Engineering aspects of encapsulation
Challenge for success

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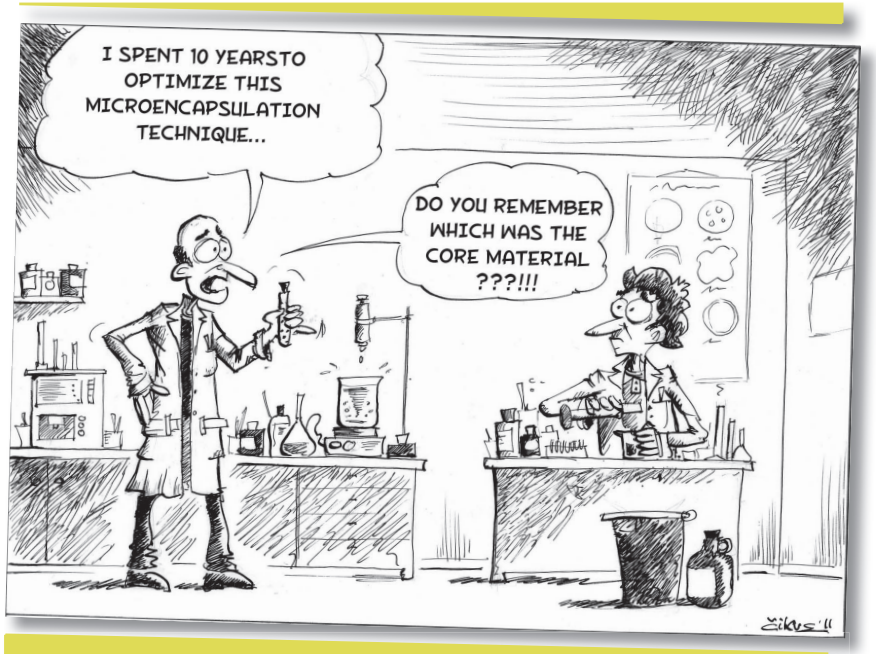
Hundreds of scientific articles are published every year on microencapsulation. Hundreds of industrials attend to seminars, symposiums or training events on encapsulation. Microcapsule production represents thousands of tons of microcapsules per year in various fields from pharmacy to food, from detergence to agriculture. But, through the numerous meetings I attended or organized with industrials (http://bioencapsulation.net), I kept a feeling that the domain is still not really mature. The reason for it, which may not be specific to microencapsulation, is the lack of integration in the research and development of the engineering aspects. In place of providing general concepts, let me illustrate my point of view by two examples.

We were conducting a research development on microencapsulation by solvent evaporation. To simplify the full process, a polymer was dissolved in an organic solvent, then dispersed in water phase. The resulting emulsion was let stand overnight to allow solvent evaporation and polymer beads were collected by filtration. The process was working correctly at lab scale but the transfer to pilot scale was unsuccessful. In the laboratory, mixing and dispersion were provided by a magnetic stirrer, while in pilot scale, it was based on a turbine system assisted by baffles. It was difficult to reproduce the same mixing conditions and get a similar emulsion. In the laboratory scale, introduction of ingredients took a few seconds and did not influence the resulting product. In the pilot scale, and even more on industrial scale, adding solutions takes minutes and the homogenization of the reactor is no more "instantaneous", interfering with other processes like the evaporation. While the time factor is not critical in the laboratory, at industrial scale, most processes are speeded up. This is why evaporation was realized under reduced pressure, in 20 minutes in place of several hours at lab scale. The microcapsule structures were very different between the lab and the pilot scale. We had to go back to the laboratory and test the production of capsules mimicking the pilot scale conditions. Scale-up may not be easy, scale-down is sometimes even more difficult: how, for example, define precisely the evaporation profile of a few millilitres of solvent? Lacking to consider the question of the large production from the beginning of the research leads us to make several "aller-et-retour" between the laboratory and the pilote plant, slowing down the transfer to real production.

On the other hand, many microencapsulation processes are often transferred "empirically" from the laboratory to the industrial plant. Such transfers are based on a strong expertise of the technicians. It leads often to mimic the small scale process and to adapt it "by feeling" to the large equipment. Such approach never leads to an optimum process and any modification or disturbance may provoke failure in the production. We especially studied the case of the fluid bed coating. Particles are suspended in an ascensional air stream (fluidisation) and a coating solution is sprayed on the particles. If the principle of the method is simple, analysing the process reveals its complexity. Air stream must be selected to maintain particles in suspension and promote a circulation of the particles in front of the spray nozzle. However, entrainment of the spray droplets out of the reactor must be limited. A good concentration of the particles must be maintained near to the nozzle. Drying the liquid on the surface of the particle must happen as quickly as possible while avoiding drying of the spray droplets before they hit the particles. To promote drying of the coating, fluidisation air must be at high temperature (often 70 to 90°C). Particles are then submitted to warming. Near to the spray zone, evaporation will limit this effect but in the annular zone, no evaporation takes place and one may observe over-heating. Engineering tools, without requiring complex modelling, may allow to analyse these questions, predicting temperature and humidity profile over the reactor, circulation and residence time of the particles in the system. Providing these information may allow to optimize and secure the process. We have demonstrated that in some processes, productivity could be doubled, yield of encapsulation (survival of probiotics) may be largely increased, and risk of production failure could be strongly reduced.



These two examples show that considering the engineering approach from the starting point and all over the research and development would speed up the transfer to production and provide a more efficient and reliable process, leading to higher productivity and profitability. However, very few research projects involved this aspects, even in large projects such as European projects or industrial development.