

Supplementary Data

Recent Advances in Aptamer-Based Biosensors for Bacterial Detection

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Summary

- Table S1. Sequence of aptamers used for bacterial detection

- References

Table S1. Sequences of aptamer used in biosensors for bacterial detection.

| Bacteria | Aptamer | Sequence | Ref |
|------------------|---------------------|---|-------|
| <i>S. aureus</i> | SA20 | GCGCCCTCTCACGTGGCATCAGAGTGCCGGAAGTTCTGCGTTAT | [1] |
| | SA23 | GGGCTGGCCAGATCAGACCCCGGATGATCATCCTTGTGAGAACCA | |
| | SA34 | CACAGTCACTCAGACGGCCGCTATTGTTGCCAGATTGCCTTTGGC | |
| | SA31 | TCCCACGATCTCATTAGTCTGTGGATAAGCGTGGGACGTCTATGA | |
| | SA43 | TCGGCACGTTTCTCAGTAGCGCTCGCTGGTCATCCCACAGCTACGTC | |
| <i>S. aureus</i> | T1 | ACTGTCrGrCrGrCrArCrGrCrGrUrGrUrGrUrArGrUrArCrArCrArCrGrArUrCrGrCrGrCrGrCrArCrArUrArU | [2] |
| | T2 | ACTGTCrArArUrUrUrGrArArUrArUrArUrArGrUrGrCrGrCrGrCrGrUrArGrUrGrUrGrUrArArArArUrU | |
| | T3 | ACTGTCrArArUrUrUrGrArGrUrGrUrGrUrGrArUrCrArUrArUrArUrCrGrUrArGrCrGrCrGrUrArCrArArCrC | |
| | A14 | ACTGTCCACACCGCAGCAGTGGGAACGTTTCAGCCATGCAAGCATCACGCCCGT | |
| <i>S. aureus</i> | H1 | GCAATGGTACGGTACTTCCTCGGCACGTTCTCAGTAGCGCTCGCTGGTCATCCCACAGCTACGTCAAAGTGCACGCTACT TTGCTAA | [3] |
| <i>S. aureus</i> | H1 | GCAATGGTACGGTACCCCTATGCGCATGTACCATTGCAGTTGTCAGAGAGCGA | [4] |
| | H2 | GGTACA/Dabcyl/TGCGCATAGGGGTACCGTACCATACCCCTATGCGCA/FAM/ | |
| | cApt | GTACCGTACCATTGCTAGCGTCTTCCCGTCCTT | |
| <i>S. aureus</i> | Apt1 | TCCCTACGGCGCTAACCCCCCAGTCCGTCCTCCCAGCCTCACACCGCCACCGTGCTACAAC | [5,6] |
| | Apt2 | TCCCTACGGCGCTAACCTCCAACCGTCCACCCTGCCTCCGCCTCGCCACCGTGCTACAAC | |
| <i>S. aureus</i> | SH-Apt ₂ | GCAATGGTACGGTACTTCCTCGGCACGTTCTCAGTAGCGCTCGCTGGTCATCCCACAGCTACGTCAAAGTGCACGCTACT TTGCTAA | [7,8] |
| <i>S. aureus</i> | A15 | AGCAG CACAGAGGTCAGATG(N40)CCTATGCGTGCTACCGTGAA- | [9] |
| <i>S. aureus</i> | APT ^{seb1} | GGTATTGAGGGTCGCATCCACTGGTCGTTGTTGTCTGTTATGTTGTTTCGTGATGGCTCTAACTCTCCTCT | [10] |
| <i>S. aureus</i> | A-SEB | TGCAGGATCCGGTATCCGTGCACACACACCCAACAACCAGCTGCCGCACCGGAGGAATTCTCGT | [11] |
| <i>S. aureus</i> | G1 | UCCGAACAGCGGAAGGUGGUUCGAAGUUGGGCUUUGGA | [12] |
| | #2 | GGGAGUUUUGAUACGGCUUCAUGCAGUAAUGUUUUUUAU | |
| | #18 | UCCGAACAGCGGAAGGUGGUUCGAAGUUGGGCUUUGGA | |

