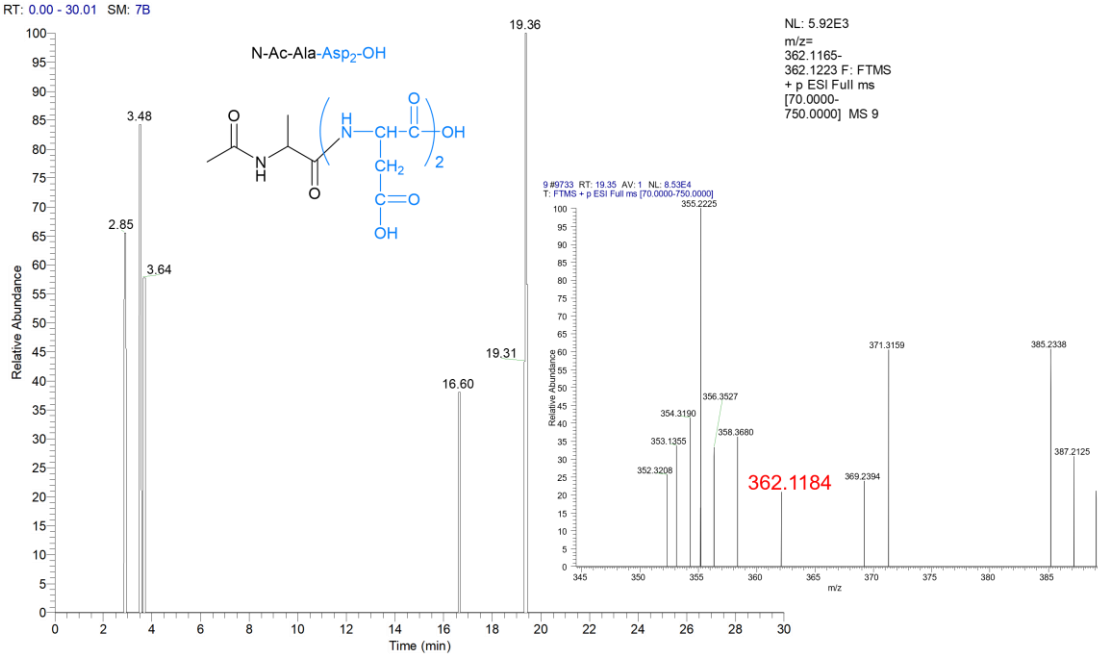

Fig. S76 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 362.1184 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Ala-Asp$_2$-OH with a retention time of 19.35 min.

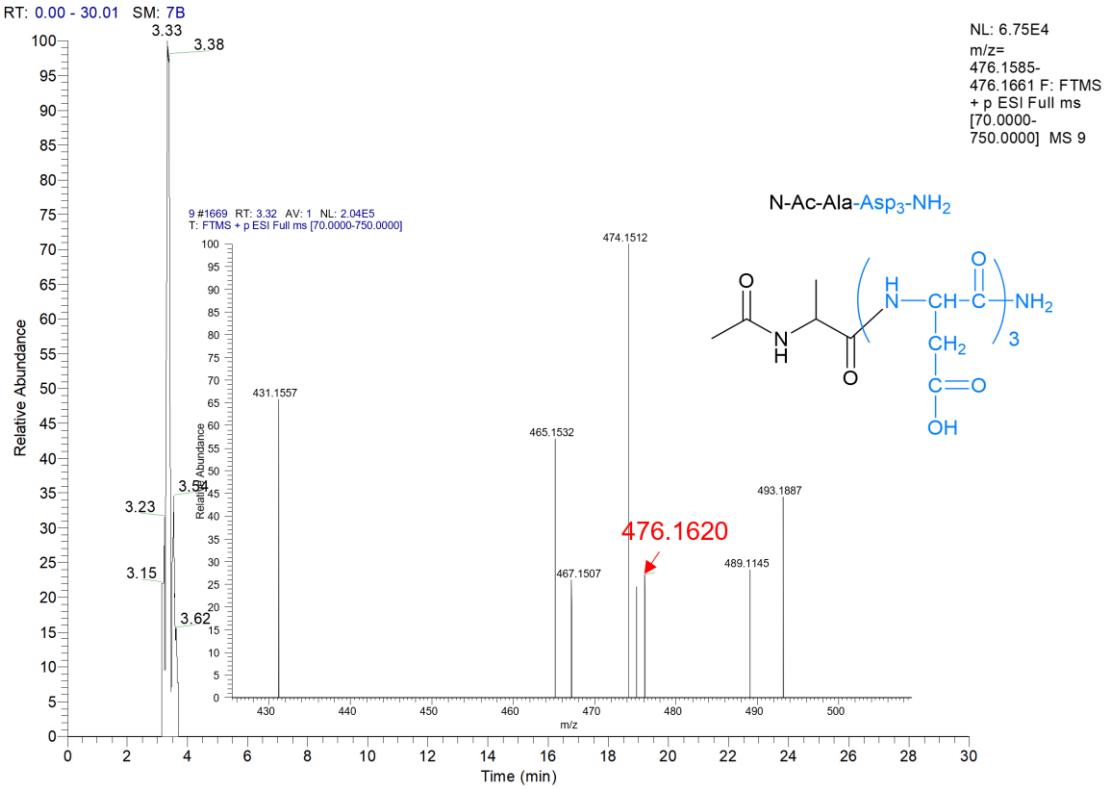

Fig. S77 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 476.1620 was analyzed and its EIC corresponded to the tetramer N-Ac-Ala-Asp_3-NH_2 with a retention time of 3.32 min.

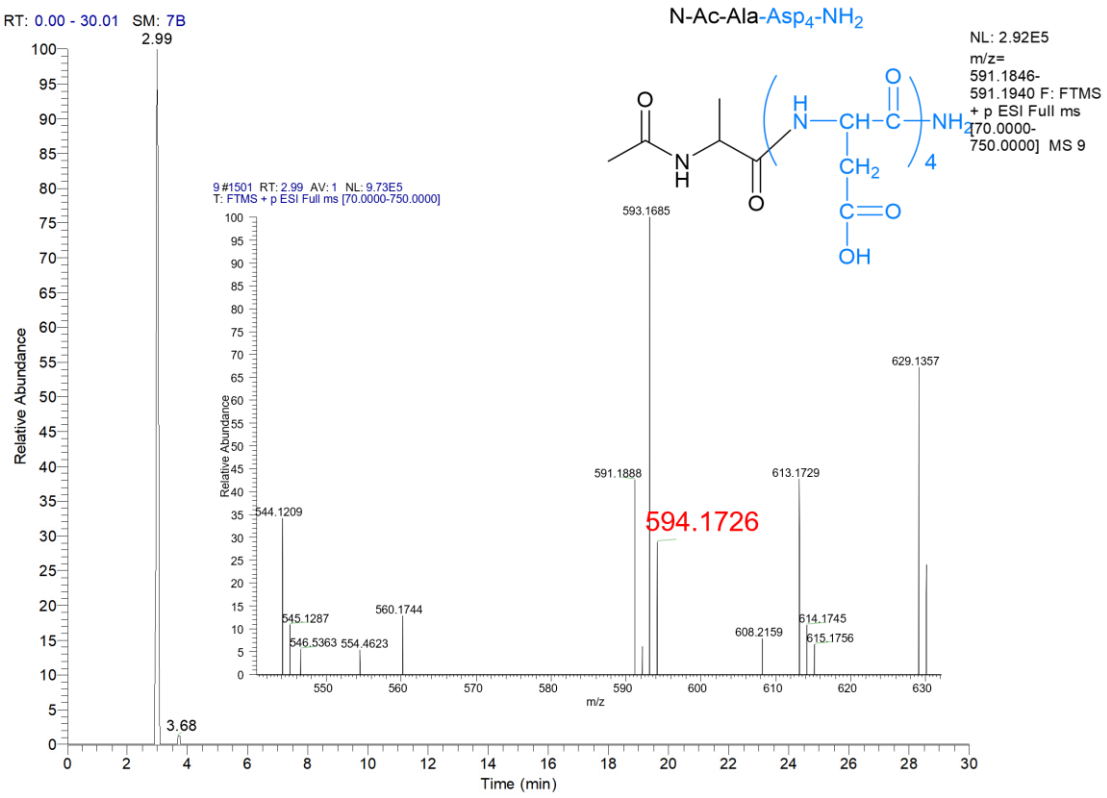

Fig. S78 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 594.1726 was analyzed, and its EIC corresponded to the pentamer N-Ac-Ala-Asp$_4$-NH$_2$ with a retention time of 2.99 min.

2.18 Oligomer produced by the polymerization of 0.1M Ac-Ala-NH_2 and 0.1M Tyr-NH_2.（Figs. S79-S81）

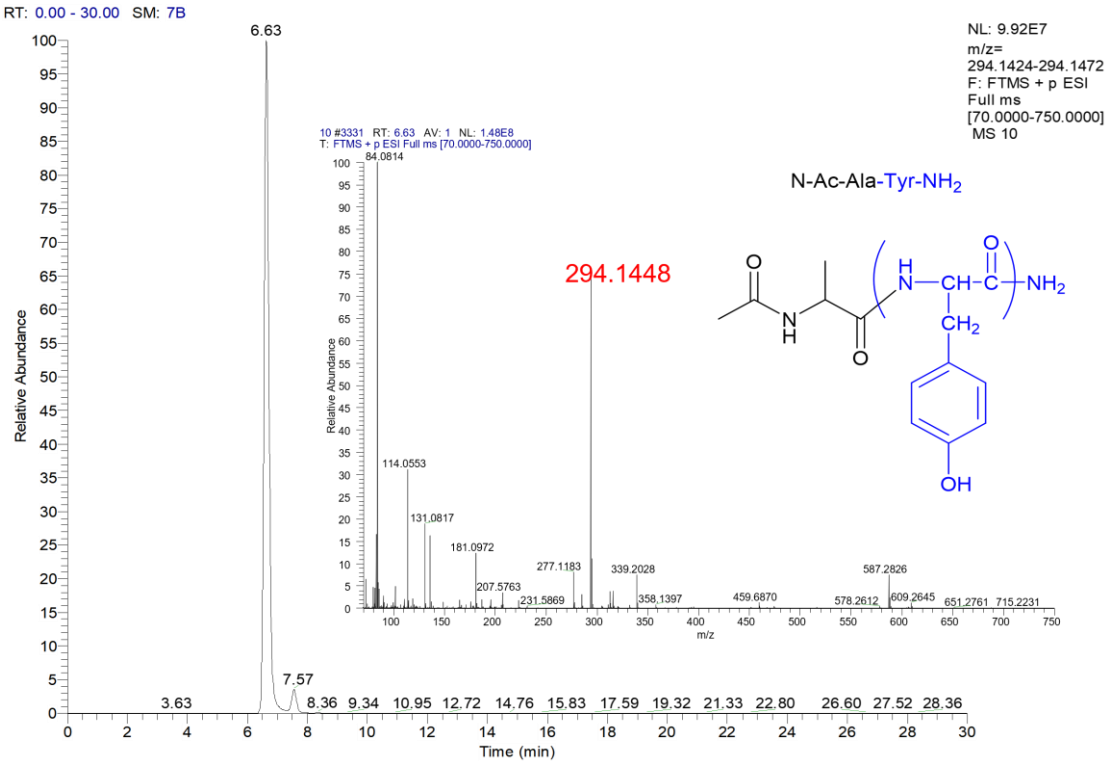

Fig. S79 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 294.1448 was analyzed and its EIC corresponded to the dimer N-Ac-Ala-Tyr-NH_2 with a retention time of 6.63 min.

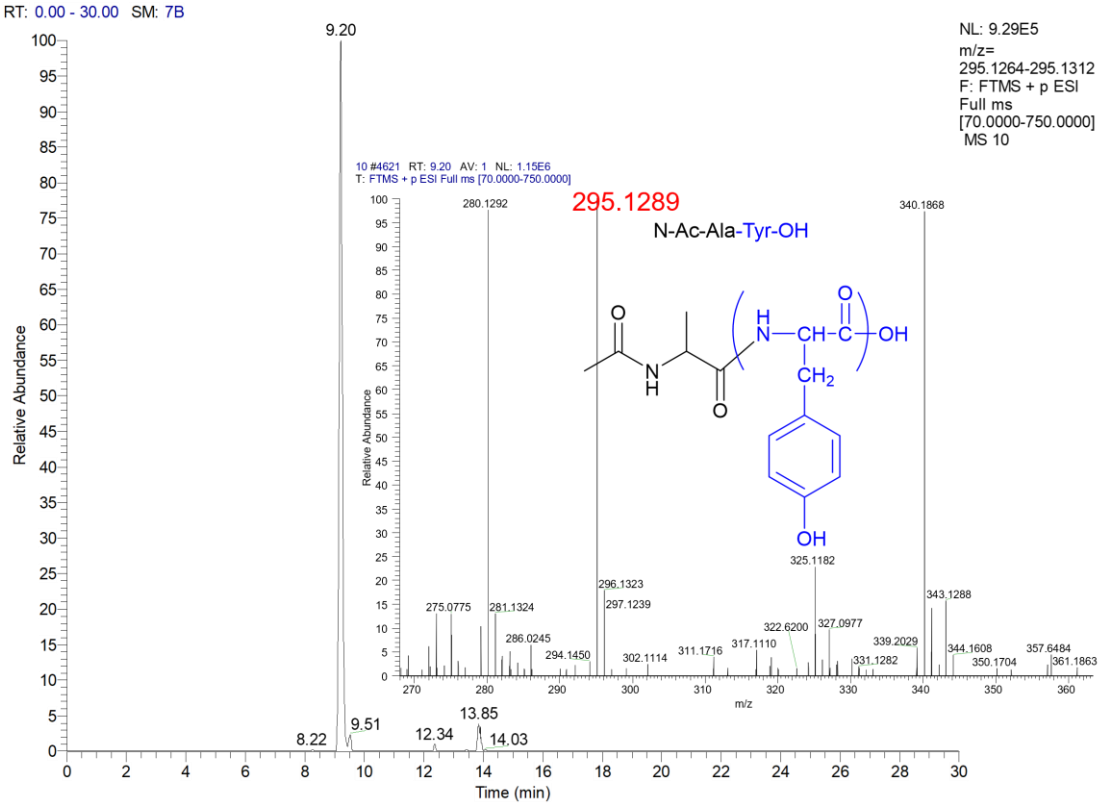

Fig. S80 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 295.1289 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Ala-Tyr-OH with a retention time of 9.20 min.

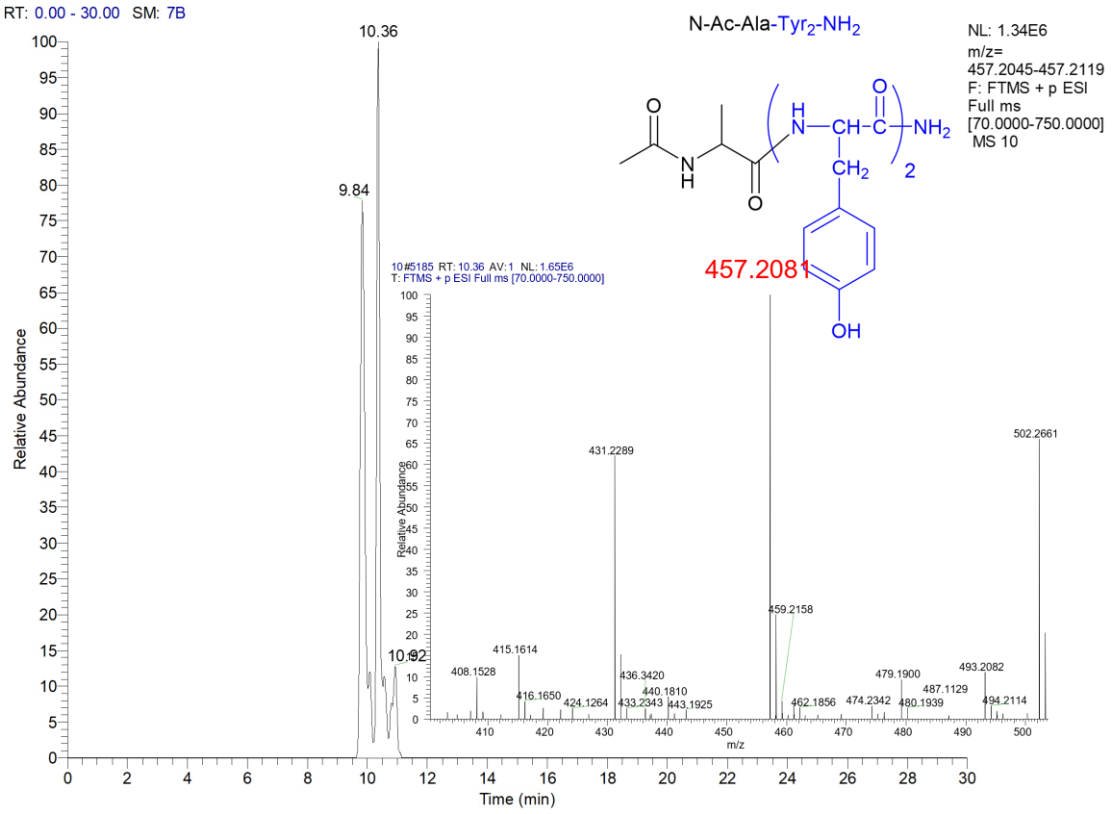

Fig. S81 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 457.2081 was analyzed and its EIC corresponded to the trimer N-Ac-Ala-Tyr$_2$-NH$_2$ with a retention time of 10.36 min.

2.19 Secondary mass spectrometry analysis of trimers from the reaction of Ac-Ala-NH_2 with AA-NH_2.（Figs. S82-S94）

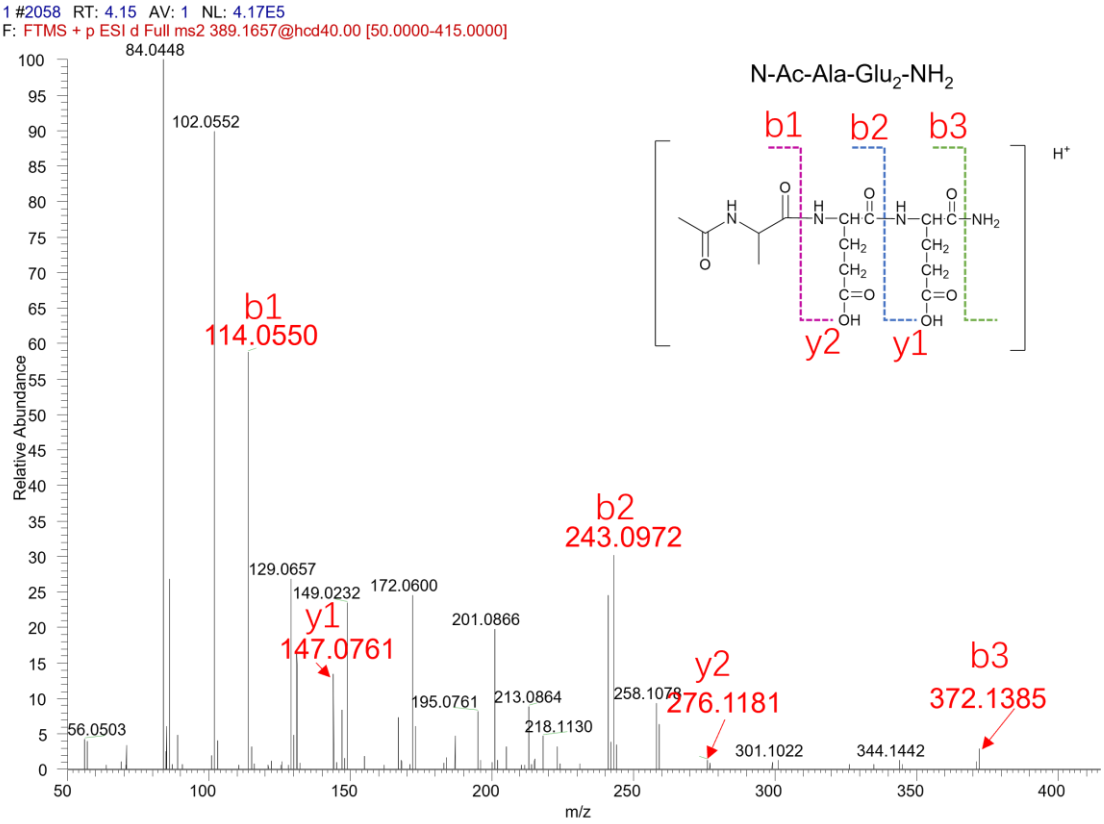

Fig. S82 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 389.1657 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Glu_2-NH_2.

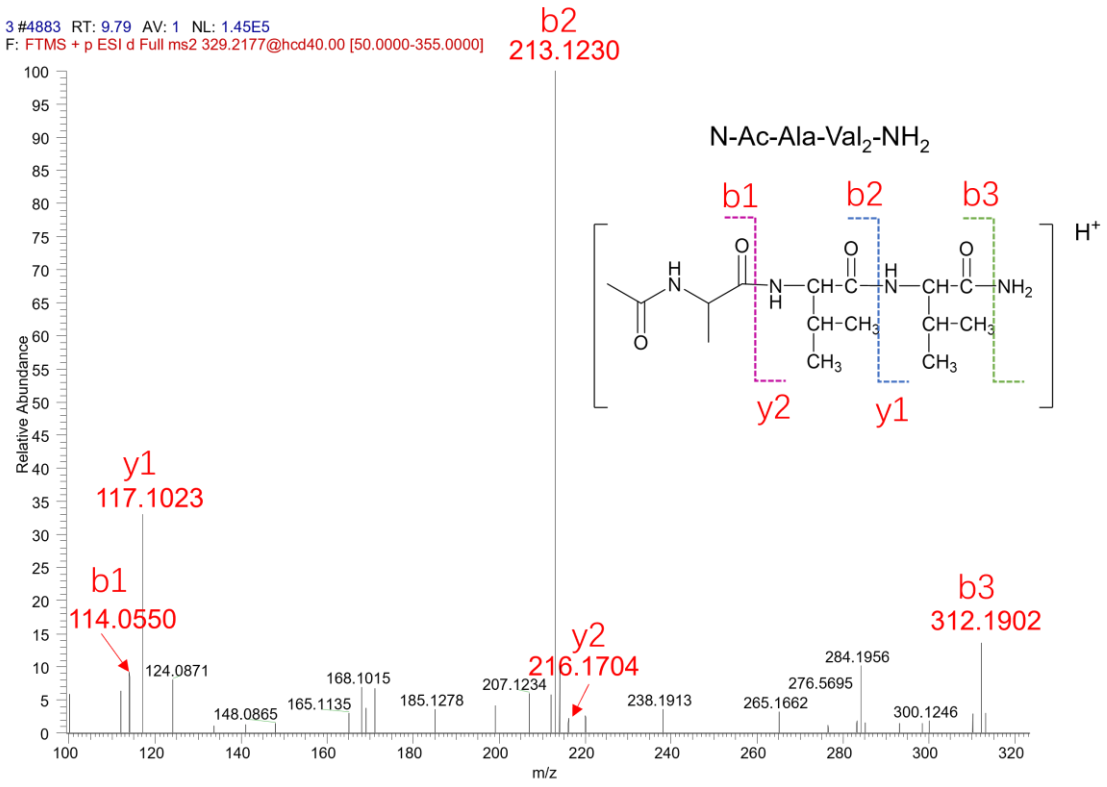

Fig. S83 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 329.2177 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Val_2-NH_2.

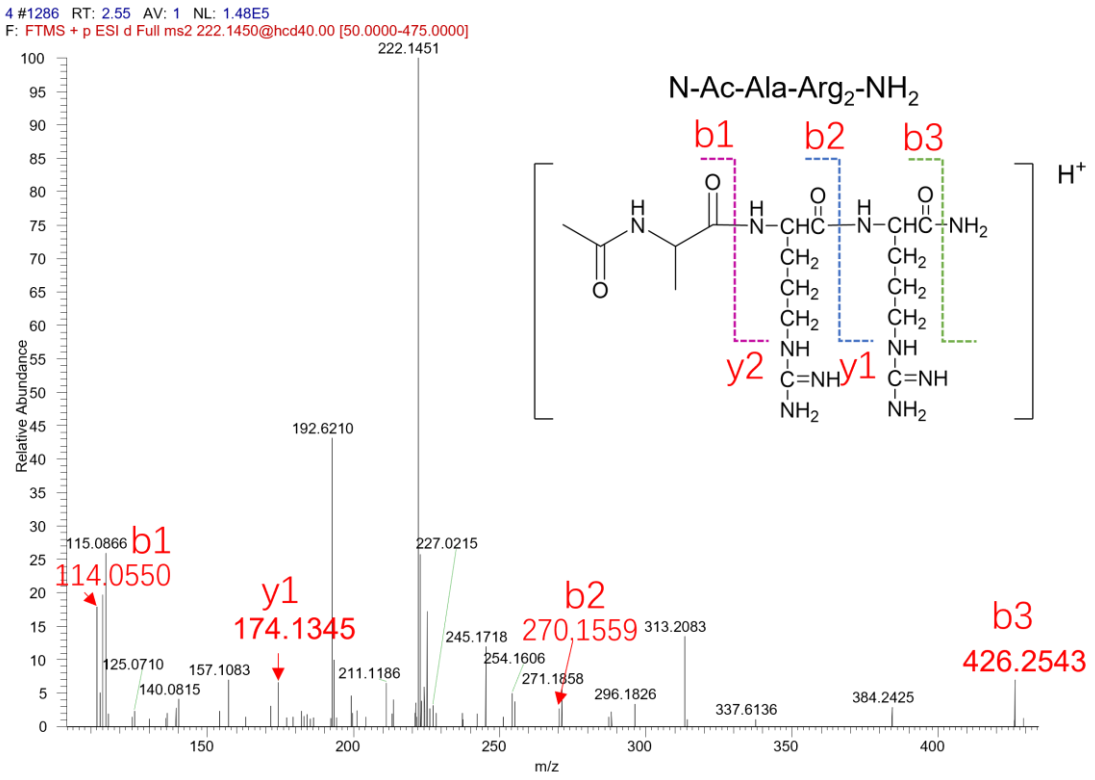

Fig. S84 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 222.1450 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Arg_2-NH_2.

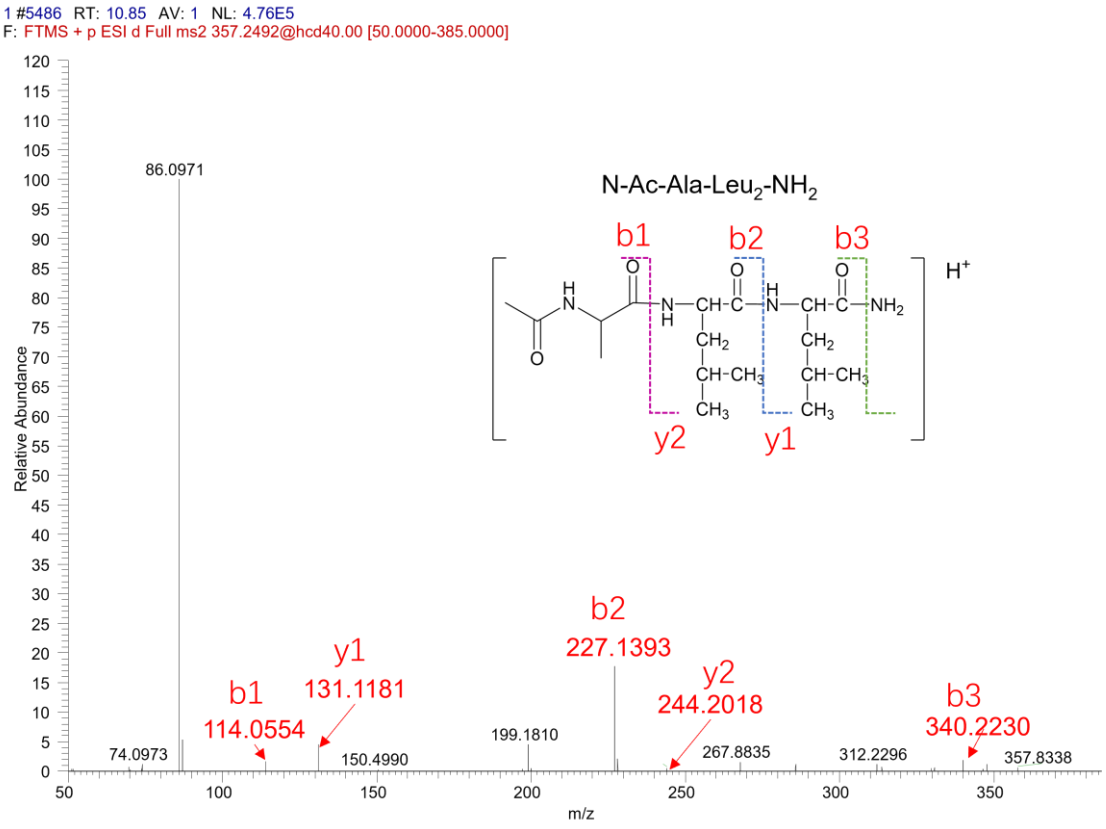

Fig. S85 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 357.2492 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Leu_2-NH_2.

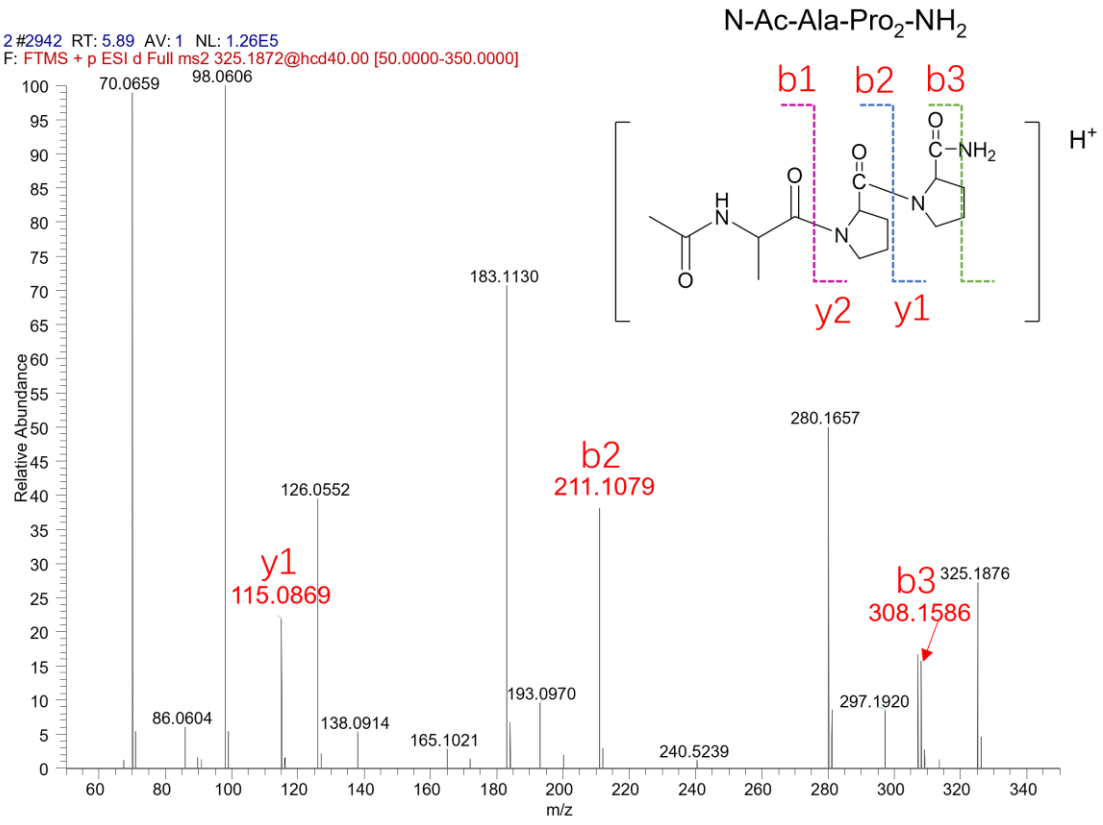

Fig. S86 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 325.1872 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Pro$_2$-NH$_2$.

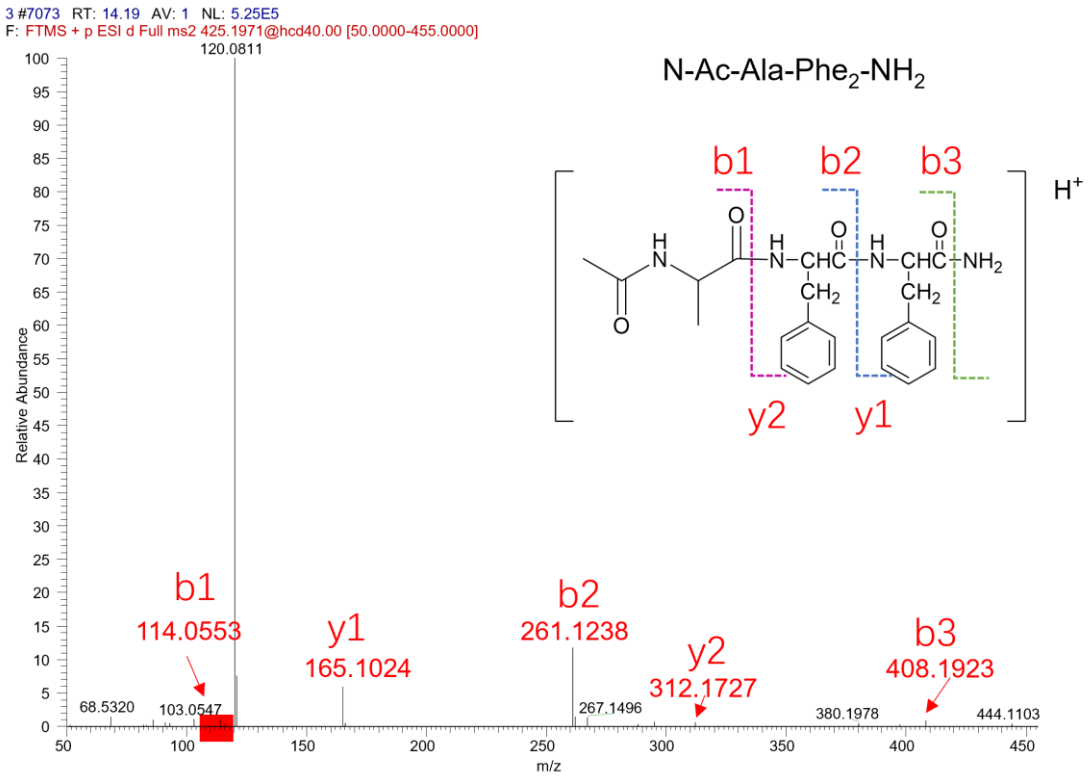

Fig. S87 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 425.1971 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Phe_2-NH_2.

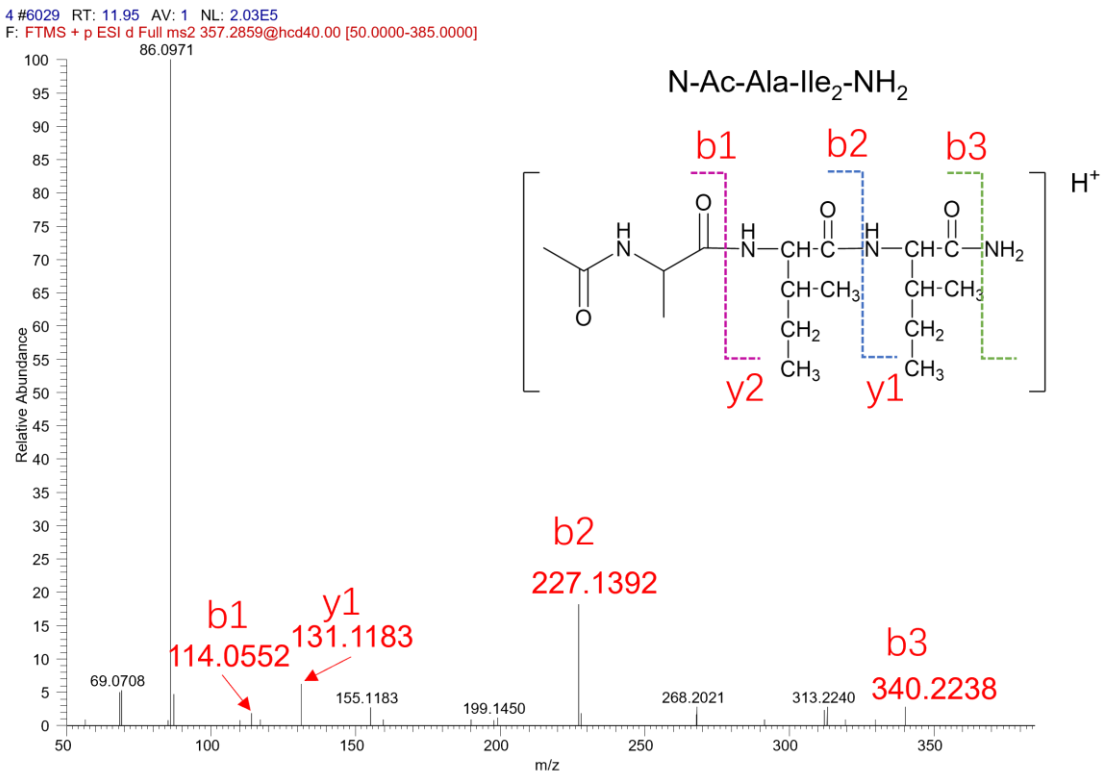

Fig. S88 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 357.2859 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Ile$_2$-NH$_2$.

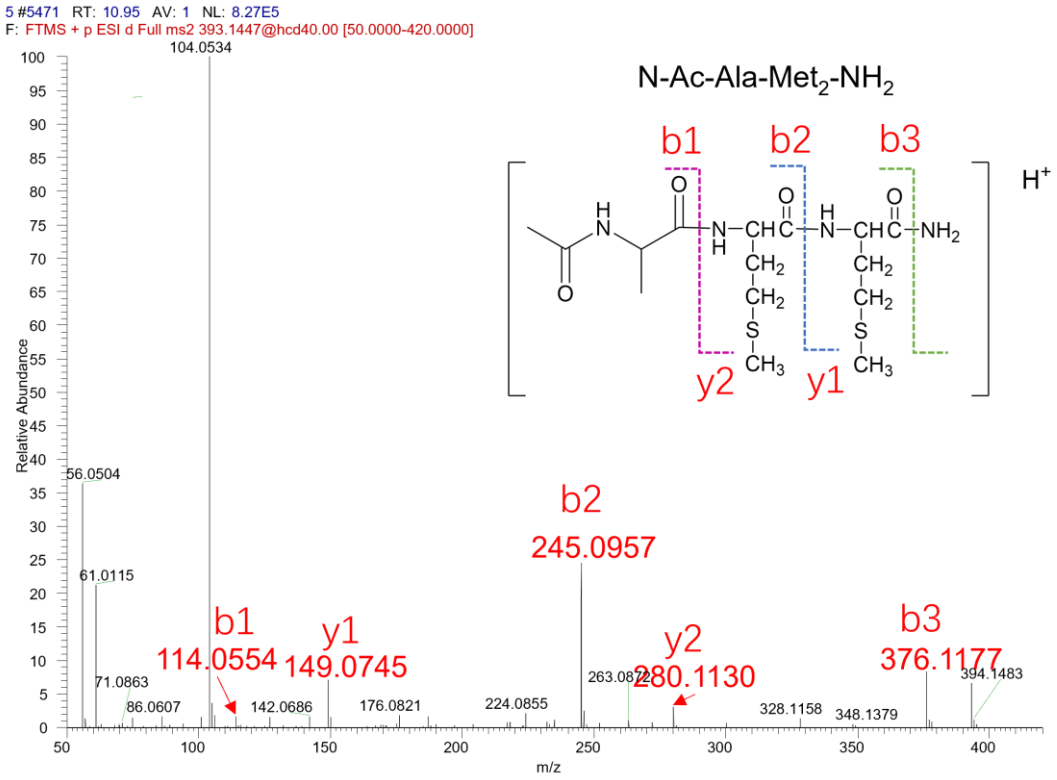

Fig. S89 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 393.1447 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Met_2-NH_2.

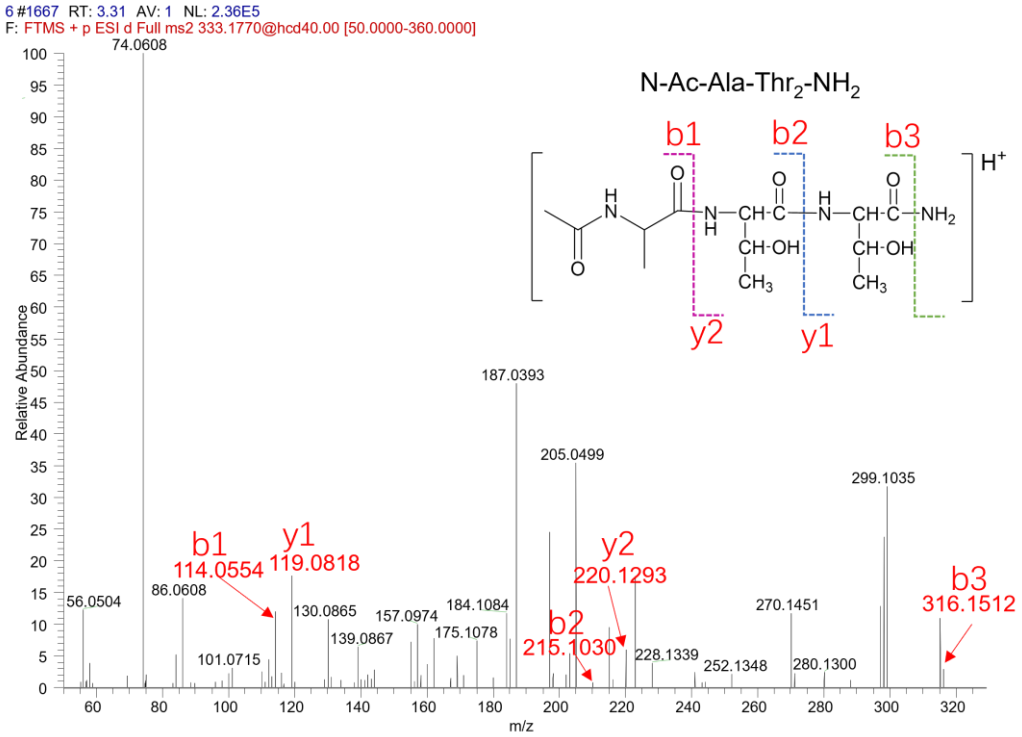

Fig. S90 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 333.1770 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Thr_2-NH_2.

