A novel shuttle for fatty acids

February 3 2015

Oils from plant seeds provide the basis for many aspects of modern life that are taken for granted, being used to make cooking oil, soap, fuel, cosmetics, medicines, flooring, and many other everyday products. Whether derived from olives, oil palm, rapeseed, soybeans, peanuts or sunflowers, the major energy-rich constituents of these oils are lipids containing fatty acids made in the plants' chloroplasts. While most of this process by which plants make fatty acids is well-known, the mechanism by which these important molecules get out of the chloroplast was unclear.

But now biologists at the Ludwig Maximilians University in Munich have discovered a previously unknown transport system for fatty acids in plant cells. LMU biologist Dr. Katrin Philippar and members of her research group have shown in a paper publishing today in the open access journal *PLOS Biology* that a novel chloroplast membrane protein plays a central role in the process of transporting fatty acids from where they are generated in chloroplasts out into the cell cytoplasm before they become incorporated into lipid molecules. The work may open new routes to improve the production of biofuels.

Fatty acids are the major constituents of lipids. In plants, fatty acids are synthesized exclusively in the chloroplasts, and must be exported into the cell cytoplasm - the aqueous interior of the cell in which the chloroplasts are suspended - before they can be incorporated into lipid molecules. "However, the mechanism for how fatty acids are transported across the membranes of the chloroplast was thus so far unclear," says LMU biologist Dr. Katrin Philippar. She and members of her research group

have shown in the paper publishing in *PLOS Biology* that a member of a previously uncharacterized protein family plays a central role in this process.

The researchers identified an integral membrane protein in the inner chloroplast envelope of the model plant Arabidopsis thaliana. They subsequently named the protein FAX1 (for 'fatty acid export 1') on the basis of studies on Arabidopsis strains that had either lost the capacity to produce FAX1 or synthesized FAX1 proteins in excess amounts. These investigations revealed that FAX1 is essential for the synthesis of the fatty acid- and lipid-rich layers that coat pollen grains and form the general waxy layer on the plant surface. In addition, in plants that are unable to express FAX1, the lipid content outside chloroplasts is decreased. In lines that overproduced FAX1, on the other hand, the researchers observed the opposite effect. In particular, levels of so-called triacylglycerol lipids (TAGs) were found to be significantly higher in leaves and flowers of these strains than in wild-type plants.

"Furthermore, we were able to show that, when introduced into yeast cells, FAX1 can transport fatty acids. On the basis of all these findings, we conclude that FAX1 in Arabidopsis mediates export of fatty acids across the inner envelope membrane of the chloroplast. Thus, our work elucidates a novel and previously entirely unknown mechanism of fatty acid transport," Philippar explains. "FAX1 also has an influence - probably indirect - on carbohydrate metabolism in the cell because lipids and carbohydrates serve as the primary sources of metabolic energy in plants," she adds.

The significance of FAX1 function for the synthesis of TAGs is of special interest, because TAG-rich plant oils provide the basis for the production of biofuels. "Our experiments indicate that overexpression of FAX1 increases the overall level of TAGs in Arabidopsis. So further investigation of the members of this protein family may lead to new

strategies for the manufacture of biofuels," Philippar concludes. Interestingly, proteins found in vertebrate mitochondria, whose biological role has remained unknown as well, are related to the FAX family. Further study of the FAX proteins therefore promises to throw new light on the function of these enigmatic gene products as well.

More information: Li N, Gügel IL, Giavalisco P, Zeisler V, Schreiber L, Soll J, et al. (2015) FAX1, a Novel
Membrane Protein Mediating Plastid Fatty Acid Export. *PLoS Biol* 13(2): e1002053. doi:10.1371/ journal.pbio.1002053