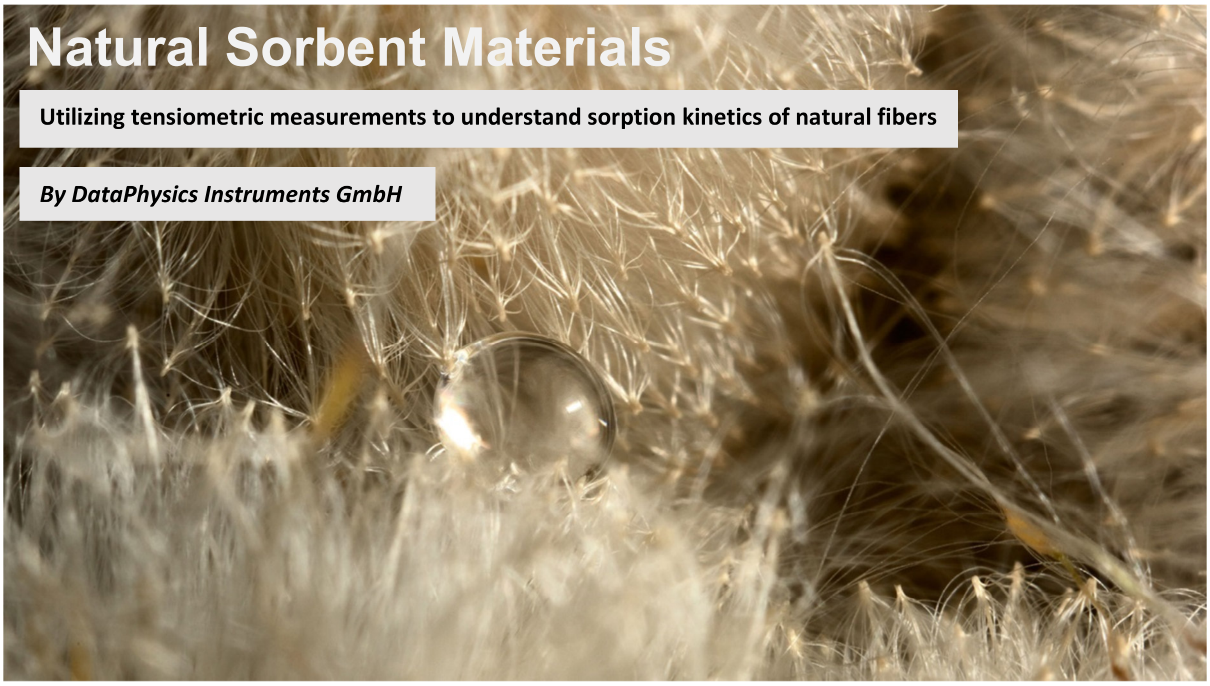
How tensiometric measurements can help understand the sorption kinetics of natural fibers

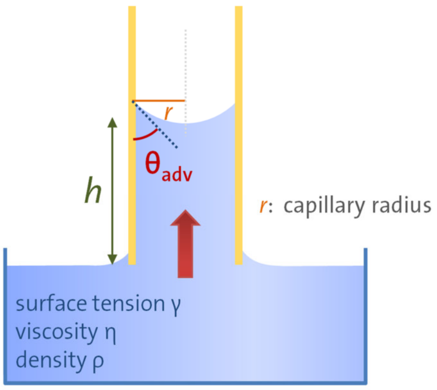


Natural fibers have been used by humans since ages to produce clothes and tools amongst others. Some of these natural fibers have now been partially replaced by synthetic fibers. Despite this trend, the unique features of some natural fiber materials make them an attractive source for sorbent materials. For example cattail fibers from the fruit of the cattail plant have been reported to be an excellent natural sorbent due to their low density, good buoyancy and hydrophobic characteristics. In this context it was for shown that cattail fibers have a sorption capacity for engine oil of 14.6 g/g with an oil retention value of 95% over 24 h. Water droplets are showing a contact angle of around 133° while oil droplets quickly penetrate into the fiber bundles showing the strong hydrophobic and oleophilic character of cattail fibers. These characteristics can be explained with a high wax content of almost 11% in the cattail fibers giving them a relatively low surface energy (45.64 mN/m) and a large ratio between disperse and polar component. Although cattail fibers are well studied, so far the influence of packing density, fiber assembly and temperature is not documented.