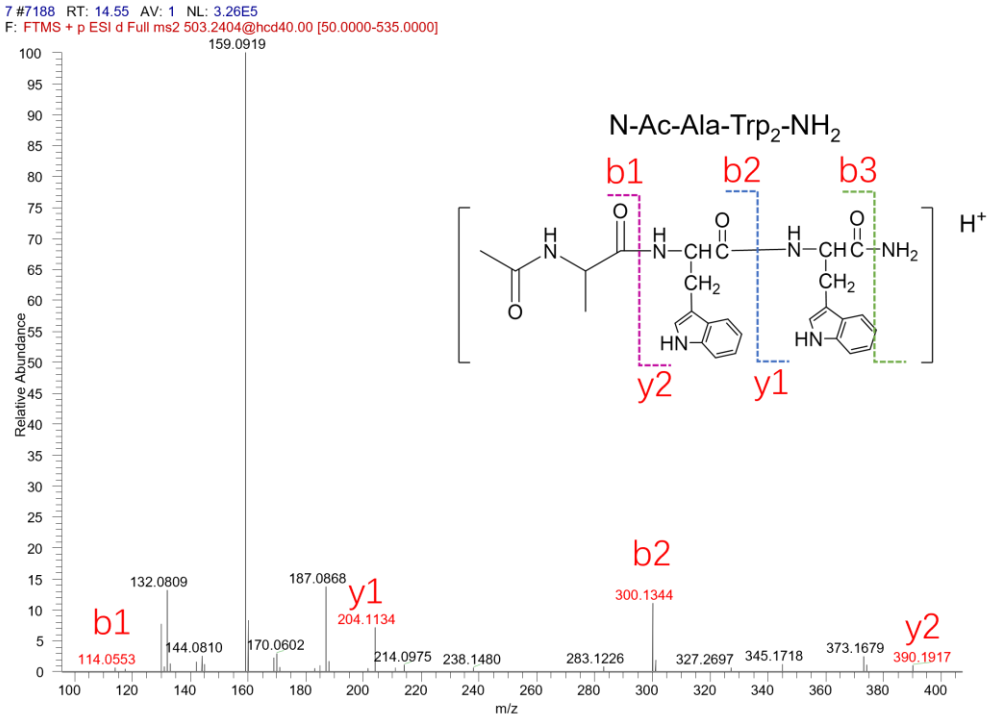

Fig. S91 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 503.2404 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Trp$_2$-NH$_2$.

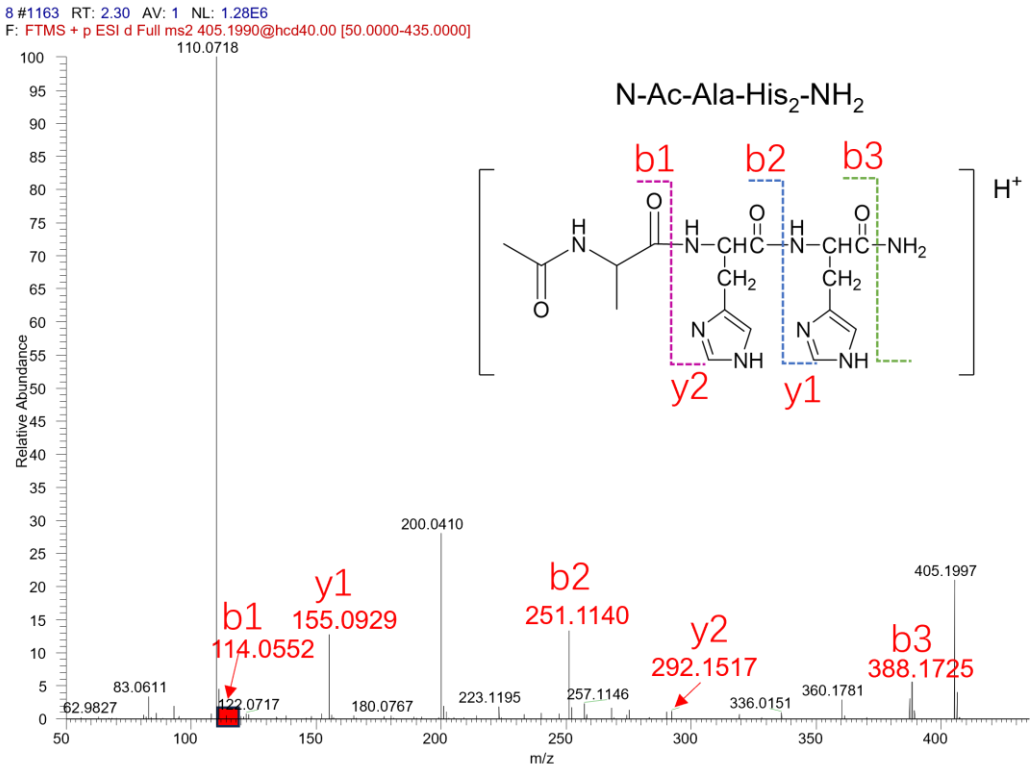

Fig. S92 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 405.1990 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-His_2-NH_2.

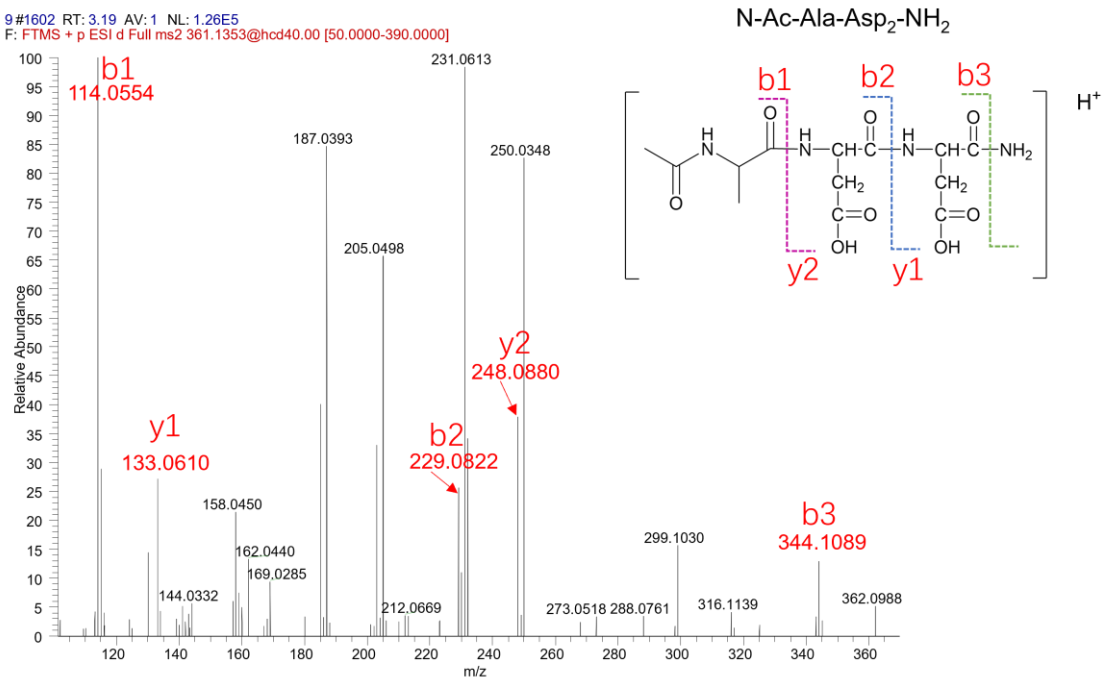

Fig. S93 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 361.1353 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Asp_2-NH_2.

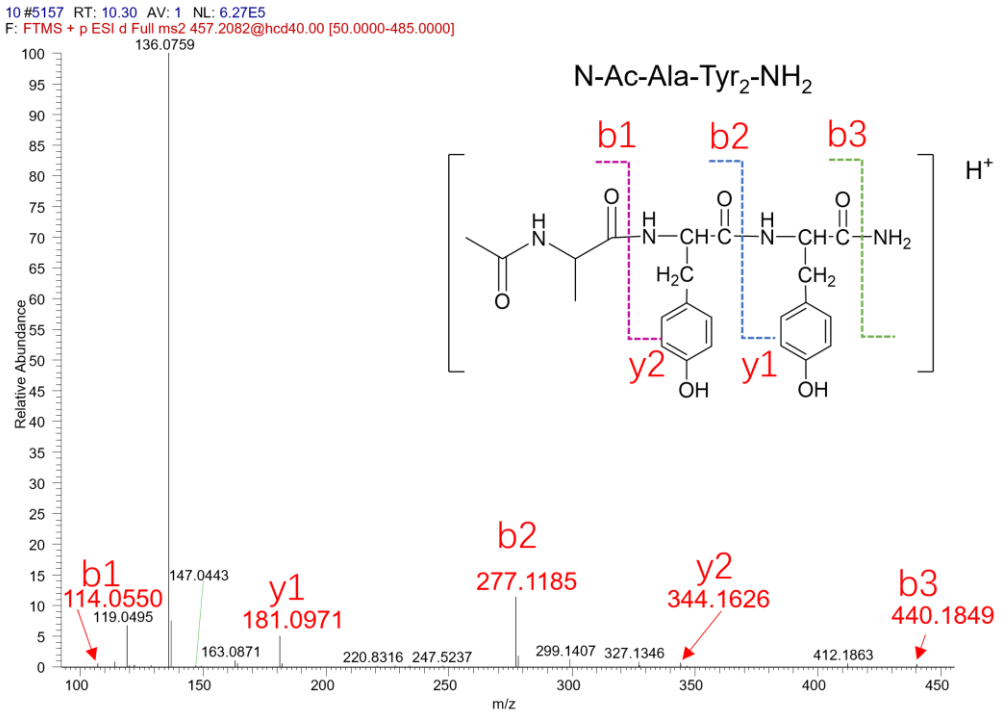

Fig. S94 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 457.2082 was extracted, revealing the presence of ion fragments generated by N-Ac-Ala-Tyr_2-NH_2

2.20 Table S1 Peptide synthesis of N-acetyl-Gly-NH_2 with AA-NH_2.

Entry	AA-NH_2	Highest polymer (N-Ac-Gly-AA_n-NH_2)	Highest polymer (N-Ac-Gly-AA_n-OH)
1	Asp-NH_2	6	4
2	Glu-NH_2	5	4
3	Met-NH_2	5	5
4	His-NH_2	5	3
5	Gly-NH_2	4	3
6	Ser-NH_2	4	4
7	Val-NH_2	4	4
8	Leu-NH_2	4	3
9	Pro-NH_2	4	3
10	Phe-NH_2	4	4
11	Thr-NH_2	4	2
12	Tyr-NH_2	4	3
13	Arg-NH_2	3	2
14	Lys-NH_2	3	2
15	Ile-NH_2	3	3
16	Trp-NH_2	3	3

2.21 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Ala-NH_2.（Figs. S95-S98）

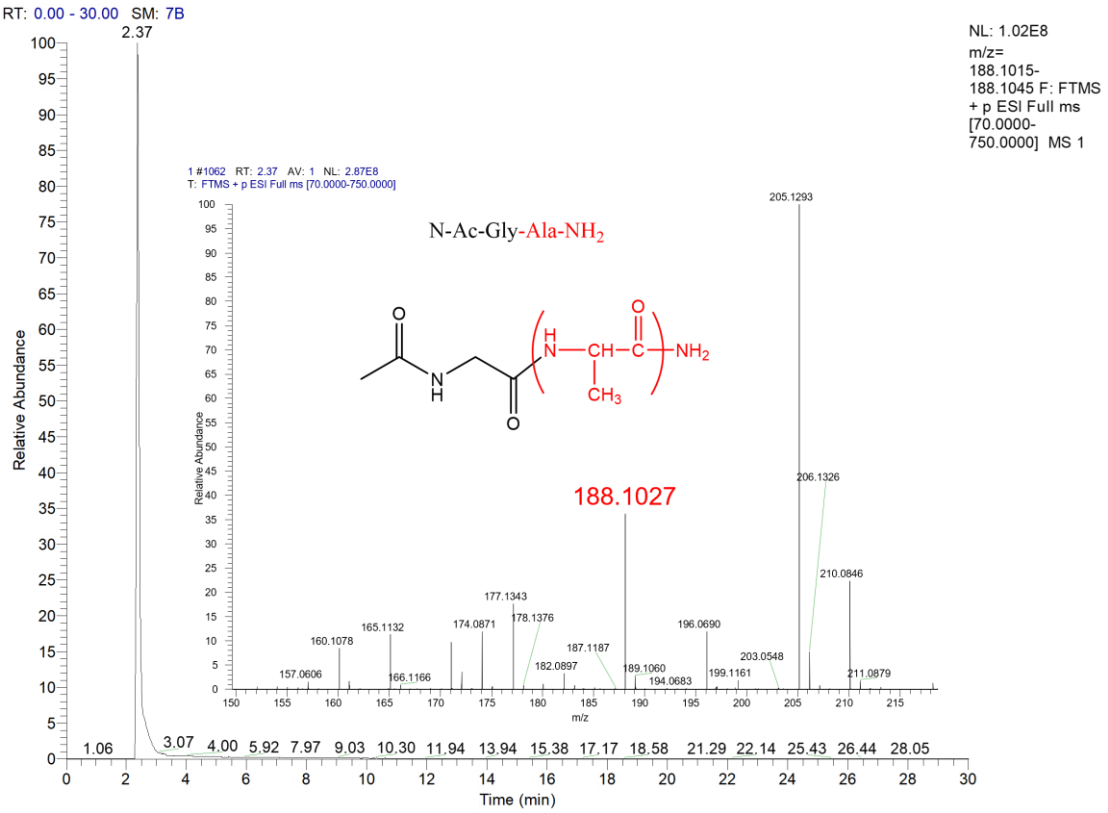

Fig. S95 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 188.1027 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Ala-NH_2 with a retention time of 2.37 min.

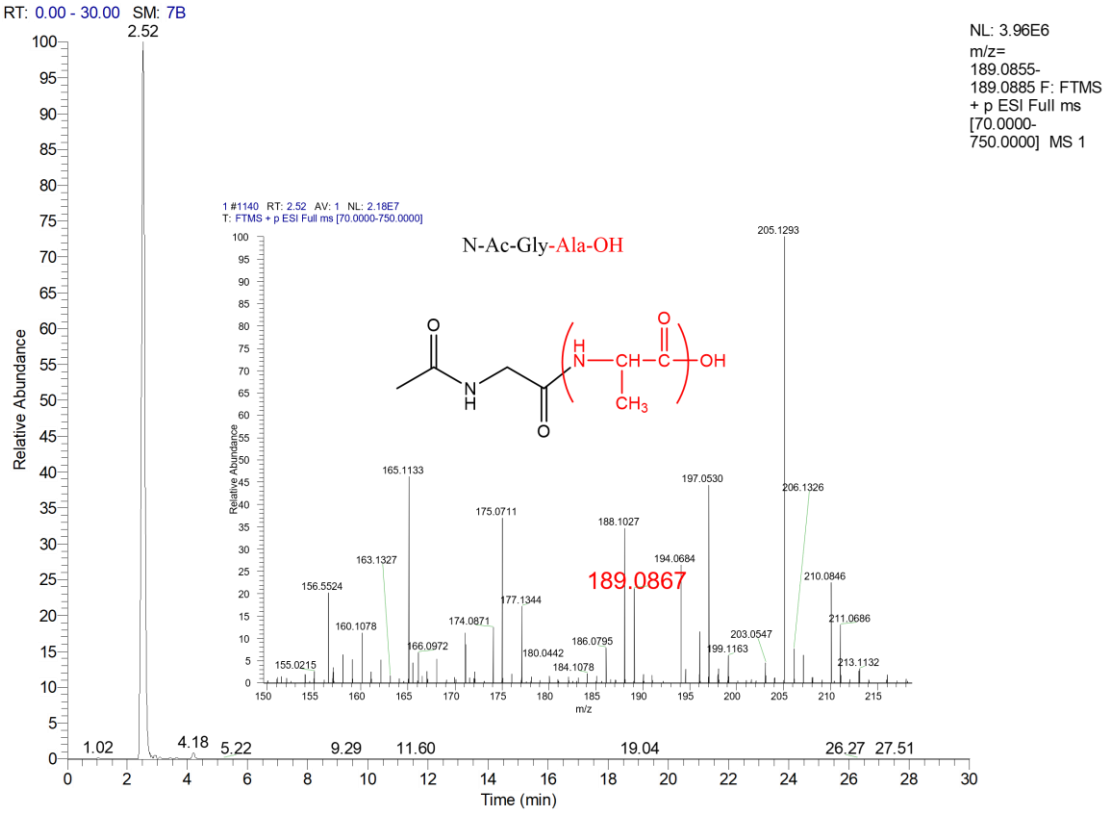

Fig. S96 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 189.0867 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Ala-OH with a retention time of 2.52 min.

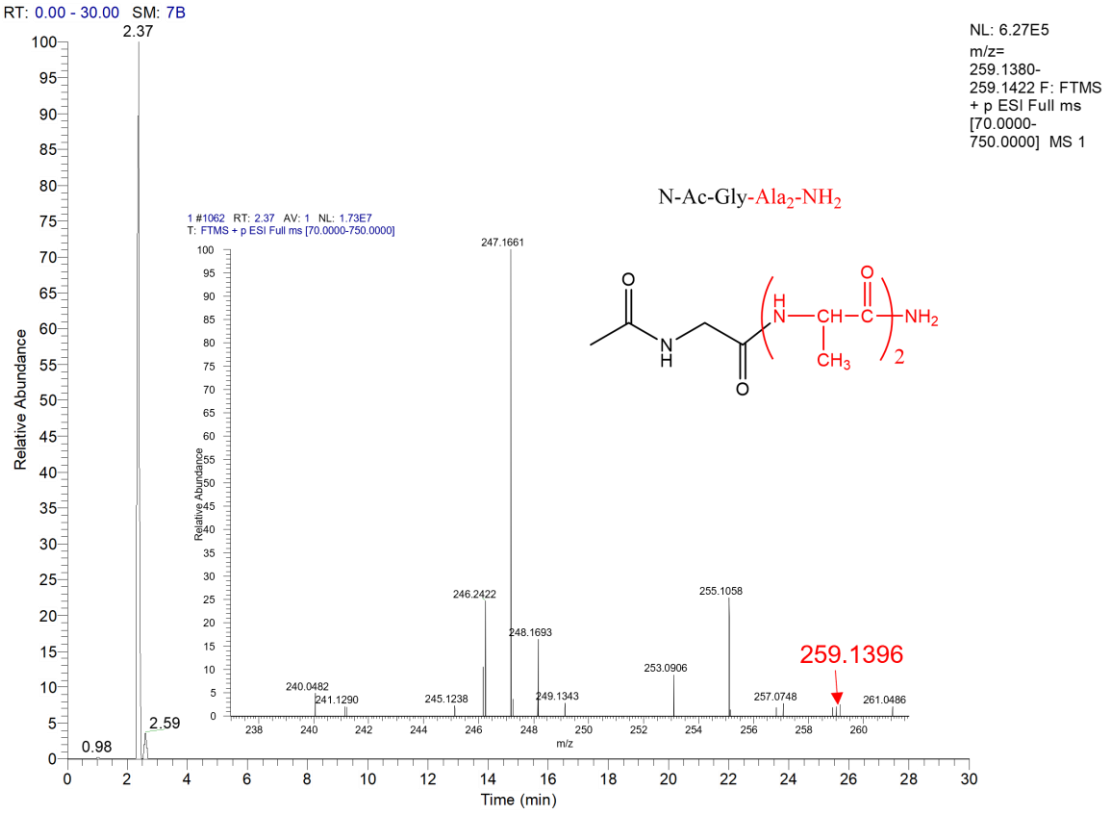

Fig. S97 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 259.1396 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Ala2-NH2 with a retention time of 2.37 min.

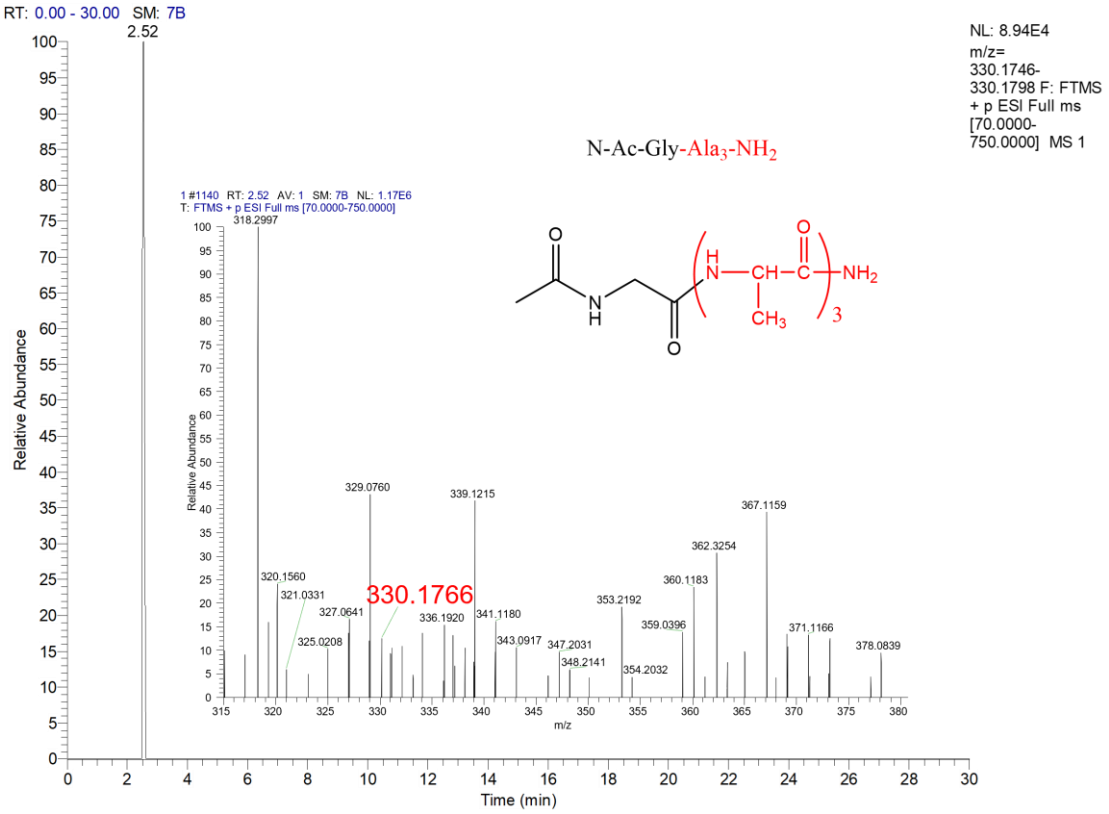

Fig. S98 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 330.1766 was analyzed and its EIC corresponded to the tetramer N-Ac-Gly-Ala_3-NH_2 with a retention time of 2.52 min.

2.22 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Glu-NH_2.（Figs. S99-S105）

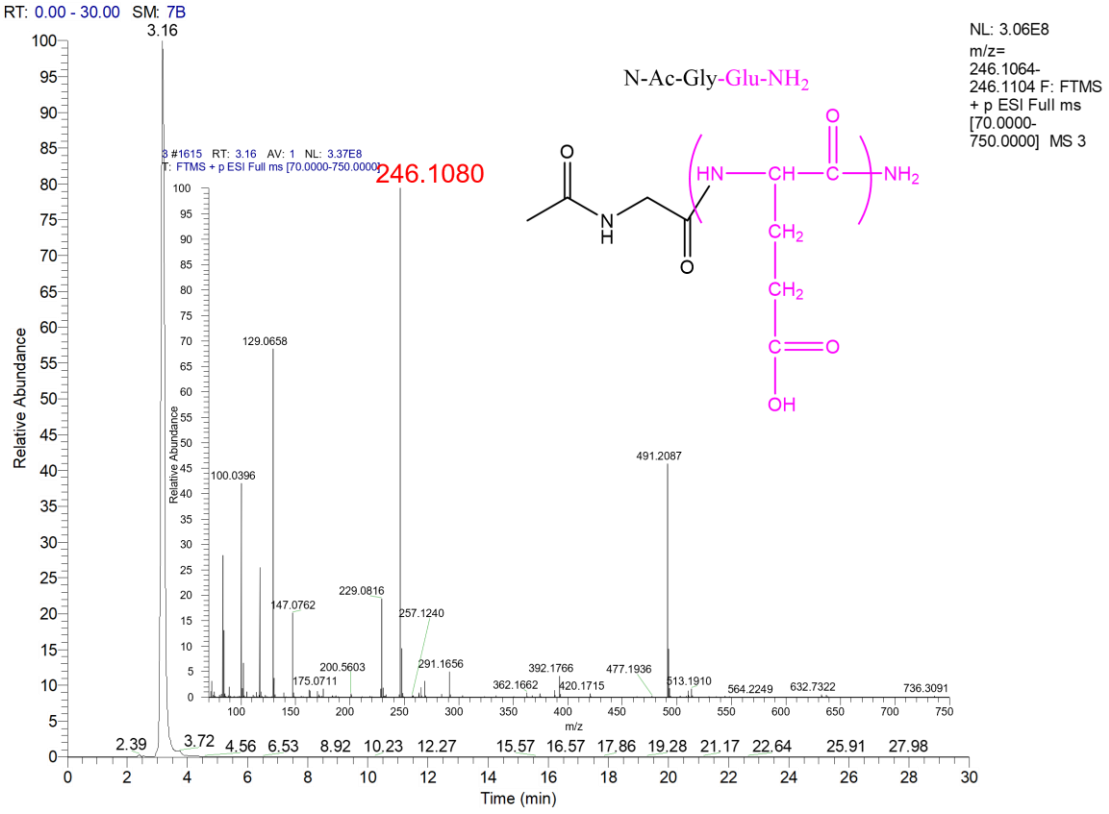

Fig. S99 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 246.1080 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Glu-NH_2 with a retention time of 3.16 min.

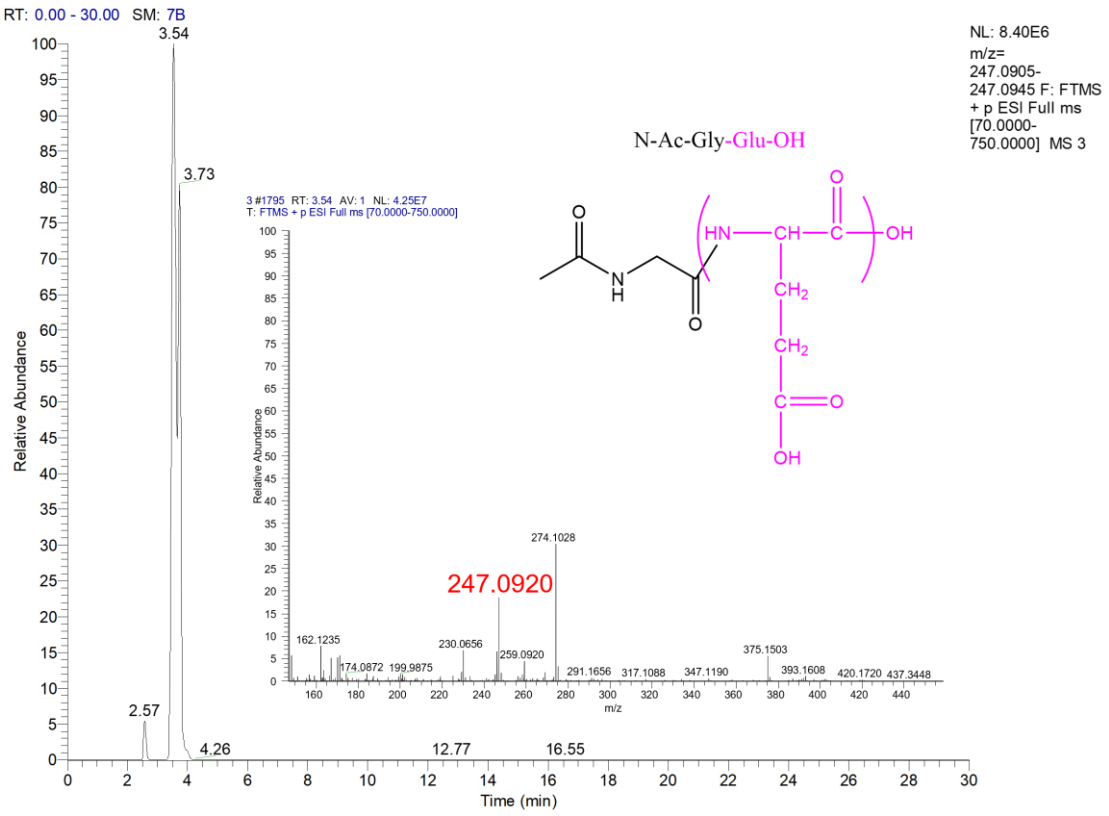

Fig. S100 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 247.0920 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Glu-OH with a retention time of 3.54 min.

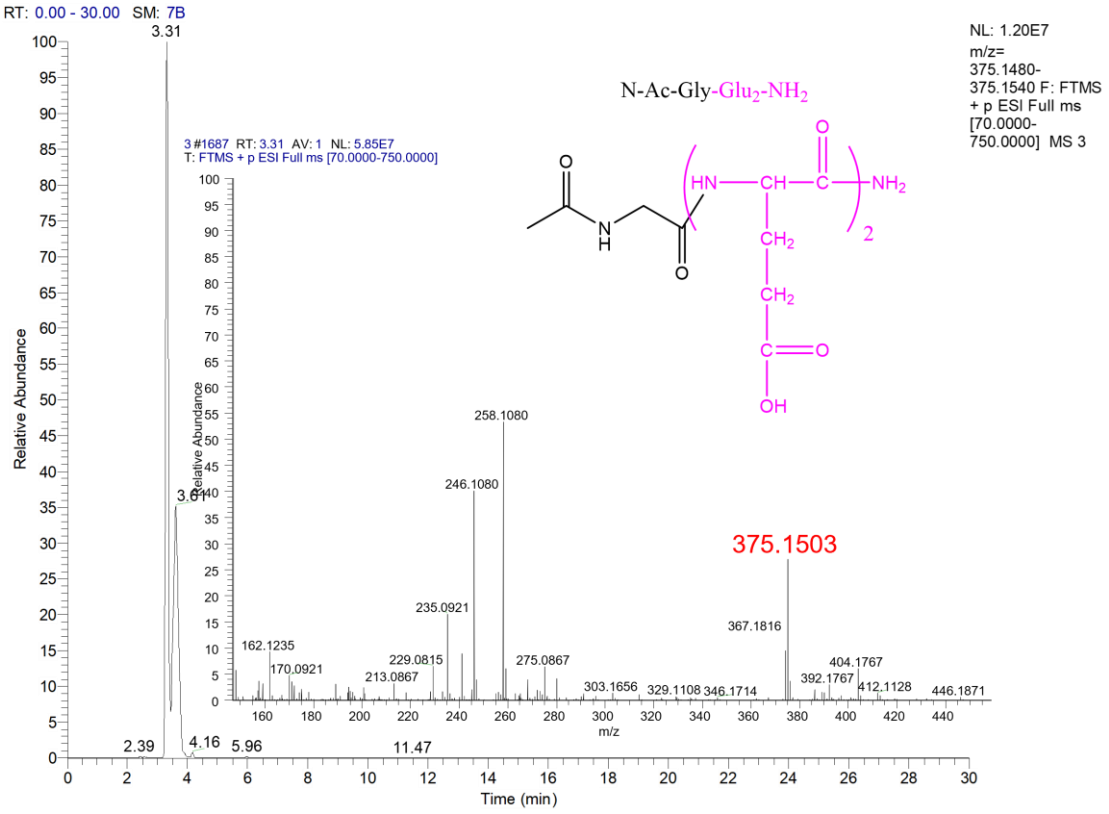

Fig. S101 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 375.1503 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Glu_2-NH_2 with a retention time of 3.31 min.

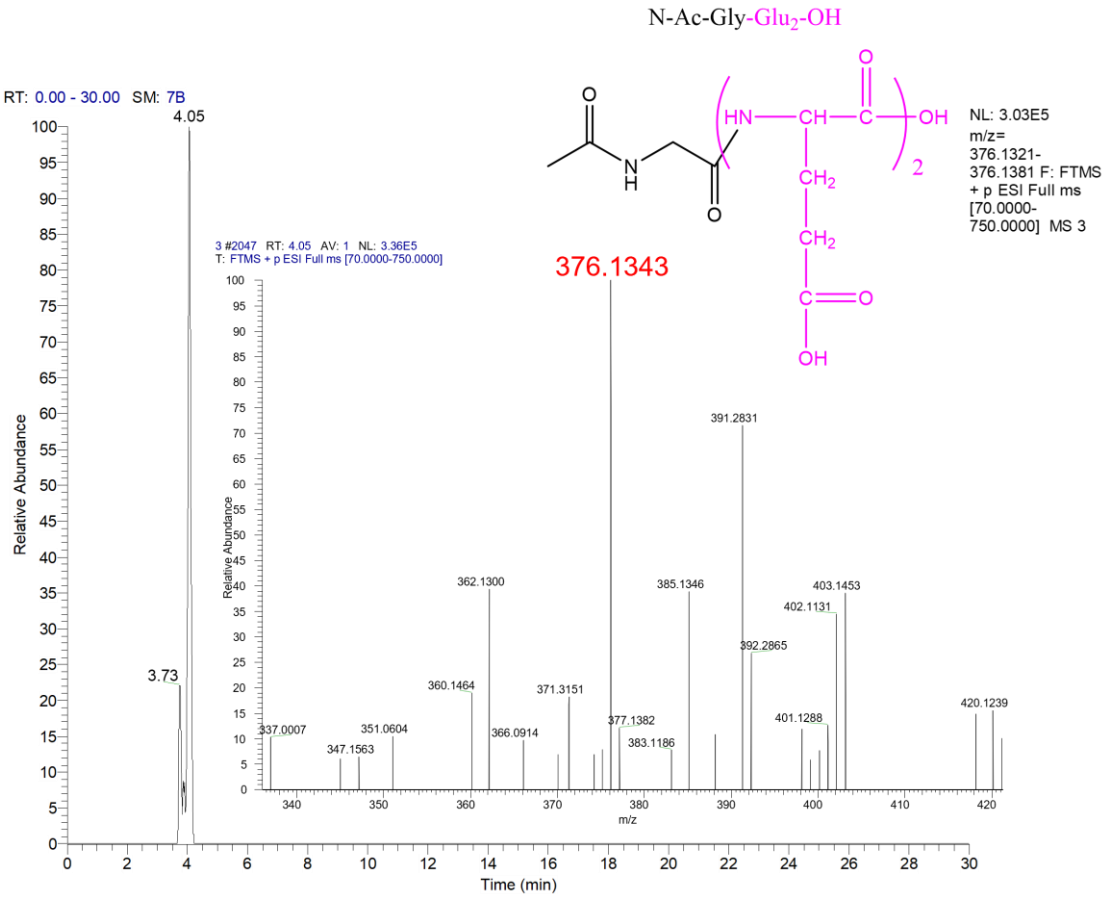

Fig. S102 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 376.1343 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Glu$_2$-OH with a retention time of 4.05 min.

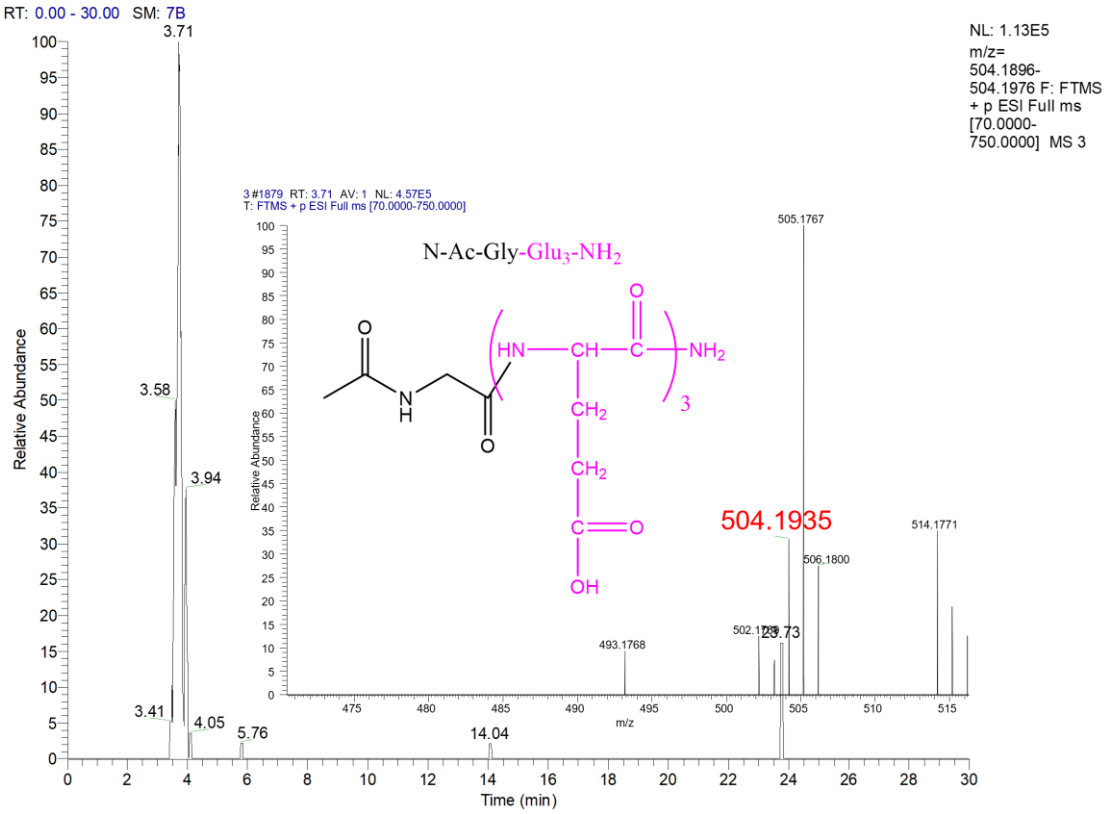

Fig. S103 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 504.1935 was analyzed and its EIC corresponded to the tetramer N-Ac-Gly-Glu_3-NH_2 with a retention time of 3.71 min.

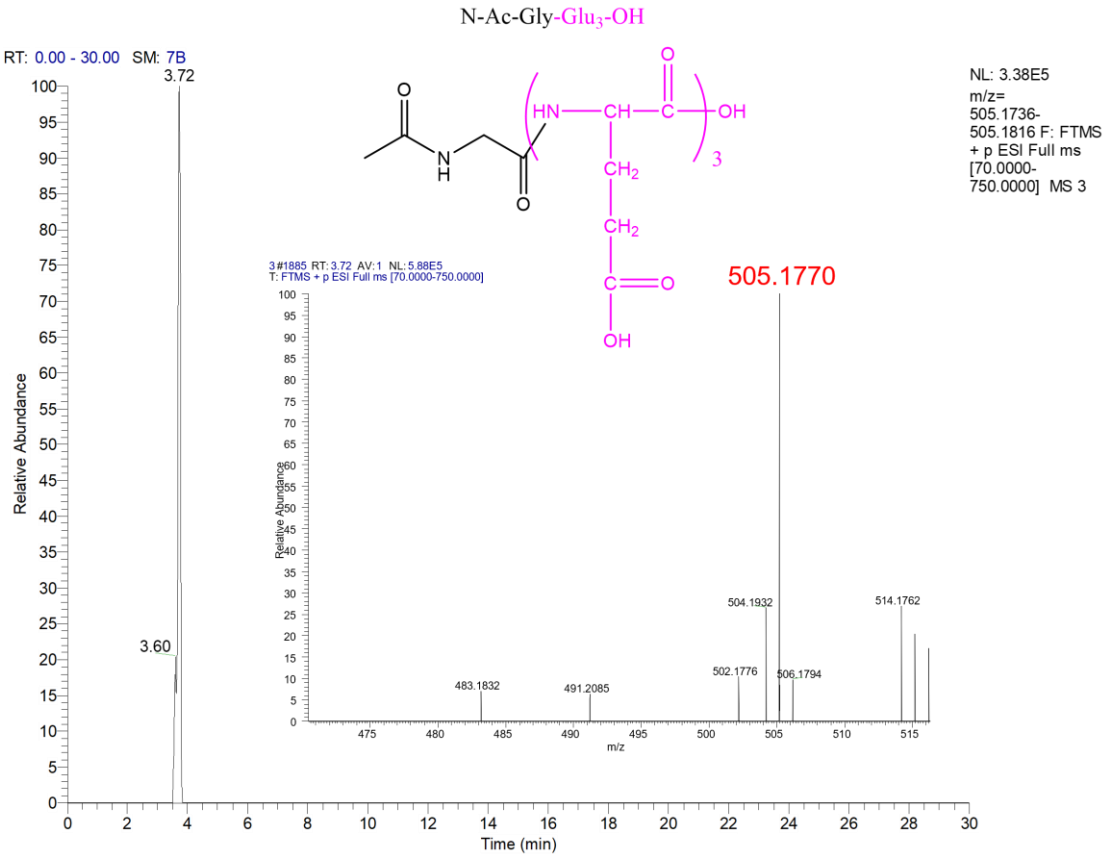

Fig. S104 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 505.1770 was analyzed and its EIC corresponded to the tetrapeptide N-Ac-Gly-Glu_3-OH with a retention time of 3.72 min.

