IB01x - 2.2 - Functional understanding of microbial nutrient requirement

Welcome back.

Previously I explained to you that the unique feature of microorganisms is that they grow by division.

For these microorganisms to grow they need certain compounds, which are called nutrients.

When you go to literature you can find all kind of nutrient suggestions; a typical list of nutrients are water, glucose, ammonia, sulfphate and phosphate. When you combine these chemicals you can make a growth medium. But why are these nutrients needed?

Sure, you could just copy the list suggested from literature without thinking and say: This is going to be my growth medium. But that is not the way to go. Remember every compound you add will cost money, so you only want to use what is needed. Therefore you have to understand exactly why you are adding a certain nutrient to the mixture.

In this unit I will explain to you the function of nutrients and how to compose your own growth medium.

To get a better understanding, first we must take a closer look to the cell. To determine the nutrients you need, you must know which molecules are present in the cell and therefore we need the composition of the cell.

Cells contain water, polymers, small organic molecules and salts. The water content of a cell is typically about 75%, the rest consists of organic and inorganic molecules. The organic compounds in cells are mainly lipids, polymers and carbohydrates. The lipids are primarily needed for the membrane of the cell; the membrane is selectively permeable to ions and organic molecules and controls the movement of substances in and out of cells.

The polymers that can be found are DNA, RNA and proteins. And the carbohydrates which are needed for the cell wall and for the storage of energy. Another group of organic material is the so called small organic molecules. These are needed as reaction intermediates, cofactors and regulatory factors.

A very important class of small organic molecules are the vitamins.

These are needed for proper functioning of many proteins, like enzymes, and are needed in the active site of the enzyme.

Or the vitamins act as a co-factor in certain reactions. These vitamins can often be synthesized by the cell itself; vitamins which cells cannot be synthesized need to be supplied as nutrients.

Apart from the organic compounds the cell also contains inorganic compounds.

A significant part of this is Sulphur, present in proteins, and Phosphate present in DNA and RNA. In addition, significant amounts of cations such as Potassium and Magnesium, called macror elements, are present, which serve as counterions for the negatively charged phosphate groups of nucleic acids and of the carboxylic acid groups in proteins.

Finally there is a multitude of very small amounts of different so-called trace metals. These metals, are just like the vitamins, present in the active site of specific enzymes, where they are essential in the catalytic mechanism.

In summary the cell contains: Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus and a lot of metals.

This is a qualitative description of the cell.

Now we want to know a more quantitative description of the cell, this leads us to the elemental composition of the cell dry matter.

When you dry the cells you are only left with the organic and inorganic material, this is called the dry mass of the cell. From this dry mass the average element composition can be determined. Usually one only determines the content of the four most abundant elements, C, H, O and N, which is considered to represent the organic dry mass. The results are represented in a biomass formula,

$C_{1.00}H_{1.80}O_{0.50}N_{0.20}$.

As you might have seen the stoichiometry is normalized to the carbon atom and is therefore called 1-Cmol of biomass.

For a more accurate calculation, the biomass formula can be extended with the macro elements that are present in the dry biomass. The 1-Cmol formula then looks like this.

When you really want to get into the details, you can even add the trace elements. These compositions are typical for most cells.

However it is always desired to measure the composition of the microorganism which you are using.

With this biomass composition formula we can now determine the amount of nutrients needed to produce 1 mol of biomass by writing down the anabolic reaction.

For example , glucose is our carbon source and ammonium will be our nitrogen source. In such a reaction water, carbon dioxide and protons are always present. So let's make our anabolic reaction , we got glucose and ammonium on the left side and 1 mol biomass, water, carbon dioxide and protons on the right side. And you can determine the right stoichiometry for every compound.

However, this anabolic reaction is not a spontaneous reaction.

To produce the polymers (RNA, protein and carbohydrates) present in biomass from small molecules such as glucose and ammonium, energy is needed. This energy is generated in the catabolism. The catabolic reaction is a redox reaction in which an electron donor and an electron acceptor are consumed. This reaction generates energy that is converted to ATP, that is used to drive the anabolic reaction. The oxidized electron donor and reduced electron acceptor are then secreted outside the cell. An example of such a catabolic reaction is when using oxygen as an electron acceptor and glucose as an electron donor. A lot of energy is generated here. But there are many other acceptors and donors, here you see a list with other donors and acceptors. Note that glucose had two functions: C-course in anabolism and electron donor in catabolism.

We have seen that for a cell to grow, we need certain compounds, called nutrients.

Understanding and quantification of the required nutrients can be based on the cell composition and on thermodynamics. Now we can make our own medium. We need water, organic compounds like glucose as a carbon source and ammonium as nitrogen source, some inorganic compounds, like $H_2PO_4^-$, SO_4^{2-}, K^+, and Mg^{2+} further we need vitamins, trace metals and some protons which can either be produced or consumed. And to drive the catabolic reaction we need an electron donor, glucose and an electron acceptor like oxygen. The cell uses these compounds. New biomass and CO_2 are created, and a certain product, like PDO, can be formed.

I will see you in the next unit!