Xu and coworkers have recently reported a detailed study on the oil sorption kinetics of cattail fibers with different packing densities and temperatures to diesel oil, vegetable oil and engine oil conducting capillary rise tests by using the dynamic contact angle measurement device and tensiometer DCAT 11 (DataPhysics Instruments GmbH).

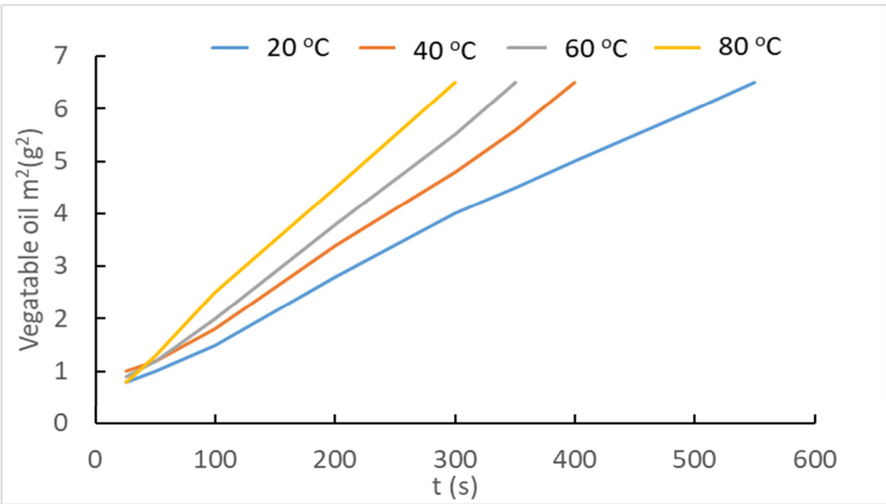
Practical Note: Capillary Rising Test

A cylindrical tube with glass filter at the bottom is filled with fibers or powders of different packing density making sure the packing density is homogeneous. The filled tube is connected to an electronic balance above the test liquid. When the measurement starts, the test liquid is lifted by the stage of the DCAT automatically to contact the lower end of the tube. Through capillary effects the liquid raises into the fibre or powder material and the balance records the mass increase. The DCAT software records the mass increase over time and can evaluate results as sorption rate diagrams. In addition, the dynamic contact angle of the powders or fibers can be determined by the Washburn equation.



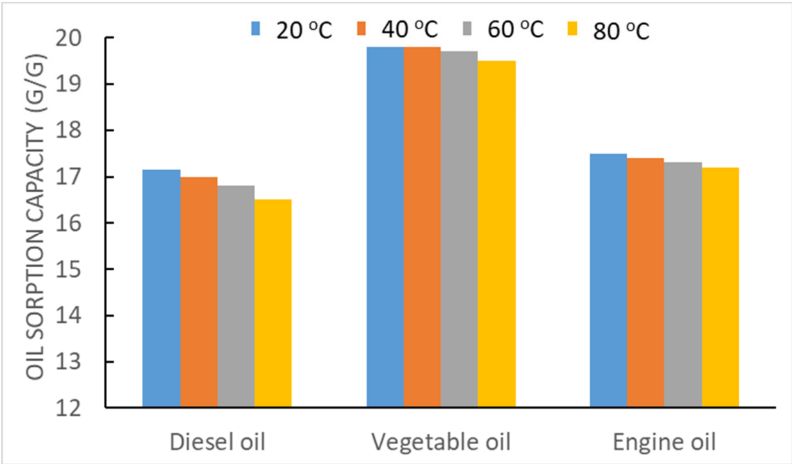
$$m^2(t) = C \cdot \frac{\rho^2 \gamma \cos \theta_{adv}}{\eta} \cdot t$$

The measurements have shown that higher packing densities lead to lower absorption capacities for all tested oils as less space is accessible for oil storage. The temperature also had a strong effect on the sorption rates. For vegetable oil the sorption speed increased significantly with the temperature since the viscosity decreases and also the surface tension of the oil decreases with temperature both being beneficial for faster sorption (**Scheme 1**). The other oils behaved similarly.