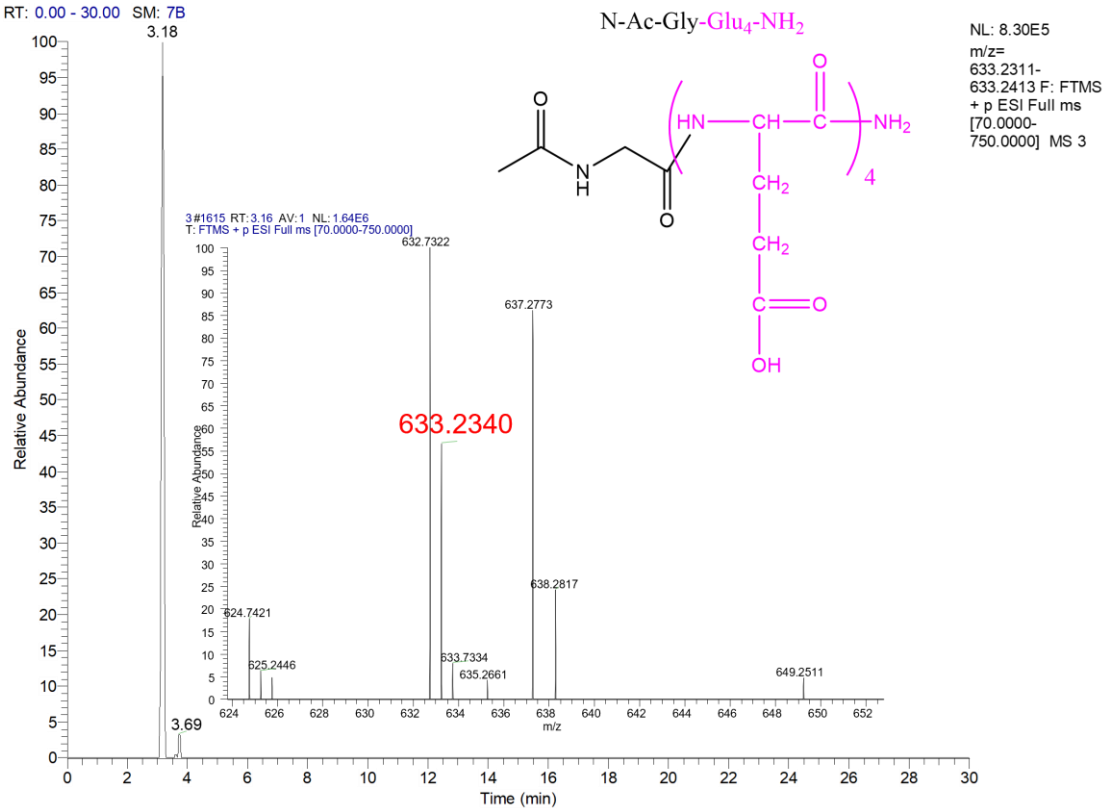

Fig. S105 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 633.2340 was analyzed, and its EIC corresponded to the pentamer N-Ac-Gly-Glu_4-NH_2 with a retention time of 3.16 min.

2.23 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Ser-NH_2.（Figs. S106-S110）

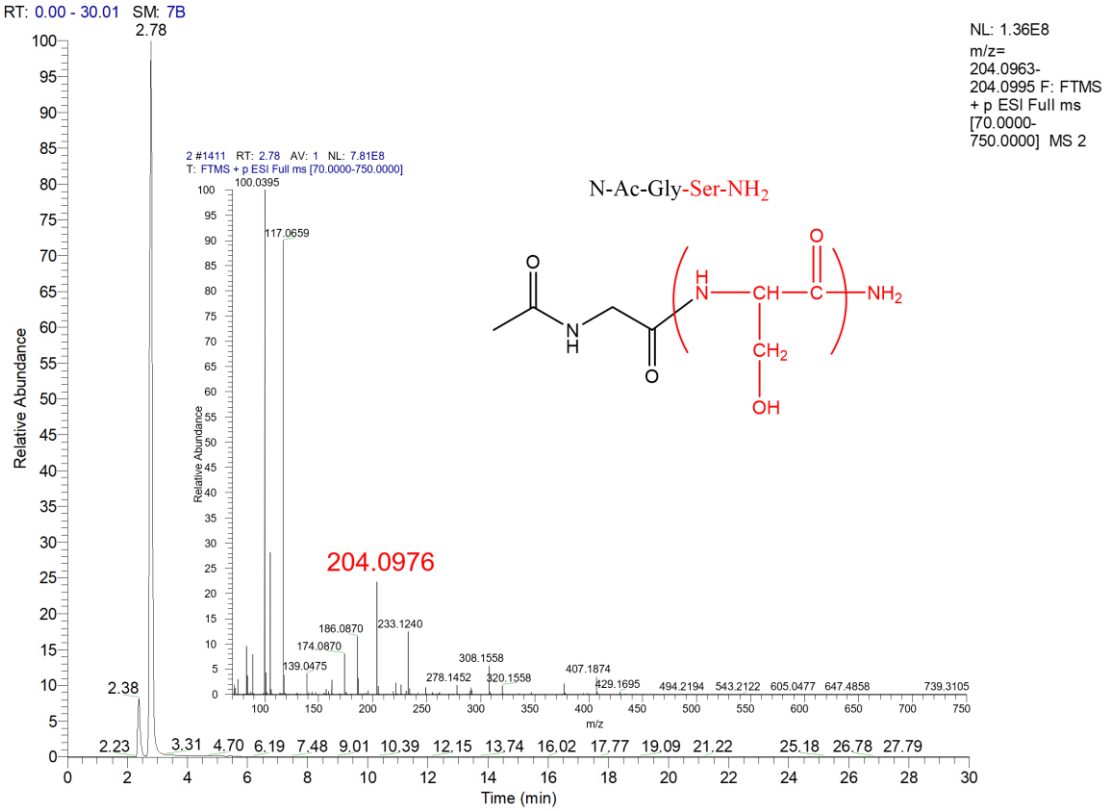

Fig. S106 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 204.0976 was analyzed and its EIC corresponds to the dimer N-Ac-Gly-Ser-NH_2 with a retention time of 2.78 min.

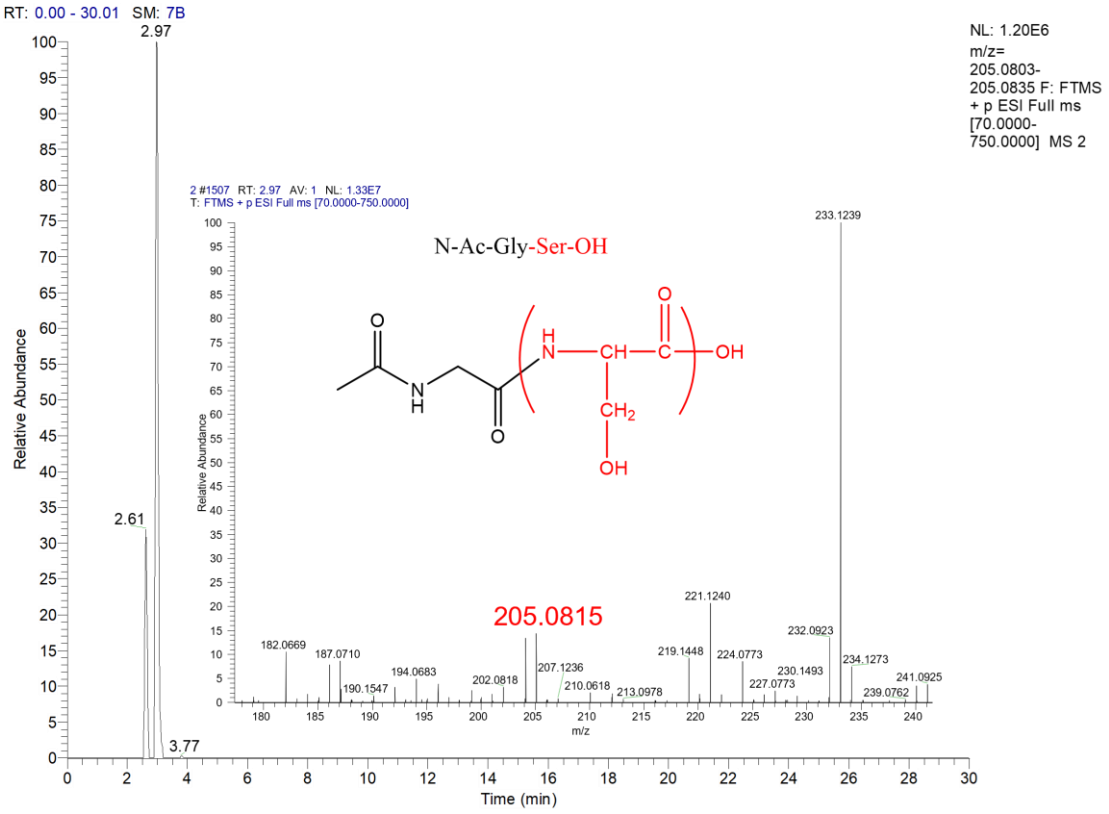

Fig. S107 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 205.0815 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Ser-OH with a retention time of 2.97 min.

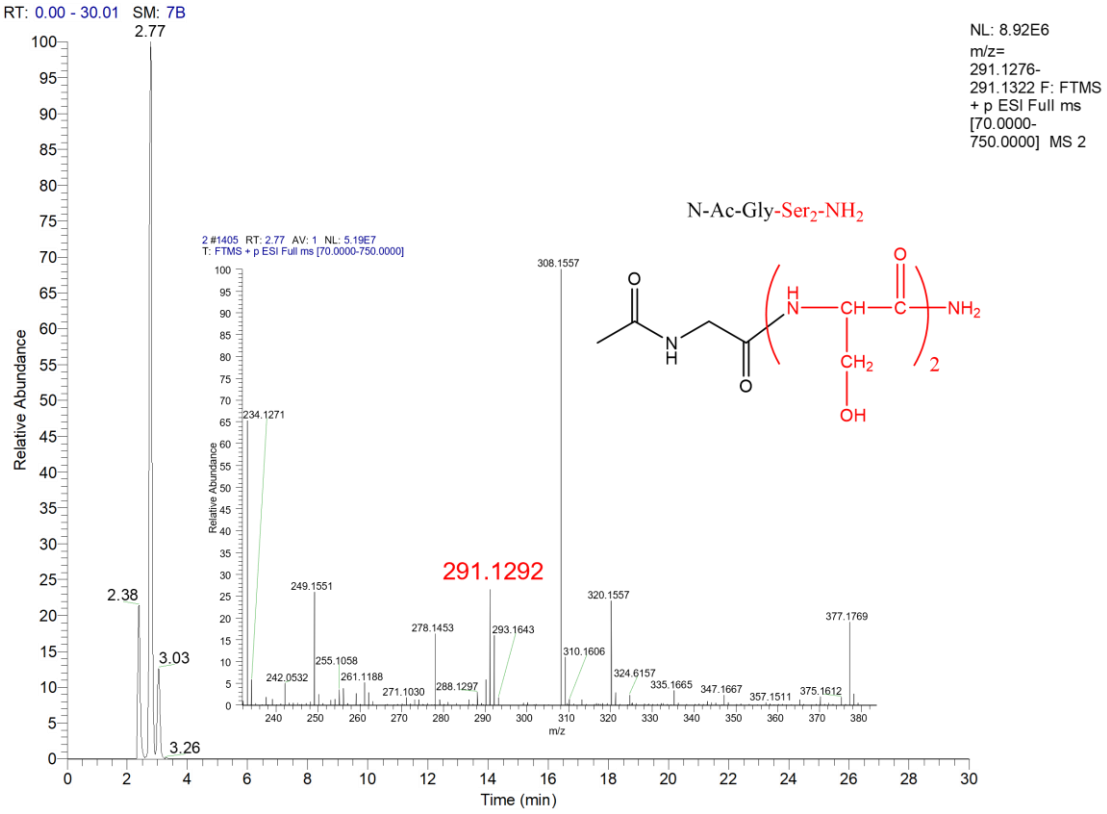

Fig. S108 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 291.1292 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Ser_2-NH_2 with a retention time of 2.77 min.

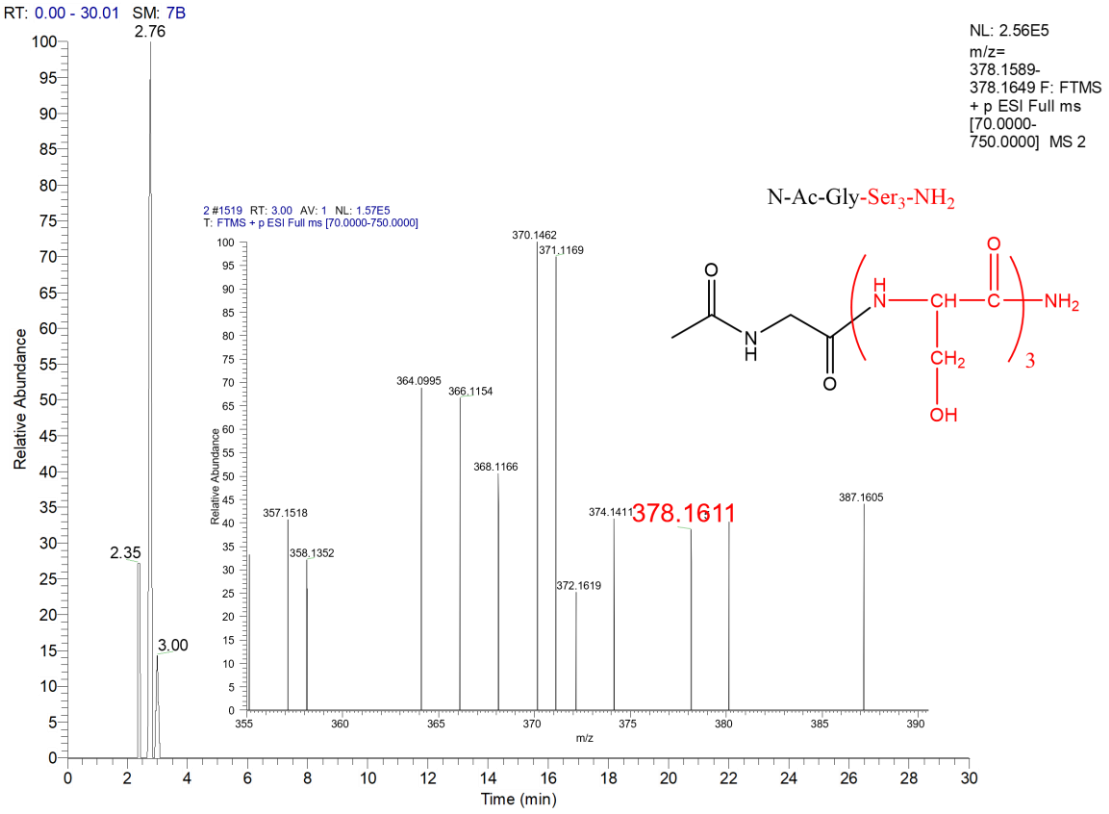

Fig. S109 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 378.1611 was analyzed and its EIC corresponded to the tetracer N-Ac-Gly-Ser_3-NH_2 with a retention time of 3.00 min.

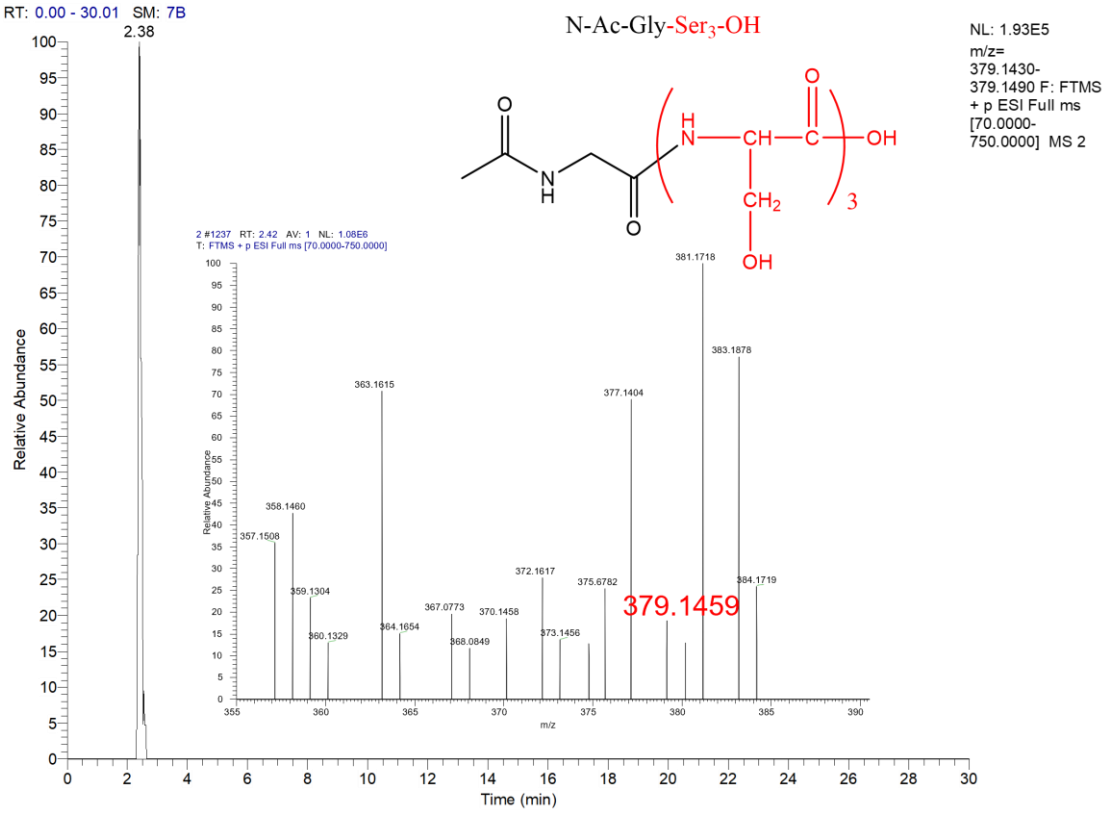

Fig. S110 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 379.1459 was analyzed, and its EIC corresponded to the tetrapeptide N-Ac-Gly-Ser$_3$-OH with a retention time of 2.42 min.

2.24 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Val-NH_2.（Figs. S111-S116）

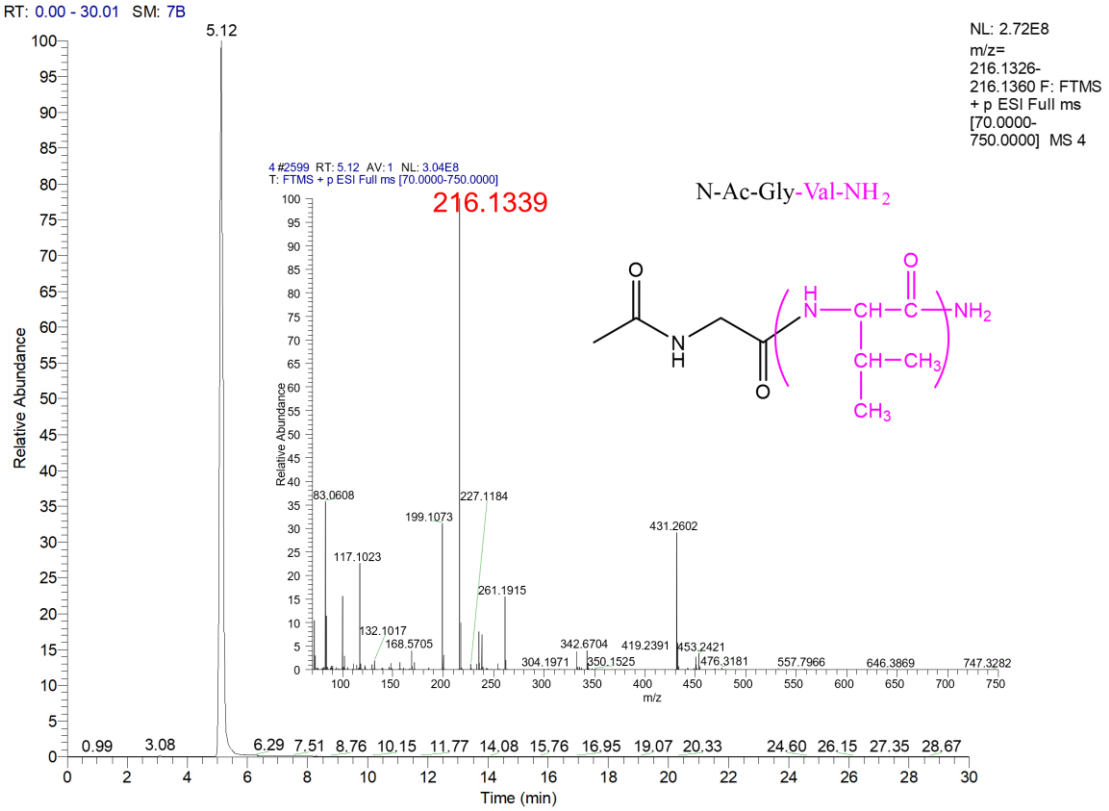

Fig. S111 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 216.1339 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Val-NH_2 with a retention time of 5.12 min.

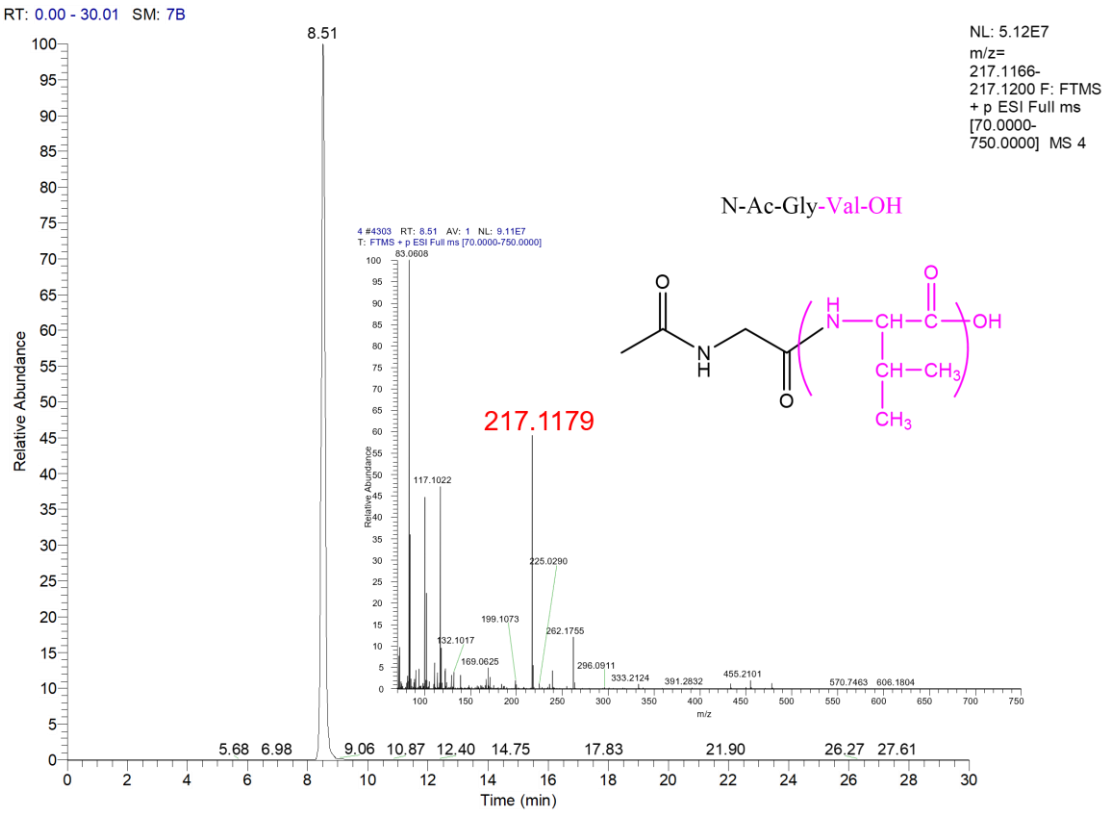

Fig. S112 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 217.1179 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Val-OH with a retention time of 8.51 min.

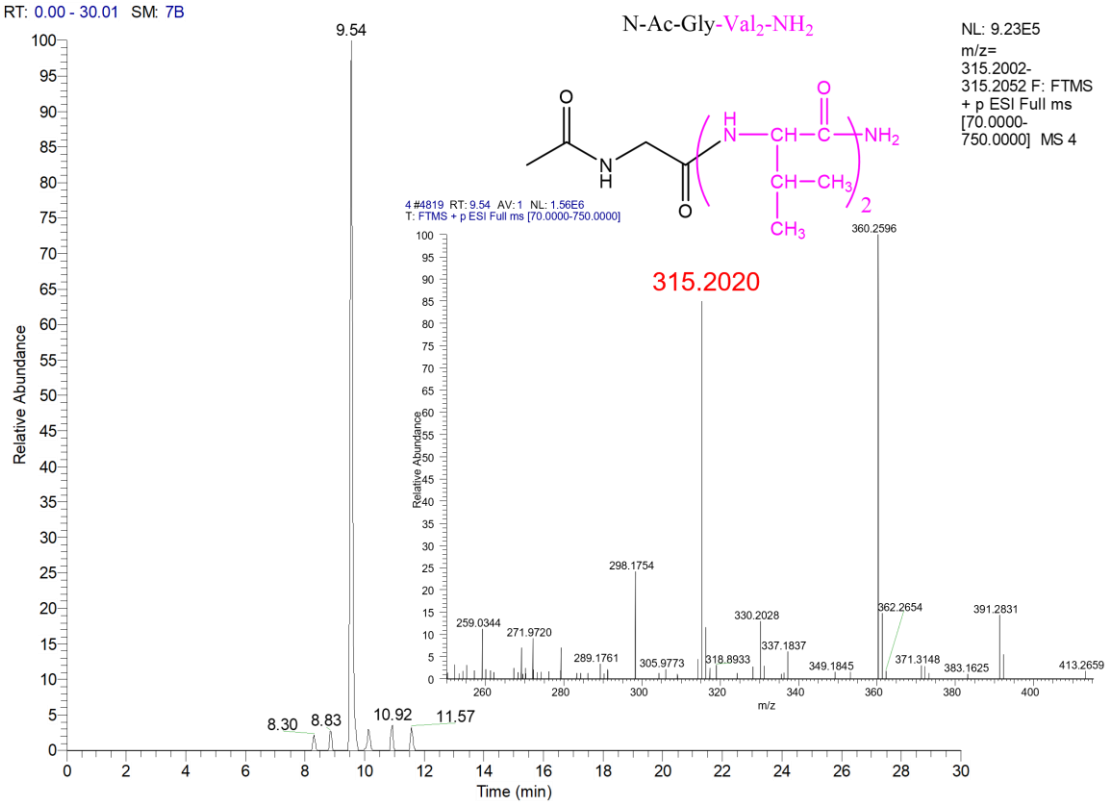

Fig. S113 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 315.2020 was analyzed and its EIC corresponds to the trimer N-Ac-Gly-Val_2-NH_2 with a retention time of 9.54 min.

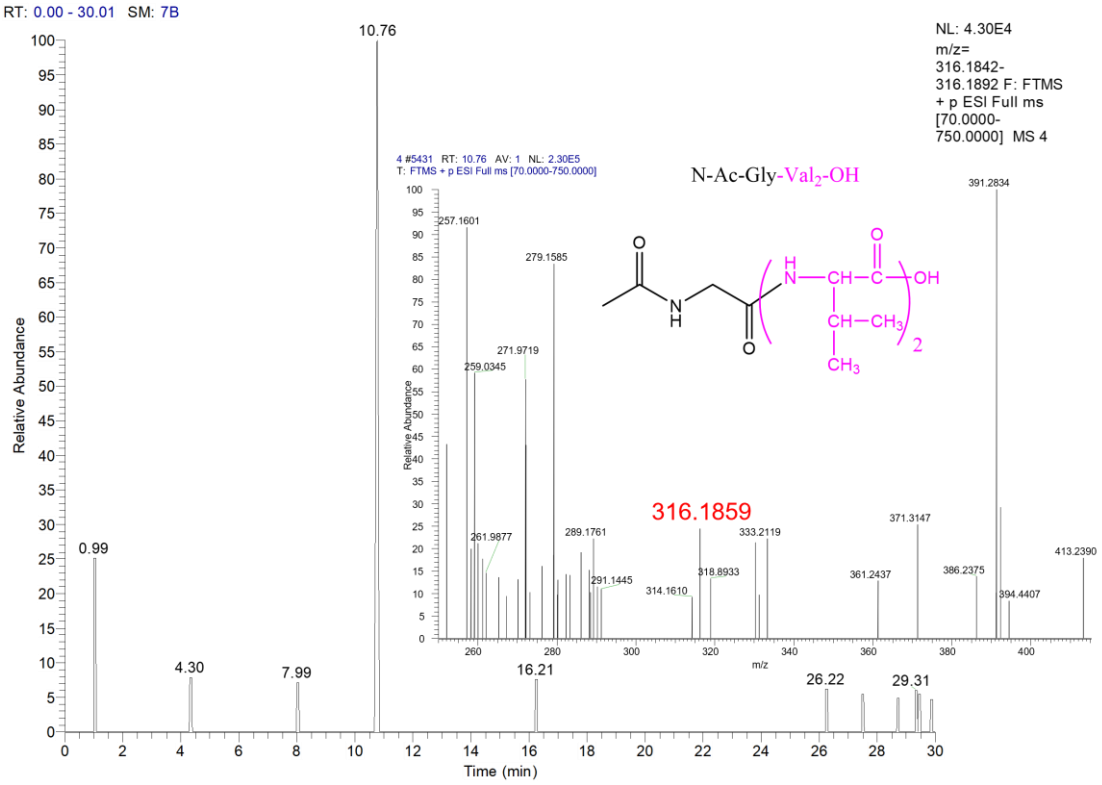

Fig. S114 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 316.1859 was analyzed and its EIC corresponded to the tripeptide N-Ac-Gly-Val_2-OH with a retention time of 10.76 min.

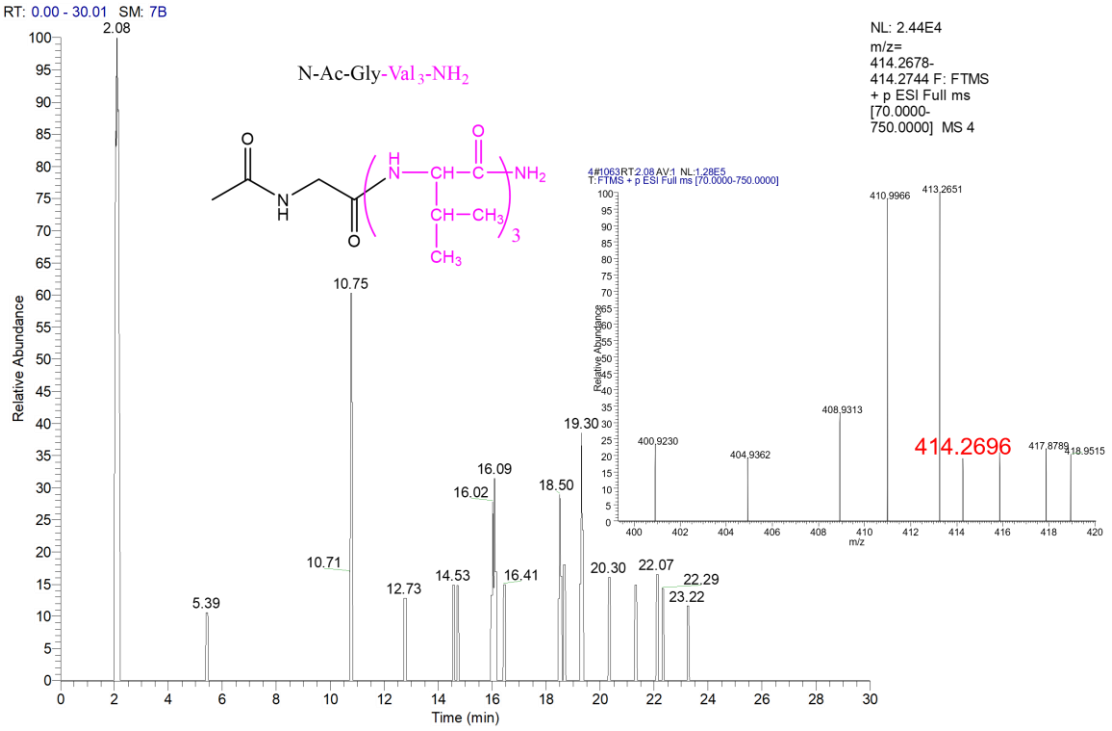

Fig. S115 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 414.2696 was analyzed and its EIC corresponded to the tetrimer N-Ac-Gly-Val_3-NH_2 with a retention time of 2.08 min.

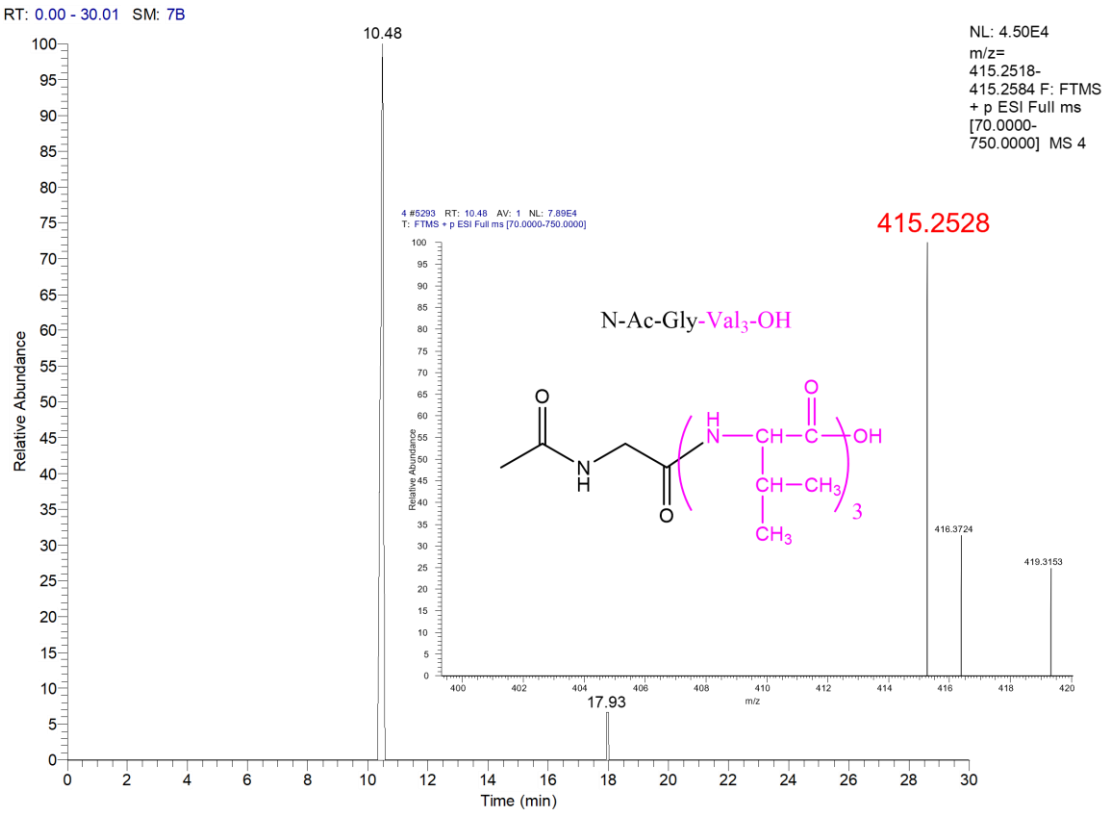

Fig. S116 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 415.2528 was analyzed and its EIC corresponded to the tetrapeptide N-Ac-Gly-Val_3-OH with a retention time of 10.48 min.

2.25 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Arg-NH_2.（Figs. S117-S119）

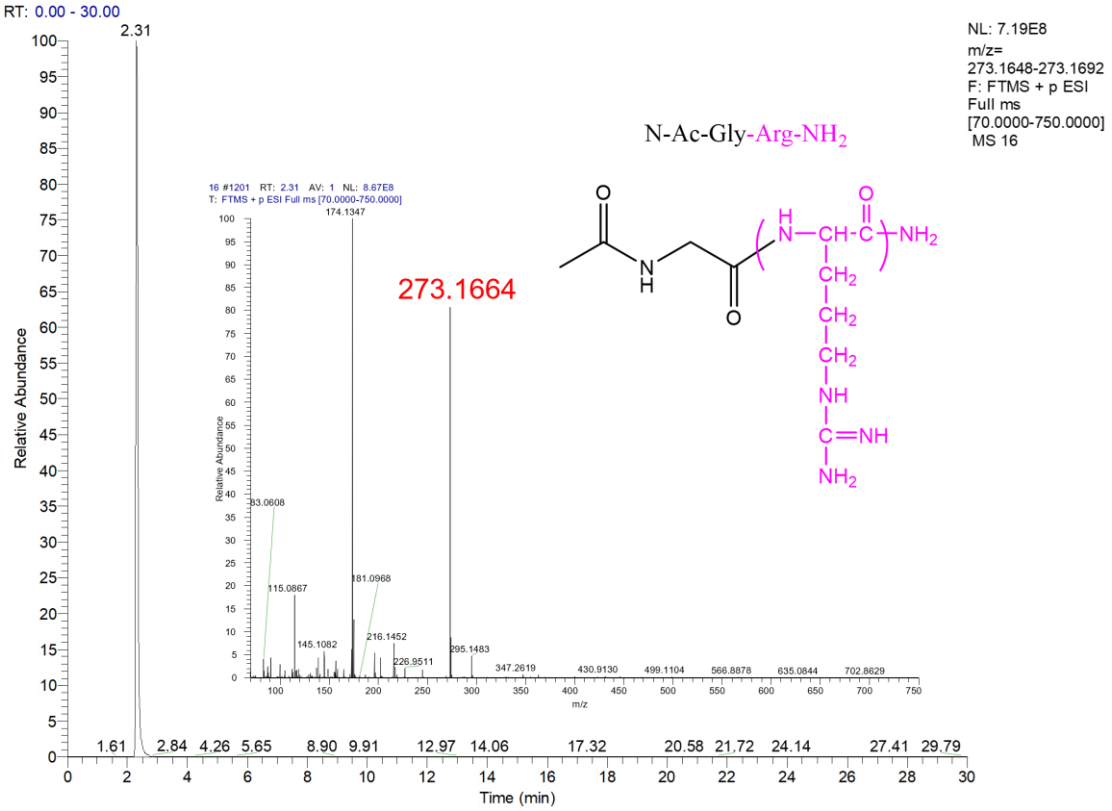

Fig. S117 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 273.1664 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Arg-NH_2 with a retention time of 2.31 min.

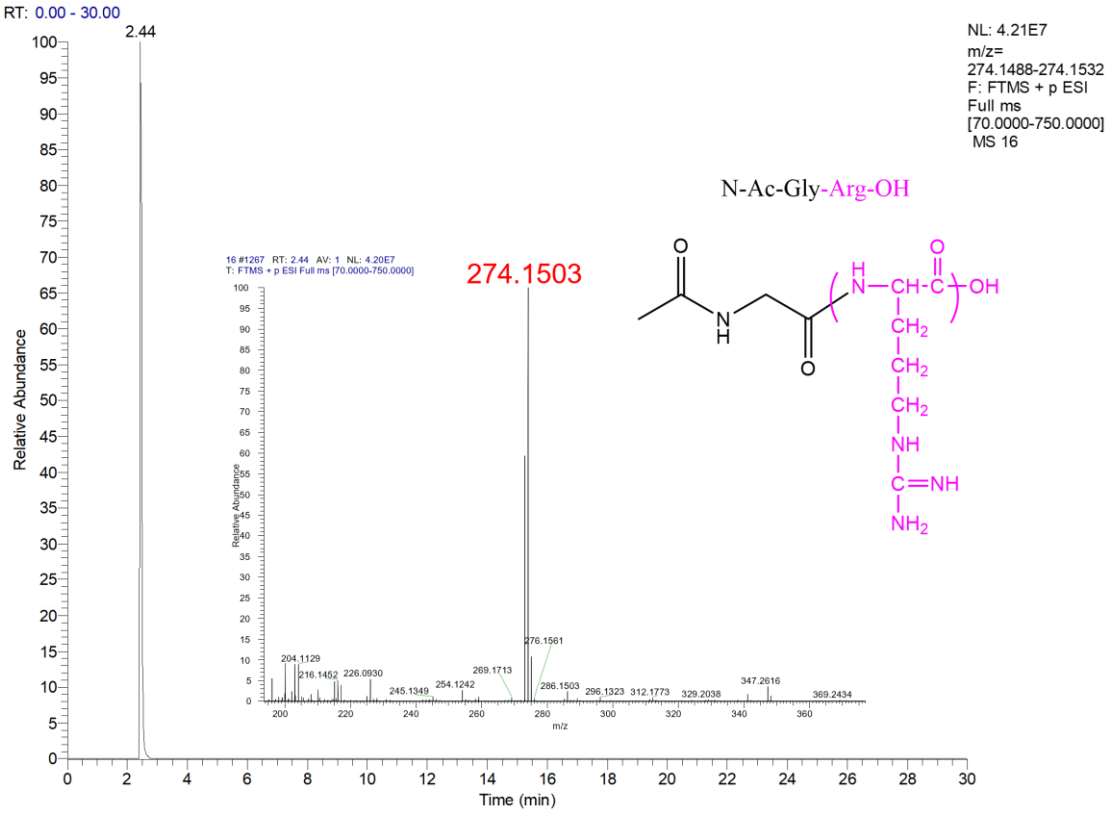

Fig. S118 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 274.1503 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Arg-OH with a retention time of 2.44 min.

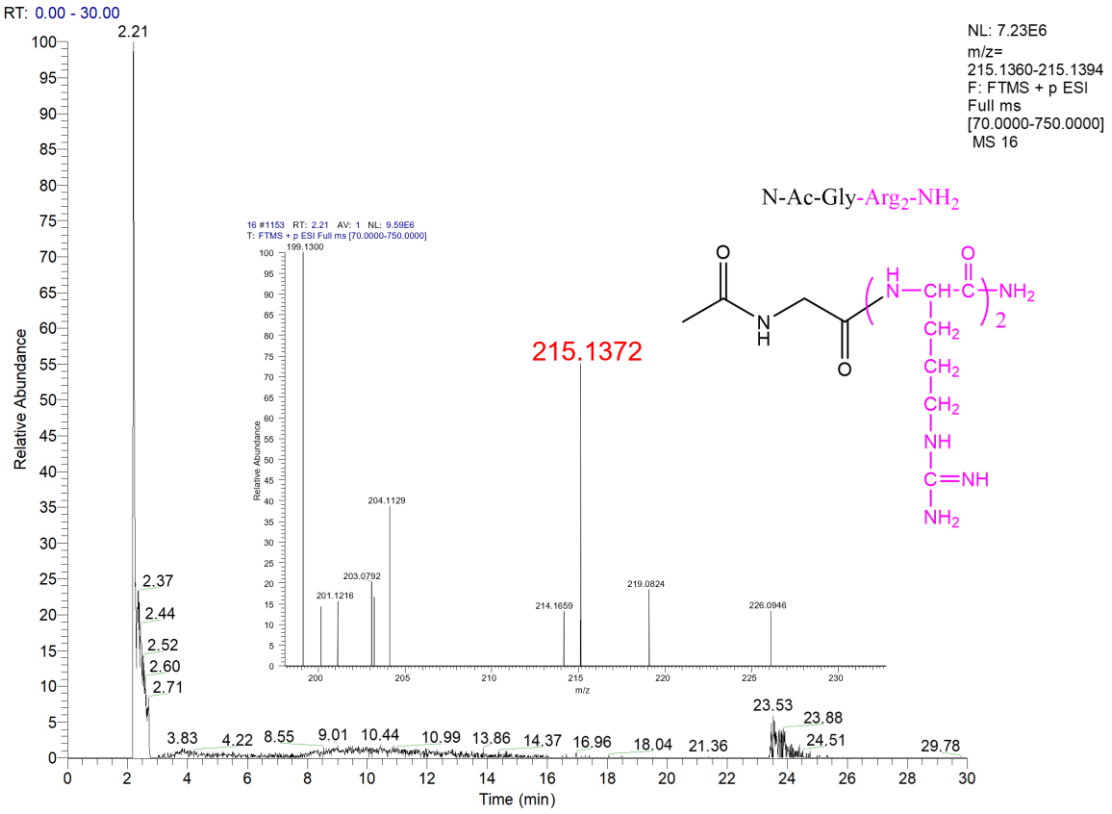

Fig. S119 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 215.1372 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Arg_2-NH_2 with a retention time of 2.21 min.