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|------------------|--|---|---------|
| <i>S. aureus</i> | AT-27 AT-33 AT-36 AT-49 | ACCCCTGCAGGATCCTTTGCTGGTACC-(N42)-AGTATCGCTAATCAGTCTAGAGGGCCCCAGAAT | [13] |
| <i>S. aureus</i> | H1, P1 | GCAATGGTACGGTACTTCCTCGGCACGTTCTCAGTAGCGCTCGCTGGTCATCCCACAGCTACGTCAAAAAGTGCACGCTACT TTGCTAA | [14] |
| <i>S. aureus</i> | Antibac1 Antibac2 | GGGACAGGGAGTGCCTGCTCCCC GGGGACTAGAGGACTTGTGCGGCC | [15,16] |
| <i>E. coli</i> | SH-Apt ₁ | GCAATGGTACGGTACTTCCCCATGAGTGTTGTGAAATGTTGGGACACTAGGTGGCATAGAGCCGCAAAAAGTGCAGCTACT TTGCTAA | [17,18] |
| <i>E. coli</i> | / | ATCCGTCACACCTGCTCTATCAAATGTGCAGATATCAAGACGATTTGTACAAGATGGTGTGGCTCCCGTAT | [19] |
| <i>E. coli</i> | GN6 GN12 | ATACCAGCTTATTCAATTGGGTGAGGGGGGGTTACAACGTTAAAGATAGACGGGGGAAGATAGTAAGTGAATCT | [20] |
| <i>E. coli</i> | 6-3 8-1 8-7 8-8 8-12 8-13 8-19 8-35 | UGGUUUCAGCGACAGGAGGGGUGUAGGUGGAUUGCUGUCCUUUGCGUGU UGCUAGUGUUGUAUGCACGUGGAGGAGGCGUACACUUGCUUUGUGGU GAUUGACCGUAUGGAGGAUGCAAAGGGAGGGAGGUCACUUGAGUUAGUUA GCAGGAUGUGGAGGAGGCAUCUGCUGCAAUCGGGACUUGUGUCGAGUAUC GCAUUGUCUGCGUGUGGAGGCAGGAGGCAAGAUAAAGAGGUGAUGCGGUUG CAUGUUGGCGAUACGUCUAAAACGGUGGGUUGUGGAGGAUUGAUUUUAUACG AGUAGUGUCAGCGUGUGGAGGUUGGCGACAUAUGUAGGGUGCGAUUG UGCGCAUACACGGUGAGGAGGUGGAGAGAUGUAGGUGCUUAGCAGUUGA | [21] |
| <i>E. coli</i> | ECA I ECA II | GTCTGCGAGCGGGGCGCGGGCCCCGGCGGGGATGCGC ACGGCGCTCCCAACAGGCCTCTCCTTACGGCATATTA | [22,23] |
| <i>E. coli</i> | / | GCAATGGTACGGTACTTCCCCATGAGTGTTGTGAAATGTTGGGACACTAGGTGGCATAGAGCCGCAAAAAGTGCACGCTAC TTTGCTAA | [24] |
| <i>E. coli</i> | Stx1 stx2 | ATCCAGAGTGACGCAGCAGTAGTTTTGTTGGTTATTACGGCGGGTTGCGATGGGTGCGAATCGGTGGACACGGTGGCTTAG T ATCCAGAGTGACGCAGCAGGAAAGGACGTCAAATTAGGGGCCGGGACAACGAAAGCCCACAACACTGGACGGTGGCTTAG T | [25] |

