IB01x - 3.7 - Aerobic PDO process: improving sustainability

We have previously designed the aerobic production process for 100,000 ton PDO per year, or 165,000 mol PDO/h.

A more sustainable process can be achieved following several lines, which all aim at pushing the limits.

First it is obvious to aim for lower glucose, NH4 and O2 consumption and for lower CO2, heat, biomass and H+ production per mol PDO.

This means that we must lower the coefficients in the process reaction. This also leads to lower variable costs. Second we need to reduce DSP processing by minimizing the amount of water added in the aqueous nutrient stream.

For instance by adding glucose in the feed at its solubility limit. This will increase the final product concentration.

Finally smaller fermenters must be pursued. This requires that volumetric transport rates in the fermenter must be maximized, which will be the subject of week 4. Smaller fermenter volumes are also achieved by lowering the O2 / PDO ratio and the heat / PDO ratio in the process reaction.

The common aspect in these approaches is that we must push the limits:

- How to lower the mol i/mol PDO coefficients in the process reaction to its lowest limit
- How to lower the amount of water added

To lower the coefficients in the process reaction we must dissect the process reaction. It is shown that the process reaction is the weighted sum of

- Black box biomass reaction with weight factor μ/qp
- Black box PDO reaction with weight factor (+1)
- Catabolic reaction for 1 mol glucose with weight factor -ms/qp

The weight factors show that we can minimize the stoichiometric coefficients of the process reaction by increasing qp, using the kinetic approach in metabolic engineering.

Here we assume that in our black box PDO model the qp(μ) relation is changed by applying metabolic engineering.

The parameter α has been doubled showing that the maximal qp value doubled from 0.05 to 0.10 mol PDO/h per mol biomass. This means that at all μ-values the mutant has higher qp-values than the wild type.

The consequences are that all the stoichiometric coefficients in the process reaction decrease. You can see that the substrate consumption per mol PDO decreases 30% and that the O2-consumption decreases by nearly a factor 2!!

We can keep increasing qp, which according to the weighing factors lowers the contribution of the biomass reaction and maintenance in the process reaction, and brings the process reaction asymptotically to the stoichiometry of the black box PDO reaction, where 0.80 mol glucose/mol PDO and 0.80 mol O2/mol PDO is consumed.

To decrease the ratios in the process reaction below the black box model PDO reaction, we must use the stoichiometric approach in metabolic engineering to change the stoichiometry of the black box model PDO reaction. To facilitate our understanding we must dissect the black box PDO reaction.

The 0.80 mol O2 which is consumed, to provide energy for PDO synthesis, represents catabolism of 0.80/6 mol glucose, as indicated. By subtraction we obtain the anabolic part, where no O2 is consumed and 0.666 mol glucose per mol PDO is consumed. Note that this last reaction is the theoretical PDO reaction, which we discussed earlier on.

The presented dissection of the black box PDO reaction shows that the stoichiometric targets of Metabolic engineering should be focussed on the decrease of O2 consumption per mol PDO. This can be achieved by aiming at improved ATP production per mol consumed O2 and/or less ATP consumption per mol produced PDO.

The limit of this approach is that O2 consumption becomes 0, leading to the anaerobic theoretical PDO reaction. The theoretical PDO reaction shows a fascinating aspect. The Gibbs energy produced from 1 mol PDO under anaerobic conditions is 110 kJ/mol PDO, which is nearly the same as for ethanol fermentation.

This shows the Holy grail of metabolic engineering, anaerobic PDO production should be possible which has obvious advantages for lowest stoichiometric ratios (near theoretical), lowest variable cost and lowest investment and lower energy consumption, since no energy is needed to drive the air compressor and stirrer.

Another important aspect is to lower Down Stream Processing costs. In order to do so we need to increase the PDO concentration. The easiest way is to increase the glucose concentration in the aqueous feed. However here we meet the glucose solubility limit which dictates the addition of water. To minimize water addition we can go to non-conventional water-free feedstocks which can be ethanol, methanol, syngas, of course obtained from green biomass. Finally one can aim at high water evaporation by working at high fermenter temperature.

This now ends week 3, where we have focussed on the process reaction stoichiometry of the aerobic PDO process.

This process reaction gives

- The input (liquid and gas flows and their compositions) for transport calculations in the second part of the PDO process design
- Insight in approach to increase sustainability

Join us next week for more “Technology for Biobased products”!