2.26 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Lys-NH_2.（Figs. S120-S122）

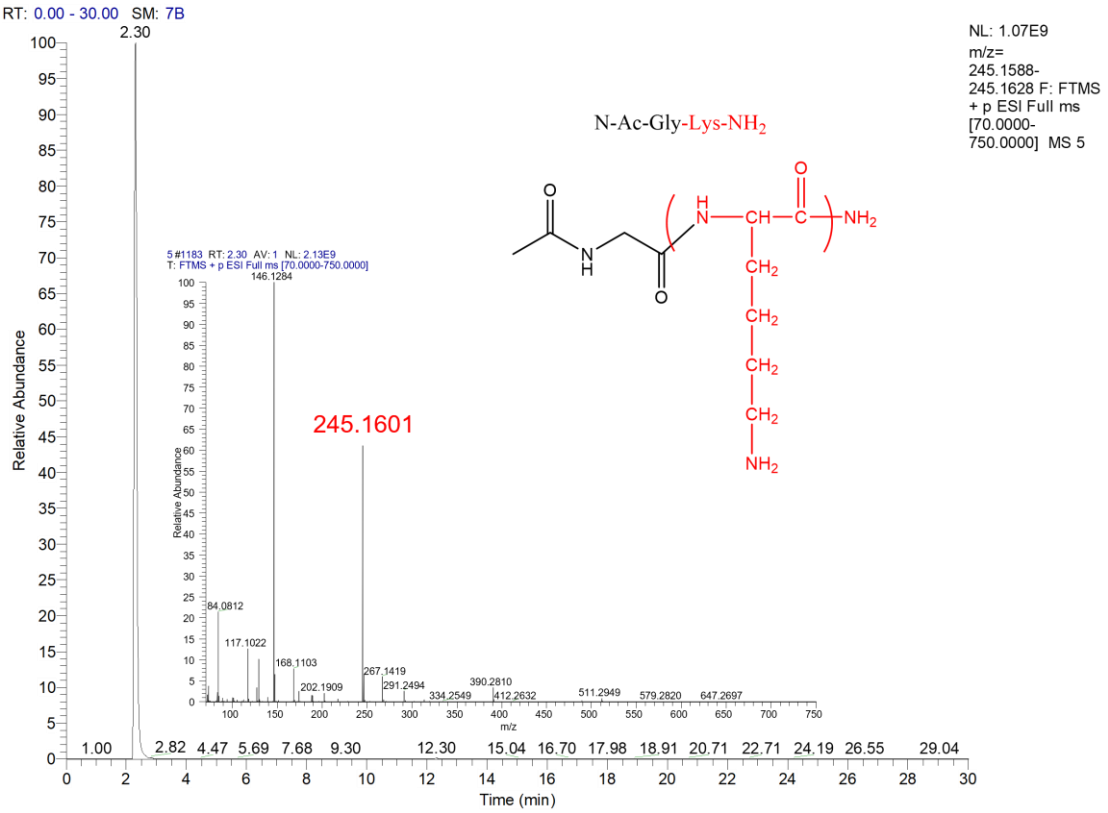

Fig. S120 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 245.1601 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Lys-NH_2 with a retention time of 2.30 min.

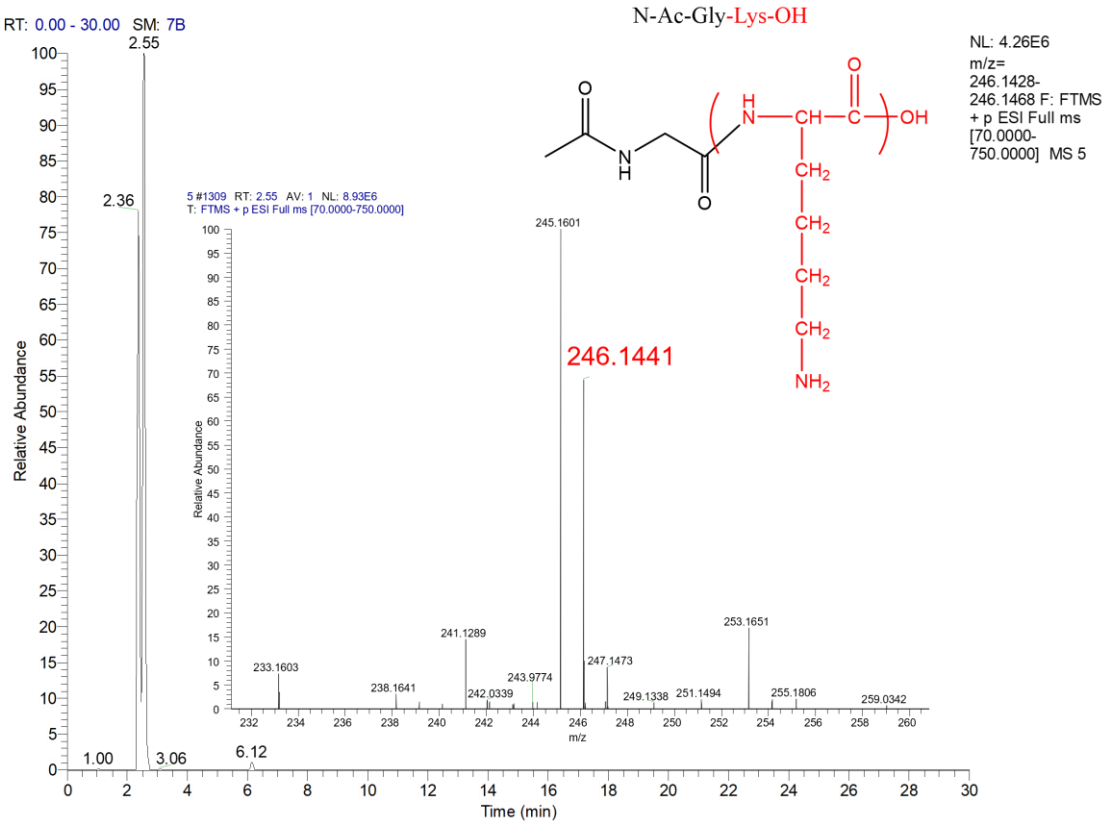

Fig. S121 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 246.1441 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Lys-OH with a retention time of 2.55 min.

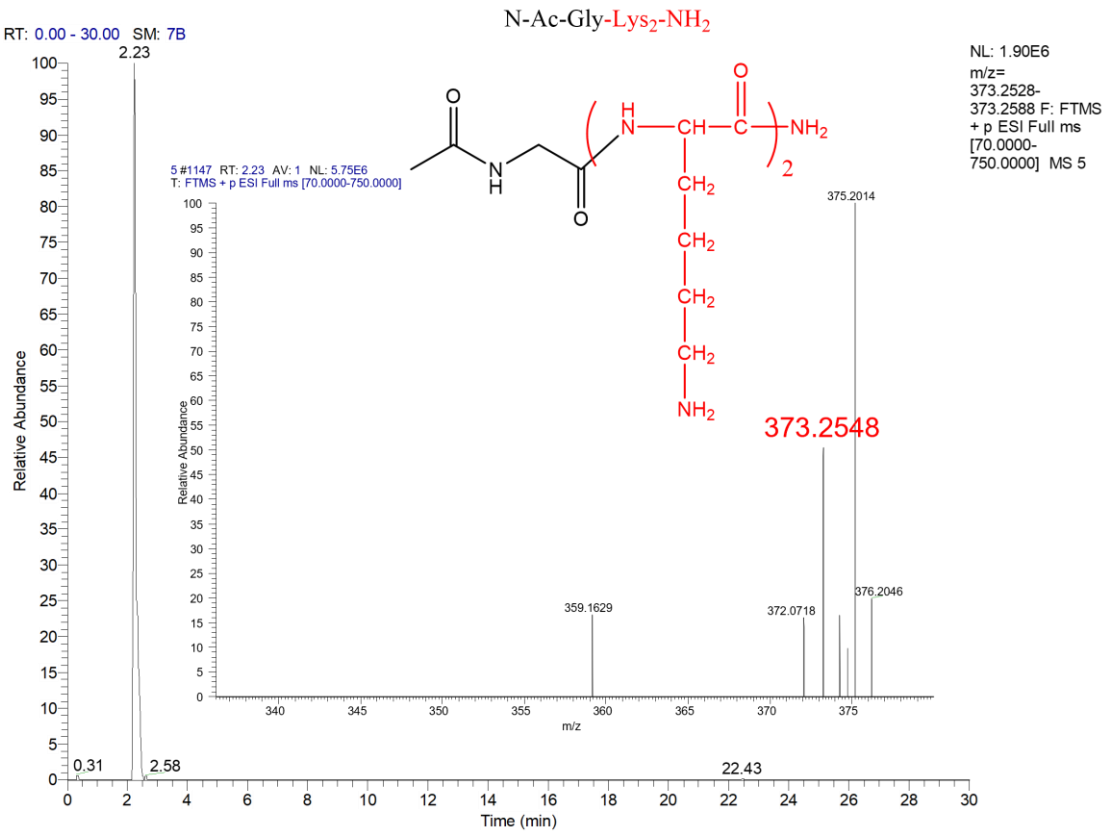

Fig. S122 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 373.2548 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Lys_2-NH_2 with a retention time of 2.23 min.

2.27 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Leu-NH_2.（Figs. S123-S127）

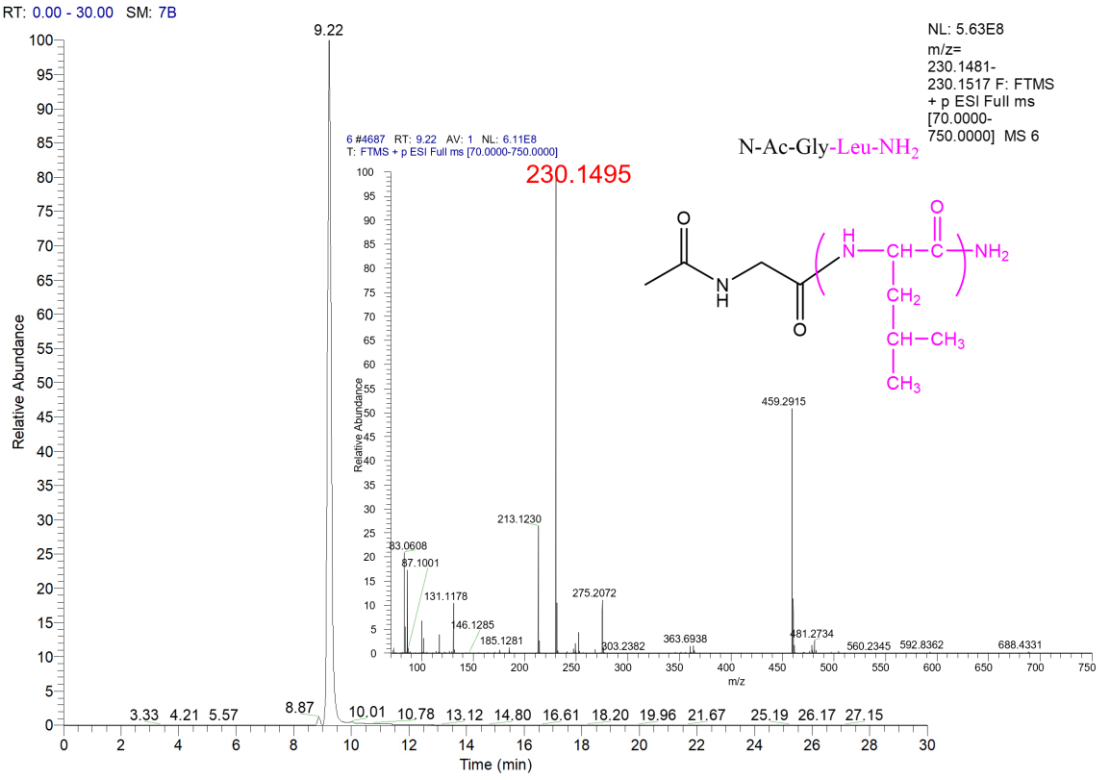

Fig. S123 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 230.1495 was analyzed and its EIC corresponded to the dimer N-Ac-Gly-Leu-NH_2 with a retention time of 9.22 min.

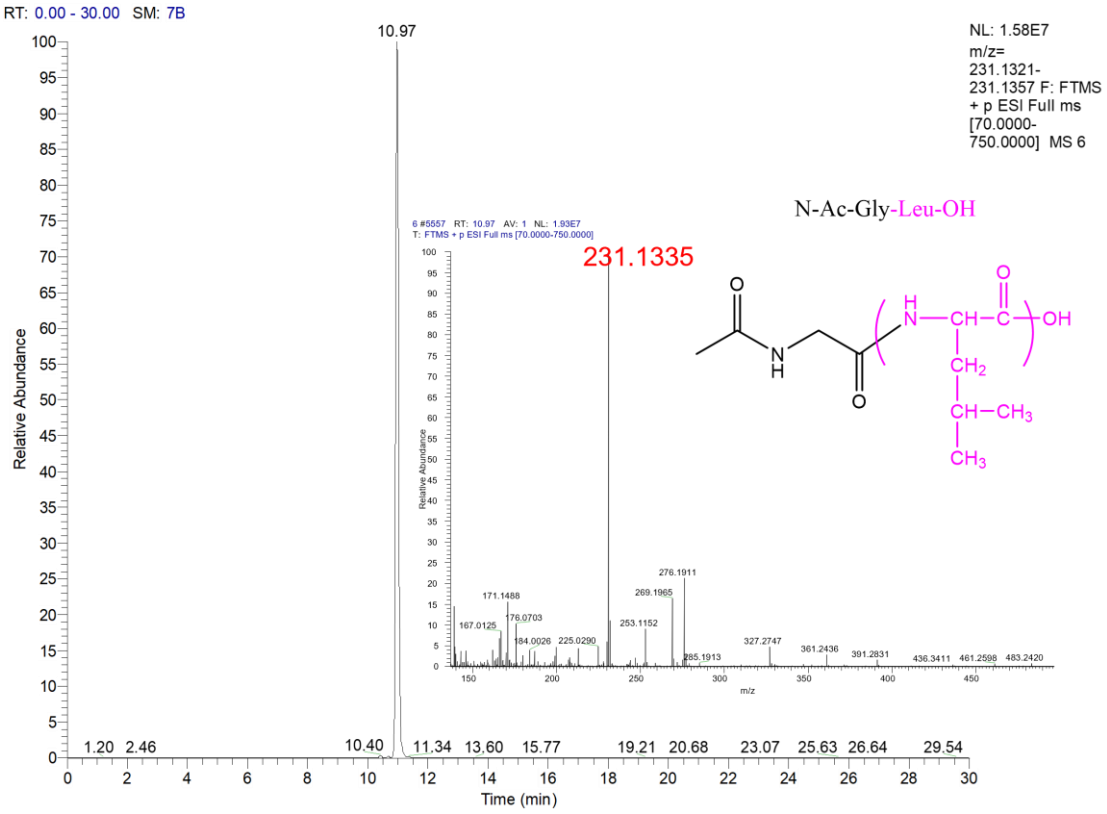

Fig. S124 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 231.1335 was analyzed and its EIC corresponded to the dipeptide N-Ac-Gly-Leu-OH with a retention time of 10.97 min.

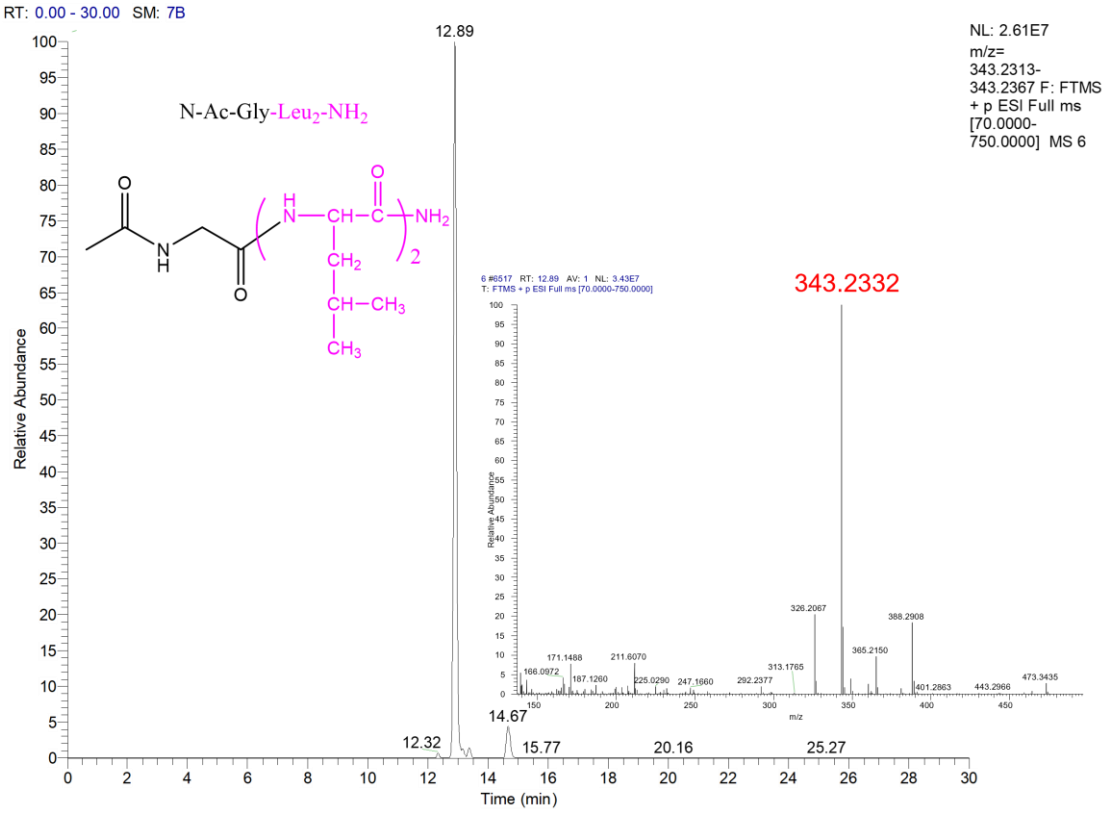

Fig. S125 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 343.2332 was analyzed and its EIC corresponded to the trimer N-Ac-Gly-Leu_2-NH_2 with a retention time of 12.89 min.

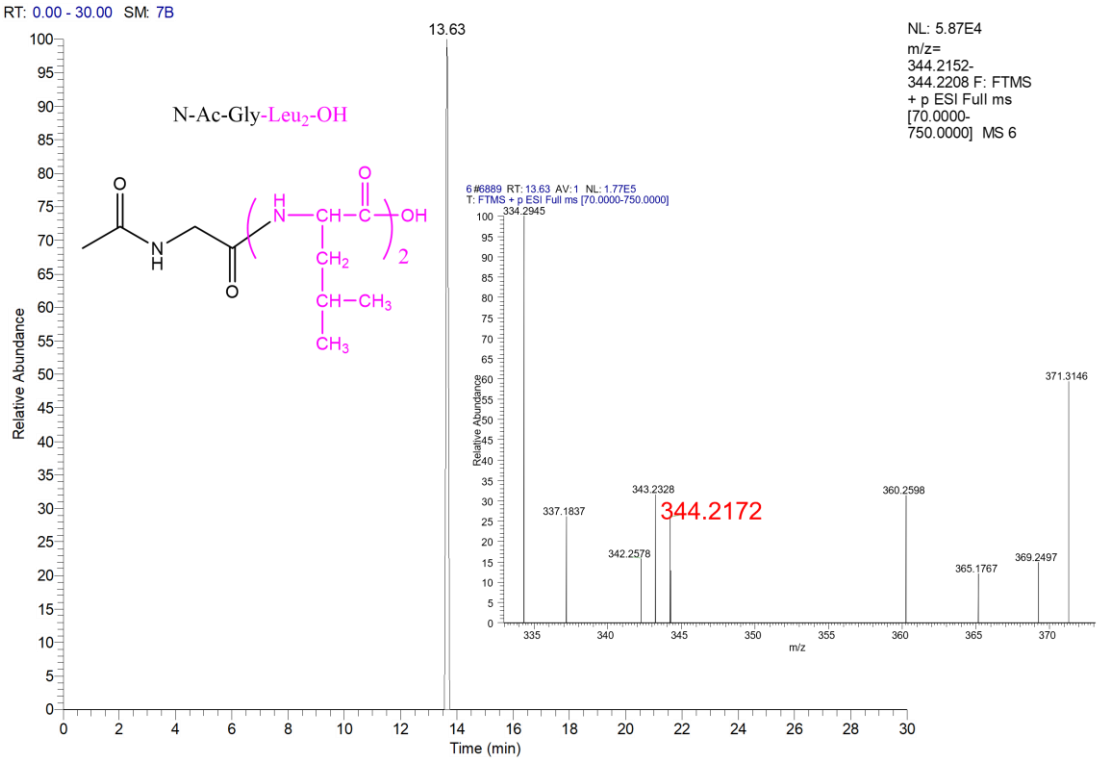

Fig. S126 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 344.2172 was analyzed and its EIC corresponded to the tripeptide N-Ac-Gly-Leu$_2$-OH with a retention time of 13.63 min.

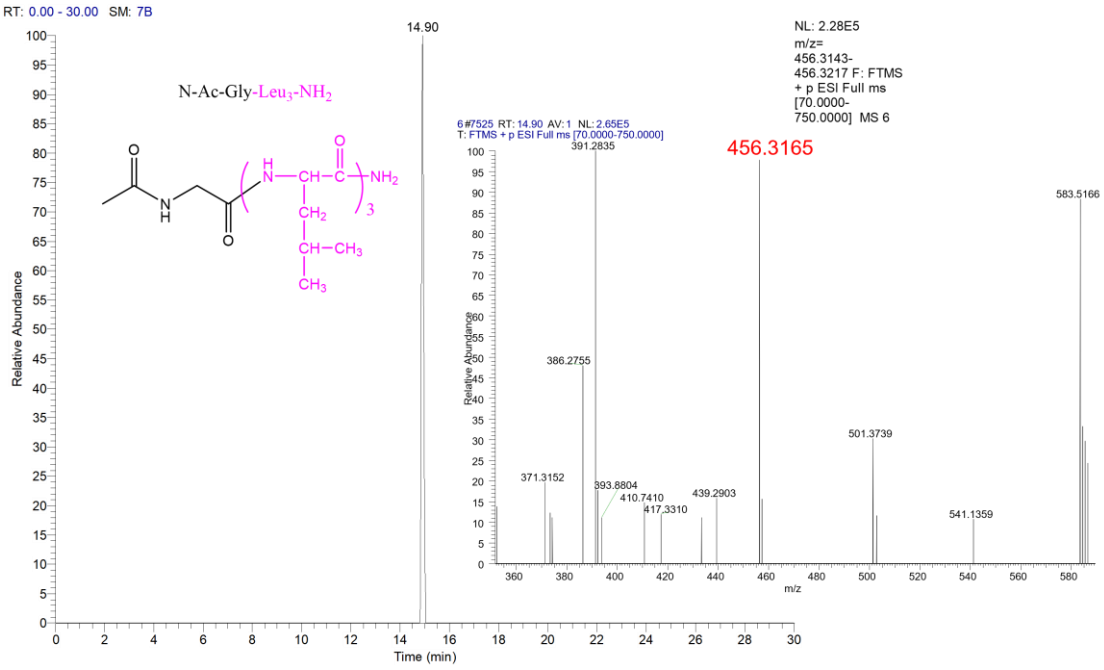

Fig. S127 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 456.3165 was analyzed and its EIC corresponded to the tetramer N-Ac-Gly-Leu$_3$-NH$_2$ with a retention time of 14.90 min.

2.28 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Phe-NH_2.（Figs. S128-S133）

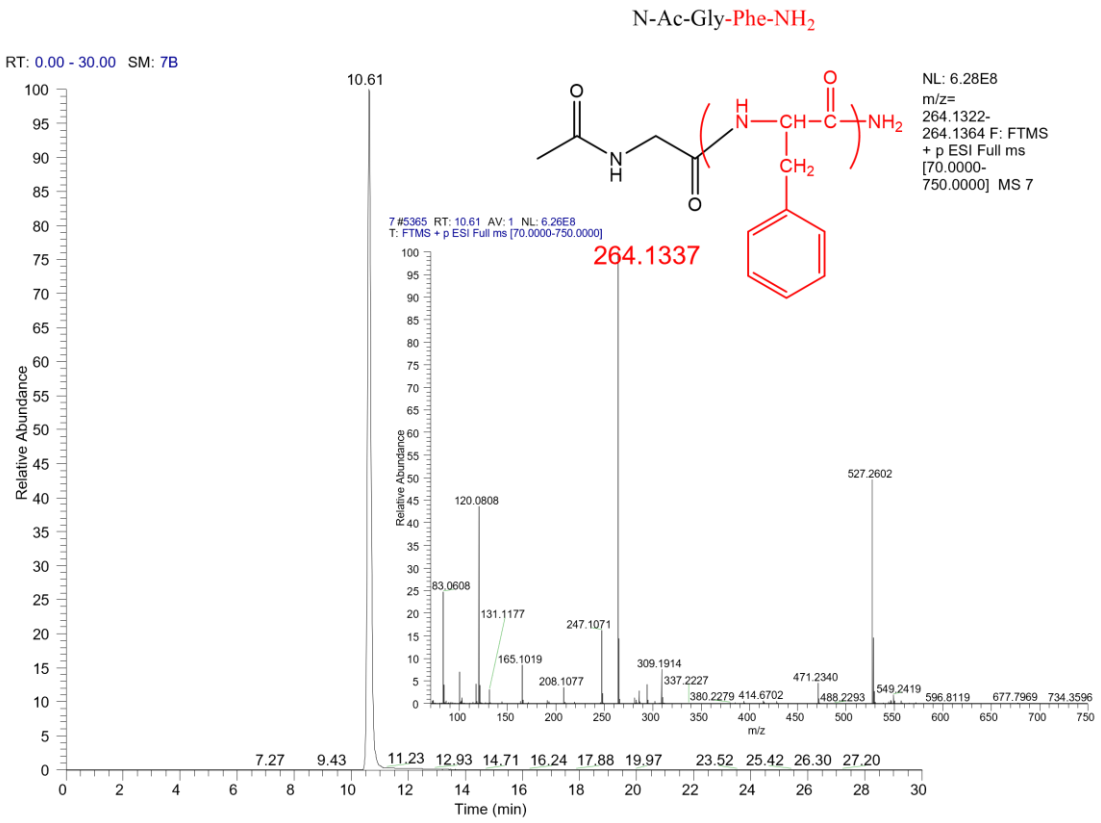

Fig. S128 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 264.1337 was analyzed, and its EIC corresponds to the dimer N-ac-Gly-Phe-NH_2 with a retention time of 10.61 min.

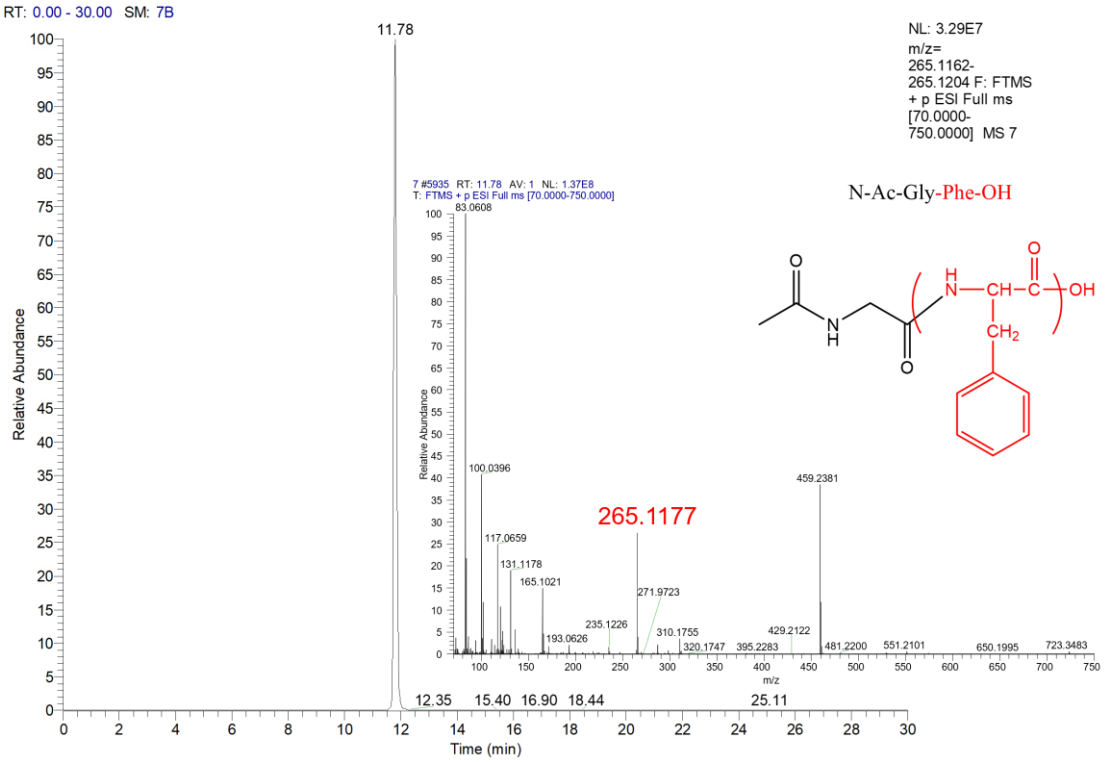

Fig. S129 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 265.1177 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Phe-OH with a retention time of 11.78 min.

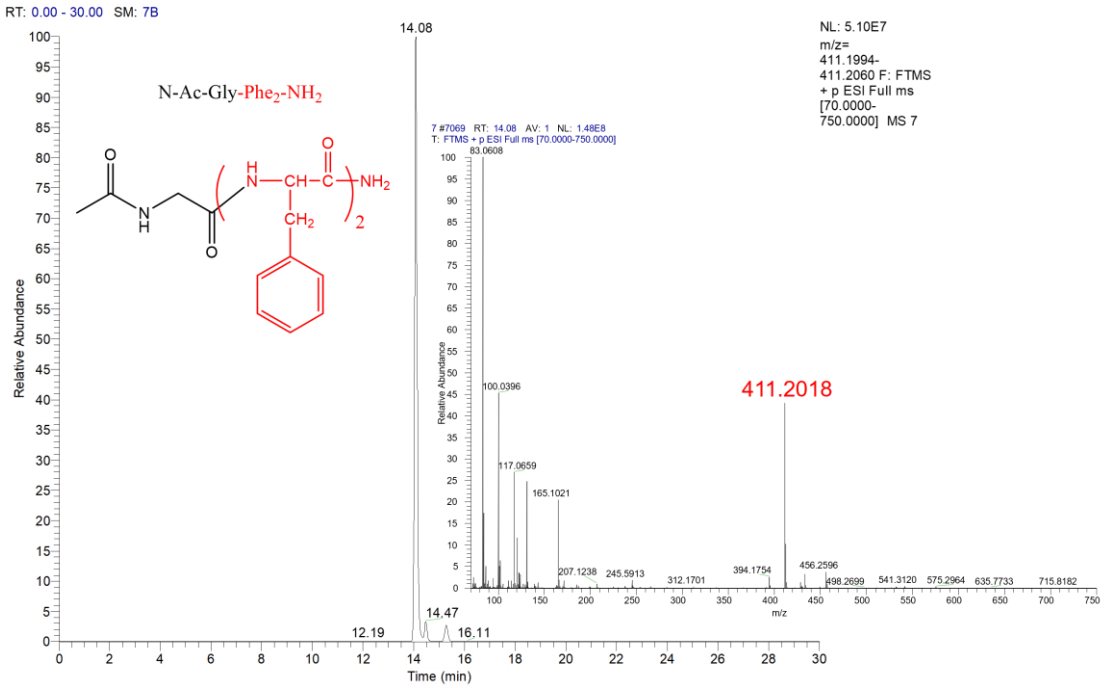

Fig. S130 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 411.2018 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-Phe_2-NH_2 with a retention time of 14.08 min.

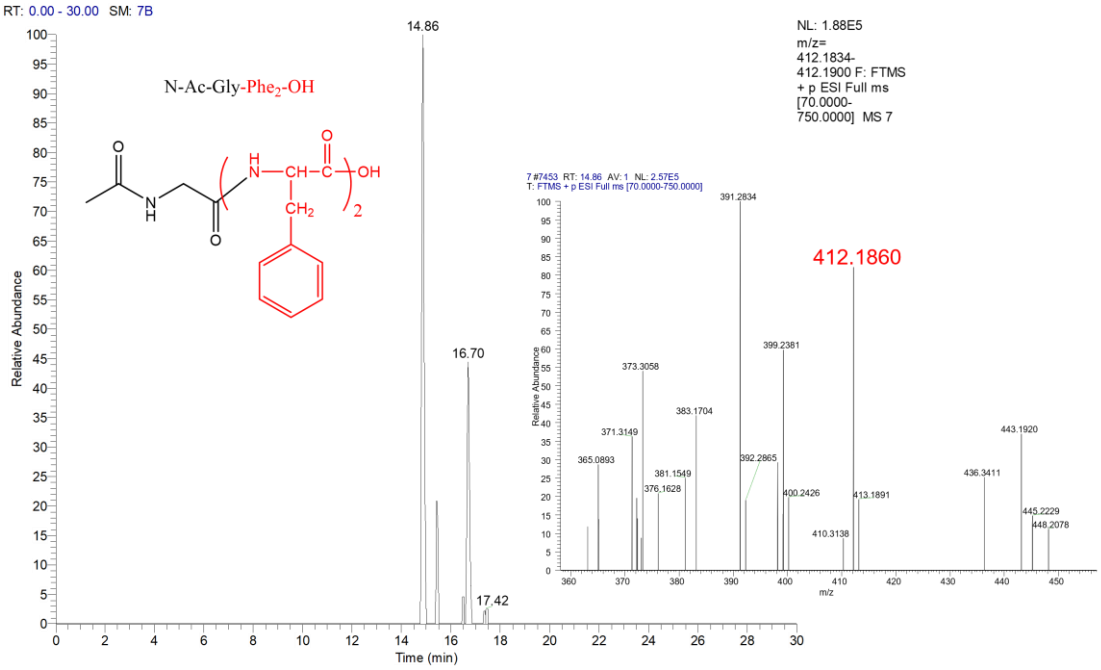

Fig. S131 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 412.1860 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Phe$_2$-OH with a retention time of 14.86 min.

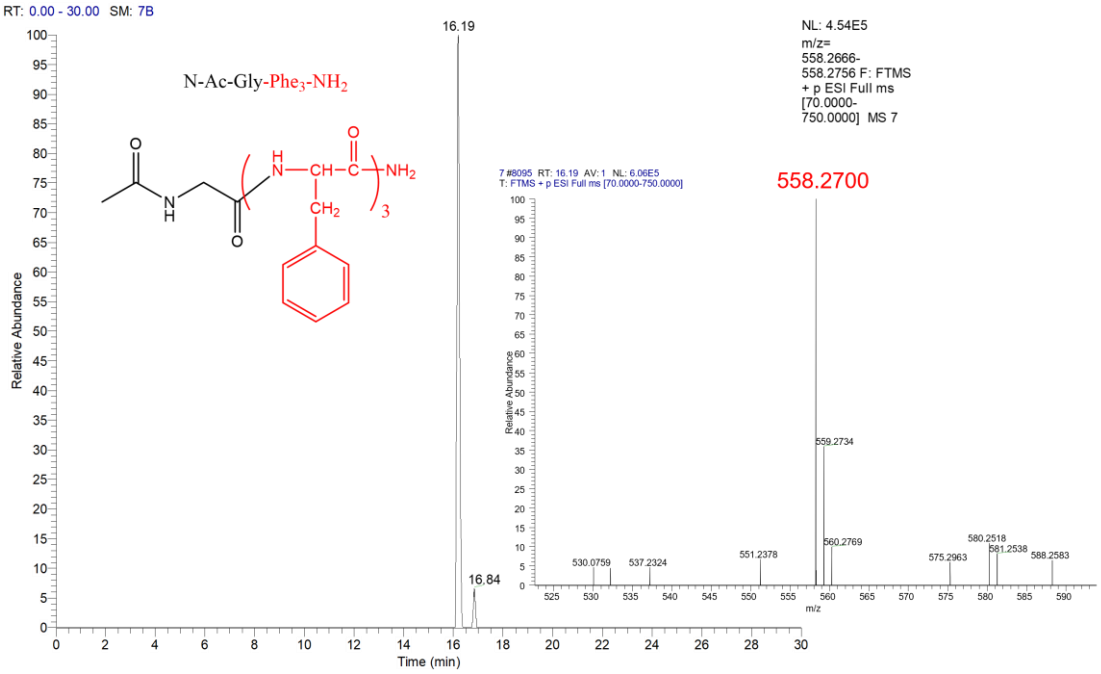

Fig. S132 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 558.2700 was analyzed, and its EIC corresponds to the tetramer N-Ac-Gly-Phe_3-NH_2 with a retention time of 16.19 min.

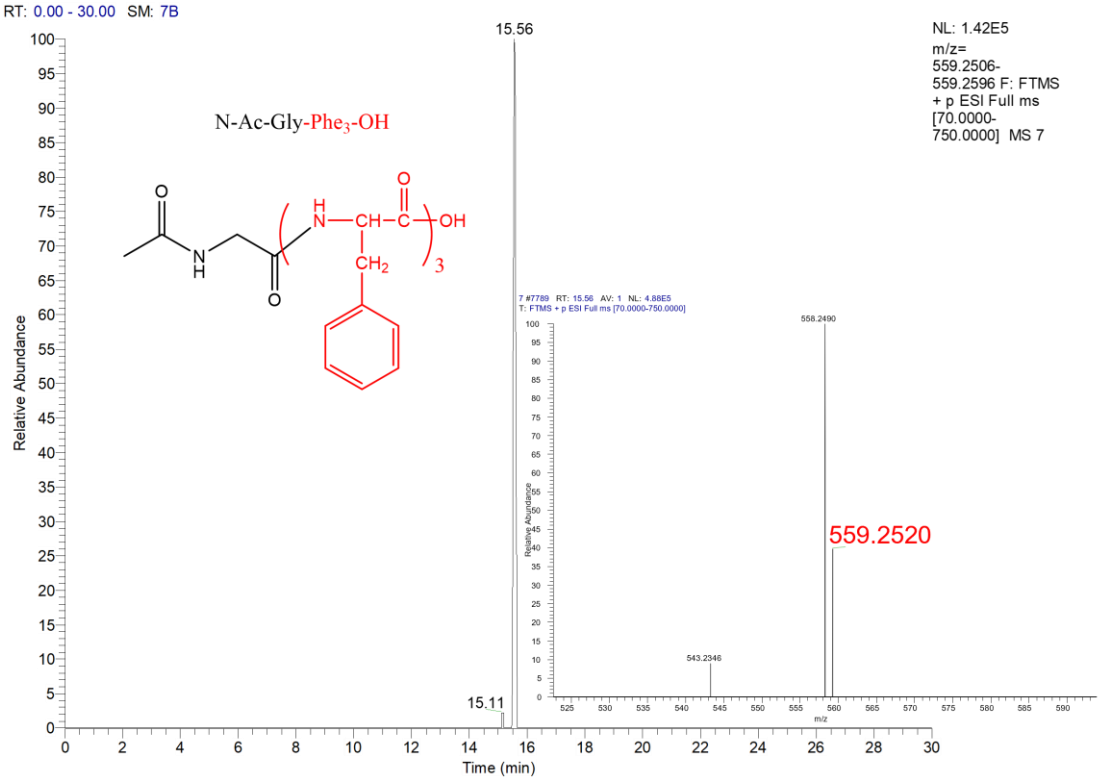

Fig. S133 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 559.2520 was analyzed. The EIC corresponds to the tetrapeptide N-Ac-Gly-Phe$_3$-OH with a retention time of 15.56 min.

2.29 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Pro-NH_2.（Figs. S134-S138）

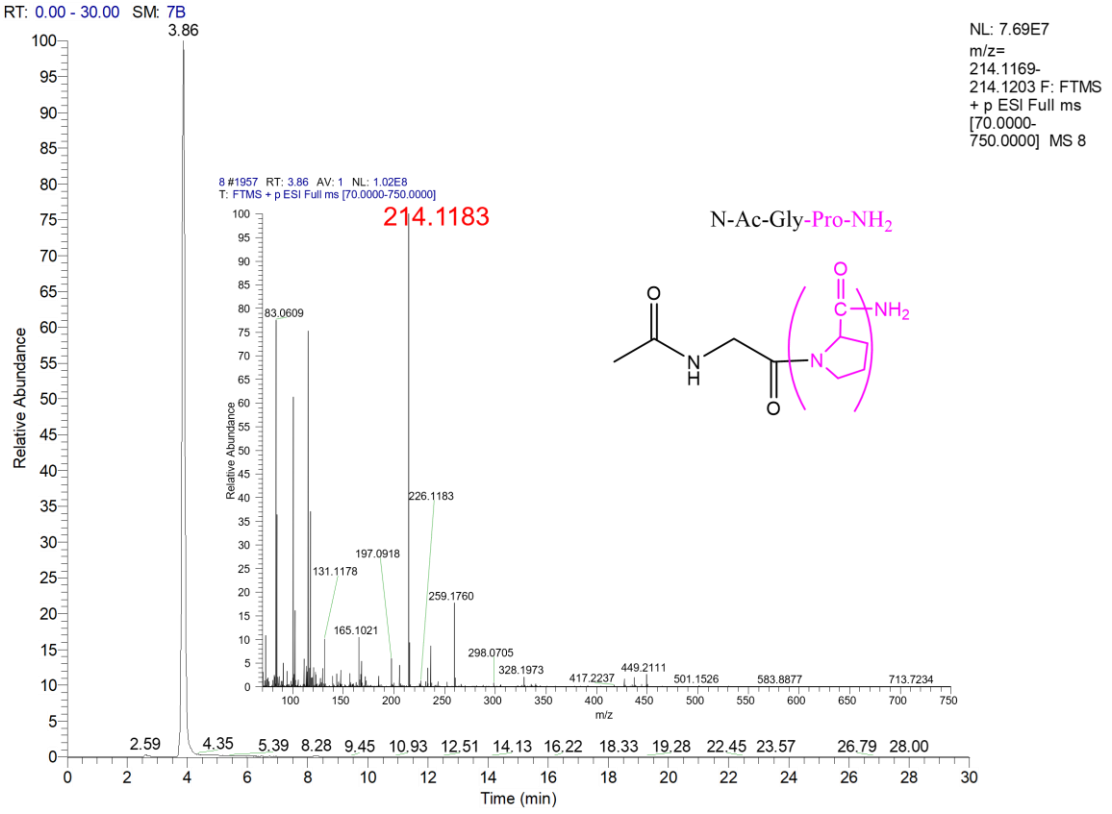

Fig. S134 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 214.1183 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Pro-NH_2 with a retention time of 3.86 min.

