The potential of Raman spectroscopy as a high-throughput phenotyping tool in aquaculture

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Analytical technology in food and agriculture

The unique potential of Raman spectroscopy in food analysis is related to the ability to capture subtle chemical distinctions in foods in a non-destructive way. One of the recent milestones in representative Raman analysis has been the development of wide area Raman probes, where a defocused laser beam is used to illuminate a larger area within the sample, and multiple collection fibers covering the same sample area are used for photon collection. Key features of wide area Raman probes include increased depth penetration and large surface coverage, paving the way for representative Raman analysis and potential in-line Raman applications. Currently we are therefore seeing a steady increase of applications using wide area Raman spectroscopy in food analysis. One highly relevant application area is the characterisation of lipids, a class of compounds that has a very favourable Raman cross-section. We have recently shown that wide area Raman spectroscopy is a feasible technique for in-line prediction of fatty acids (FAs) in salmon fillets. This application shows promise for real-time industrial documentation, but it also opens the possibility for high-throughput phenotyping in salmon breeding, where rapid quantification of FAs is of high interest. Hence, in a recent study, we have evaluated the potential of Raman spectroscopy as a high-throughput phenotyping tool for predicting FA composition in Atlantic salmon (Salmo salar) fillets. The study comprised Raman spectra and corresponding phenotypic and genetic information of 613 salmon samples, and a total of 33 FA traits, including individual and grouped FAs, were evaluated. The results showed that 15 of 33 Raman-predicted FA traits had strong genetic correlations (0.84–0.99) and similar heritability estimates with their directly measured counterparts, indicating that these traits could effectively contribute to genetic improvement. While individual FA prediction was more challenging in lower abundance or low heritability FA traits, Raman-predicted EPA and DHA showed high genetic correlations with reference measurements (RG = 0.88), with a combined EPA+DHA trait achieving an even stronger correlation (RG = 0.97). Raman spectroscopy offers a cost-effective and high-throughput alternative to traditional GC analysis, but its effectiveness depends on factors such as fatty acid abundance, heritability, and model performance. Nevertheless, the results of the current study show that Raman-predicted EPA and DHA, individually or combined, make promising targets for genetic selection in breeding programs, and that Raman spectroscopy meets the necessary requirements as a rapid phenotyping tool for breeding purposes.