An Alternative Green Process for Protein Powder Production

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Introduction

Proteins are complex organic molecules with functional and nutritional properties. They are essential to life for every living organism, from animals to plants and bacteria, and can be found in all of them.

Because of their various properties and biological activity, proteins are commercialized as ingredients in numerous products such as food supplements, drugs, cosmetics and food additives.

Most of these proteins are commercialized as powders. The downstream process is composed of two major phases: extraction/purification and drying. The first phase produces a dilute solution of purified proteins. Since proteins are thermo-labile molecules, which can be easily denatured by heat, this solution is dried, most of the time, using lyophilization. This technology is particularly energy consuming and time-consuming. The more the solution is dilute, the more water needs to be removed, and the more time and energy are needed.

The **evapeos®** process, patented by **ederna**, could concentrate protein solutions at room temperature and pressure. These mild operating conditions would guarantee no degradation of the proteins. Using this innovative process as a concentration step before freeze-drying would reduce the amount of water to be removed and, subsequently, the cost of the drying step.

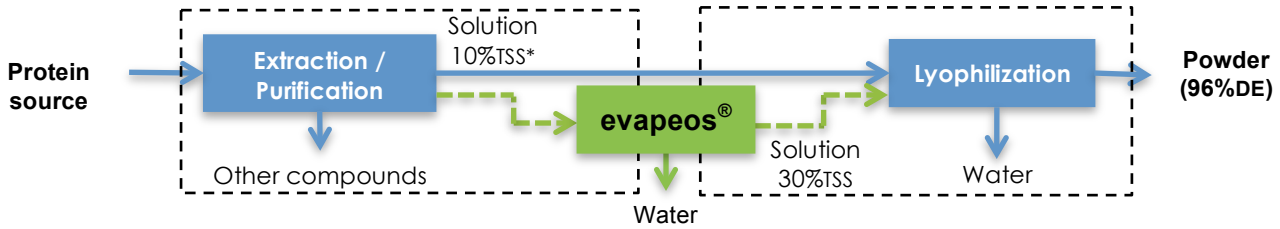

Figure 1: Possible incorporation of the evapeos process into a typical protein powder production process

**TSS = Total Soluble Solids*

The company: ederna

ederna is a French company which has developed a proprietary process that permits vegetal and biological products to be concentrated in very mild conditions.

After several years of intensive research and development activities, the company now offers its process for testing by universities, research institutes and corporate innovation departments worldwide.

For that purpose, **ederna** offers trials in its laboratory, the renting or sale of test equipment and also the development of industrial processes along with its partner T.I.A. (for more information: www.tia.fr).

An alternative green process for protein powder production

A new option for protein concentration: evapeos®

Principle

evapeos® uses the principle of osmotic concentration. Water transfers across a **membrane** from the **product** to an extraction liquid, the **osmotic agent**. The transfer is done naturally, due to an activity difference between the compartments on each side of the membrane. Moreover, only water can transfer across the membrane; the other compounds remain in the product.

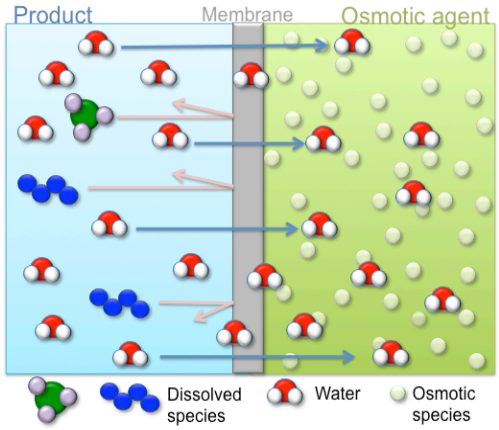

Figure 2: Osmotic concentration principle

Thanks to the osmotic principle, this concentration is performed at **ambient temperature and pressure**. Therefore, the product is concentrated under mild operating conditions and without direct contact with the osmotic agent.

Operation

Concentration using the **evapeos**® process is driven in batch or semi-batch mode. The product flows on one side of the membrane, while the osmotic agent flows on the other side. The solution is concentrated and the osmotic agent is diluted. After flowing through the membrane module, the osmotic agent is regenerated continuously by Mechanical Vapour Recompression (MVR) as detailed in ***Figure 2***. **ederna** recommends the use of an MVR to lower the energy consumption of the operation but virtually any evaporation equipment could be used.

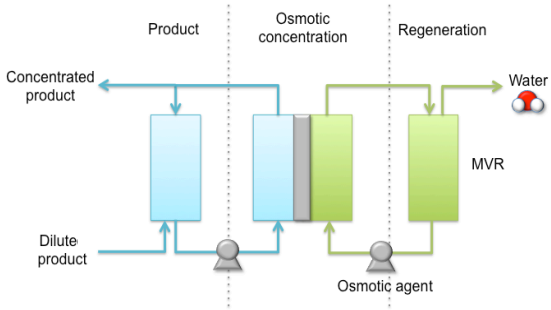

Figure 3: Description of the evapeos® process

Protein concentration assays

Protein solution concentration experiments with the **evapeos**® process were carried out in the laboratory. A model solution of whey proteins was concentrated using the ***ederna*** *Lab Unit 2*.

