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Dry powder coating for food and feed applications

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ABSTRACT: A dry coating process using starch has been developed. It allows cost and energy reduction, avoids the use of solvent (water) and is realised in soft conditions : room temperature. At this stage, the coating is essentially suitable to modify particle surface but not to form impermeable coating. However, it may be applied to other types of coating materials with subsequent progress in the quality of the coating.

MICROENCAPSULATION CHALLENGES IN FOOD APPLICATIONS

Microencapsulation is actually a fashion. More and more research groups and industrials feel concerned by the potentiality of encapsulation to solve numerous problems going from simple material structuration to sophisticated delivery systems. Food and feed domains are largely involved in this evolution.

Technologies such as spray drying (spray of a solution as fine droplets in warm air), coacervation (precipitation of polymers around small oil droplets) and spray coating (spraying a polymer solution on solid particles) are used for several decades in food and feed fields, and production can sometimes reach thousand tons of capsules per year. However, the actual methods do not satisfy all industrial demands. Especially, it is a great challenge for providing food grade microcapsules impermeable to water.

Food and feed ingredients are often thermo-sensible. Spray drying processes have to be conducted very carefully to maintain the product temperature under a certain level while being in contact with a very hot air (up to 180°C). In traditional spray coating, we demonstrated that well selecting the design promotes more homogeneous particle circulation and avoids temperature gradient in the reactor, permitting for example to double probiotic survival during the coating process (1).

An other challenge is to reduce the cost of microencapsulation as the acceptable over-cost in food and feed is very limited. One approach to reduce the cost is to move from batch process to continuous process, decreasing the process cost it-self by up to a factor 3 (2). An other possibility is to develop a process control system, consisting of predicting the process evolution and reacting before any problem occurs. We developed such a system to avoid agglomeration during spray coating, leading to a decreased time of coating by 50 percent with regard to a manual coating (3). The present paper concerns a new technology allowing to realise a coating in soft conditions (room temperature) without use of solvent (including water) and requiring low energy consumption.

DEVELOPING A NEW TECHNOLOGY

In spray coating, a polymer solution is sprayed on solid particles. An upward air stream insures both the fluidisation-circulation of the particles and the evaporation of the polymer solvent (water). The evaporation slows down the process and represents an important part of the process cost and energy (due to evaporation enthalpy). Moreover, malfunction of the evaporation process leads to agglomeration of the particles.

Then why not to suppress the solvent in spray coating? The first approach consists to spray a melt material on the particles. However, suitable food grade materials that could melt at reasonable temperature are limited (fatty acid, some esters...). Moreover, the reactor temperature must be kept just below the coating melt point to avoid to fast solidification (then often higher than 50°C).

Shin-Etsu (Japan) has developed a process called *dry powder coating*, consisting to inject fine powder on the solid particles while spraying a plastifier. The "coalescence" of the powder grains on the surface of the particles leads to a continuous coating. However, their formulation (hydroxymethylcellulose acetate succinate) is suitable for pharmaceutical applications but not food grade.

Starch may be considered as the most popular food grade material. We then have conducted a study to adapt the *dry powder coating* to the use of starch as the main coating material (4, 5).

FOOD DRY POWDER COATING

Most previous works done on dry powder coating were realised in a fluid bed. However, our preliminary experiments showed that the coating efficiency (percentage of the powder fixed on the particles) was lower than 10 percent. The main reason seems that the air flow serving to circulate the particles is too high and blows the fine powder in the filter. This is why the following experiments were conducted in a pan coater (horizontal cylindrical reactor equipped with baffles). In such a system, the coating efficiency was generally higher than 80 percent.

A series of starches (Roquette, France; National Stach Germany) and two plastifiers (glycerol and triethylcitrate) have been tested for dry powder coating of microcrystalline cellulose beads as core particles. The main conclusions are that:

- Coating may be realised in 15 to 30 minutes while for similar levels of coating, spraying a solution would require between 1 and 1.5 hours,
- Main parameter controlling the quality of coating is the powder grain size : lower is better, generally lower than 30 micrometers,
- Powders with a size distribution and non spherical grains allow a better packing, and more stable and homogenous coating,
- Electron microscopy does not show a real coalescence of the powder. The "plastifier" acts more as a binder and the coating stability is insured by capillary forces and less by fusion of the powder grains.

Lycoat RS780 (hydroxypropyl pea starch from Roquette, France) was used to verify the first observation, as native starch and spray dried starch powder. The native form (large particles) gives poor coating efficiency (30 percent) while the spray dried form (small particles) allows to reach 60 percent coating efficiency. More over, we have sieved the particles on a metal mesh as a test of coating mechanical resistance. The coating efficiency drops to 10 for particle coated with native starch and 50 percent with spray dried starch, showing a lot more resistant coating when powder grains are smaller.

A few binders have been tested, not enough to draw final conclusions, but one could expect that viscous binders with a low interfacial tension with both the particles and powder grains will favour strong coatings.

The type of starch (except the size of the grains) didn't seem to affect the quality of the coating. In some cases, electron-microscopy reveals some coalescence but in most cases the coating appears as a stacking of grains. This leads to porous coatings not suitable for either slow delivery or protection against oxygen or water vapour. However, such coatings would fit well with applications like taste masking or improving flowing properties of particles. A fast heat curing of the coating permitted to get the melting of the powder and a more continuous coating. But the advantage of a fast and low temperature process is lost.

Preliminary tests have been done on a pilot scale reactor (done at Nicomac srl, Milano, Italy). Batch of 10 kg have been produced after a short adaptation time to transfer the process from lab scale (400 g) to the pilot scale. The quality of the coating was even better than in the lab scale experiments.

CONCLUSIONS

Both the conditions and the materials used in this study are compatible with food and feed applications. Moreover, our process may also be fruitfully applied in other fields like pharmacy and cosmetics. One could also expect that many other materials would fit to realise dry powder coating. We have for example successfully tested coating with fine palmitic powder using vegetal oil as binder. Some combinations of powder and binder may even allow to get continuous and possibly impermeable coatings. But this is for the future !

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