Osmotic shock occurs when there is a difference in concentrations on either side of a cell membrane. This membrane tries to keep the concentration of ions inside the cell constant, but when the difference is high enough the building pressure from diffusion wins and the membrane will fail. There are two ways for this to occur, with a higher concentration of ions outside the membrane, or a higher concentration of ions inside the membrane. In the case of a high concentration of ions outside the membrane, water from inside the cell flows out to raise the concentration inside the cell to better match the outside. This causes the cell and membrane to shrink and shrivel. In the case of a lower concentration outside the cell, water will flow inside, causing the cell to expand, possibly even to the point of bursting. In both cases, these disruptions make it easier for other ions and compounds to flow in and out of the cell because the membrane is in a weakened state. In industry, normally people use high concentrations outside the membrane due to the higher difference possible and thus osmotic pressure being applied to the membrane. An example of this is normally ions concentrations range from 0.001M to 0.5M inside cells [1]. A saturated NaCl (tablesalt) solution can reach up to ~6M [2].

There are several issues with this process, the first and most obvious one is the waste produced. The exiting stream from this process needs to be high in concentration of ions. The best case scenario is using table salt due to its relatively neutral effect on the environment, however unless stationed near a salt water reservoir like the ocean, dumping becomes an issue. Even then, the concentration of salt seen in most papers to effectively increase extraction is at or higher than the waste streams of desalination plants [3]. However, NaCl doesn't always work as the best agent and may require different compounds to increase extraction yields, like shown in this paper where Sorbitol (a sugar alcohol) worked better when the cell was at different life cycles [3] A high concentration of salts also make anaerobic digestion inviable [4]. This means there'll need to be waste treatment for the solids leftover after extraction. Overall, the waste stream from this process adds quite a bit of cost to an already expensive process.

The next issue is the yield increases aren't great when you try to minimize for environmental hazards. The big issue with algae is it normally requires a drying step that is very energy intensive (removing loads of water from the system). Papers that have managed to use less concentrated algae solutions using osmotic shock do see a 2-fold increase in their extraction efficiency [3]. However, the actual value is close to 35% of the total lipid content, which when compared to 88% extraction of total lipid contents seen from higher solids algae, it doesn't compete well [5]. Other research has also showed that the process of drying the algae changes more of the lipids into FAME (the lipids which are actually converted into biodiesel) allowing for almost a 20% increase in biodiesel production from the same amount of lipids extracted [5]. So while using osmotic shock is better than not when extracting lipids from wet algae, it doesn't quite reach the numbers it needs to.

Another thing to consider is a high concentration of certain compounds could negatively affect the product you are trying to extract. Besides algae extraction, osmotic shock is usually used for extraction of certain proteins or other cell constituents on the lab-scale.

While this is usually better than heating the cells (which destroy the products even more), there is a lot of care in selecting certain osmotic agents to achieve extraction without compromising the product. My last point is that other comparable methods have similar increases in efficiency compared to osmotic shock. Grinding showed similar increases in lipid extraction from the control and would be a much cheaper substitution in terms of operating cost [6]. While it didn't work as well with the other cell type, as I mentioned before osmotic shock with simpler salts don't always work either. There are some possibilities with scaling up some extraction of pharmaceuticals from cells where the cost is already quite high and extraction yields are low (like for antibodies for vaccines). However, these are niche markets compared to the bulk of extraction seen in the world and would be hard to enter as most are still done on a semi-batch scale.

Sources:

[1]: http://book.bionumbers.org/what-are-the-concentrations-of-different-ions-in-cells/ [2]: https://en.wikipedia.org/wiki/Sodium_chloride
[3]: https://www.sciencedirect.com/science/article/pii/S096085241201156X
[4]: https://www.ncbi.nlm.nih.gov/pubmed/27120641
[5]: http://www.mdpi.com/1996-1073/5/5/1613/htm [6]: https://www.ncbi.nlm.nih.gov/pubmed/26270668

Review by: EG