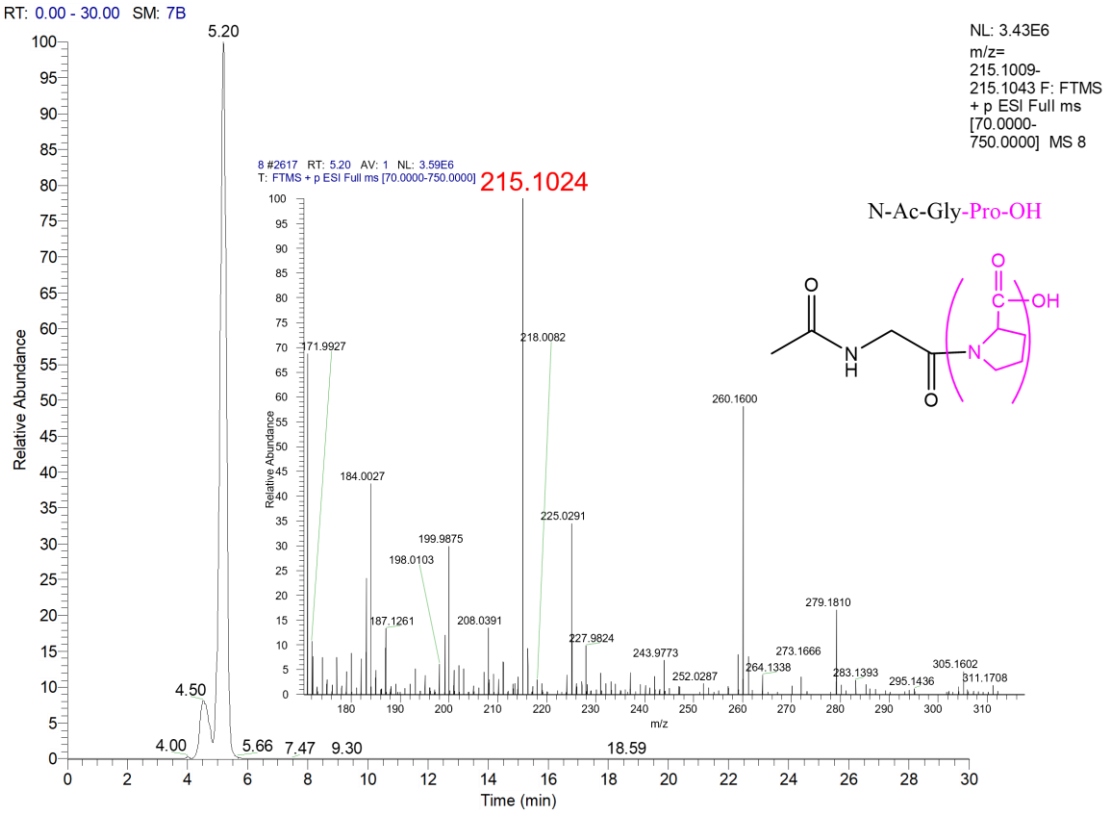

Fig. S135 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 215.1024 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Pro-OH with a retention time of 5.20 min.

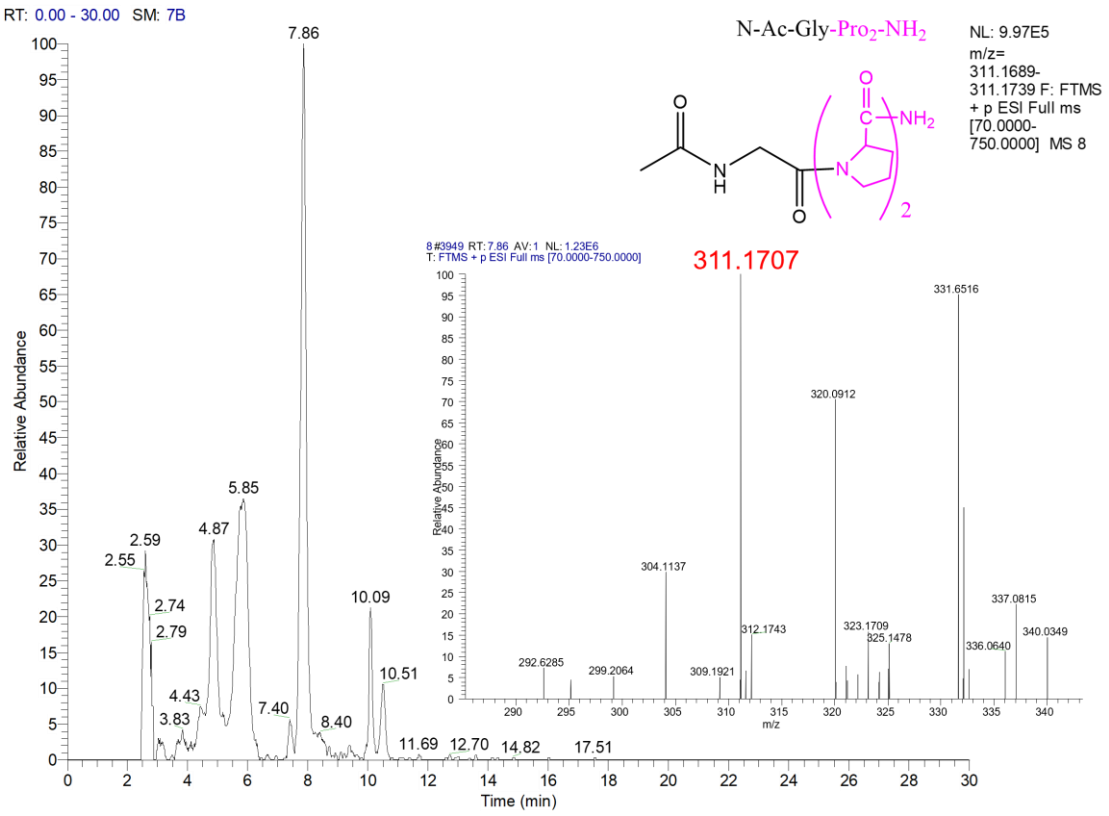

Fig. S136 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 311.1707 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-Pro_2-NH_2 with a retention time of 7.86 min.

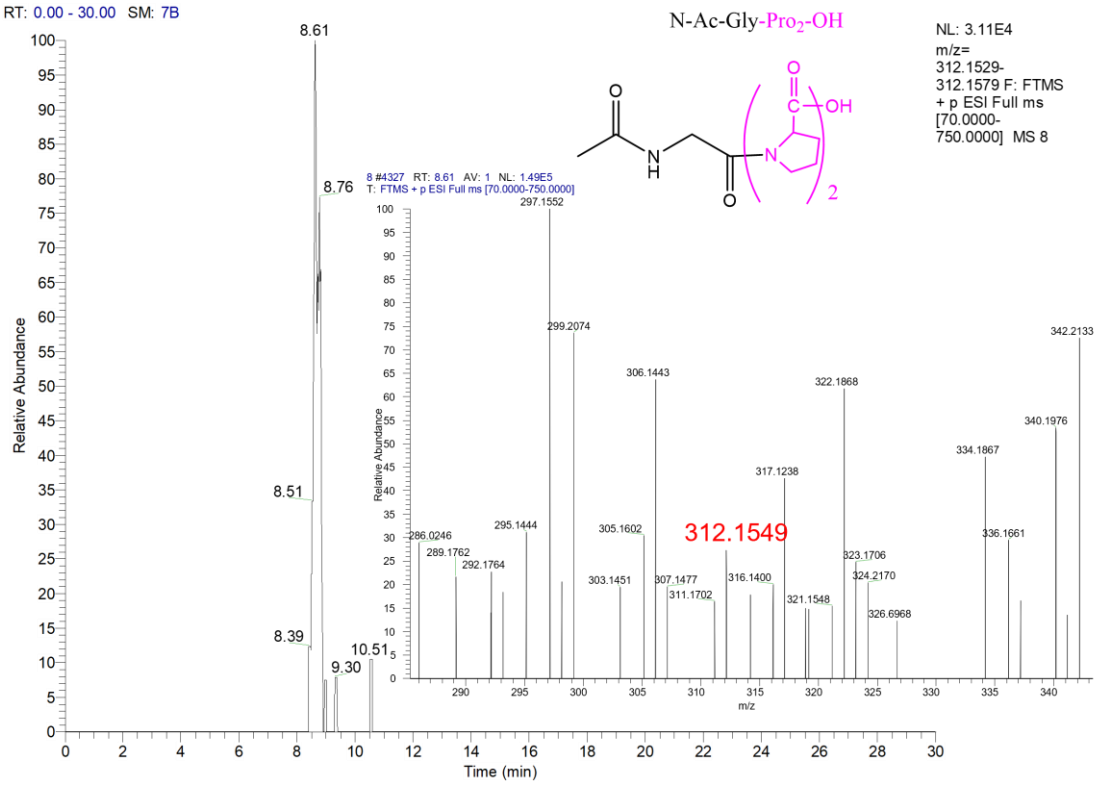

Fig. S137 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 312.1549 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Pro$_2$-OH with a retention time of 8.61 min.

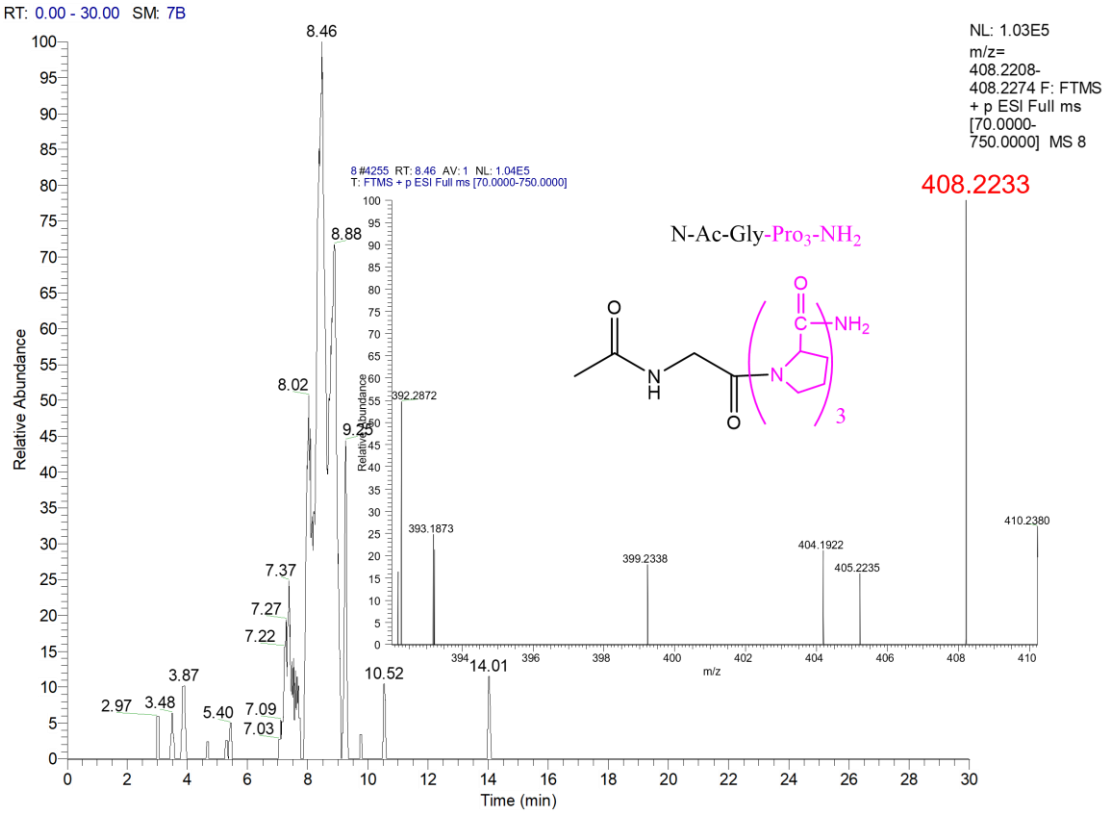

Fig. S138 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 408.2233 was analyzed, and its EIC corresponded to the tetramer N-Ac-Gly-Pro$_3$-NH$_2$ with a retention time of 8.46 min.

2.30 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Ile-NH_2.（Figs. S139-S142）

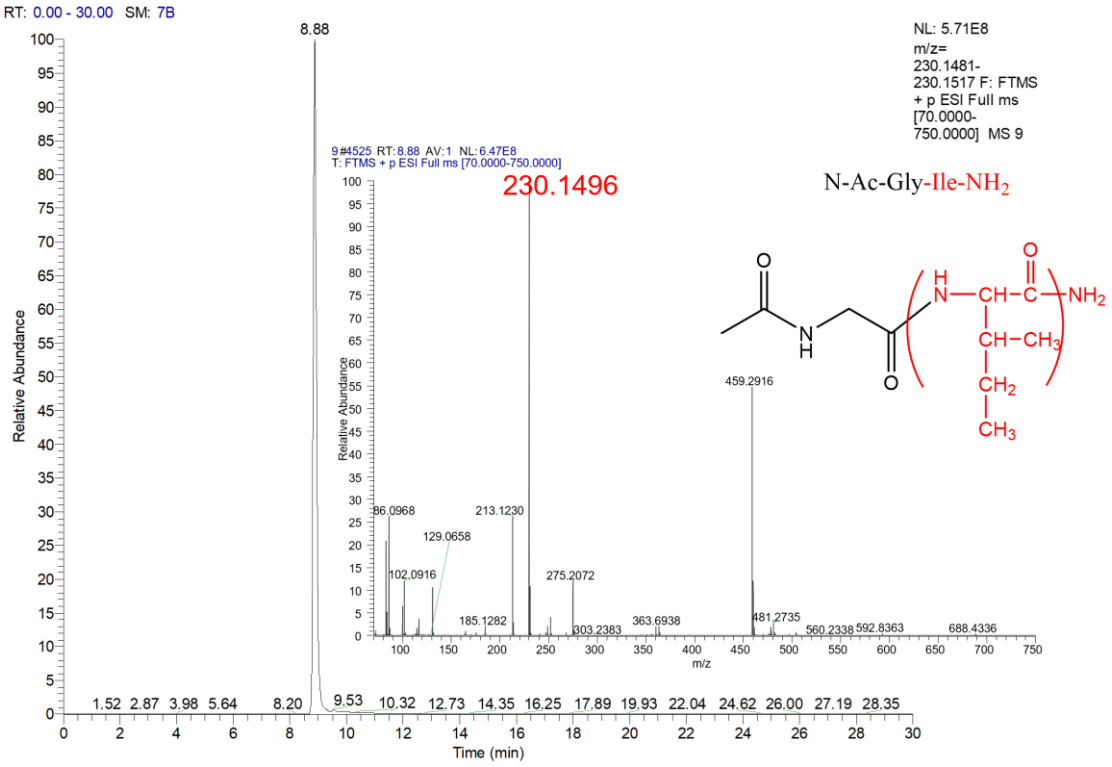

Fig. S139 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 230.1496 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Ile-NH_2 with a retention time of 8.88 min.

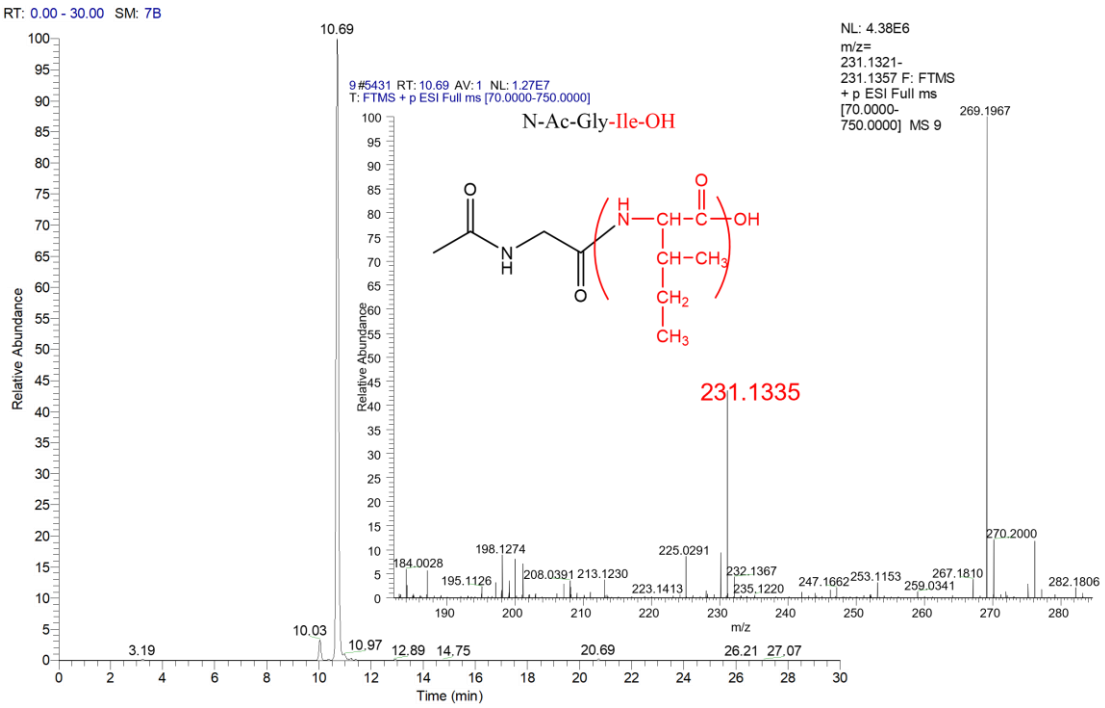

Fig. S140 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 231.1335 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Ile-OH with a retention time of 10.69 min.

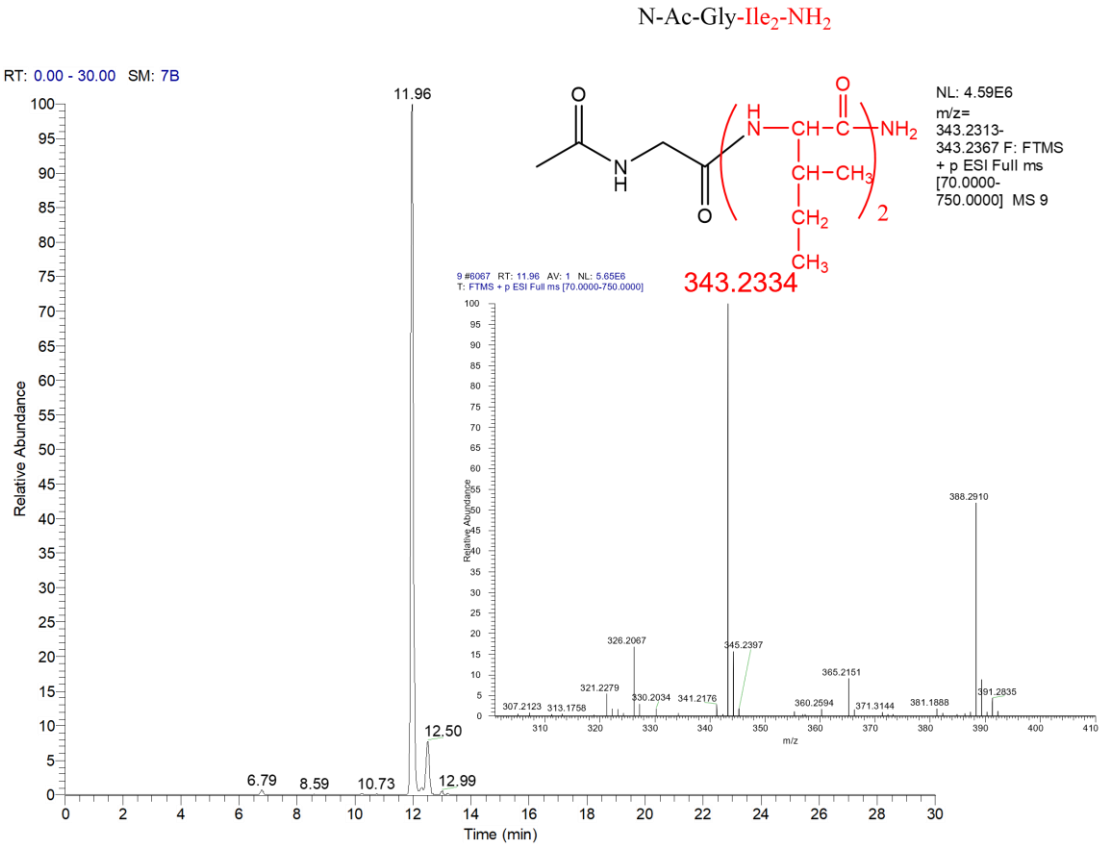

Fig. S141 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 343.2334 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-Ile$_2$-NH$_2$ with a retention time of 11.96 min.

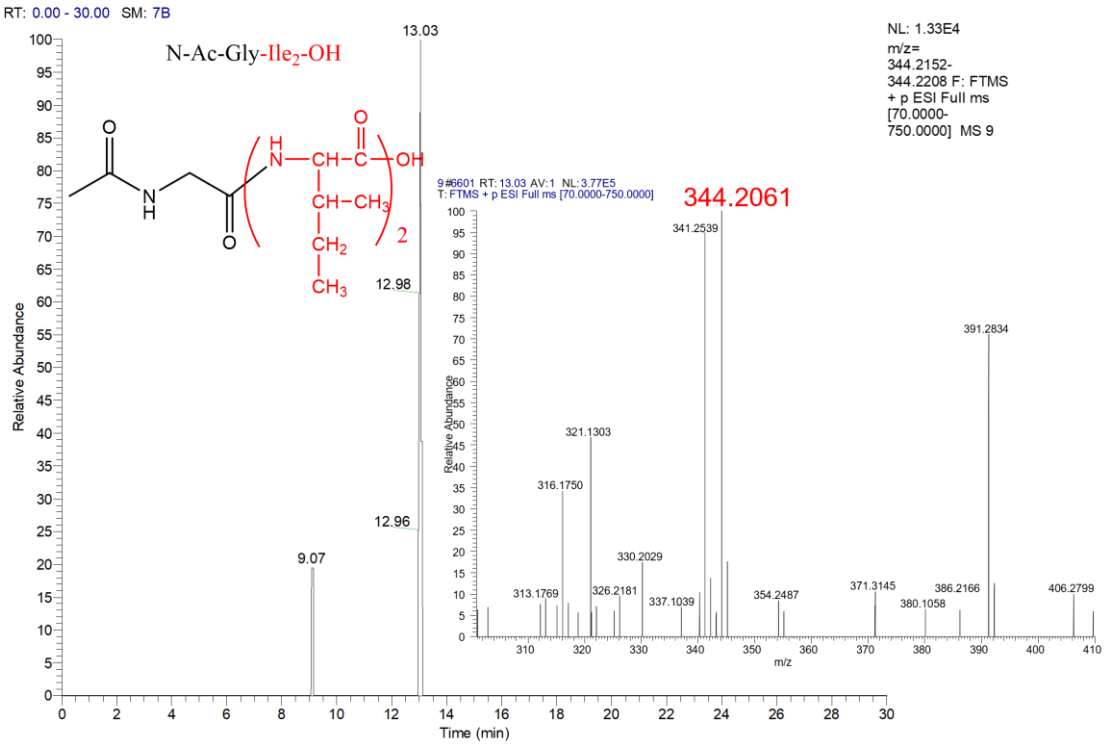

Fig. S142 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 344.2061 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Ile$_2$-OH with a retention time of 13.03 min.

2.31 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Met-NH_2.（Figs. S143-S150）

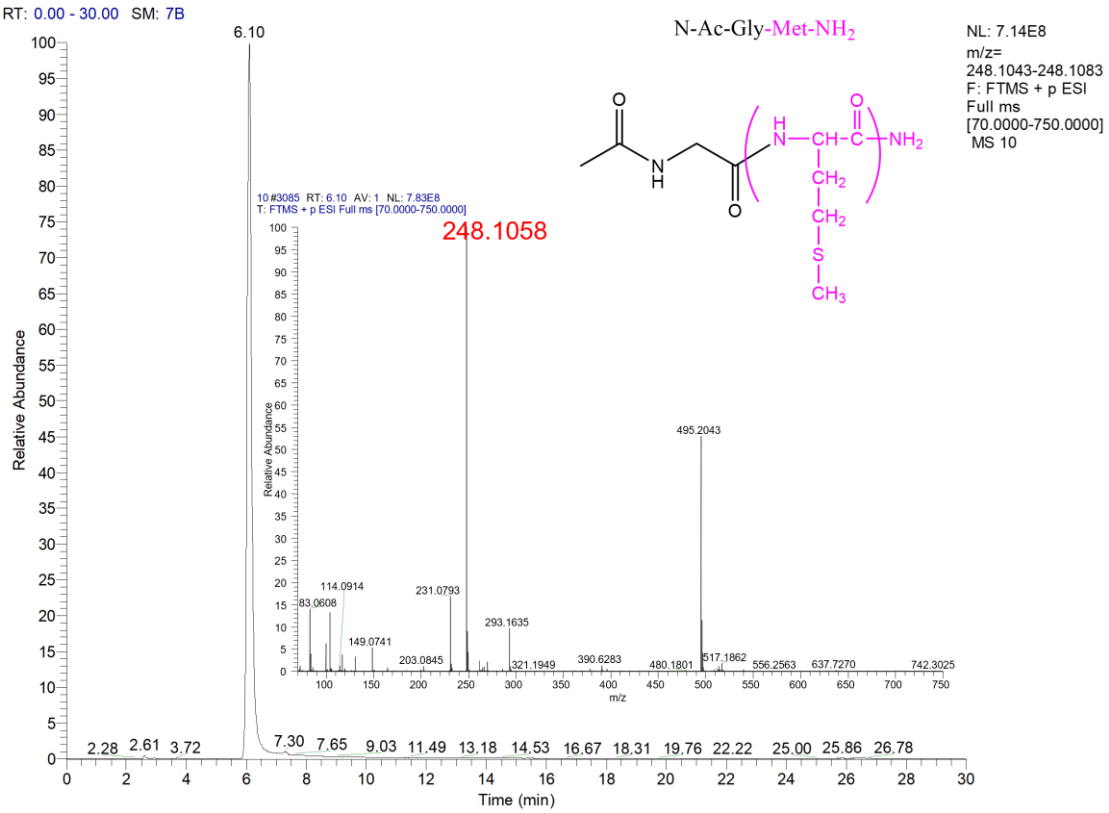

Fig. S143 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 248.1058 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Met-NH_2 with a retention time of 6.10 min.

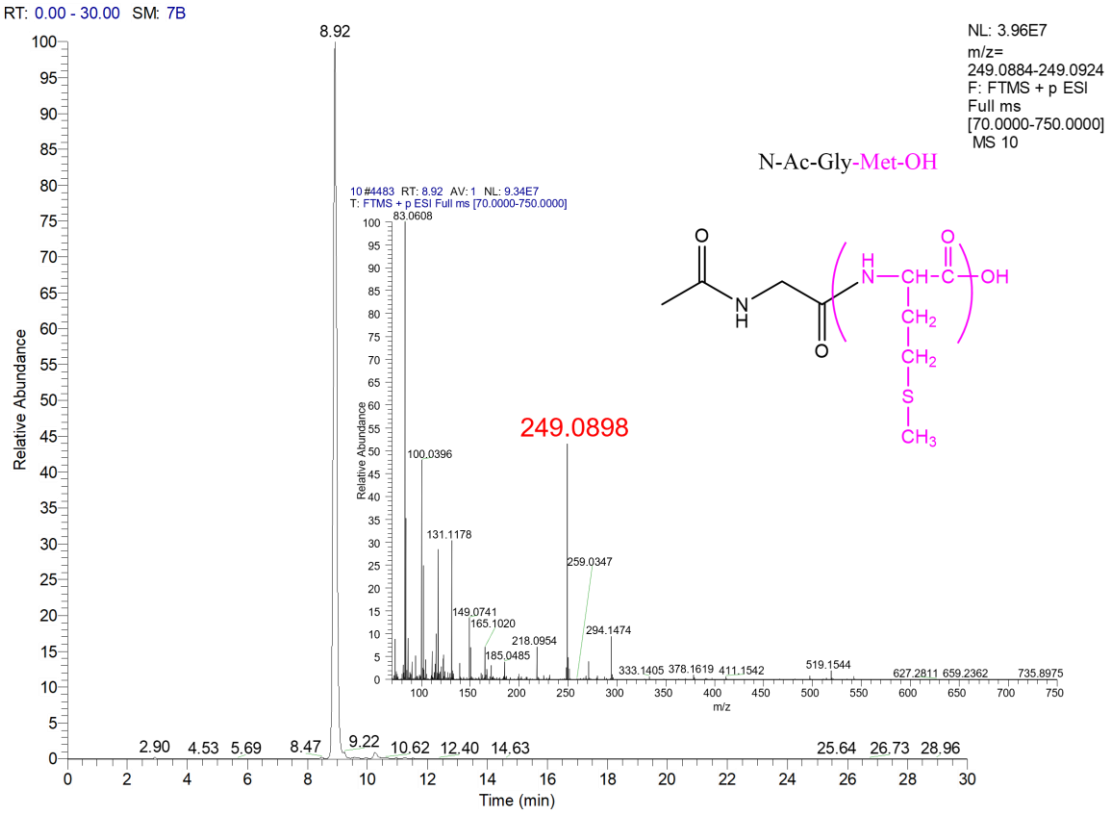

Fig. S144 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 249.0898 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Met-OH with a retention time of 8.92 min.

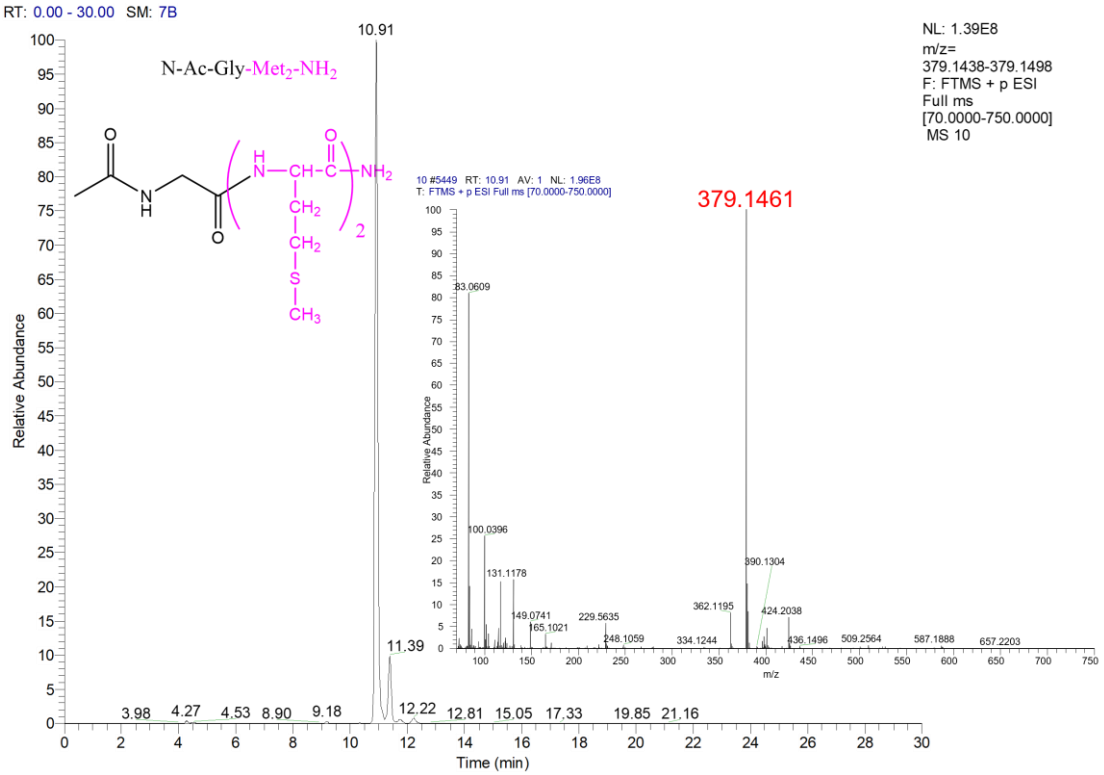

Fig. S145 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 379.1461 was analyzed, and its EIC corresponds to the trimer N-Ac-Gly-Met_2-NH_2 with a retention time of 10.91 min.

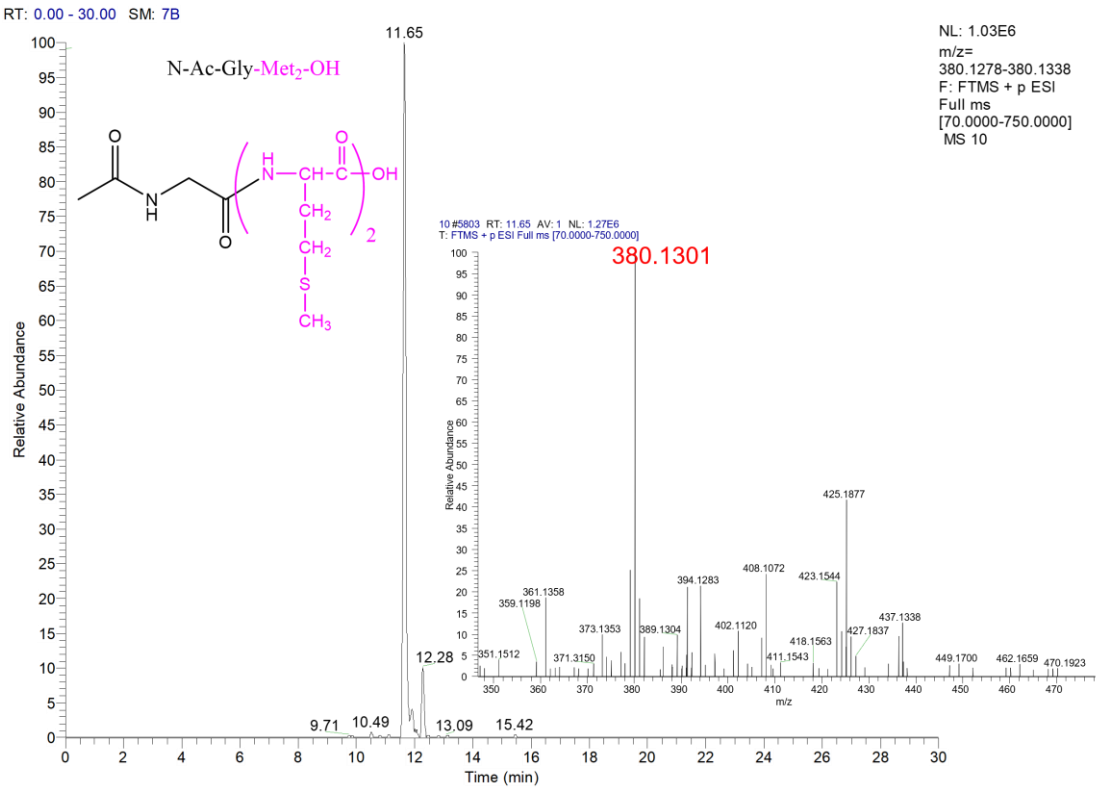

Fig. S146 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z380.1301 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Met$_2$-OH with a retention time of 11.65 min.

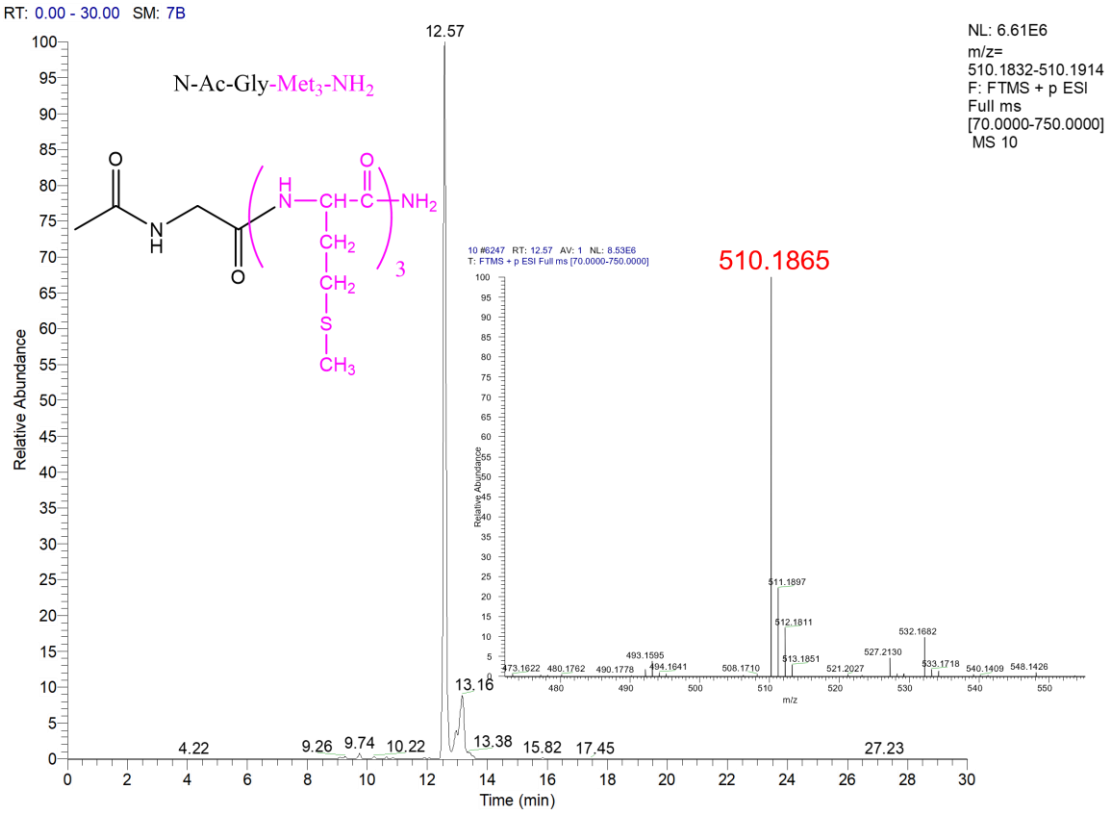

Fig. S147 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 510.1865 was analyzed and its EIC corresponded to the tetramer N-Ac-Gly-Met_3-NH_2 with a retention time of 12.57 min.

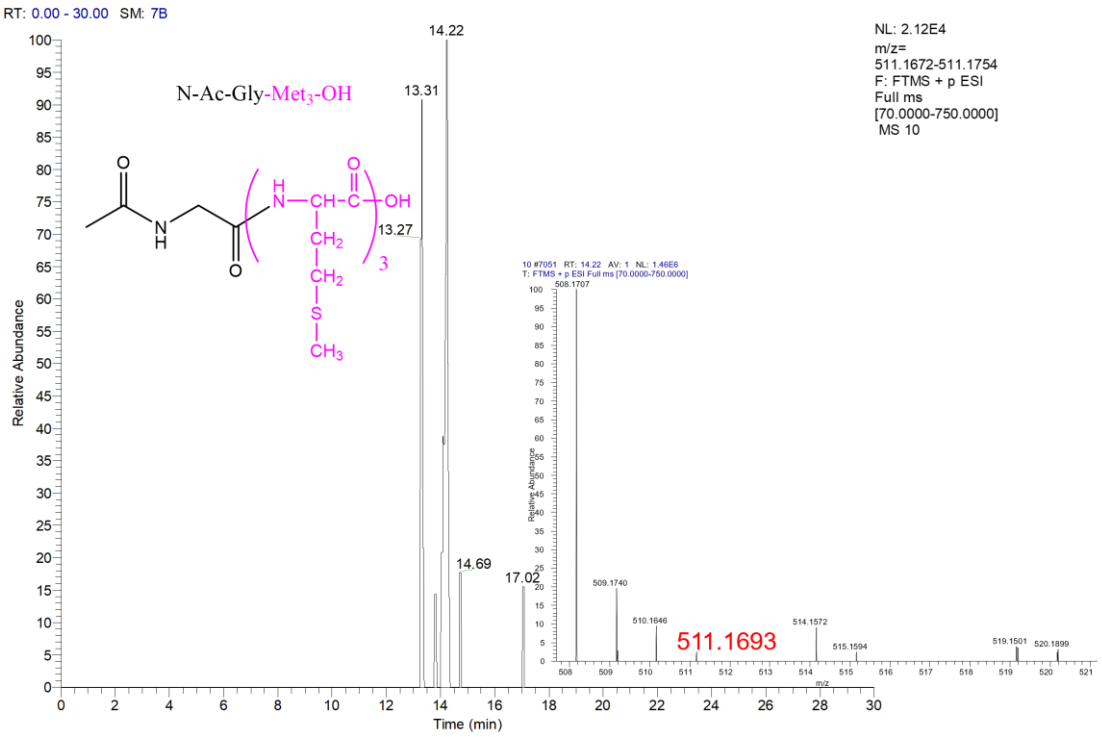

Fig. S148 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 511.1693 was analyzed, and its EIC corresponded to the tetrapeptide N-Ac-Gly-Met$_3$-OH with a retention time of 14.22 min.

