Sustainable Production of a Biodegradable Plastic by Photosynthetic Cell Factories

Alexander Zwirzitz[1] and Kevin Trenzinger[1]

[1] AG Biosciences, University of Applied Sciences Upper Austria, Austria

Abstract

The production of plastics and the incineration of waste generate around 400 million tons of carbon dioxide (CO_2) per year. [1] One way to reduce the CO_2 emissions in manufacturing plastics could be established by using photosynthetically active organisms, which can metabolize CO_2 under the influence of light and in a further step to plastic alternatives like polyhydroxy butyrate (PHB). By using cyanobacteria to produce this alternative to polypropylene (PP), not only already emitted CO_2 can be fixed, but additional savings can be achieved compared to the production of petrochemically produced plastics [2]. By using wastewater as a source of nutrients for the cultivation of cyanobacteria, valuable raw materials can be saved while establishing a circular economy. To increase the yield of PHB with simultaneous utilization of wastewater (dairy industry) relevant genes should be optimized. This was to be achieved by eliminating two genes (*spsA* and *glgC*) related to Glycogen production as well as the overexpression of genes for the promotion of PHB production (*phaA* and *phaB*) and lactose utilization (*beta-Gal*) in the UV irradiated cyanobacterium *Synechocystis* sp. PCC 6714 Mt_a24, with a PHB productivity of 37 % ± 4 % DCW [3].

Background

Dairy wastewater is usually treated in in-house or municipal wastewater treatment plants. Thus, valuable raw materials such as sugars or proteins are wasted [4]. By adapting photosynthetically active organisms, such as the unicellular non-nitrogen fixing cyanobacterial strain *Synechocystis* sp. PCC 6714, these can be used for the production of valuable substances. One of these metabolites is the storage compound polyhydroxy butyrate (PHB) [5]. As the Organism can not utilize lactose it has to be adopted accordingly.

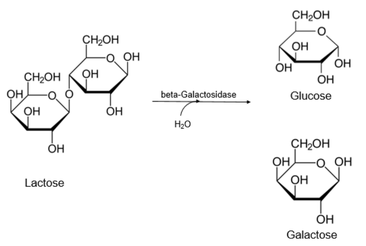

Fig. 1: Conversion of Lactose to Glucose and Galactose via beta-Galactosidase

Strategies

Strategies for enhancement of PHB productivity on lactose containing waste materials:

1. Increase of PHB accumulation by overexpression of two genes (blue, Fig. 2); beta-ketothiolase (*phaA*) and acetoacetyl-CoA reductase (*phaB*)
2. Increase of PHB accumulation by knock-down/knock-out of metabolic processes producing alternative storage compounds (red lightning, Fig. 2) like Glycogen
3. Introduce and overexpress genes for the utilization of Lactose (blue, Fig. 2); beta-Galactosidase (*beta-Gal*)

All strategies will be combined to achieve high yields of PHB

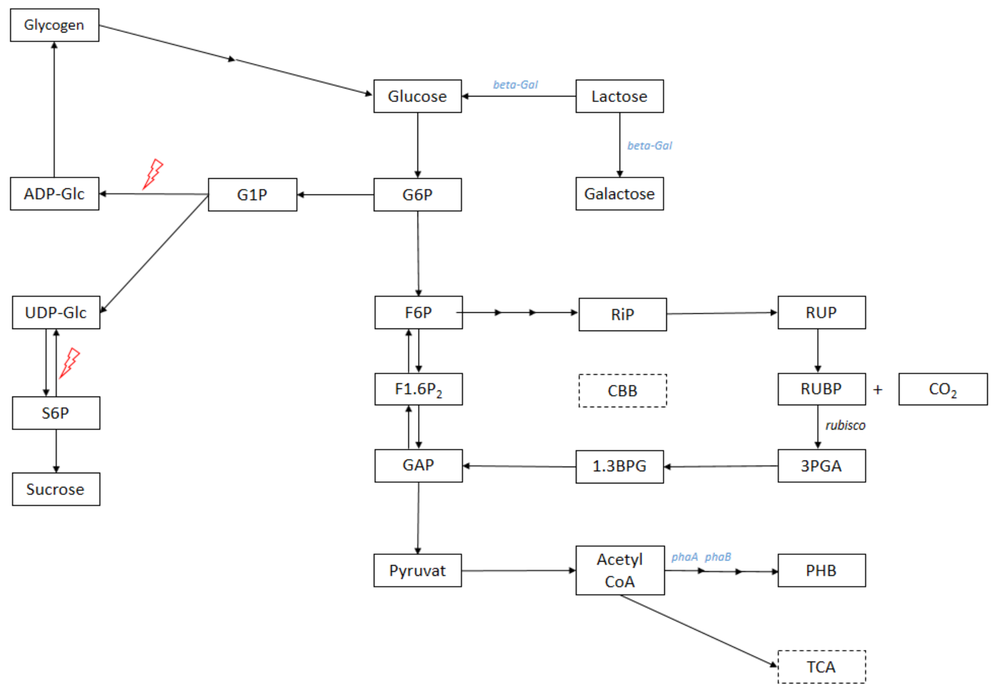

Fig. 2: PHB Metabolism of Synechocystis sp. PCC 6714*; blue: genes which will be overexpressed; red lightning: knock-down/knock out of metabolic pathways [3,6,7].*

Outlook

Future studies will focus on further increasing the yield of PHB in transgenic cyanobacteria. A knock-out of other storage compounds as well as the overexpression of relevant enzymes for the PHB production should lead to a higher yield of that valuable bioplastic. Additional adoption of genes and the cultivation process can be utilized for further optimization.

Acknowledgements The authors would like to thank the team of Univ.Prof. Dipl.-Ing. Dr.techn. Christoph Herwig, Dr. Donya Kamravamanesh and Dr. Maximilian Lackner for the supply of *Synechocystis* sp. PCC 6714 Mt_a24

References

[1] European Commission, (2018): A European strategy for plastics in a circular economy. https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf
[2] Markl *et al*.; (2019): Cyanobacteria for PHB Bioplastics Production: A Review; Algae; IntechOpen
[3] Braunegg *et al*.; (1998): Polyhydroxyalkanoates, biopolyesters from renewable resources: Physiological and engineering aspects; Journal of Biotechnology; Volume 65, p. 127-161
[4] A. Kolev Slavov (2017); Dairy Wastewater Treatment Review; Food Technol. Biotechnol. 55 (1); p. 14–28
[5] Kamravamanesh *et al.,* (2018): Increased poly-β-hydroxybutyrate production from carbon dioxide in randomly mutated cells of cyanobacterial strain Synechocystis sp. PCC 6714: Mutant generation and characterization; Bioresource Technology; Volume 266; p. 34-44
[6] Gonzalez-Fernandez, C.; Ballesteros, M. (2012): Linking microalgae and cyanobacteria culture conditions and key-enzymes for carbohydrate accumulation. Biotechnology advanced. Vol. 30. Issue 6., p. 1655-1661
[7] Osanai, T.; Azuma, M.; Tanaka, K. (2007): Sugar catabolism regulated by light- and nitrogen-status in the cyanobacterium Synechocystis sp. PCC 6803; Photochemical and Photobiological Sciences; Issue 5., p. 508-514

Contact Alexander Zwirzitz alexander.zwirzitz@fh-wels.at
Kevin Trenzinger kevin.Trenzinger@fh-wels.at