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|--------------------------------|----------------|--|---------|
| <i>E.coli</i> | E1 E2 E3 | GCAATGGTACGGTACTTCCACTTAGGTCGAGGTTAGTTTGTCTTGCTGGCGCATCCACTGAGCGCAAAGTGCACGCTACT TTGCTAA GCAATGGTACGGTACTTCCCCATGAGTGTTGTGAAATGTTGGGACACTAGGTGGCATAGAGCCGCAAAGTGCACGCTAC TTTGCTA GCAATGGTACGGTACTTCCGTTGCACTGTGCGGCCGAGCTGCCCCCTGGTTTGTGAATACCCTGGGCAAAGTGCACGCT ACTTTGCTAA | [26] |
| <i>P. aeruginosa</i> | F23 | CCCCCGTTGCTTTCGCTTTTCCTTTCGCTTTTGTTCGTTTCGTCCCTGCTTCCTTTCTTG | [27] |
| <i>B. cereus</i> | / | AGCAGCACAGAGGTCAGATGCCCCCTTTTATCCGTCGGCATGATGTCTCCCGATCCGGTCCTATGCGTGCTA | [28] |
| <i>B. cereus</i> | B15 B16 | AGCAGCACAGAGGTCAGATGGGCGGGTTTGGATCTTTGGTTGGCGCCTGTTTCTTTATGACCTATGCGTGCTACCGTGAA AGCAGCACAGAGGTCAGATGATATGTTTACGCCAGTGGTATTATTGGGGTTGATATGTCACCTATGCGTGCTACCGTGAA | [29] |
| <i>B. cereus</i> | 13-18 13-24 | AGCACAGAGGTCAGATGGGCTACTGGAGCATCTGGTAACGAAGTACCCTCGGGCGG AGCACAGAGGTCAGATGATCGAGGGCGCAGACCGAACCCGCGTGCGCAGTACAAGGGC | [30] |
| <i>Acinetobacter baumannii</i> | AB | AATCAGGCTCAGCATGGAGTTGCGAGGCCAATATCCGGTTAAGCG | [31,32] |
| <i>Acinetobacter baumannii</i> | K2 | ACAGCACCACAGACCACATATCACATGCTGTGCGCTTGGGATATCAATCCAGTGATGTTTGTCTTCCTGCC | [31] |
| <i>Leptospira interrogans</i> | LAP3 | TGGCGTTAGAGATACCGGAACCGGTGTCGGGCGTCTGAAGAATCC | [33] |
| <i>Bacillus cytotoxicus</i> | BAS6R | ATCCGTCACACCTGCTCTGCACGGGCTCAGTTTGGCTTTGTATCCTAAGAGGATGGTGTGGCTCCCGTAT | [34] |
| <i>Vibrio cholerae</i> | CT916 | GGCAAAAAGGATTGCCCAGGTCTGCTGTCTAGCCGGATTC | [35] |
| <i>Clostridium difficile</i> | / | TAGTGATGCCTTTGTTGAGA-[N40]-TCTTCATCGTCCACTAAATT | [36] |
| <i>S. typhimurium</i> | H2 | TATGGCGGCGTCACCCGACGGGGACTTGACATTATGACAG | [14] |
| <i>S. Typhimurium</i> | Apt S.T | TGGCTAGCTCAGTCATATGGCGGCGTCACCCGACGGGGACTTGACATTATGACAGCCGCG | [37] |

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| <i>Vibrio</i> <i>parahaemolyticus</i> | Apt VP | TGGCTAGCTCAGTCATCTAAAAATGGGCAAAGAAACAGTGACTCGTTGAGATACTCCGCG | [37] |
| <i>Clostridium</i> <i>perfringens</i> | / | TCAACGGCAGTAACATTAGC | [38] |

1. Cao X, Li S, Chen L, Ding H, Xu H, Huang Y, et al. Combining use of a panel of ssDNA aptamers in the detection of *Staphylococcus aureus*. *Nucleic Acids Research*. 2009 Aug;37(14):4621–8.
2. Wijesinghe KM, Sabbih G, Algama CH, Syed R, Danquah MK, Dhakal S. FRET-Based Single-Molecule Detection of Pathogen Protein IsdA Using Computationally Selected Aptamers. *Anal Chem*. 2023 Jul 4;95(26):9839–46.
3. Lian Y, He F, Wang H, Tong F. A new aptamer/graphene interdigitated gold electrode piezoelectric sensor for rapid and specific detection of *Staphylococcus aureus*. *Biosensors and Bioelectronics*. 2015 Mar;65:314–9.
4. Kang Q, Xing X yan, Zhang S qi, He L, Li J zhao, Jiao J bo, et al. A novel Aptamer-induced CHA amplification strategy for ultrasensitive detection of *Staphylococcus aureus* and NIR-triggered photothermal bactericidal Activity based on aptamer-modified magnetic Fe₃O₄@AuNRs. *Sensors and Actuators B: Chemical*. 2023 May;382:133554.
5. Abbaspour A, Norouz-Sarvestani F, Noori A, Soltani N. Aptamer-conjugated silver nanoparticles for electrochemical dual-aptamer-based sandwich detection of *staphylococcus aureus*. *Biosensors and Bioelectronics*. 2015 Jun;68:149–55.
6. Marin M, Rizzotto F, Léguillier V, Péchoux C, Borezee-Durant E, Vidic J. Naked-eye detection of *Staphylococcus aureus* in powdered milk and infant formula using gold nanoparticles. *Journal of Microbiological Methods*. 2022 Oct;201:106578.
7. Zhao W, Yang S, Zhang D, Zhou T, Huang J, Gao M, et al. Ultrasensitive dual-enhanced sandwich strategy for simultaneous detection of *Escherichia coli* and *Staphylococcus aureus* based on optimized aptamers-functionalized magnetic capture probes and graphene oxide-Au nanostars SERS tags. *Journal of Colloid and Interface Science*. 2023 Mar;634:651–63.
8. Kim YS, Song MY, Jurng J, Kim BC. Isolation and characterization of DNA aptamers against *Escherichia coli* using a bacterial cell–systematic evolution of ligands by exponential enrichment approach. *Analytical Biochemistry*. 2013 May;436(1):22–8.
9. Huang Y, Chen X, Xia Y, Wu S, Duan N, Ma X, et al. Selection, identification and application of a DNA aptamer against *Staphylococcus aureus* enterotoxin A. *Anal Methods*. 2014;6(3):690–7.
10. DeGrasse JA. A Single-Stranded DNA Aptamer That Selectively Binds to *Staphylococcus aureus* Enterotoxin B. Kourentzi K, editor. *PLoS ONE*. 2012 Mar 16;7(3):e33410.
11. Mousavi Nodoushan S, Nasirizadeh N, Amani J, Halabian R, Imani Fooladi AA. An electrochemical aptasensor for staphylococcal enterotoxin B detection based on reduced graphene oxide and gold nano-urchins. *Biosensors and Bioelectronics*. 2019 Feb;127:221–8.