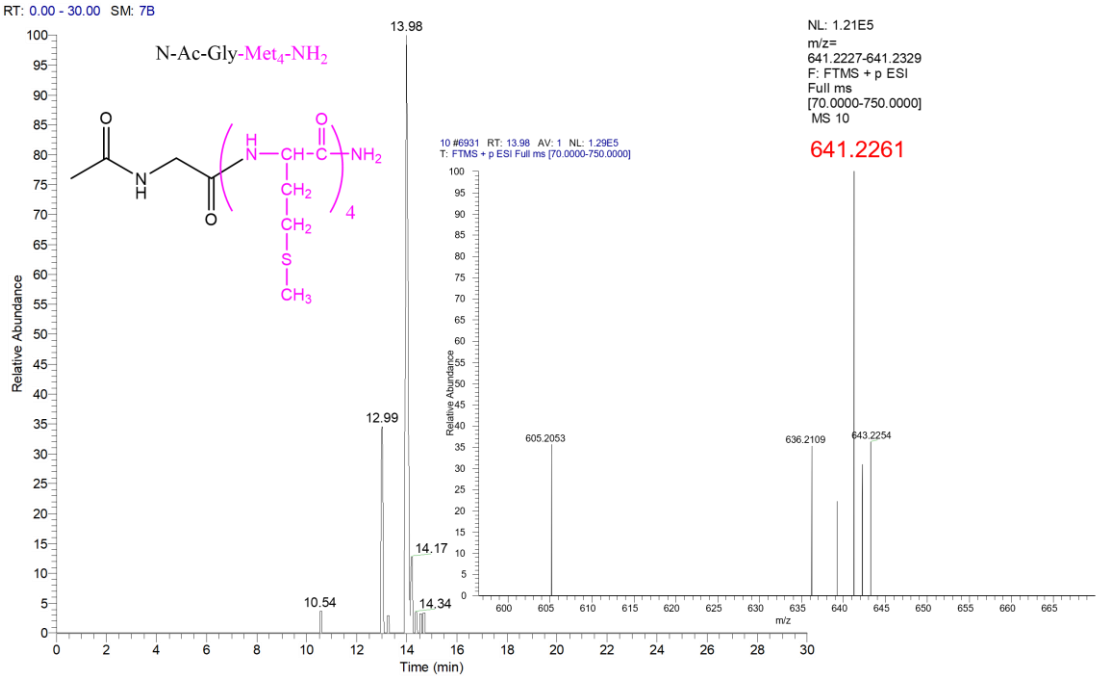

Fig. S149 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 641.2261 was analyzed, and its EIC corresponded to the pentamer N-Ac-Gly-Met_4-NH_2 with a retention time of 13.98 min.

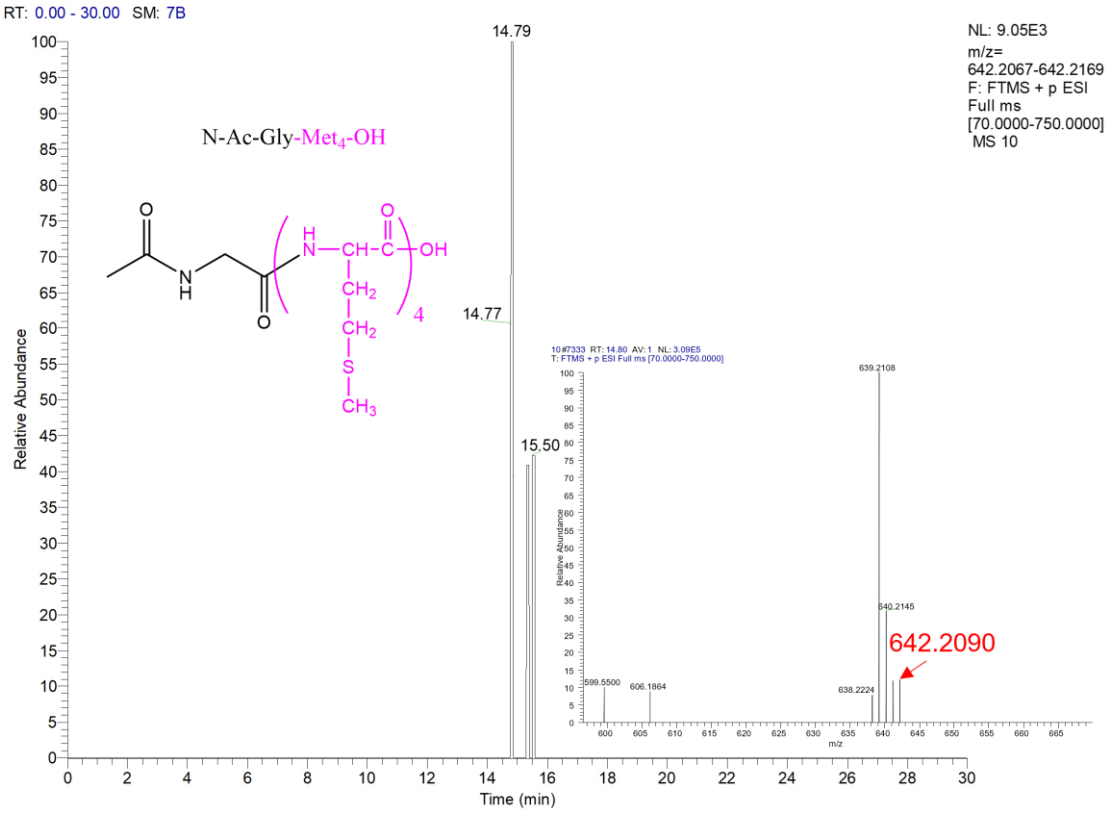

Fig. S150 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 642.2090 was analyzed, and its EIC corresponded to pentapeptide N-Ac-Gly-Met$_4$-OH with a retention time of 14.80 min.

2.32 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Thr-NH_2.（Figs. S151-S154）

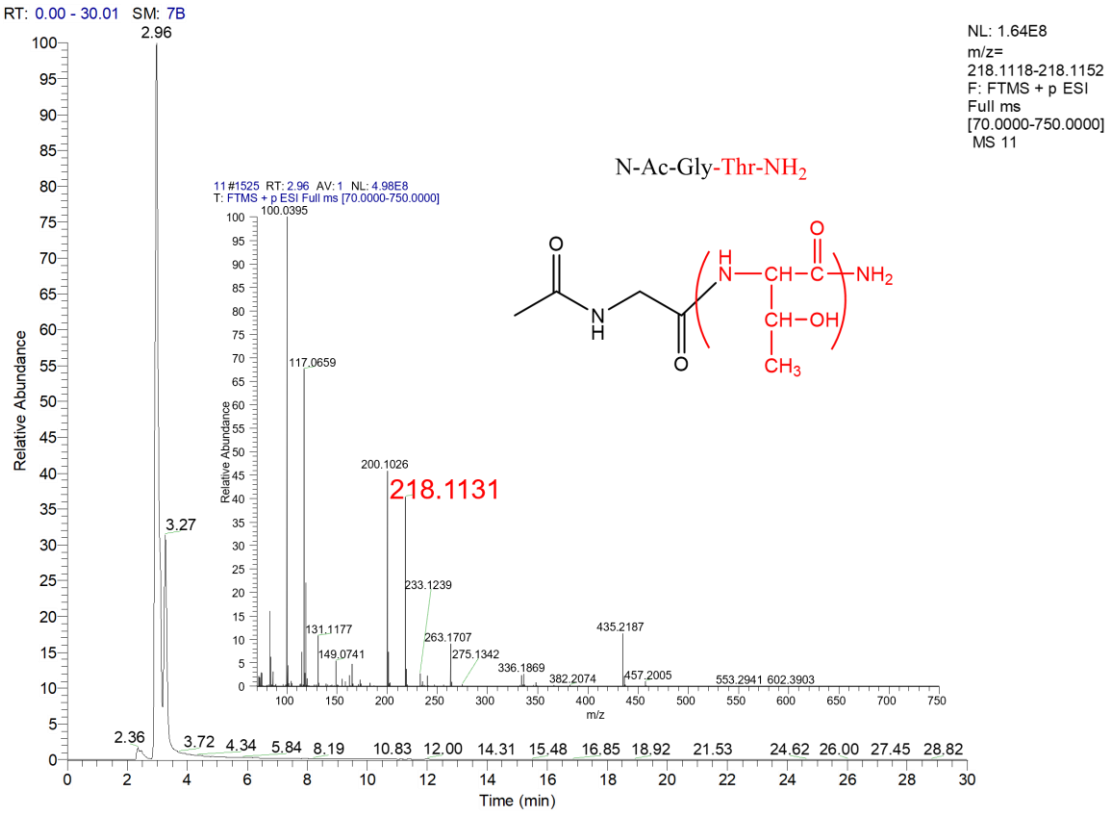

Fig. S151 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 218.1131 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Thr-NH_2 with a retention time of 2.96 min.

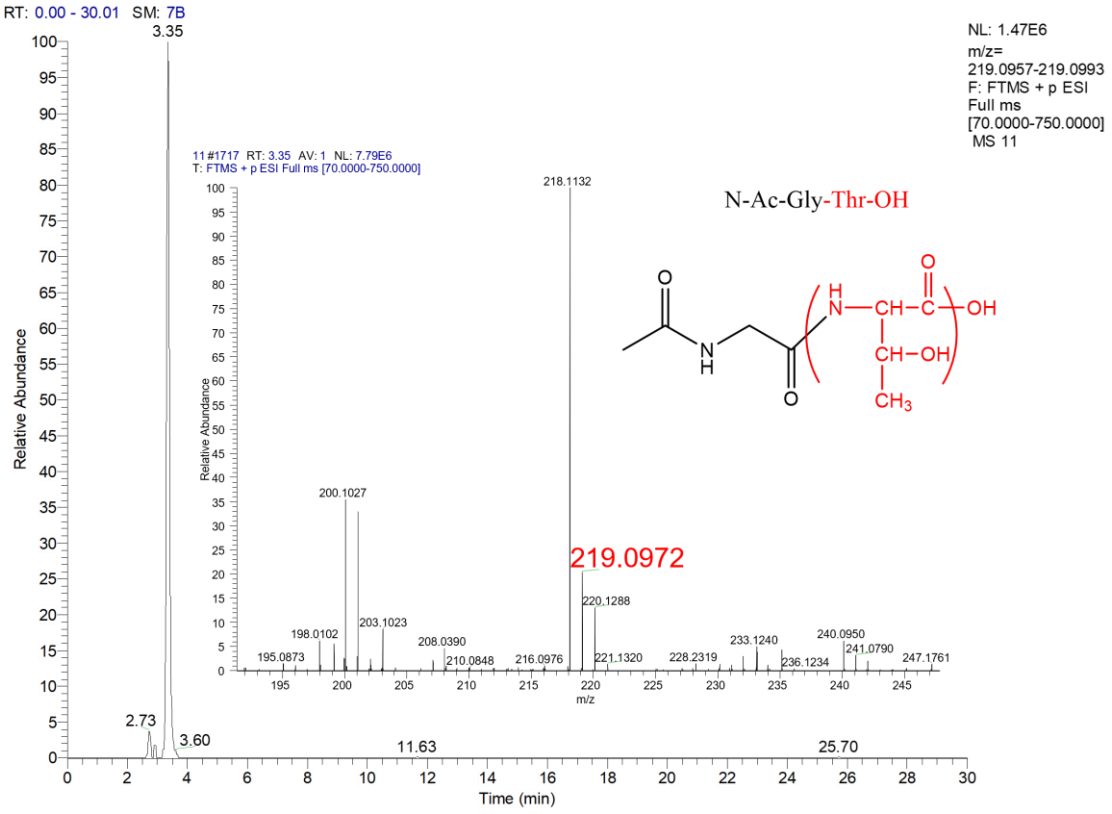

Fig. S152 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 219.0972 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Thr-OH with a retention time of 3.35 min.

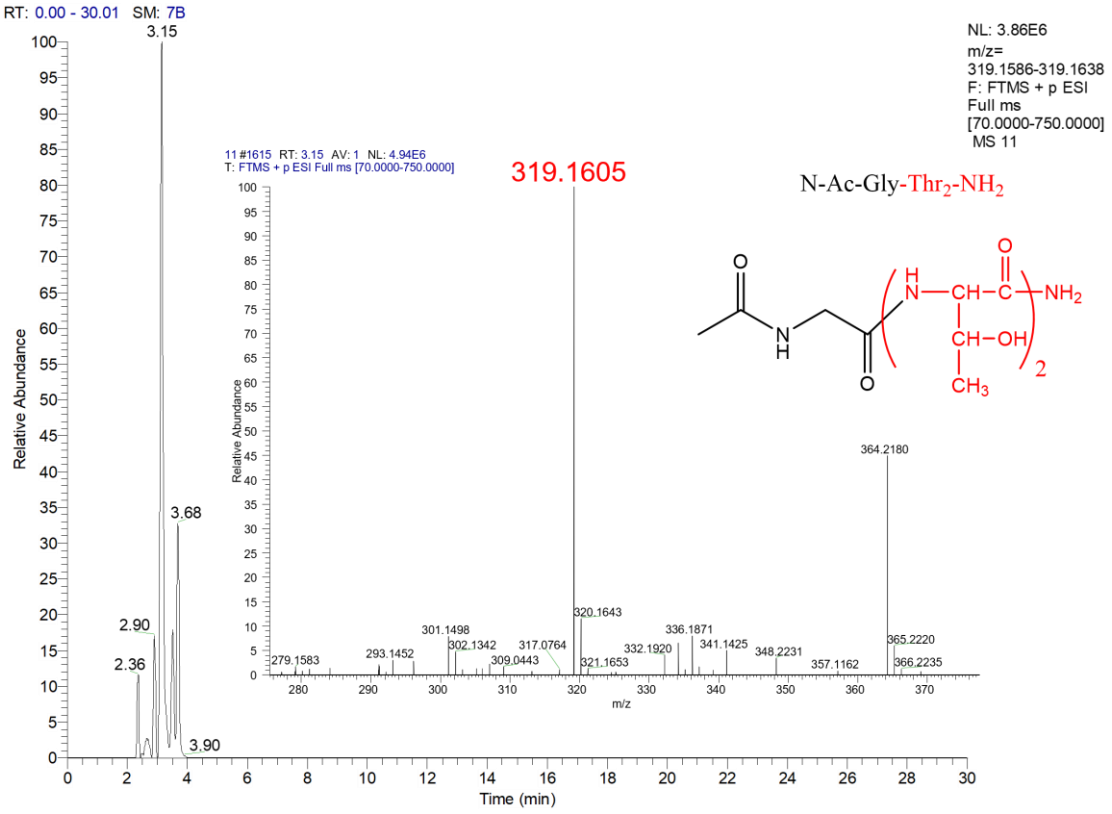

Fig. S153 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 319.1605 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-Thr_2-NH_2 with a retention time of 3.15 min.

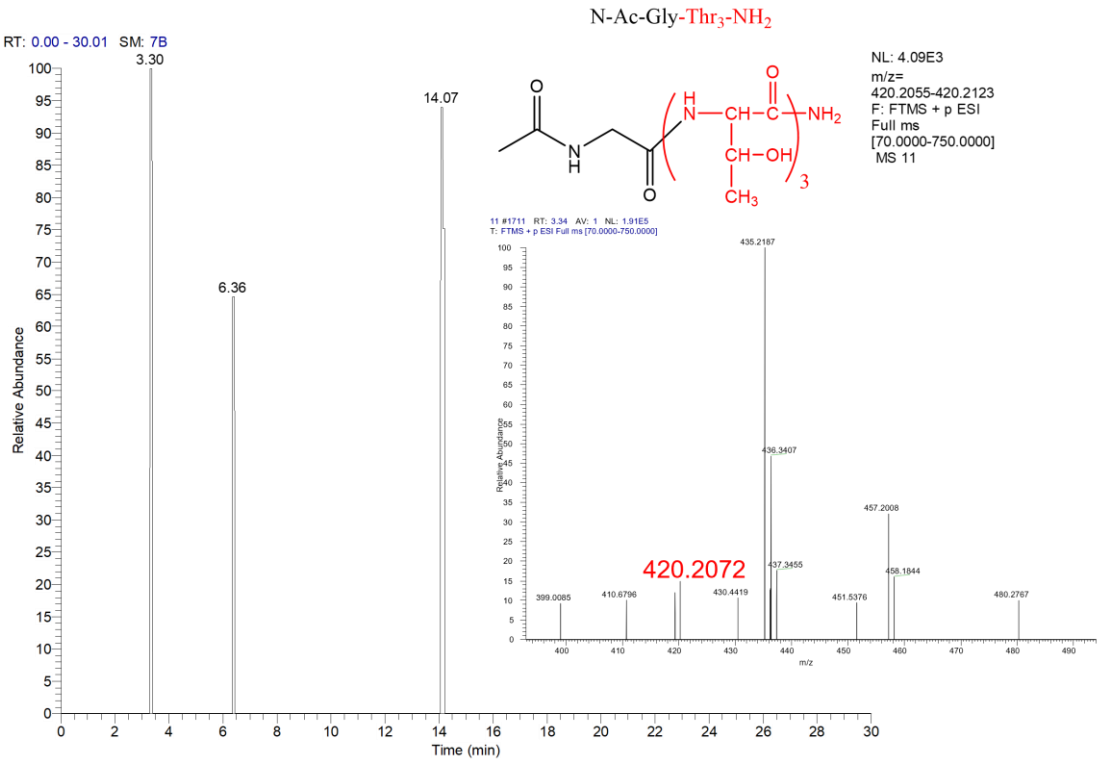

Fig. S154 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 420.2072 was analyzed, and its EIC corresponded to the tetramer N-Ac-Gly-Thr$_3$-NH$_2$ with a retention time of 3.34 min.

2.33 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Trp-NH_2.（Figs. S155-S158）

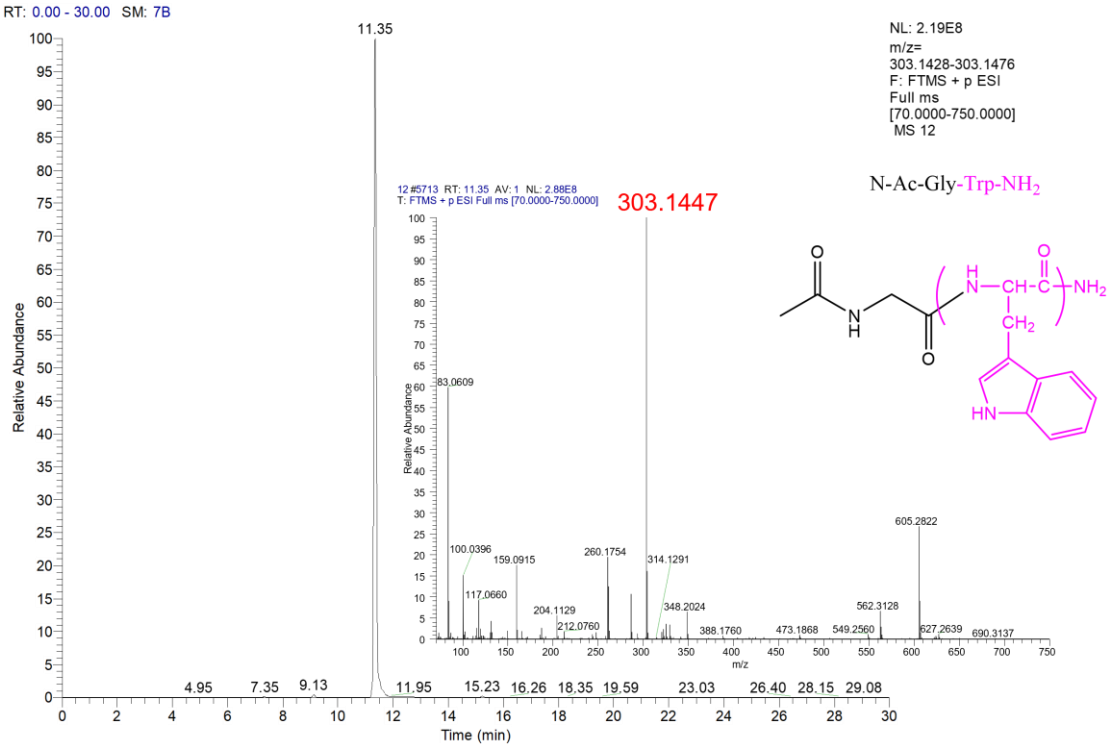

Fig. S155 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 303.1447 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Trp-NH_2 with a retention time of 11.35 min.

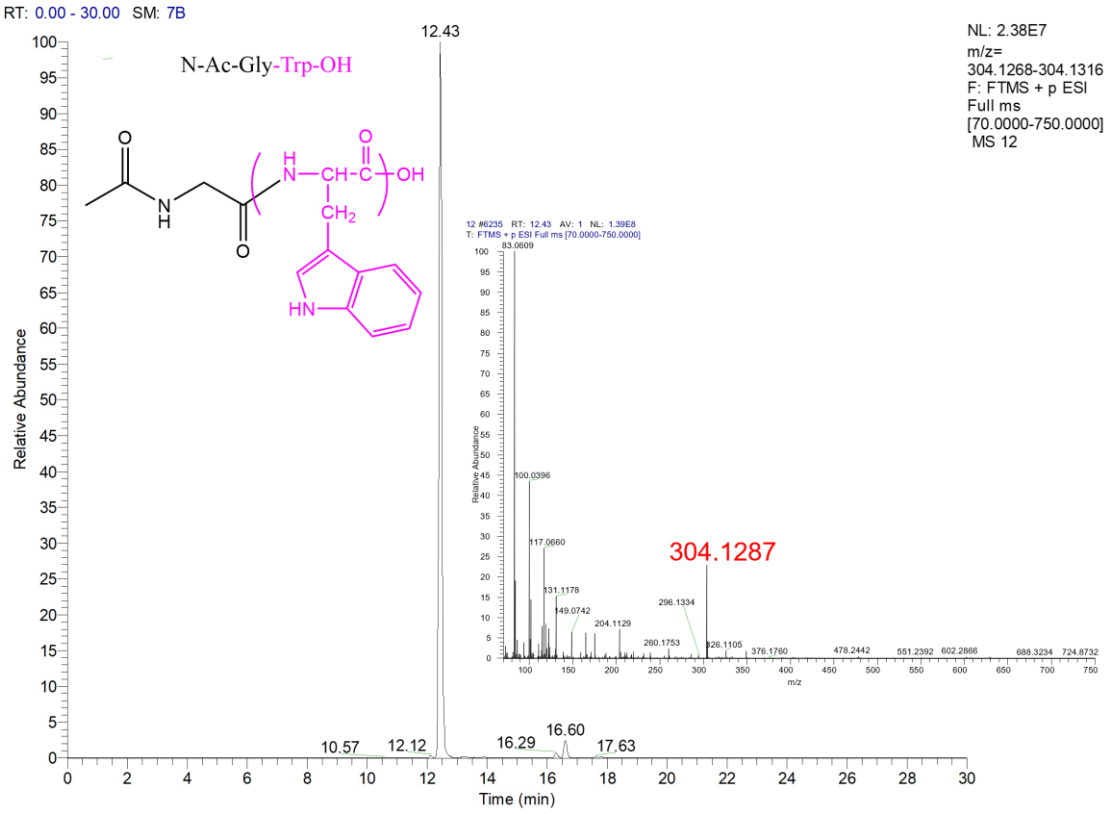

Fig. S156 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 304.1287 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Trp-OH with a retention time of 12.43 min.

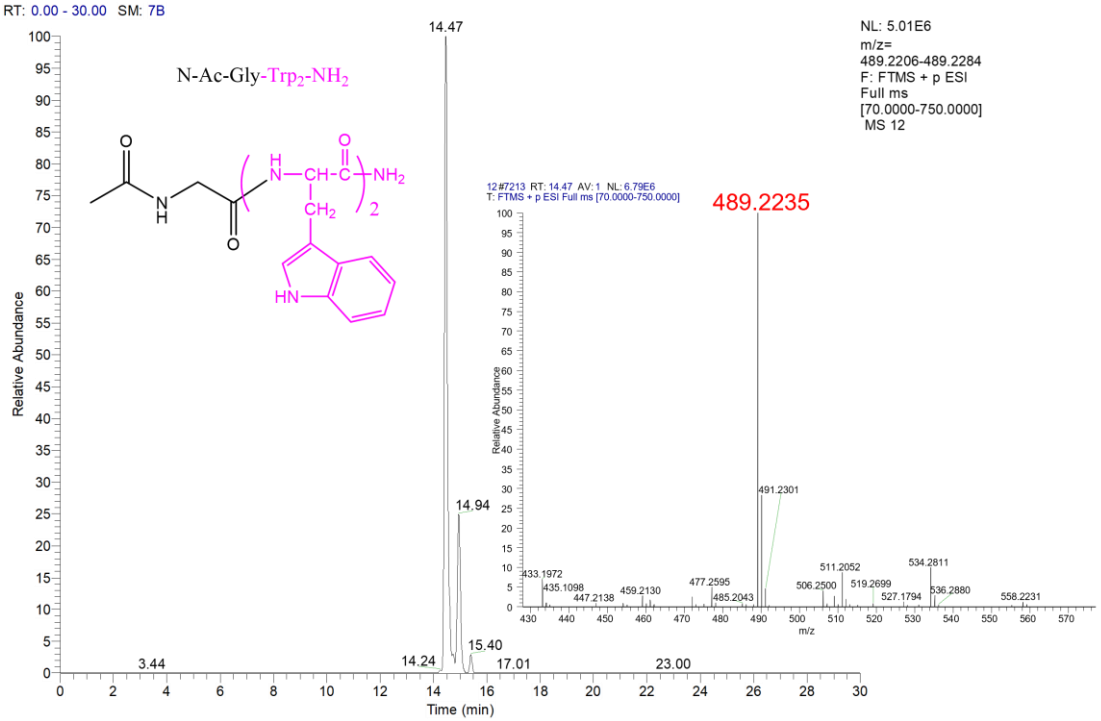

Fig. S157 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 489.2235 was analyzed, and its EIC corresponds to the trimer N-Ac-Gly-Trp_2-NH_2 with a retention time of 14.47 min.

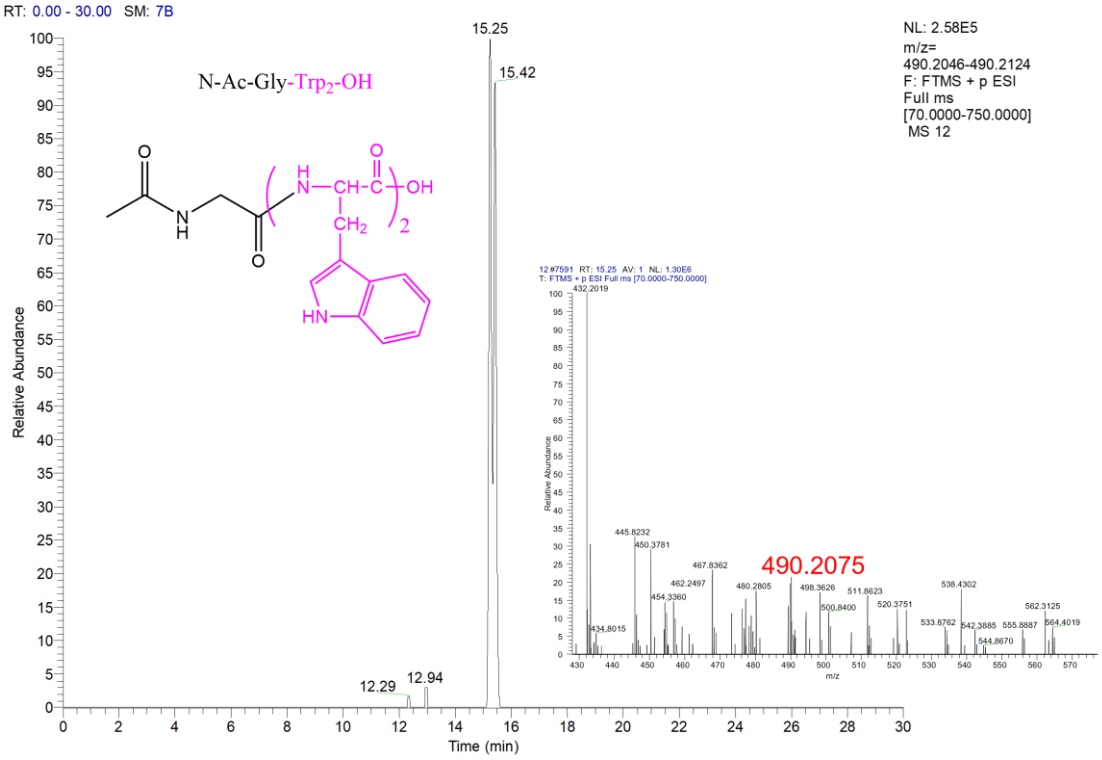

Fig. S158 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 490.2075 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Trp$_2$-OH with a retention time of 15.25 min.

2.34 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M His-NH_2.（Figs. S159-S164）

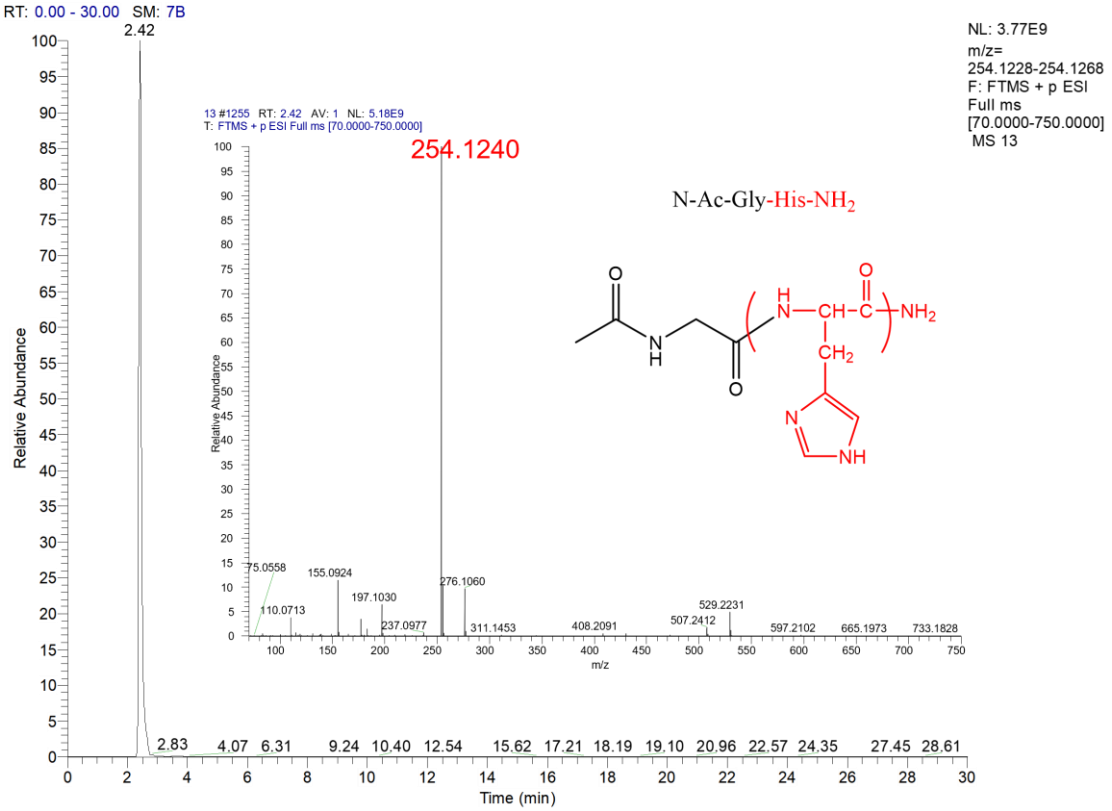

Fig. S159 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 254.1240 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-His-NH_2 with a retention time of 2.42 min.

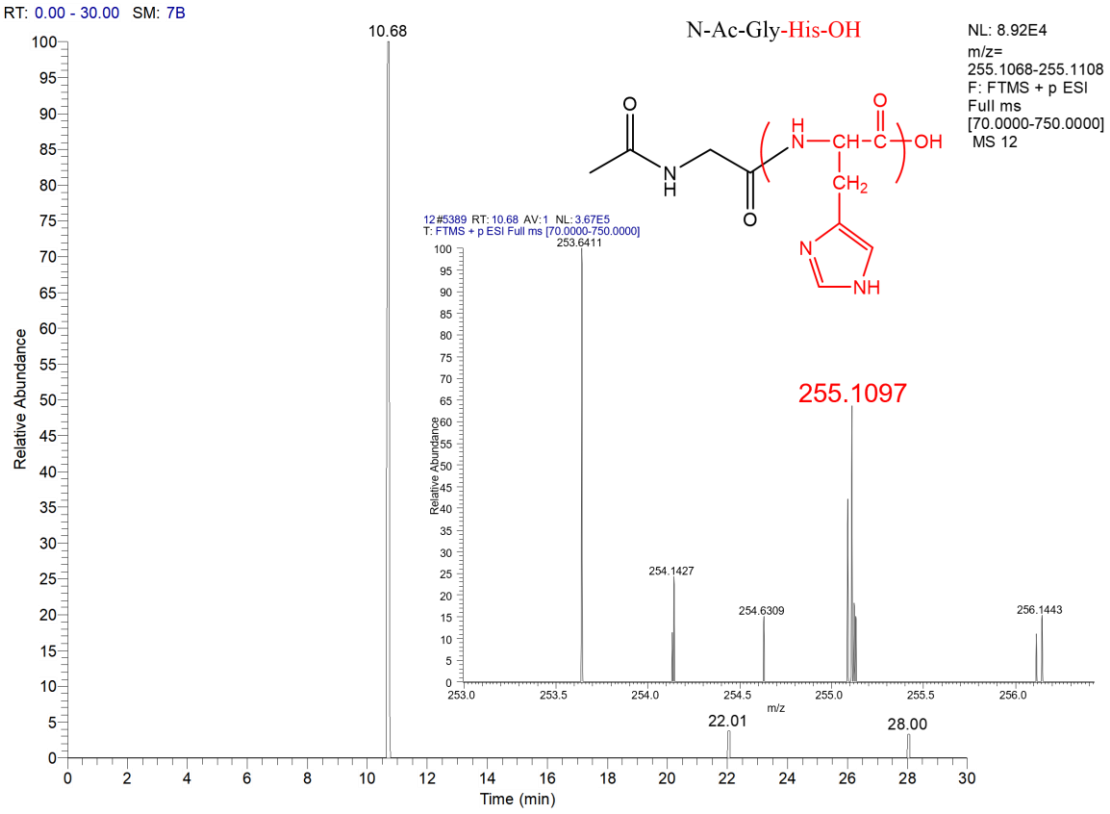

Fig. S160 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 255.1097 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-His-OH with a retention time of 10.68 min.

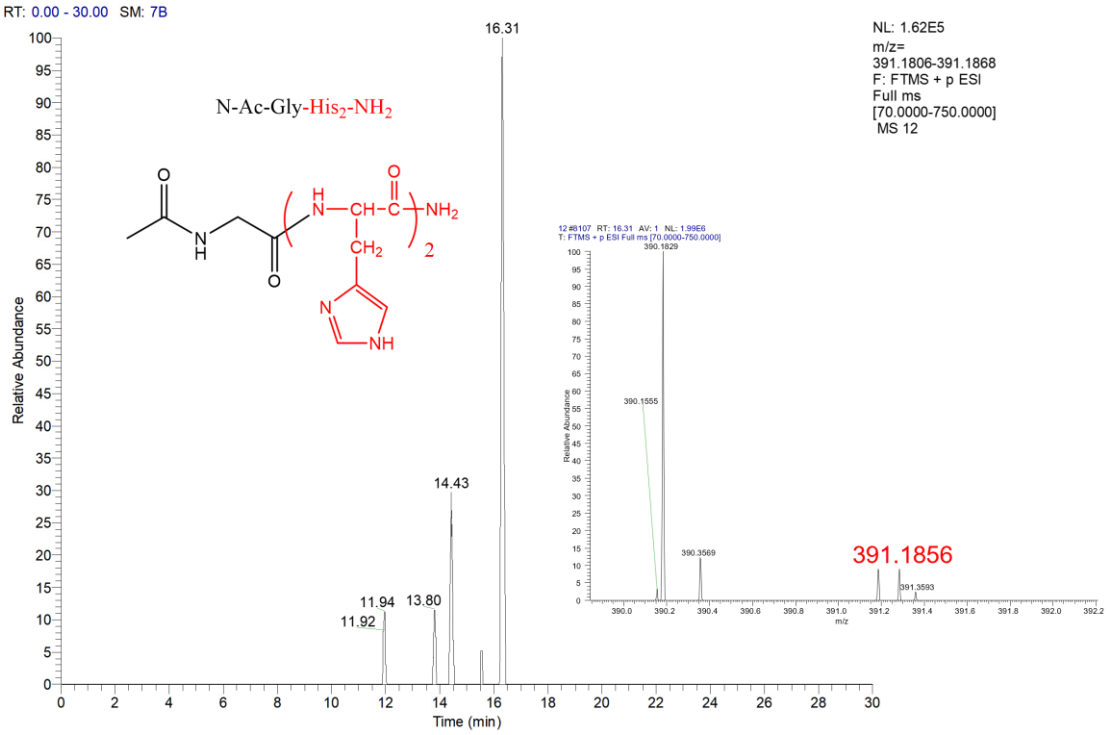

Fig. S161 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 391.1856 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-His_2-NH_2 with a retention time of 16.31 min.

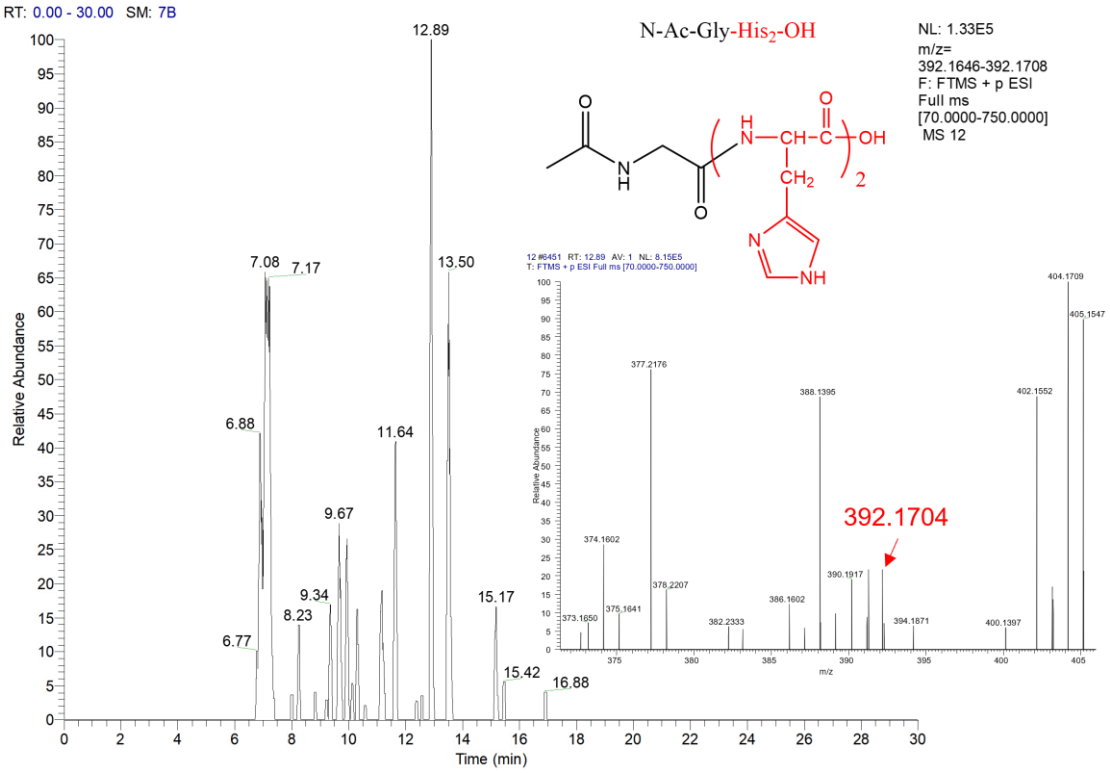

Fig. S162 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z392.1704 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-His_2-OH with a retention time of 12.89 min.

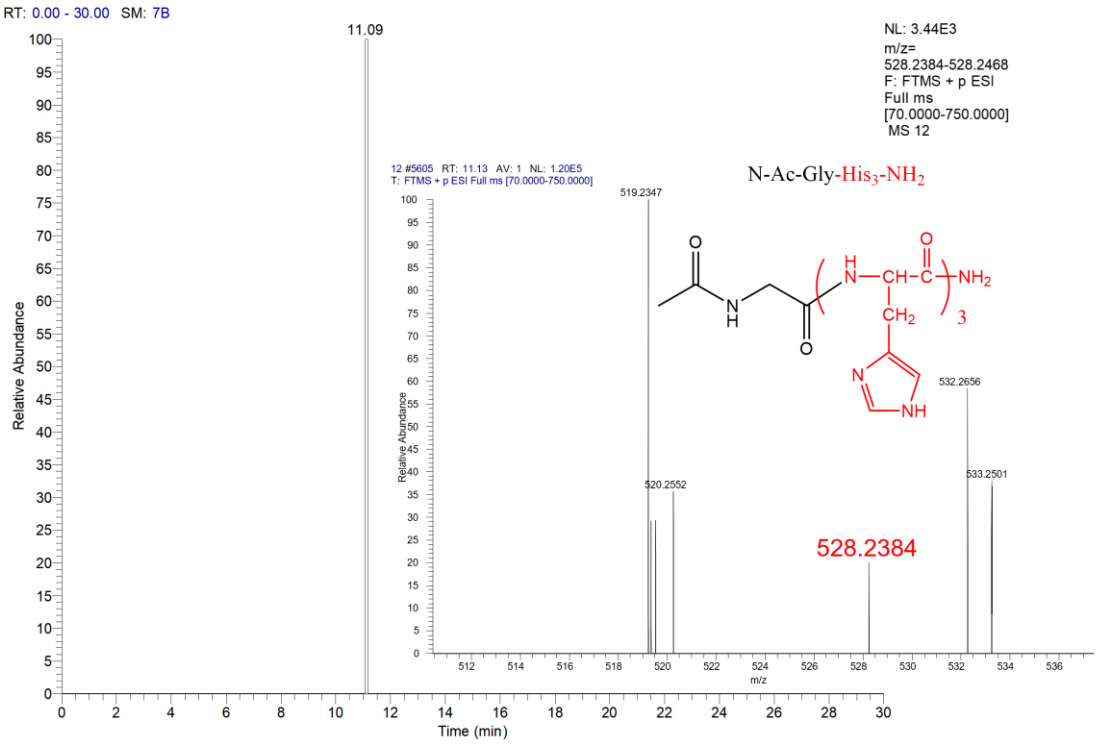

Fig. S163 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 528.2384 was analyzed, and its EIC corresponded to the tetramer N-Ac-Gly-His_3-NH_2 with a retention time of 11.13 min.

