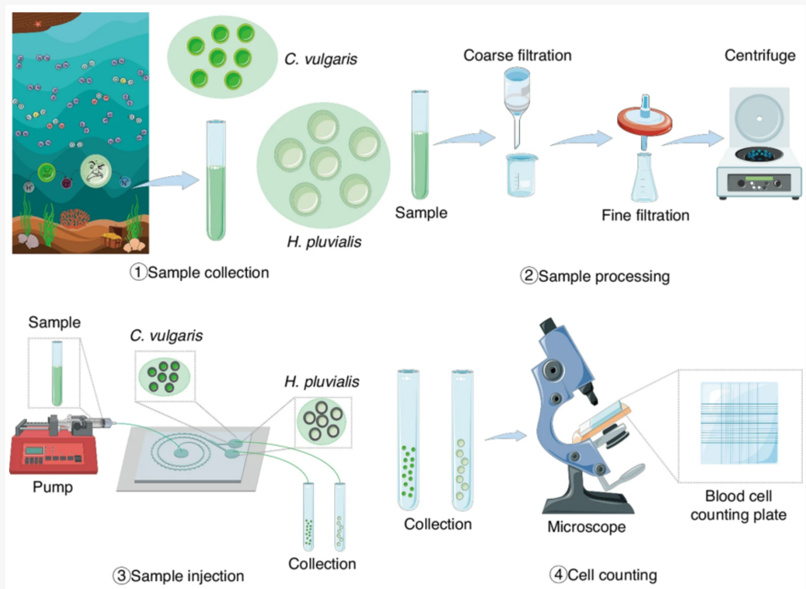
New microfluidic design boosts efficient sorting of antioxidant-rich microalgae

FAYETTEVILLE, GA, UNITED STATES, February 7, 2026 /EINPresswire.com/ -- Efficient separation of microalgae is essential for biotechnology, food science, and sustainable bio-production, yet conventional sorting methods often suffer from low throughput, high cost, or cell damage. Researchers have developed a novel microfluidic strategy that enables high-throughput, sheathless, and label-free separation of flexible microalgae based solely on size differences. By integrating spiral microchannels with contraction–expansion structures, the system exploits inertial lift and secondary flow effects to guide different microalgal species into distinct outlets. The approach achieves precise separation while preserving cell viability, offering a scalable and energy-efficient alternative to existing technologies. This advance provides a new foundation for gentle, continuous sorting of valuable microalgae across diverse biological and industrial applications.



Experimental Procedure Schematic. The experimental procedure is divided into four specific parts, Sample Collection, Sample Processing, Sample Injection, and Cell Counting.

Microalgae such as Chlorella vulgaris and Haematococcus pluvialis are widely used in nutrition, aquaculture, and functional foods, with the latter serving as a major natural source of astaxanthin. However, separating microalgae with similar appearances but different sizes remains technically challenging. Traditional techniques—including centrifugation, flow cytometry, and manual sorting—are often slow, labor-intensive, and may compromise cell integrity. Although microfluidic approaches have emerged as promising alternatives, many rely on external forces or sheath flows that increase system complexity. Based on these challenges, there is a clear need to develop a high-throughput, passive, and cell-friendly microalgal separation strategy.

In a study published (DOI: 10.1038/s41378-025-01087-y) in Microsystems & Nanoengineering in

2025, researchers from Hainan University and collaborating institutions reported a new microfluidic platform for separating microalgae with high efficiency and viability . The team designed spiral microchannels coupled with contraction–expansion structures to achieve continuous, sheath-free sorting of microalgal cells based on size. By carefully tuning channel geometry and flow conditions, the system successfully separated Chlorella vulgaris and Haematococcus pluvialis, demonstrating both high purity and preserved biological activity.

The newly developed microfluidic device combines spiral channels with contraction–expansion units to create synergistic inertial and secondary flow effects. As microalgae travel through the curved microchannels, inertial lift forces and Dean vortices drive cells of different sizes toward distinct equilibrium positions. The added contraction–expansion structures further amplify lateral migration, enhancing separation resolution without the need for sheath flows or external fields.

Three coupling configurations—single-sided, double-sided, and interleaved—were systematically evaluated. Among them, the single-sided configuration achieved the best overall performance, delivering 100% purity for Chlorella vulgaris and over 76% purity for Haematococcus pluvialis at an optimized flow rate of 200 μL/min. Importantly, all configurations maintained 100% cell viability, confirming that the process is gentle enough for living, flexible microalgae.

The researchers also demonstrated that separated cells retained their ability to regrow after sorting, validating the platform's biological compatibility. Compared with conventional spiral microfluidic chips, the coupled-channel design showed superior adaptability across a wide size range, making it suitable for dynamic biological samples and real-world cultivation conditions.

"This work shows how careful microchannel design can unlock powerful hydrodynamic effects without relying on external forces," said the study's lead investigator. "By integrating spiral and contraction–expansion geometries, we achieved high-throughput separation while fully preserving cell viability. This is particularly important for microalgae, which are flexible and sensitive to mechanical stress. Our results suggest that passive microfluidic systems can be both precise and biologically safe, opening new possibilities for scalable algal processing."

The microfluidic platform offers broad potential across microalgae-related industries, including functional foods, nutraceuticals, biofuels, and environmental monitoring. Its sheath-free, label-free operation reduces cost and complexity, making it attractive for continuous, large-scale processing. Beyond microalgae, the design principles may be extended to other biological particles with size variability, such as cells, spores, or microorganisms. Future integration with multi-channel arrays or intelligent flow optimization could further boost throughput, supporting industrial-scale deployment. Overall, this technology provides a promising route toward efficient, gentle, and sustainable biological separation systems.

References

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