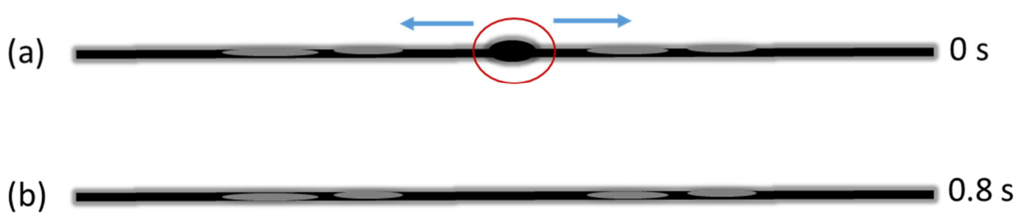
Scheme 1: *Sorption rate for vegetable oil on cattail fibers*

The oil sorption capacity for all oils decreased slightly with increasing temperature (because the density decreases with increasing temperature) and was in general highest for vegetable oils since it has a higher density compared to diesel or engine oil (**Scheme 2**).

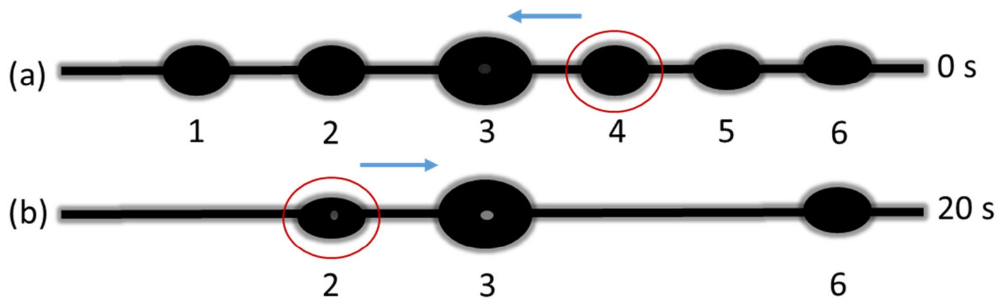


Scheme 2: *Sorption capacity of different oils in cattail fibers*

The authors furthermore studied wetting characteristics of diesel oil and engine oil adsorbed on single cattail fibers. The wettability of single cattail fibers by oils was explored with the drop-on fiber test utilizing an optical contour analysis system OCA 15EC (DataPhysics instruments GmbH). While the diesel oil droplets (low viscosity) spread rapidly over the surface of the fibre to form an oil film after already 0.8 s (**Scheme 3**), engine oil did not spread completely and rather smaller droplets recombined to bigger ones to lower the contact area (**Scheme 4**). The flow of engine oil droplets can be attributed to the unique longitudinal grooves on the surface which function as channels for liquid flow and its low surface energy. The high viscosity of engine oil compared to diesel makes the drop migration and recombination much slower.



Scheme 3: *Wetting process of diesel oil on single cattail fiber at a) 0 s, b) 0.8 s*



Scheme 4: *Wetting process of engine oil on single cattail fiber at a) 0 s, b) 20 s*

Overall, the oil sorption kinetics of cattail fiber for diesel oil, vegetable oil and engine oil were quantitatively studied utilizing capillary rise tests which showed that the sorption rate increases with the temperature and sorption capacities are generally better for lower fiber packing densities. Furthermore, drop-on fiber tests have shown the largest spreading speed for diesel oil while engine oil spread the slowest which correlates well to the viscosity trends. This research provides a valuable precondition for future application of cattail fibers in oil spill management.

The dynamic contact angle measurement device and tensiometer DCAT 11 as well as the optical contour analysis system OCA 15EC (DataPhysics Instruments GmbH, Germany) were used in this research.

For more information, please refer to the following article:

Evaluation of oil sorption kinetics behavior and wetting characteristic of cattail fiber; Yanfang Xu, Hua Shen, Guangbiao Xu; *Cellulose* **2020,** 27, 3, 1531-1541; DOI:10.1007/s10570-019-02879-y