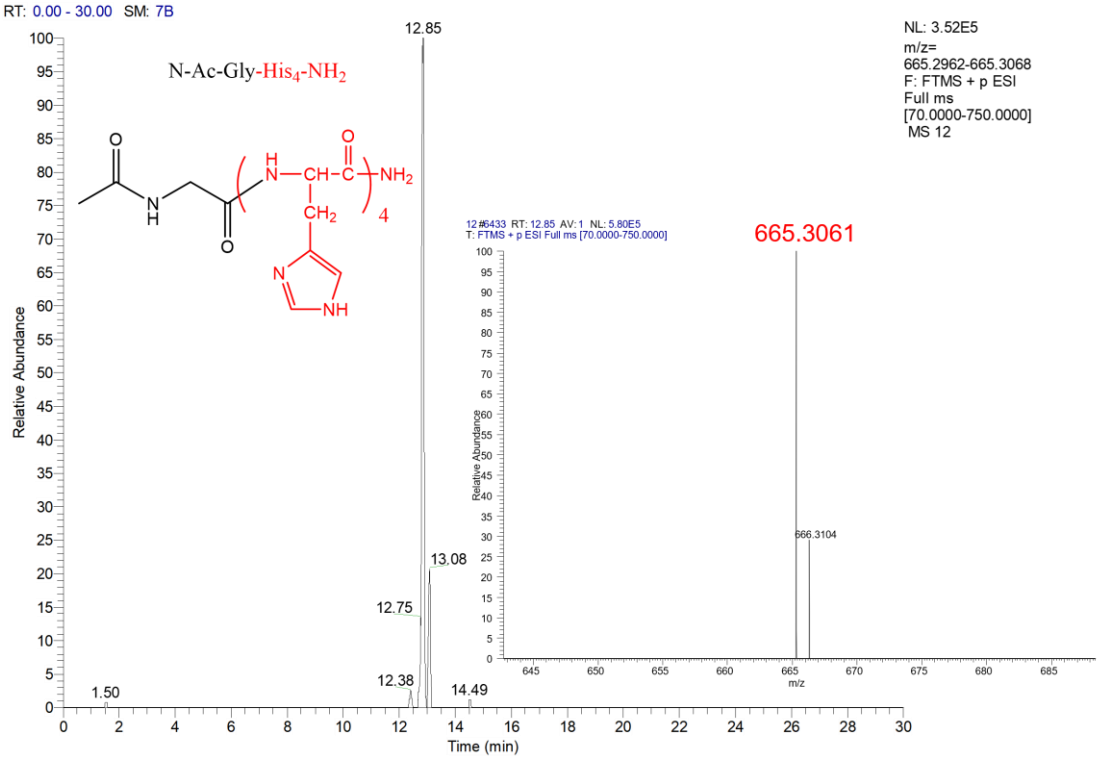

Fig. S164 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 665.3061 was analyzed, and its EIC corresponded to the pentamer N-Ac-Gly-His_4-NH_2 with a retention time of 12.85 min.

2.35 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Asp-NH_2.（Figs. S165-S172）

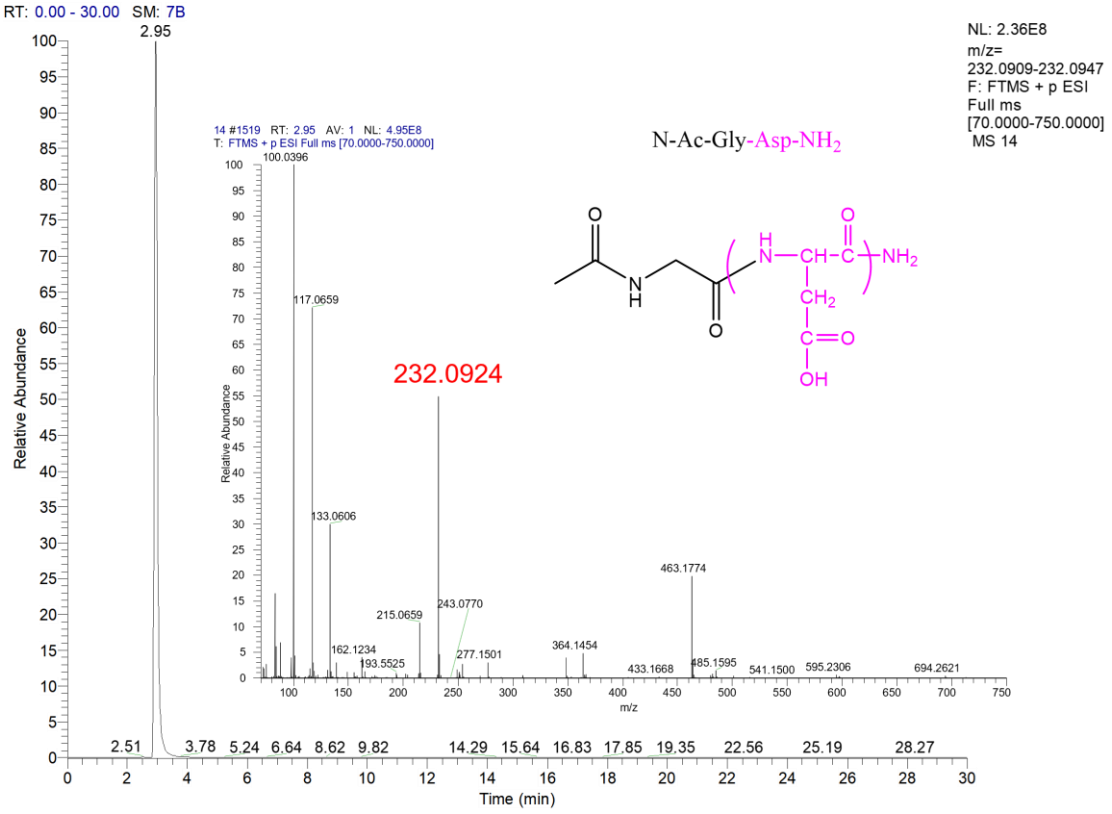

Fig. S165 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 232.0924 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Asp-NH_2 with a retention time of 2.95 min.

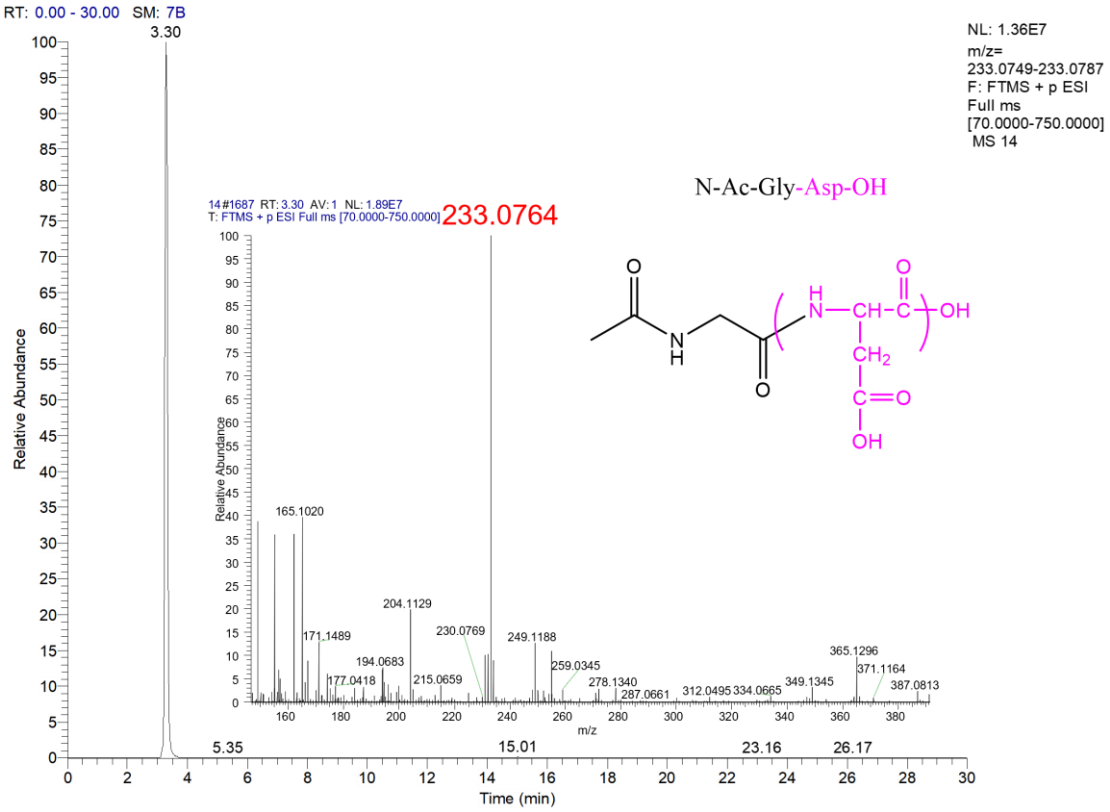

Fig. S166 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 233.0764 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Asp-OH with a retention time of 3.30 min.

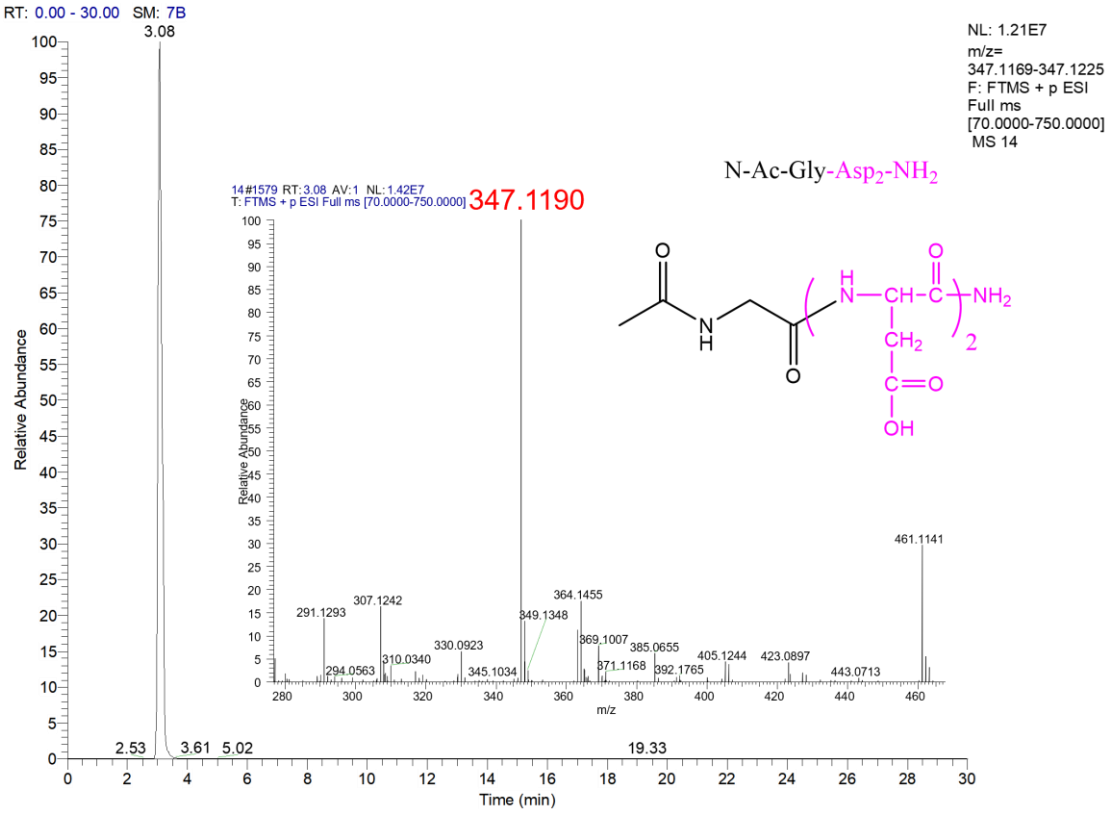

Fig. S167 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 347.1190 was analyzed, and its EIC corresponded to the trimer N-Ac-Gly-Asp_2-NH_2 with a retention time of 3.08 min.

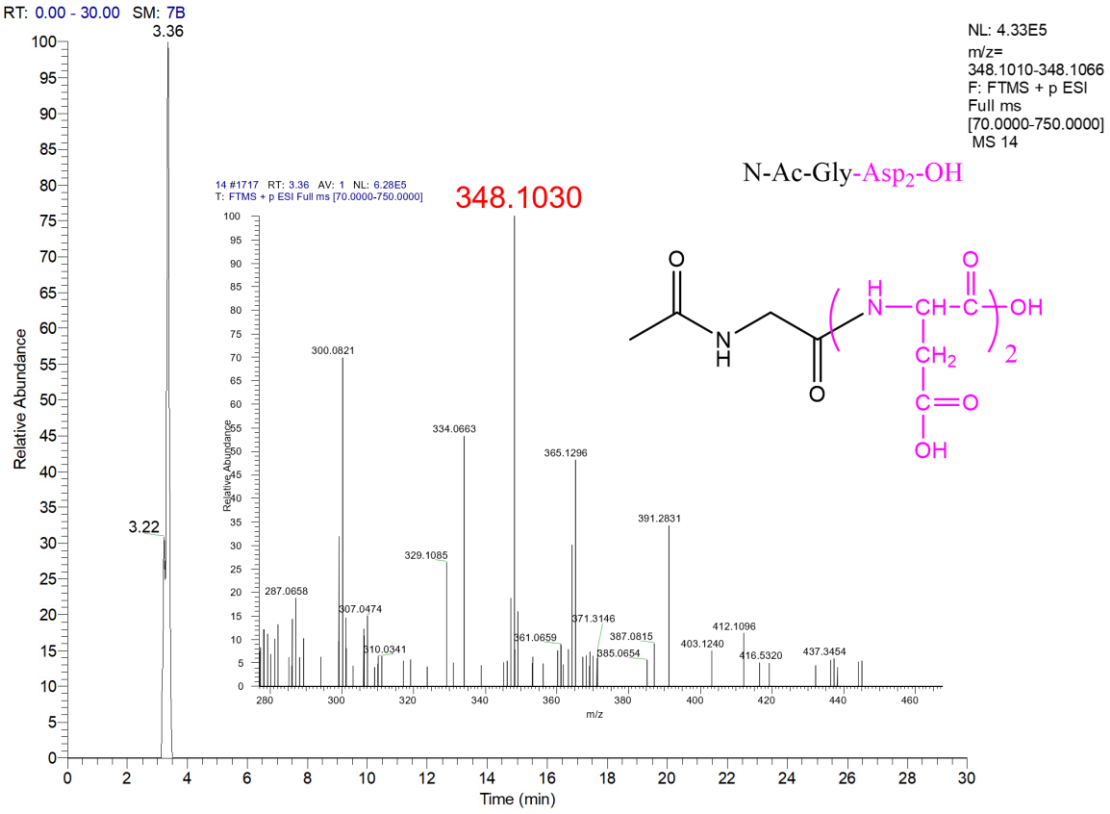

Fig. S168 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 348.1030 was analyzed. The EIC corresponds to the tripeptide N-Ac-Gly-Asp_2-OH, and the retention time is 3.36 min.

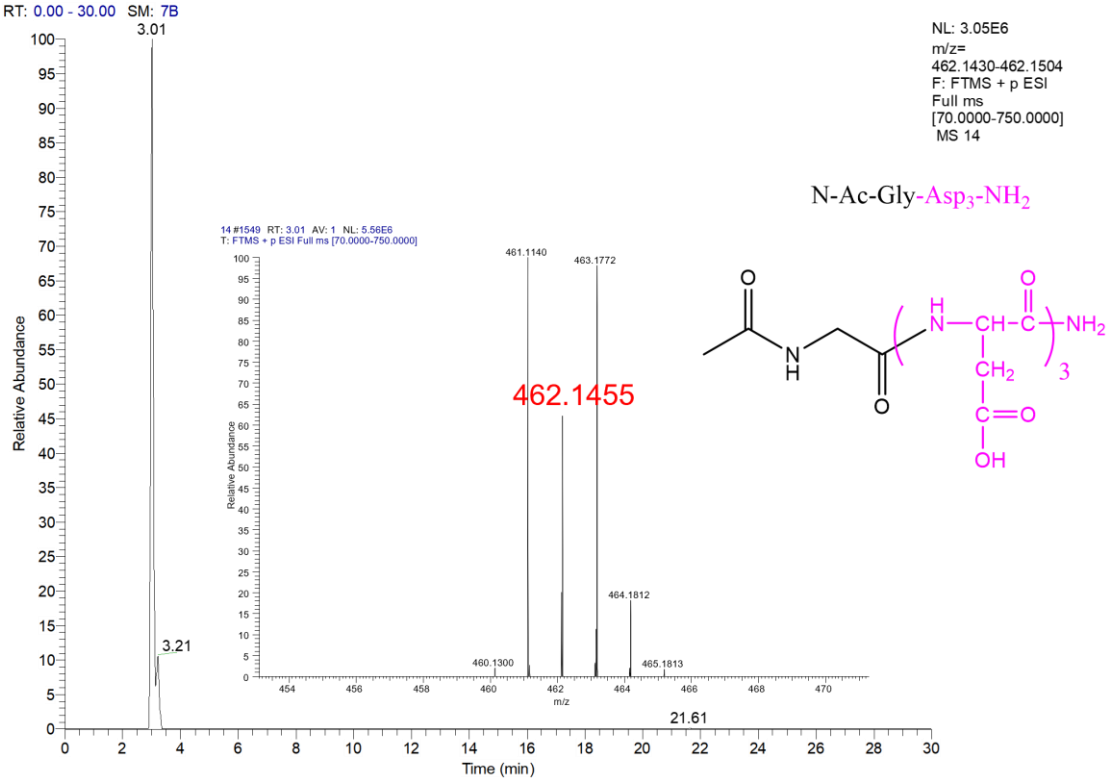

Fig. S169 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 462.1455 was analyzed, and its EIC corresponded to the tetramer N-Ac-Gly-Asp_3-NH_2 with a retention time of 3.01 min.

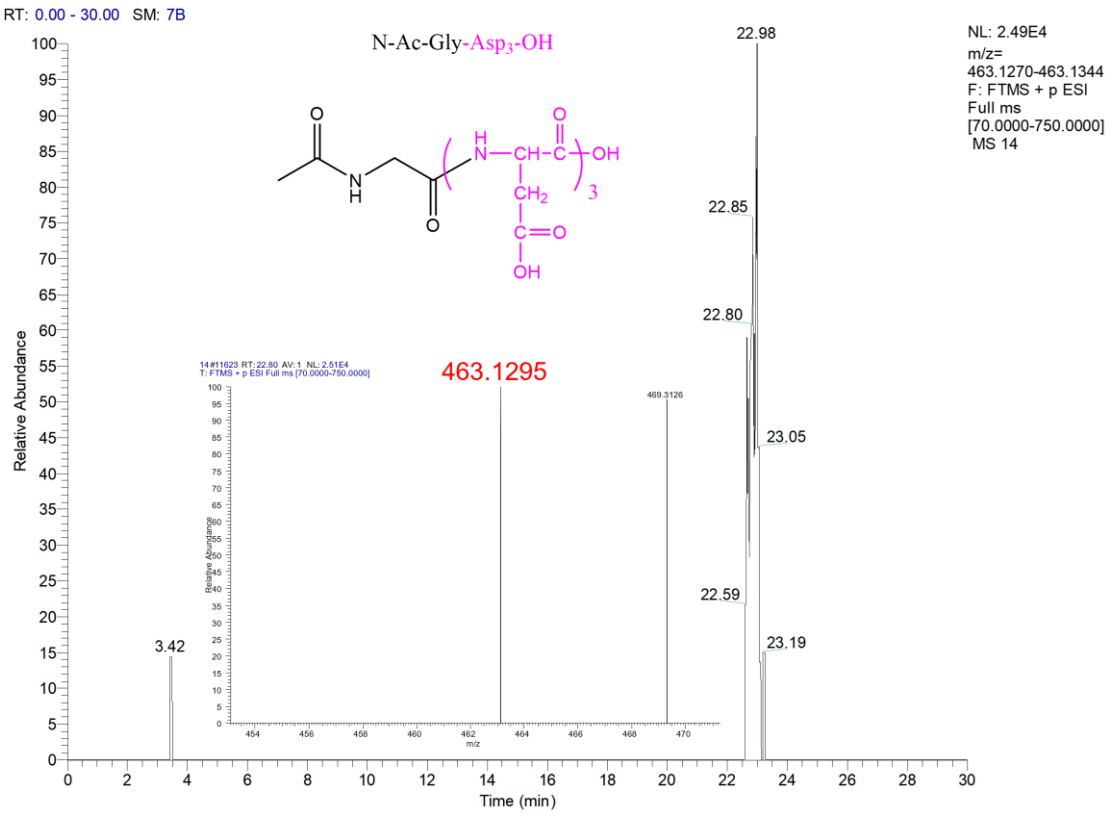

Fig. S170 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 463.1295 was analyzed, and its EIC corresponded to the tetrapeptide N-Ac-Gly-Asp$_3$-OH with a retention time of 22.80 min.

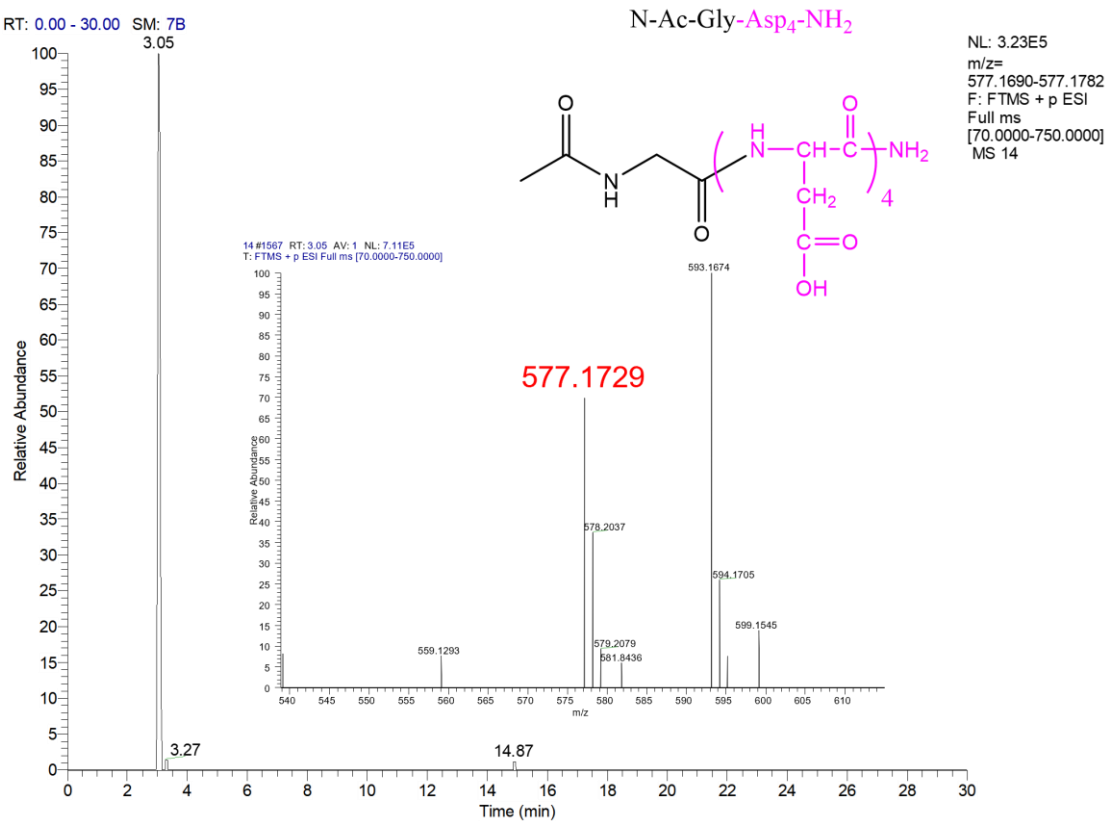

Fig. S171 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 577.1729 was analyzed, and the EIC corresponds to the pentamer N-Ac-Gly-Asp_4-NH_2 with a retention time of 3.05 min.

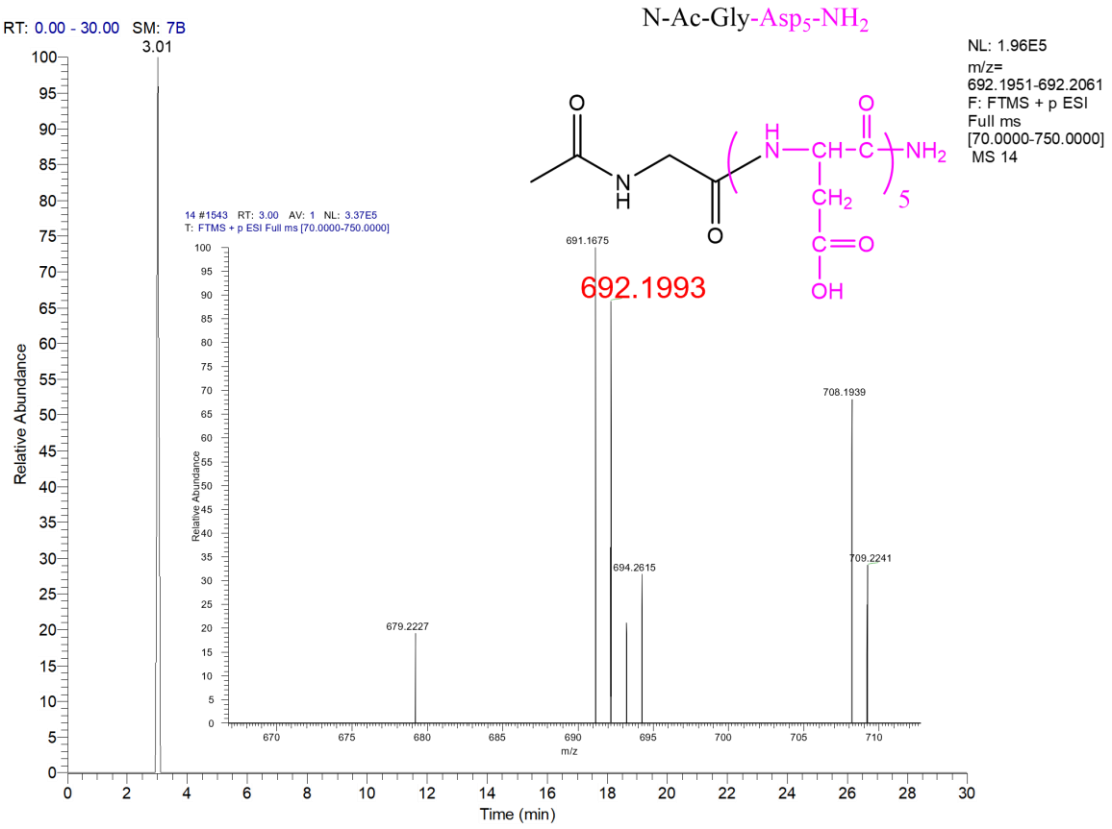

Fig. S172 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 692.1993 was analyzed, and its EIC corresponded to the hamerer N-Ac-Gly-Asp_5-NH_2 with a retention time of 3.00 min.

2.36 Oligomer produced by the polymerization of 0.1 M Ac-Gly-NH_2 and 0.1 M Tyr-NH_2.（Figs. S173-S177）

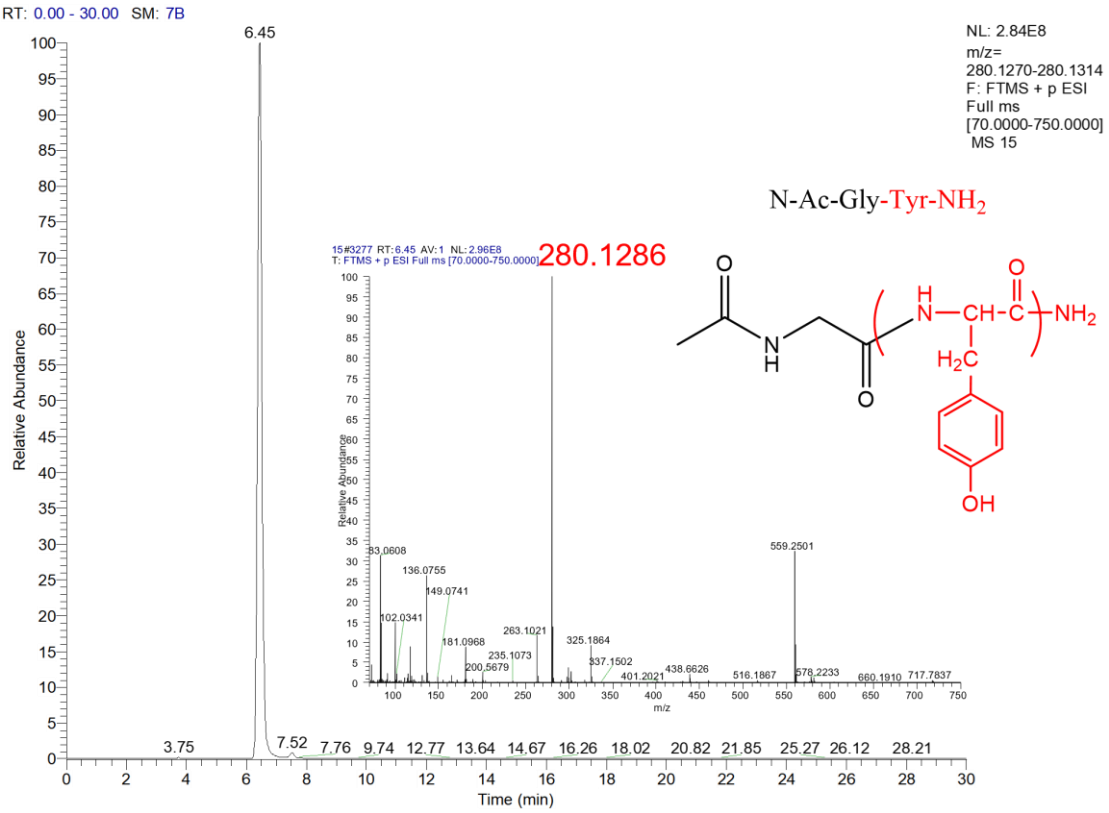

Fig. S173 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 280.1286 was analyzed, and its EIC corresponded to the dimer N-Ac-Gly-Tyr-NH_2 with a retention time of 6.45 min.

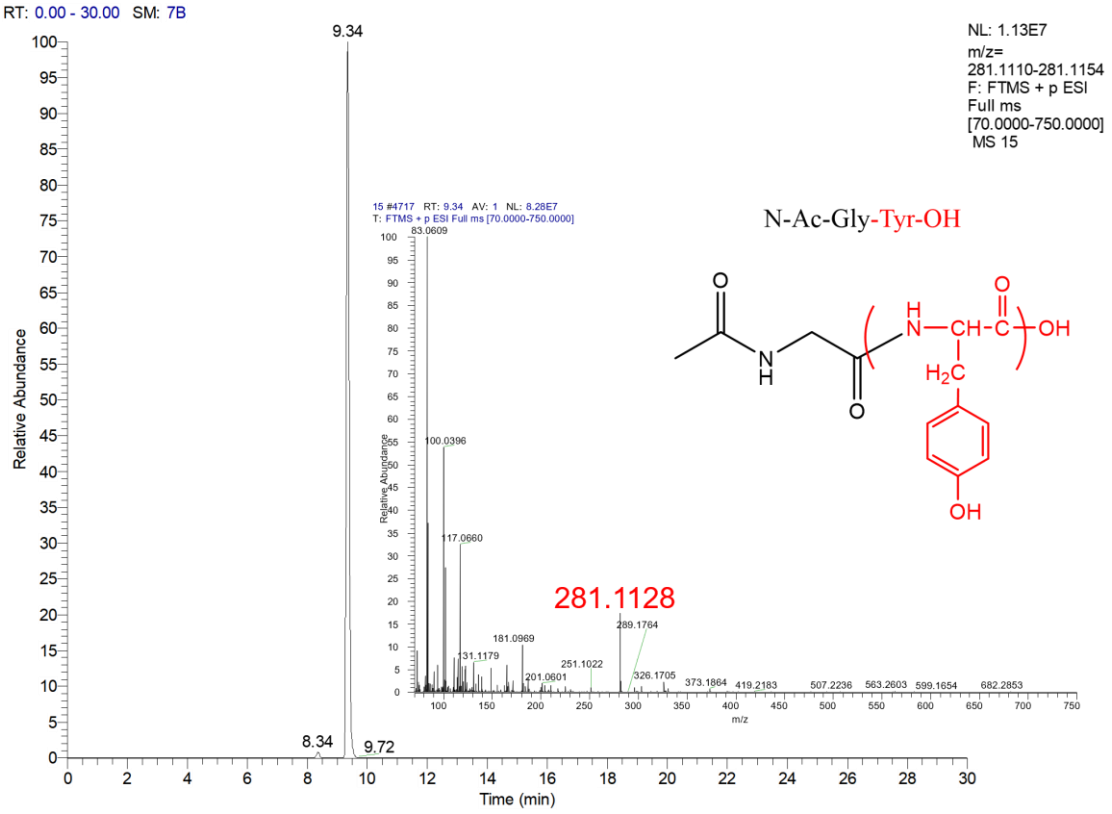

Fig. S174 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/ z281.1128 was analyzed, and its EIC corresponded to the dipeptide N-Ac-Gly-Tyr-OH with a retention time of 9.34 min.

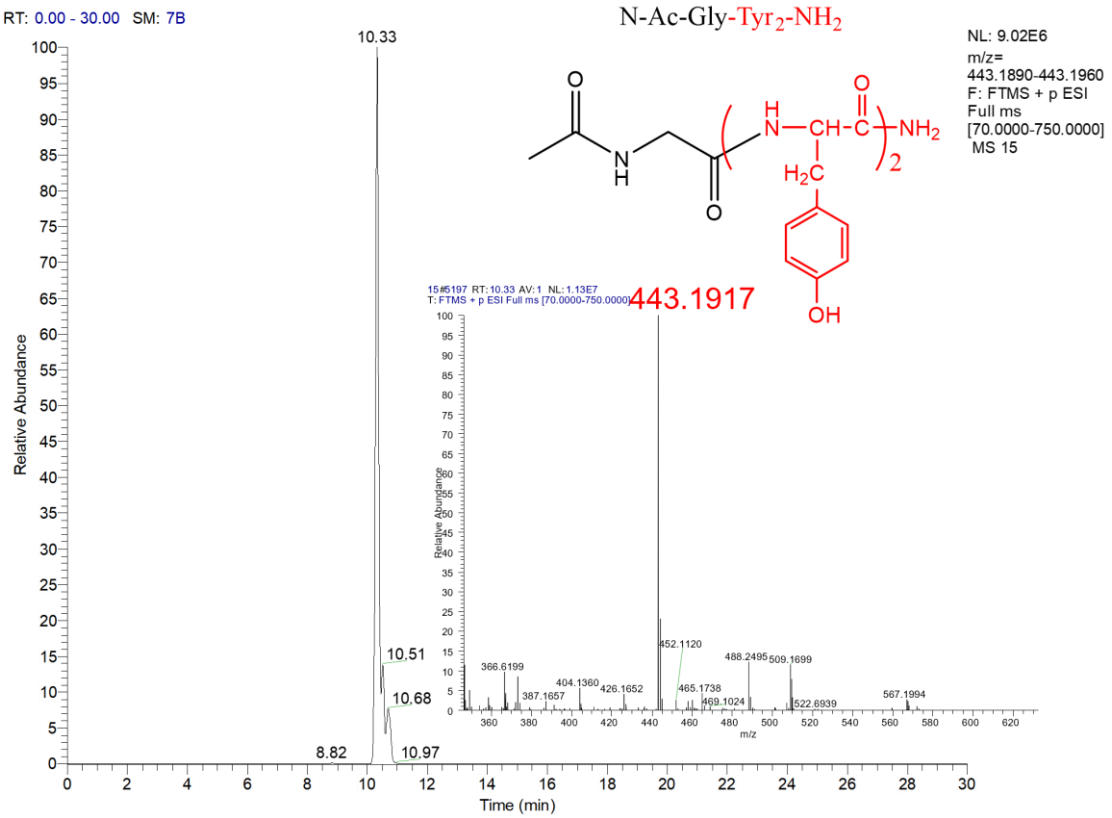

Fig. S175 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 443.1917 was analyzed, and its EIC corresponds to the trimer N-Ac-Gly-Tyr_2-NH_2 with a retention time of 10.33 min.

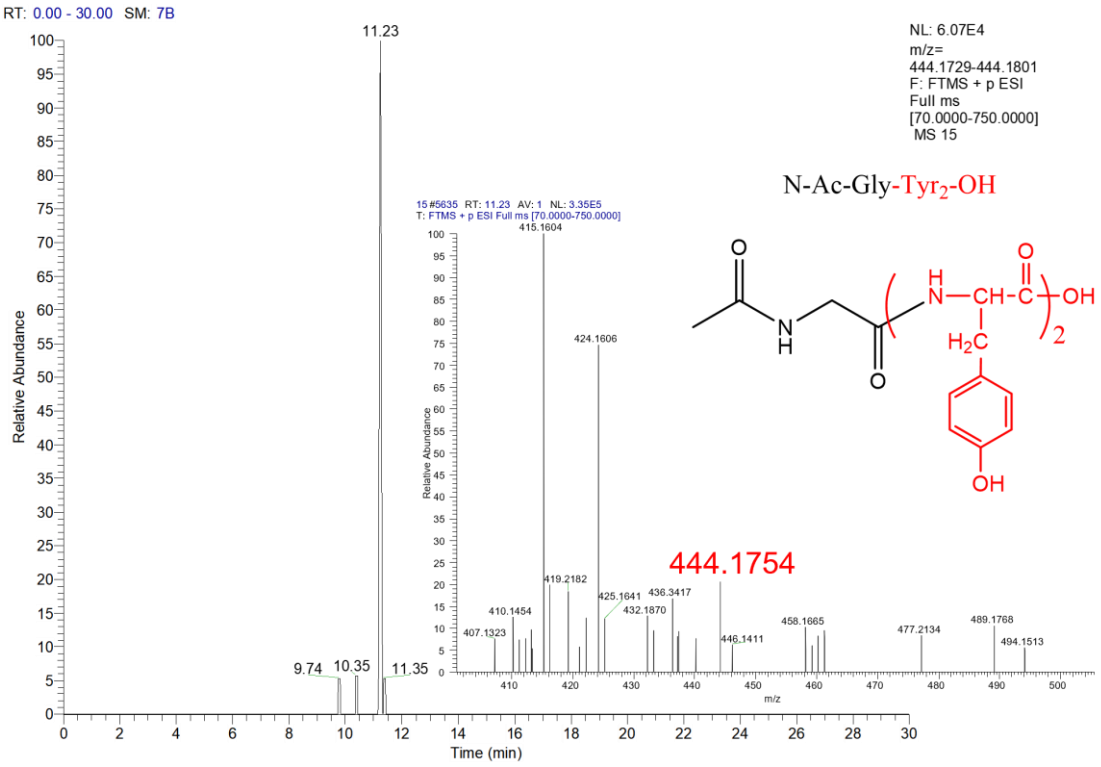

Fig. S176 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 444.1754 was analyzed, and its EIC corresponded to the tripeptide N-Ac-Gly-Tyr_2-OH with a retention time of 11.23 min.

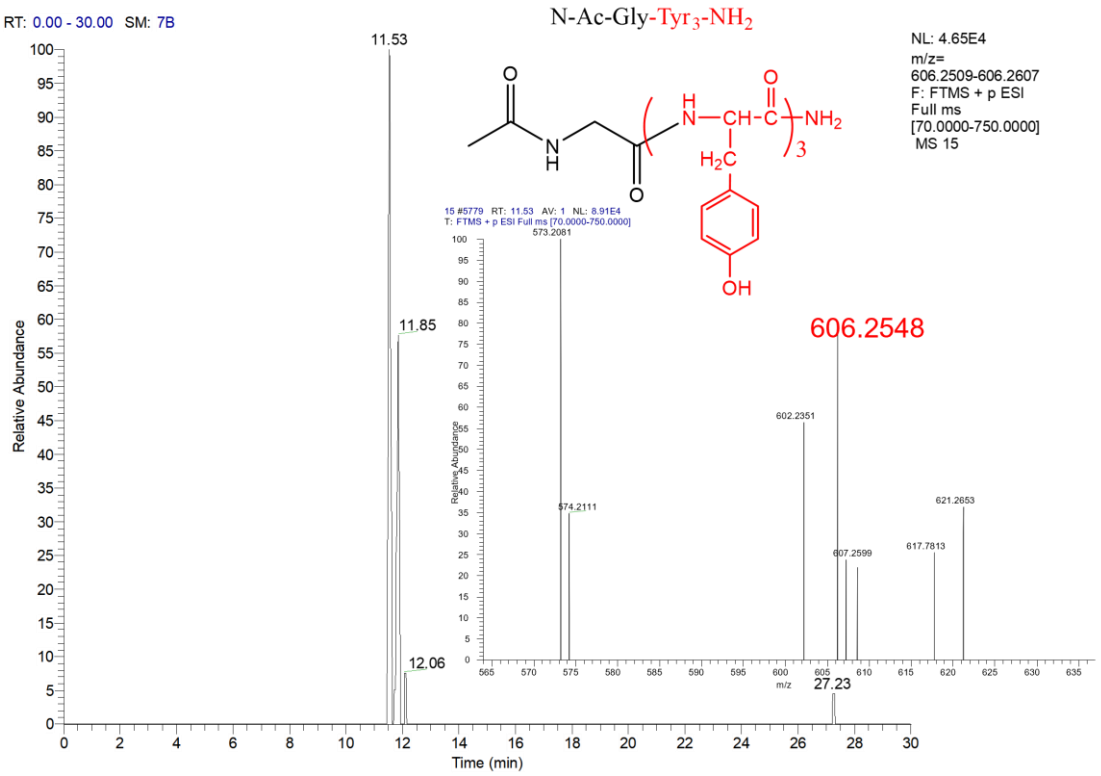

Fig. S177 Extraction ion chromatography-mass spectrometry analysis of the product. The EIC of m/z 606.2548 was analyzed, and its EIC corresponded to the tetramer N-Ac-Gly-Tyr_3-NH_2 with a retention time of 11.53 min.