12. Han SR, Lee SW. In vitro selection of RNA aptamer specific to *Staphylococcus aureus*. *Ann Microbiol*. 2014 Jun;64(2):883–5.
13. Alizadeh N, Memar MY, Mehramuz B, Abibiglou SS, Hemmati F, Samadi Kafil H. Current advances in aptamer-assisted technologies for detecting bacterial and fungal toxins. *J Appl Microbiol*. 2018 Mar;124(3):644–51.
14. Chen J, Huang Z, Luo Z, Yu Q, Xu Y, Wang X, et al. Multichannel-Structured Three-Dimensional Chip for Highly Sensitive Pathogenic Bacteria Detection Based on Fast DNA-Programmed Signal Polymerization. *Anal Chem*. 2018 Oct 16;90(20):12019–26.
15. Ferreira IM, De Souza Lacerda CM, De Faria LS, Corrêa CR, De Andrade ASR. Selection of Peptidoglycan-Specific Aptamers for Bacterial Cells Identification. *Appl Biochem Biotechnol*. 2014 Dec;174(7):2548–56.
16. Bakhshandeh F, Saha S, Sen P, Sakib S, MacLachlan R, Kanji F, et al. A universal bacterial sensor created by integrating a light modulating aptamer complex with photoelectrochemical signal readout. *Biosensors and Bioelectronics*. 2023 Sep;235:115359.
17. Moon, J.; Kim, G.; Park, S.B.; Lim, J.; Mo, C. Comparison of Whole-Cell SELEX Methods for the Identification of *Staphylococcus Aureus*-Specific DNA Aptamers. *Sensors* **2015**, *15*, 8884–8897. <https://doi.org/10.3390/s150408884>
18. Chen, C.; Li, M.; Xing, Y.; Li, Y.; Joedecke, C.C.; Jin, J.; Yang, Z.; Liu, D. Study of pH-Induced Folding and Unfolding Kinetics of the DNA i-Motif by Stopped-Flow Circular Dichroism. *Langmuir* **2012**, *28*, 17743–17748
19. Zhang Y, Liu Y, Yang Y, Li L, Tao X, Song E. Rapid detection of pathogenic bacteria based on a universal dual-recognition FRET sensing system constructed with aptamer-quantum dots and lectin-gold nanoparticles. *Chinese Chemical Letters*. 2023 Aug;34(8):108102.
20. Shin HS, Gedi V, Kim JK, Lee D ki. Detection of Gram-negative bacterial outer membrane vesicles using DNA aptamers. *Sci Rep*. 2019 Sep 11;9(1):13167.
21. Niles JC, Marletta MA. Utilizing RNA Aptamers To Probe a Physiologically Important Heme-Regulated Cellular Network. *ACS Chem Biol*. 2006 Sep 1;1(8):515–24.
22. Bruno JG, Carrillo MP, Phillips T, Andrews CJ. A Novel Screening Method for Competitive FRET-Aptamers Applied to *E. coli* Assay Development. *J Fluoresc*. 2010 Nov;20(6):1211–23.
23. Queirós RB, de-los-Santos-Álvarez N, Noronha JP, Sales MGF. A label-free DNA aptamer-based impedance biosensor for the detection of *E. coli* outer membrane proteins. *Sensors and Actuators B: Chemical*. 2013 May;181:766–72.