Figure 4: ederna Lab Unit 2

Material

The **ederna** Lab Unit 2 is an easy-to-use laboratory device designed to test the **evapeos**® process at laboratory scale.

The protein solution was prepared by dilution of whey protein powder in water. The initial concentration was 10% by mass.

Operating conditions

Initial volumes: - Osmotic agent = 0.3 L
- Protein solution = 0.3 L

Average temperature: 20°C
Membrane area: 0.2 m^2

Results

A concentration equivalent to 30%TSS was reached for a protein solution at 20°C using the **evapeos**® process.

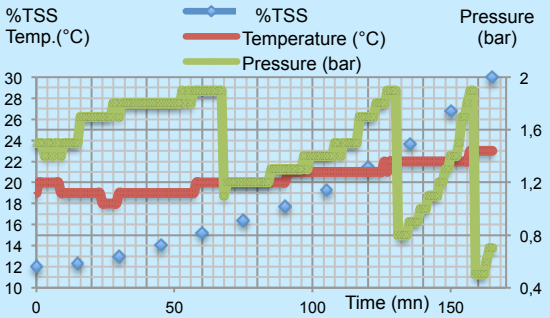

Figure 5: Evolution of the concentration, the temperature and the pressure

The proteins were not denatured. Analysis of the protein content with the Bradford method showed that a solution containing 10%TSS could be concentrated 3 times.

Economic optimization of the protein lyophilization process

Based on the experimental concentration results, an economic study was carried out to quantify the benefits of incorporating the **evapeos**® process into a lyophilized protein production process.

Aim of the study

Comparison of two lyophilized protein production model units:
In both processes, proteins were extracted from their natural source and purified to obtain a dilute solution of 10%TSS. This solution was then processed in different ways to obtain a protein powder of 96%TSS.

Unit 1 "without evapeos": the purified dilute solution was lyophilized directly.

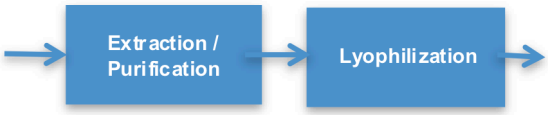

Figure 6: Unit 1

Unit 2 "with evapeos": the dilute solution was concentrated up to 30%TSS using the **evapeos**® process and then lyophilized.

Figure 7: Unit 2

Hypothesis

- Both units are equipped with a freeze-dryer able to remove a maximum of 250L of water.
- Annual protein powder production of unit 1 is 5 tonnes.
- 180 lyophilizations are done each year. One lasts 48h* (250L of water removed).
- 4 **evapeos**® concentration batches are done within 48h. The concentrated solutions are kept in a cold room until the following lyophilization.
- After concentration, the membranes in the **evapeos**® unit are cleaned (CIP). All operations are automated.

Method

1. Determination of the quantities to be treated in each lyophilization step for unit 1, according to the annual production.

2. Evaluation of the optimized quantities for unit 2. The freeze-dryer can remove the same amount of water as in unit 1 but from a more concentrated solution. The dry protein extract introduced is more highly concentrated which implies a larger final quantity of powder.

3. Estimation of annual costs (including investment payoff, maintenance, energy, wages and consumables), energy consumption and emissions, for both units, according to their production capacities.

Energy data

Lyophilization*: 5,000 kWh/m^3
evapeos®: 70 kWh/m^3

Vasseur J., Séchage Industriel: principes et calculs d'appareil, Ed. Techniques Ingénieur, 2010, J 2452-21

evapeos® Incorporation

The **evapeos**® process could be incorporated easily into an existing process. In this specific case, concentration could last 5 hours. After this operation, the evapeos device would be cleaned using a CIP system. All these operations can be organized according to the following scheme:

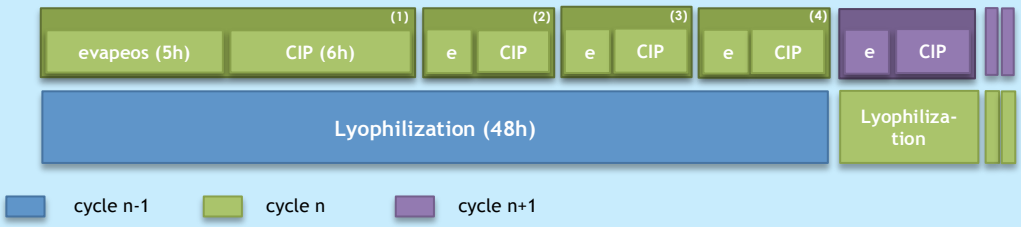

Figure 8: Possible incorporation of the evapeos process

Results

Unit 2, which includes the **evapeos**® process, could produce about 4 times more than unit 1 each year. Annual costs could be reduced by more than 60% and equivalent CO_2 emissions by 73%.