2.37 Secondary mass spectrometry analysis of the product trimers from the reaction of Ac-Gly-NH_2 with AA-NH_2.（Figs. S178-S189）

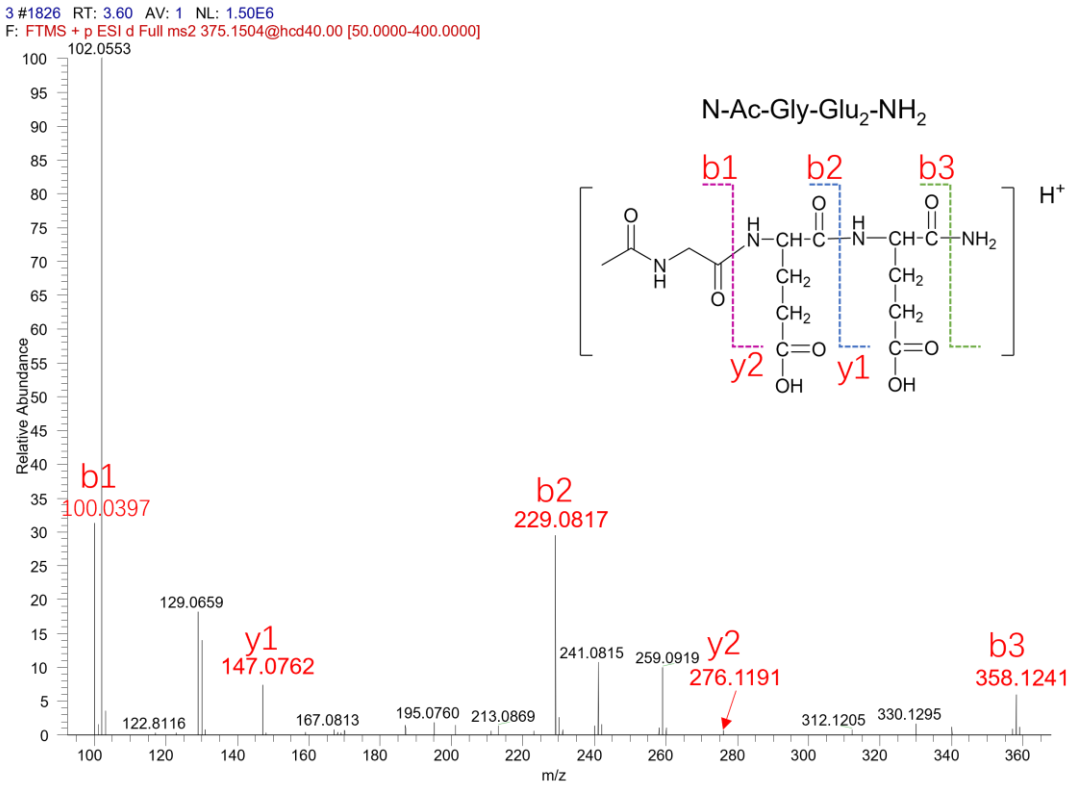

Fig. S178 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 375.1504 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Glu_2-NH_2.

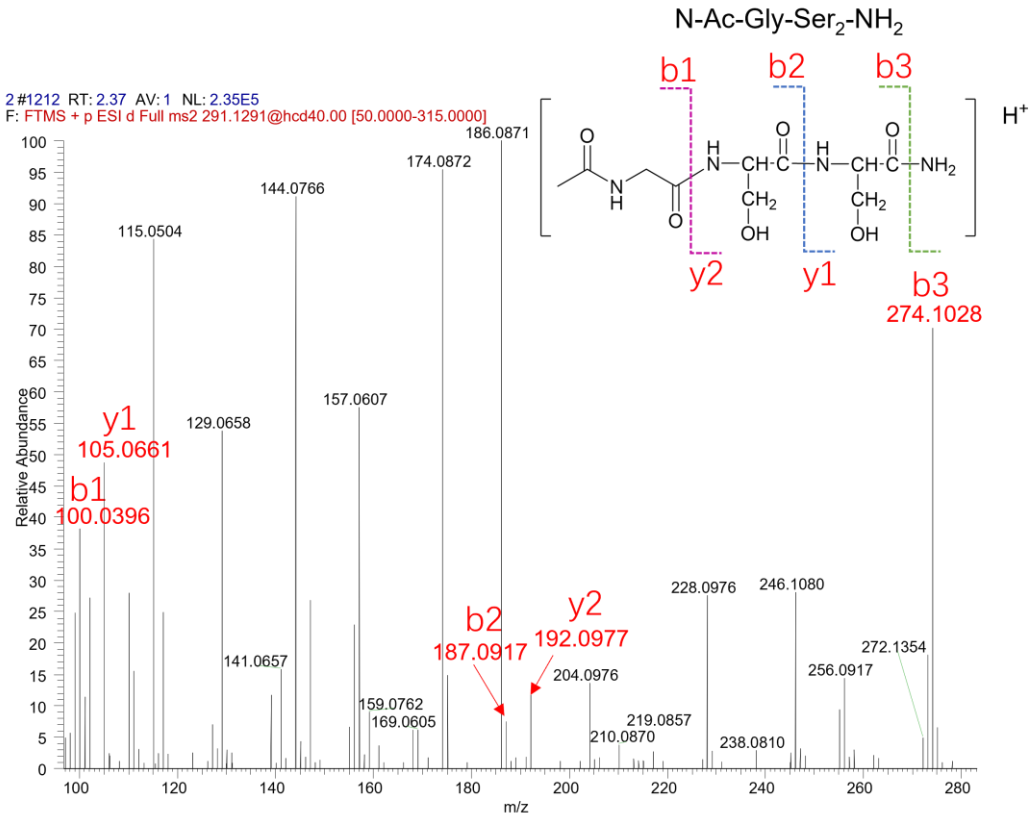

Fig. S179 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 291.1291 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Ser_2-NH_2.

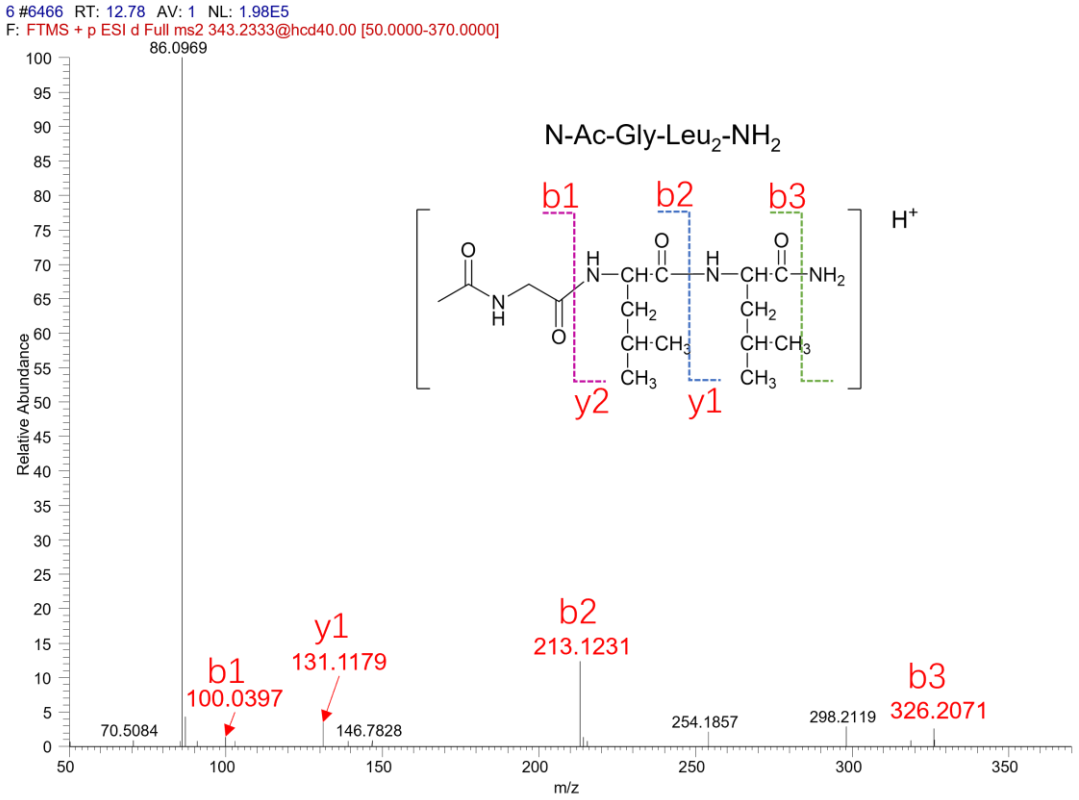

Fig. S180 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 343.2333 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Leu_2-NH_2.

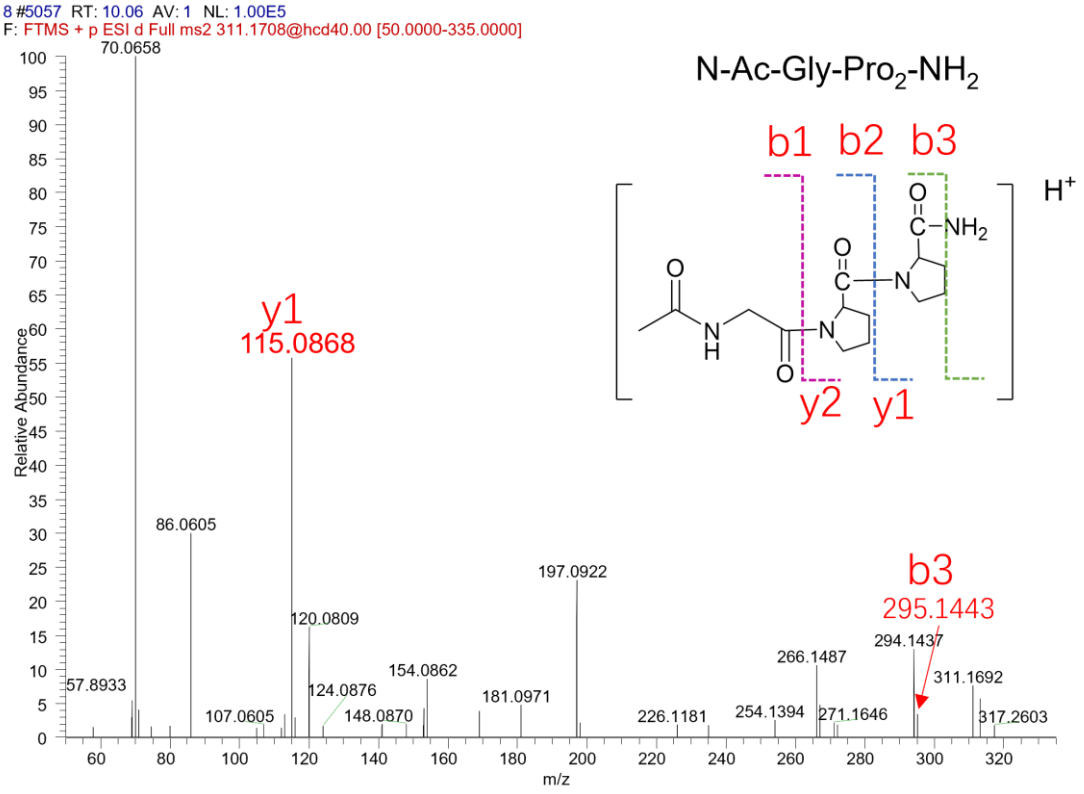

Fig. S181 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 311.1708 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Pro_2-NH_2.

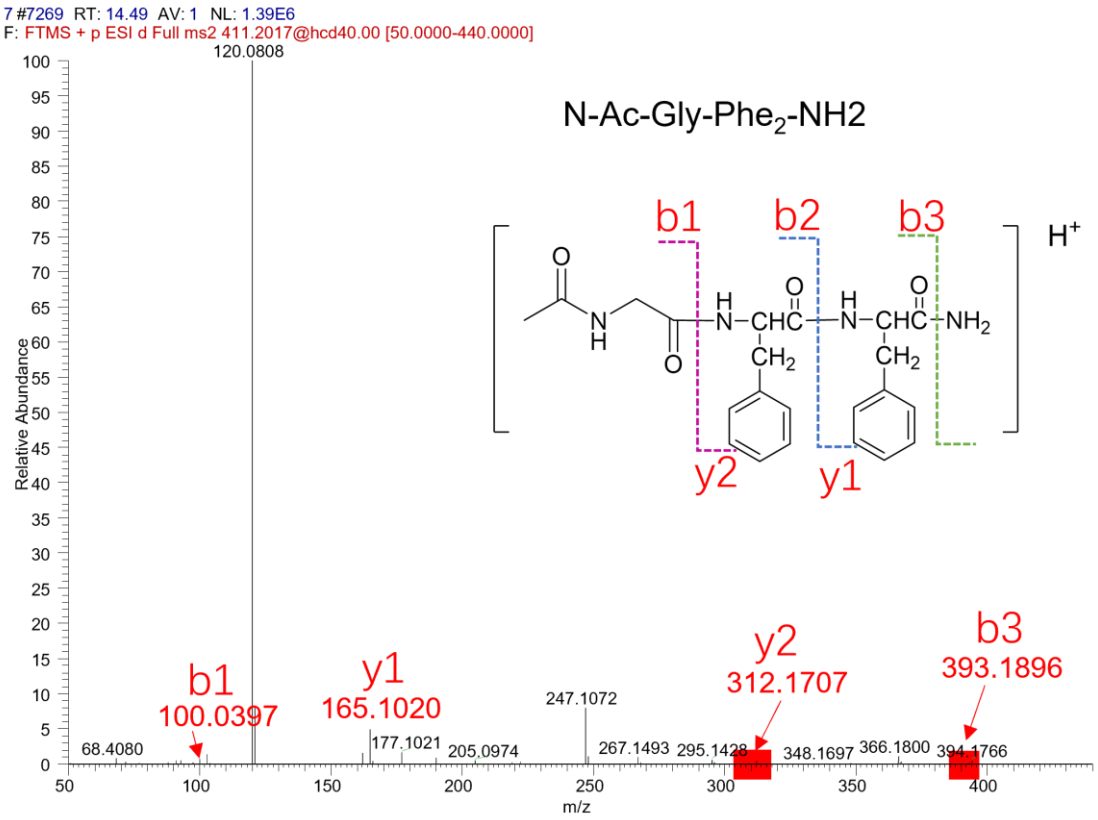

Fig. S182 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 411.2017 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Phe_2-NH_2.

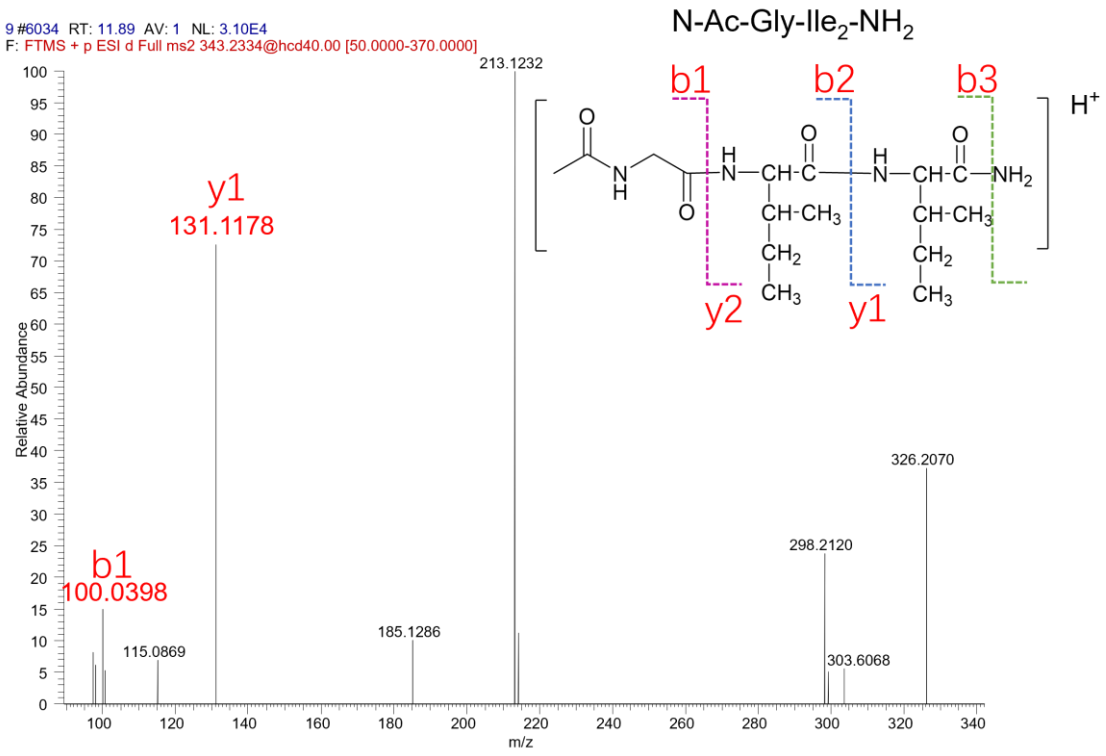

Fig. S183 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 343.2334 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Ile_2-NH_2.

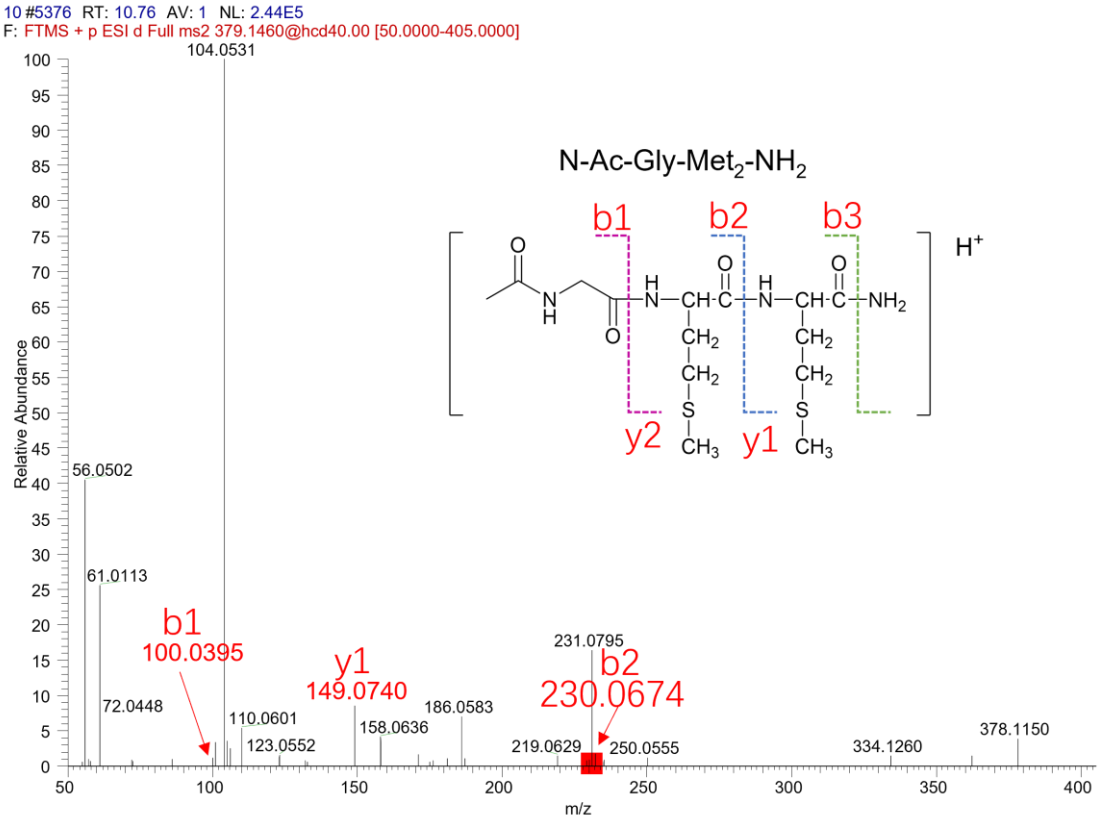

Fig. S184 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 379.1460 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Met_2-NH_2.

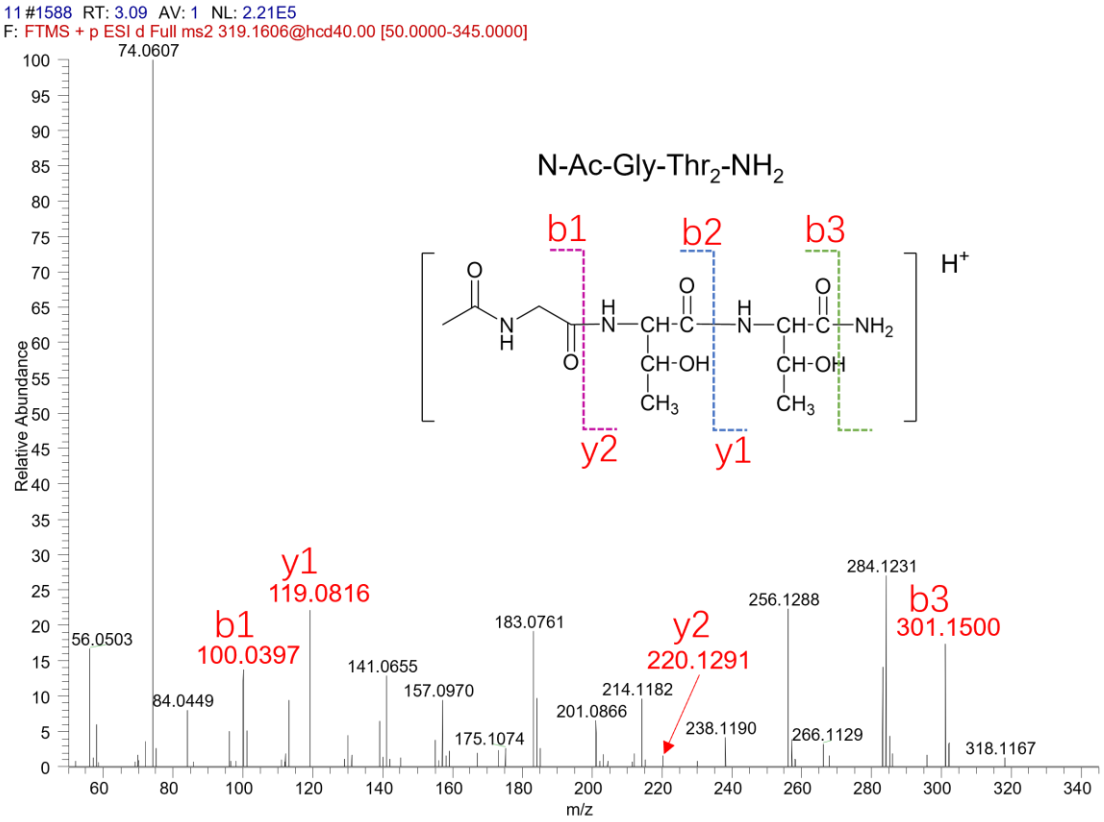

Fig. S185 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 319.1606 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Thr_2-NH_2.

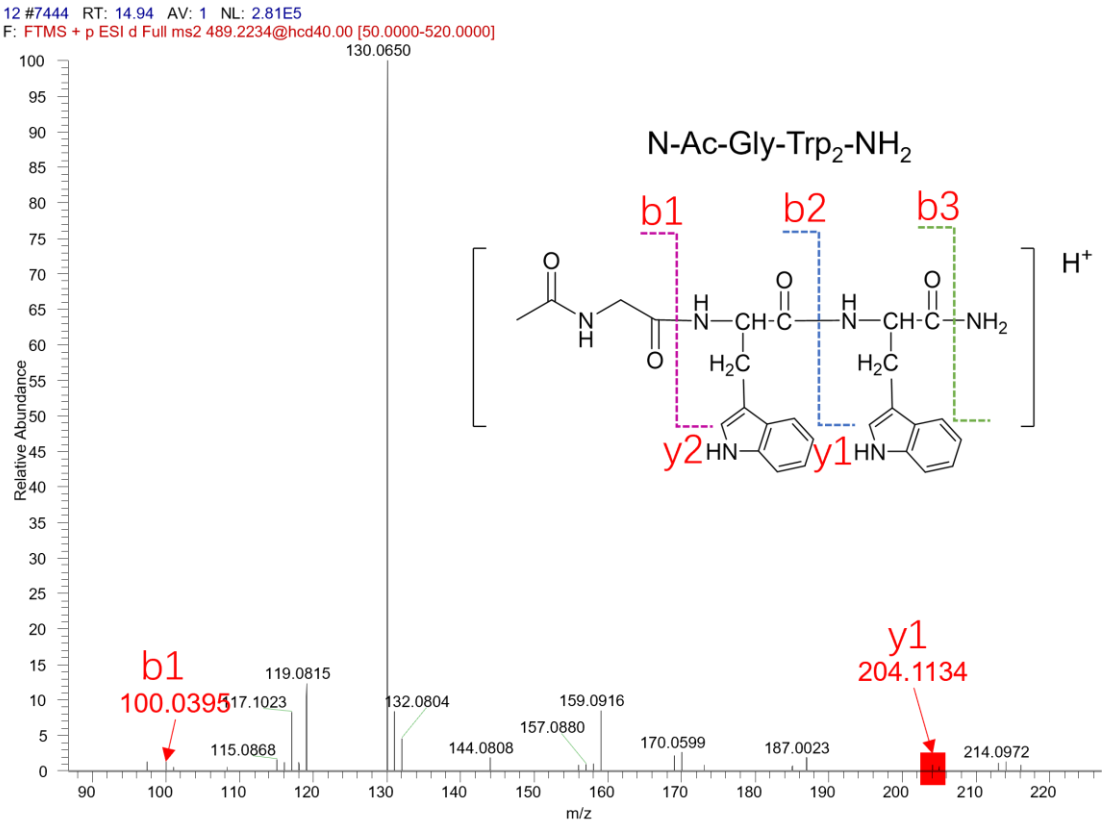

Fig. S186 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 489.2234 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Trp_2-NH_2.

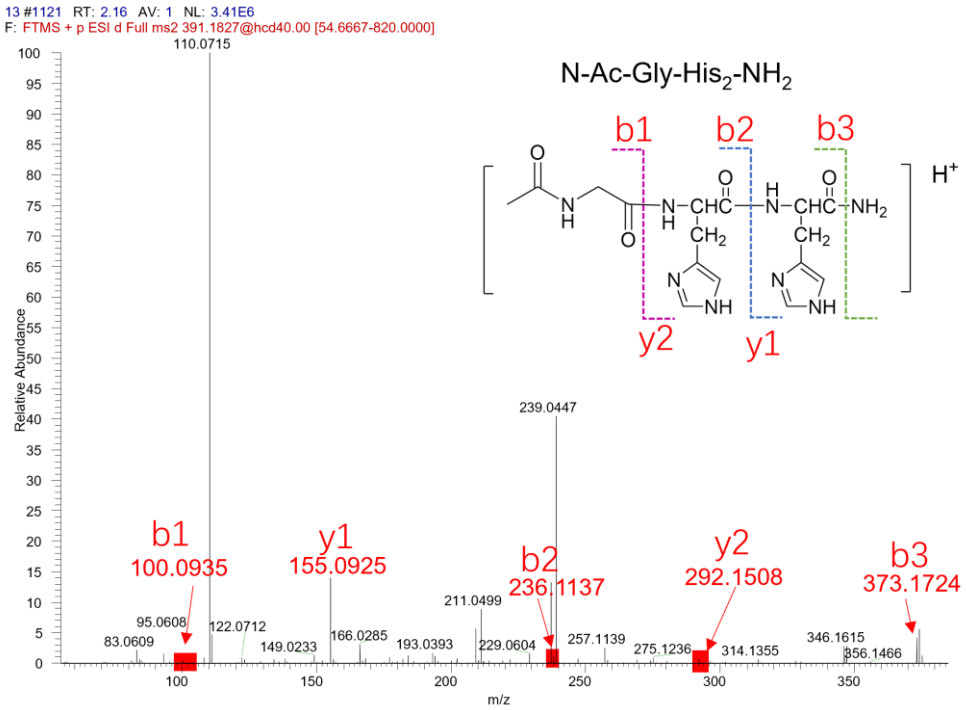

Fig. S187 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 391.1827 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-His_2-NH_2.

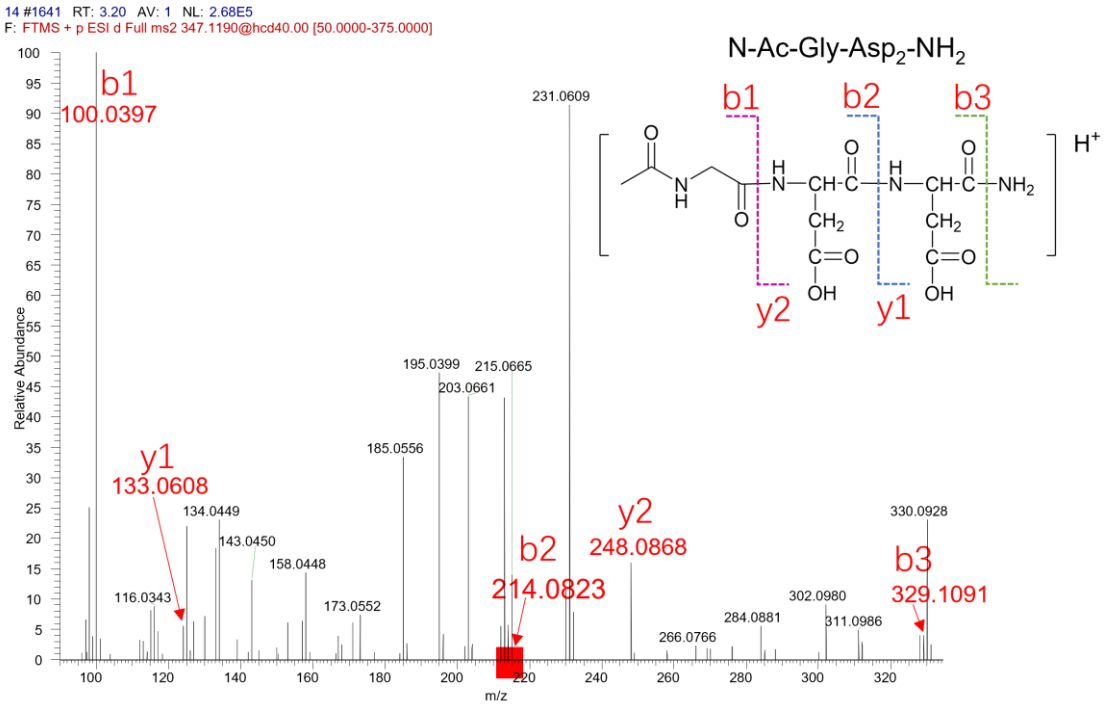

Fig. S188 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 347.1190 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Asp_2-NH_2.

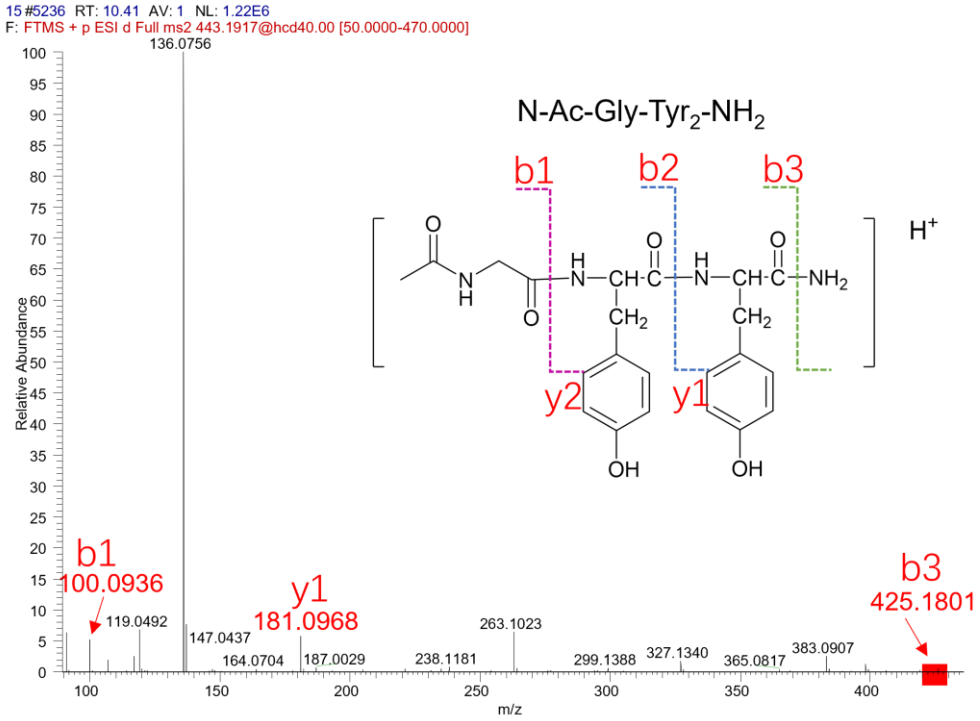

Fig. S189 The extension direction of the trimer was verified by secondary mass spectrometry. The ion flow signal at m/z 443.1917 was extracted, revealing the presence of ion fragments generated by N-Ac-Gly-Tyr_2-NH_2.

2.38 Two-component reaction and one-pot reaction. (Fig. S190)

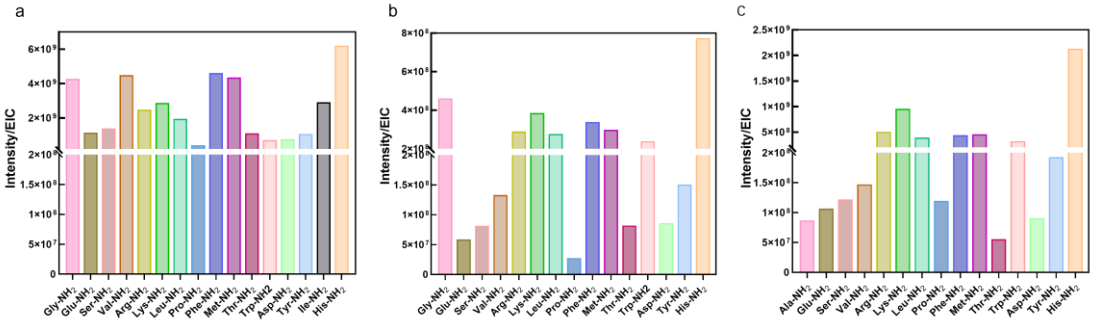

Fig. S190 Peak area extraction for Ac-AA-AA-NH_2 was performed in the mass spectrum. a) Two-component reaction between Ac-Ala-NH_2 and AA-NH_2 b) One-pot reaction of Ac-Ala-NH_2 with 15 kinds of AA-NH_2. c) One-pot reaction of Ac-Gly-NH_2 with 15 kinds of AA-NH_2.

2.39 Conversion efficiency of Ac-Ala-NH_2. (Fig. S191)

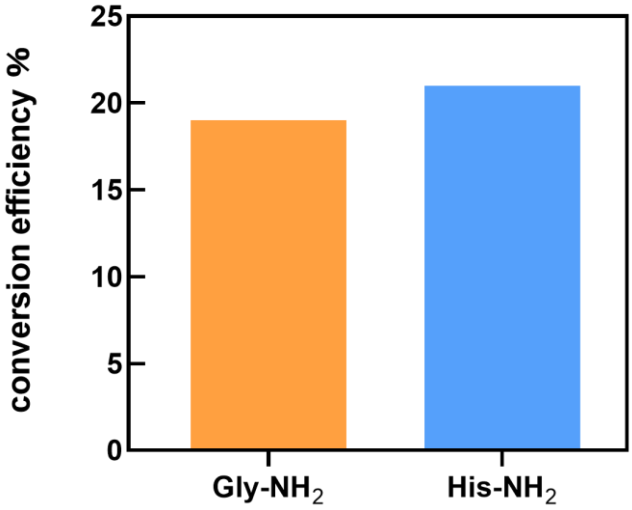

Fig. S191 Conversion efficiency of Ac-Ala-NH_2 in two reactions (Ac-Ala-NH_2+Gly-NH_2, Ac-Ala-NH_2+His-NH_2). The yellow bar chart represents Ac-Ala-NH_2+Gly-NH_2, while the blue bar chart represents Ac-Ala-NH_2+His-NH_2.

2.40 The reaction of Ac-Ala-NH_2 and Gly-NH_2. (Fig. S192)

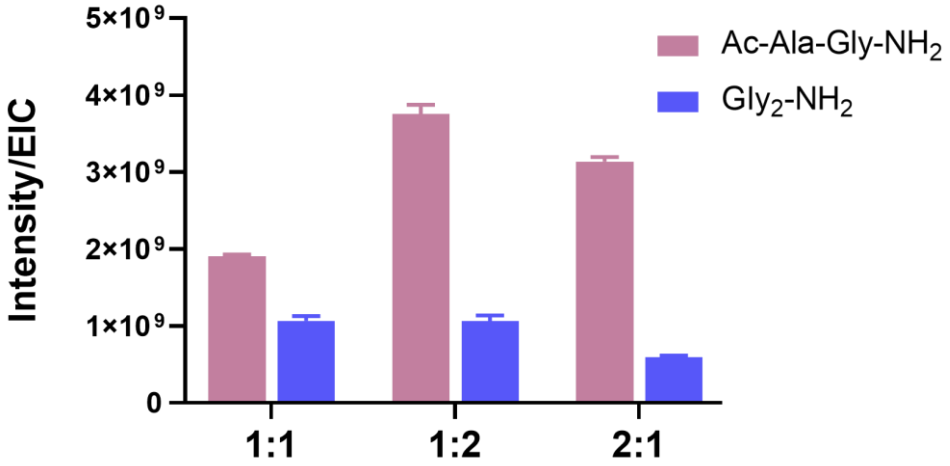

Fig. S192. Adjusting the ratio between Ac-Ala-NH_2 and Gly-NH_2, the proportion of products Ac-Ala-Gly-NH_2 to Gly_2-NH_2 can be increased. We have carried out additional experiments as follows: We used a combination of Ac-Ala-NH_2 and Gly-NH_2 and established three different molar ratios - 1:1 (where both are at 0.1 M), 1:2 (with Ac-Ala-NH_2 at 0.1 M and Gly-NH_2 at 0.2 M), and 2:1 (Ac-Ala-NH_2 at 0.2 M and Gly-NH_2 at 0.1 M). Upon completion of the reaction, we meticulously extracted and compared the peak areas of Ac-Ala-Gly-NH_2 and Gly_2-NH_2 using HPLC-MS. Using HPLC-MS for sample analysis, the extracted ion chromatogram (EIC) of m/z 188.1028 and 132.0767 corresponds respectively to the molecular ions $[M+H]^+$ of Ac-Ala-Gly-NH_2 and Gly_2-NH_2.

2.41 Mechanism. (Fig. S193)

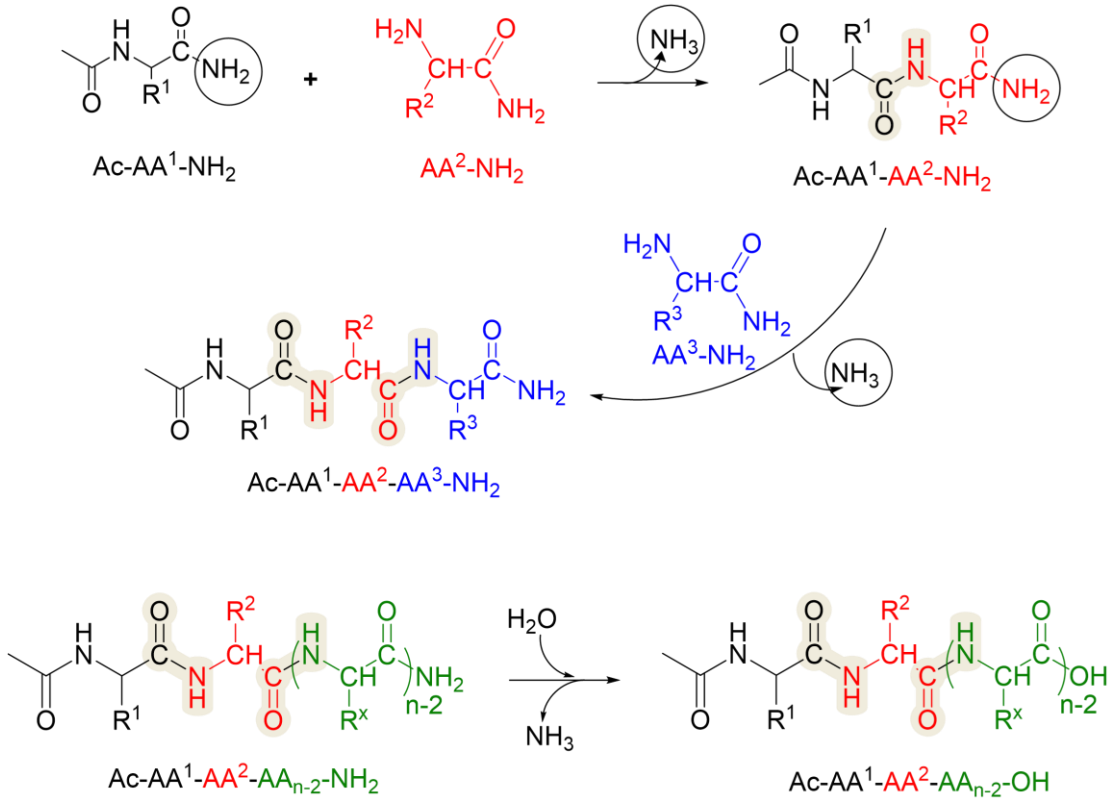

Fig. S193 Mechanism of Ac-AA-NH_2 and AA-NH_2 extension from N→C terminal in polymerization reaction.

Ac-AA^1-NH_2 is employed as the N-terminus of the peptide chain, while AA^2-NH_2 is used as the synthetic substrate. The -$CONH_2$ group in both Ac-AA^1-NH_2 and AA^2-NH_2 is activated, enabling Ac-AA^1-NH_2 to act as a nucleophile. It attacks the -NH_2 group on another AA^2-NH_2 molecule, leading to the release of an NH_3 unit and the creation of an amide bond. This process promotes the polymerization of amino acids under prebiotic conditions conducive to life. The resultant dimer, Ac-AA^1-AA^2-NH_2, functions as the N-terminal unit for initiating further synthesis, reacting with another AA^3-NH_2 to form the trimer Ac-AA^1-AA^2-AA^3-NH_2. This mechanism allows for continuous N→C polypeptide synthesis. Throughout this process, the oligomer Ac-AA^1-AA^2-AA_{n-2}-NH_2 undergoes hydrolysis, yielding a linear peptide Ac-AA^1-AA^2-AA_{n-2}-OH.