CABBI Highlight
February 2022

Elucidation of Triacylglycerol Overproduction in the C_4 Bioenergy Crop *Sorghum bicolor* by Constraint-Based Analysis

Background/objective

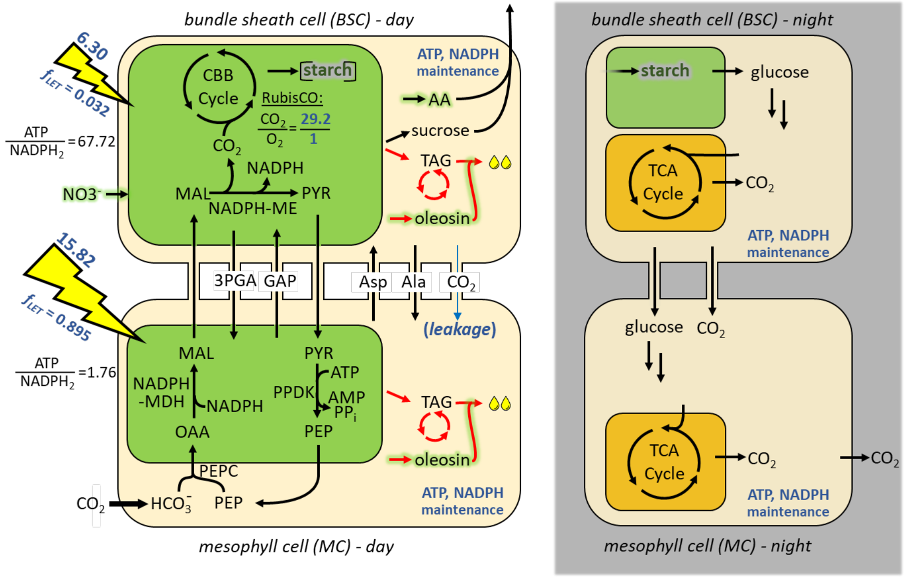
There is growing interest in increasing the energy density in bioenergy crops by improving the capacity to accumulate triacylglycerols (TAG) in above-ground vegetative tissues. For such metabolic engineering efforts, a theoretical benchmark for the capacity of photosynthetic tissues to accumulate oils is needed.
In this study, a genome-scale metabolic model of sorghum (*Sorghum bicolor*) was developed. Based on metabolic pathway modeling, the theoretical capacity of a leaf to accumulate TAG at economically viable levels was explored.

Approach

- A metabolic model was constructed and parametrized to represent photosynthetic CO_2 assimilation in a mature sorghum leaf.
- Daily photosynthetic rates were simulated for varying carbon allocation ratios (assimilate export vs. TAG accumulation) and in dependence of increasing impact of metabolic futile cycles.
- The relative demands in energy cofactors (ATP, NADPH) for sucrose and oil synthesis were compared with the supply by the photosynthesis light reactions (supply/demand balance).

Results

- Energy demands in NADPH and ATP are ~1.3 to 1.4 times higher for TAG synthesis than for sucrose (on a per carbon basis).
- Based on empirical daily net CO_2 assimilation rates, a leaf TAG level of 20% (w/dw) is achievable within one month if only 5% of the photosynthetic net assimilation is re-allocated into oil droplets and if fatty acid futile cycling processes can be largely suppressed.
- Complete re-allocation of fixed carbon into TAG might be impeded by a supply/demand imbalance in energy cofactors (ratio ATP/NADPH).



Diel model of NADP-ME subtype of C4 photosynthesis in Sorghum: Shown are major metabolic processes that take place across two cell types: photo-assimilation of CO_2 (day) and respiration of starch (night). Photosynthetically fixed CO_2 is exported (sucrose, amino acids). In engineered plants, carbon is re-allocated into oil droplets (red).

Significance

Relative to carbohydrates, the biosynthetic energy demands to photo-assimilate CO_2 into oils are not as high as often assumed. Since high TAG levels should be achievable within a month, engineering efforts could aim to limit the activation of genetic factors of TAG accumulation to the final phase of a plant's life cycle. This could mitigate yield drag effects that are often observable for transgenics where expression of TAG factors is active in all tissues and development stages.

Clark, T.J., Schwender, J. 2022. "Elucidation of Triacylglycerol Overproduction in the C_4 Bioenergy Crop Sorghum bicolor by Constraint-Based Analysis." Frontiers in Plant Science 13:787265. doi:10.3389/fpls.2022.787265.

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