Although the **evapeos**® process would require the use of consumables (cleaning solutions, membranes, osmotic agent), it would consume far less energy than freeze-drying. This key point explains why costs could be significantly reduced. The cost distribution for unit 2 is detailed in the following charts.

Extraction and purification steps leading to the dilute solution of 10%TSS are not taken into account in the estimations since they are identical with or without ***evapeos***®*.*

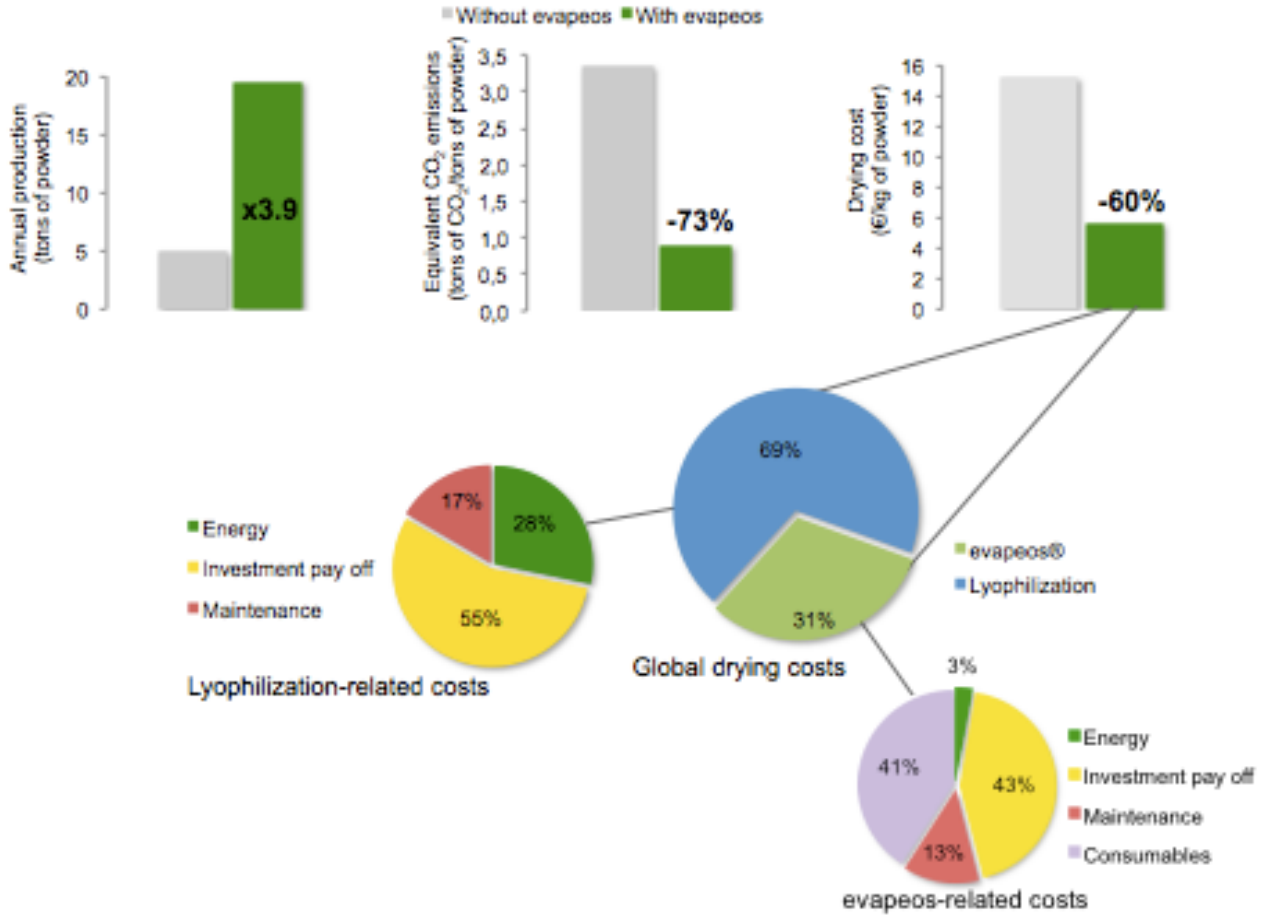

Figure 9: Annual production, CO_2 emissions and costs

Conclusion

The **evapeos**® process could be incorporated easily into the lyophilized protein production process. Its technical performance and low energy consumption could make it possible to increase the productivity by nearly 400%. In the case of lyophilization subcontracting, the incorporation of the **evapeos**® process would bring even more benefits by reducing transport cost and improving the productivity. The **evapeos**® process can also be of interest for the production of new high added-value products in the fields of cosmetics, health and food & beverages ingredients.

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