24. Jiang D, Yang C, Fan Y, Polly Leung HM, Inthavong K, Zhang Y, et al. Ultra-sensitive photoelectrochemical aptamer biosensor for detecting *E. coli* O157:H7 based on nonmetallic plasmonic two-dimensional hydrated defective tungsten oxide nanosheets coupling with nitrogen-doped graphene quantum dots (dWO₃•H₂O@N-GQDs). *Biosensors and Bioelectronics*. 2021 Jul;183:113214.
25. Kaur H, Shorie M, Sabherwal P. Biolayer interferometry-SELEX for Shiga toxin antigenic-peptide aptamers & detection via chitosan-WSe₂ aptasensor. *Biosensors and Bioelectronics*. 2020 Nov;167:112498.
26. Kim YS, Chung J, Song MY, Jurng J, Kim BC. Aptamer cocktails: Enhancement of sensing signals compared to single use of aptamers for detection of bacteria. *Biosensors and Bioelectronics*. 2014 Apr;54:195–8.
27. Schmitz FRW, Cesca K, Valério A, De Oliveira D, Hotza D. Colorimetric detection of *Pseudomonas aeruginosa* by aptamer-functionalized gold nanoparticles. *Appl Microbiol Biotechnol*. 2023 Jan;107(1):71–80.
28. Zheng H, Sheng R, Li H, Ahmad W, Chen Q. Rapid and selective detection of *Bacillus cereus* in food using cDNA-based up-conversion fluorescence spectrum copy and aptamer modified magnetic separation. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2022 Feb;267:120618.
29. Duan N, Ye M, Lu M, Chen X, Wu S. DNA aptamers selection and characterization for development of impedimetric aptasensor for *Bacillus cereus* at different growing stages. *Advanced Agrochem*. 2023 Sep;2(3):284–90.
30. Zhou Z, Lan X, Zhu L, Zhang Y, Chen K, Zhang W, et al. Portable dual-aptamer microfluidic chip biosensor for *Bacillus cereus* based on aptamer tailoring and dumbbell-shaped probes. *Journal of Hazardous Materials*. 2023 Mar;445:130545.
31. Effah CY, Ding L, Tan L, He S, Li X, Yuan H, et al. A SERS bioassay based on vancomycin-modified PEI-interlayered nanocomposite and aptamer-functionalized SERS tags for synchronous detection of *Acinetobacter baumannii* and *Klebsiella pneumoniae*. *Food Chemistry*. 2023 Oct;423:136242.
32. Abedi R, Raof JB, Mohseni M, Bagheri Hashkavayi A. Development of a label-free impedimetric aptasensor for the detection of *Acinetobacter baumannii* bacteria. *Analytical Biochemistry*. 2023 Oct;679:115288.
33. Vishwakarma A, Meganathan Y, Ramya M. Aptamer-based assay for rapid detection, surveillance, and screening of pathogenic *Leptospira* in water samples. *Sci Rep*. 2023 Aug 17;13(1):13379.
34. Rizzotto F, Marin M, Péchoux C, Auger S, Vidic J. Colorimetric aptasensor for detection of *Bacillus cytotoxicus* spores in milk and ready-to-use food. *Heliyon*. 2023 Jul;9(7):e17562.

35. Frohnmeyer E, Frisch F, Falke S, Betzel C, Fischer M. Highly affine and selective aptamers against cholera toxin as capture elements in magnetic bead-based sandwich ELAA. *Journal of Biotechnology*. 2018 Mar;269:35–42.
36. Luo P, Liu Y, Xia Y, Xu H, Xie G. Aptamer biosensor for sensitive detection of toxin A of *Clostridium difficile* using gold nanoparticles synthesized by *Bacillus stearothermophilus*. *Biosensors and Bioelectronics*. 2014 Apr;54:217–21.
37. Hu J, Shen Z, Tan L, Yuan J, Gan N. Electrochemical aptasensor for simultaneous detection of foodborne pathogens based on a double stirring bars-assisted signal amplification strategy. *Sensors and Actuators B: Chemical*. 2021 Oct;345:130337.
38. Wang W, Yuan W, Wang D, Mai X, Wang D, Zhu Y, et al. Dual-mode sensor based on the synergy of magnetic separation and functionalized probes for the ultrasensitive detection of *Clostridium perfringens*. *RSC Adv*. 2022;12(39):25744–52.