

Synchrotron Tomography and WAXS Reveal Structural Features Influencing Wheat Bran Processing into Food Ingredients

THE INDUSTRIAL CHALLENGE

Wheat bran is a by-product of milling that contains valuable components for food and material applications. Lantmännen and KTH have previously developed wet processing methods to fractionate bran into dietary fibre, protein, and phenolics. However, low extraction yields hinder upscaling due to the complex physico-chemical interactions in the cereal cell wall. The possibility to reveal the multiscale structural features of wheat bran could aid its efficient fractionation.

WHY USING A LARGE-SCALE FACILITY

Multiscale structural elucidation of plant materials from the molecular level to the microscale requires a combination of imaging and scattering techniques. Synchrotron X-ray tomography imaging can reveal larger spatial associations ($>1\mu\text{m}$) in the bran layers, whereas wide angle x-ray scattering (WAXS) can provide information of the molecular organisation (10-30 nm), such as crystallinity, which is of relevance for cereal biopolymers. Laboratory tomography imaging requires long sampling times to obtain the necessary resolution and contrast, whereas high-flux beams in synchrotron facilities enable rapid, high-resolution imaging of low-contrast structures, such as those present in wheat bran. Moreover, laboratory tomography does not allow for WAXS scanning. Finally, tomography provides whole-sample analysis without specialised sample preparation, compared to labour-intensive microscopy.

HOW THE WORK WAS DONE

Native and treated (destarched, subcritical water and alkaline treated) wheat bran samples were provided by Lantmännen and processed at KTH. Tomography and WAXS scanning experiments were first conducted at the ForMAX beamline in MAX IV Laboratory, Sweden. A second set of experiments was performed at the DIAD beamline of Diamond Light Source (UK). MAX IV experiments provided high intensity and tomographic resolution, but alternation between tomography and WAXS was not possible. Contrarily, the DIAD beamtime enabled simultaneous tomography and WAXS at the

expense of poor resolution. All experiments were performed at ambient temperature without any cell holder. The tomography images were segmented using Dragonfly (Comet Technologies Canada Inc.).

THE RESULTS AND EXPECTED IMPACT

We developed a method for reconstruction and segmentation of the X-ray tomography imaging data, which enables 3D visualisation of wheat bran and the quantification of specific structural features (Fig 1A-C). This method can be extrapolated to other plant tissues and has large potential for high-resolution histological visualisation in plant biology. Tomographic imaging showed that subcritical and alkaline treatments disrupted the integrity of the aleurone cells, resulting in thinner walls with reduced surface area. WAXS scanning measurements further revealed that alkaline treatments enriched the crystalline domains in the wheat bran, by either increasing internal ordering and/or by mainly removing the amorphous layers (Fig 1D-E). The project identified the pericarp layer and crystalline domains as key barriers to efficient fractionation, highlighting them as targets for improving processing yields.

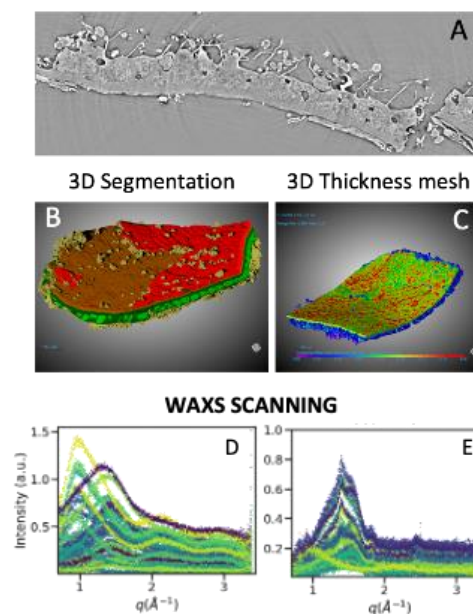


Fig 1. A) Tomography imaging of wheat bran. B) 3D reconstruction and segmentation. C) 3D thickness mesh of the aleurone cell wall. WAXS patterns of (D) untreated and (E) alkaline treated wheat bran.

Contacts: Annelie Moldin – Lantmännen, annelie.moldin@lantmannen.com
Francisco Vilaplana – Kungliga Tekniska Högskola, franvila@kth.se

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