PROTOTYPE DEVELOPMENT AND MONITORING

Bedding from separated solids, a new biocell technology

di **Claudio Fabbri, Lorella Rossi, Fabio Verzellesi**

The prototype HBC biocell demonstrated that it could guarantee consistent quality and sanitization of the bedding produced from recycled separated solids even under the most unfavourable conditions, permitting substitution of straw bedding

In modern dairy sheds dung management represents a significant cost item, closely linked to the acquisition of bedding and its distribution and removal (50 to 150 €/cow/year). **In an attempt to reduce these costs and simplify shed management, companies equipped with mechanical solid/liquid separators have the possibility of using the solid fraction produced as bedding material.** In Italy, despite the obvious financial advantages, to date this technique has seen very limited application, probably due to the potential health and hygiene risks which could compromise the quality of the milk (bacterial load, spore-forming microbes).

The key factor for the success of separated solids as bedding appears to be their chemical, physical, and microbiological characteristics, which can vary depending on the type of slurry being treated, the solid/liquid separation method available (type and form of control of the separator), and the storage of the solid fraction before use as bedding. Past experience has demonstrated that forming a static or dynamic accumulation (with periodic turning) during which aerobic processes can develop, capable of raising the internal temperature to around 60 to 70°C, is the minimum requirement to sanitize the product from a health and hygiene perspective. However, circulation of air inside the accumulation is essential in order to encourage aerobic processes by permitting the entry of oxygen and simultaneously the escape of vapour and heat produced by the oxidative biological processes. The success of the process is directly proportion to the dry content of the separated fraction, which must be more than 28 to 30% at least. This is because the dry product is more friable and porous and tends to clump together less compared to the damp product. The aerobic process achieved by turning over the accumulation requires large spaces and careful management to be effective. Otherwise there is the risk of achieving an inhomogeneous product with health and hygiene characteristics that vary over time.

Figure 1 HBC biocell installed with solid/liquid separator and unloading screw conveyor

Starting from these premises, **CRPA worked with an Italian company** (CRI-MAN) **for the definition, development, and monitoring of an automated vertical flow biocell prototype called the HBC** (Hygienizing BioCell) **for the production of sanitized bedding** (*Diagram 1*). The project was realized under the research tender financed by the Emilia-Romagna Region: "Intervention in support of industrial research in companies operating in the production chains most affected by the seismic events of May 2012".

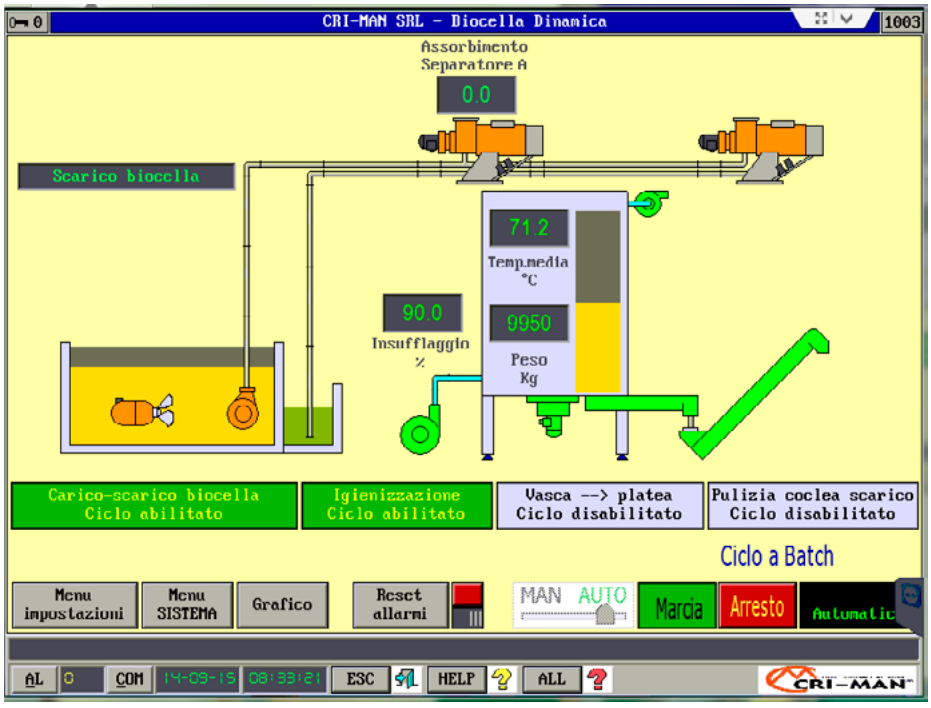
The prototype development and monitoring was conducted in a cowshed housing 480 dairy cows of the Friesian breed. The dairy cows are housed in head to head stalls with feeding and access aisles cleaned with scrapers. The milk produced is used for making Parmigiano Reggiano cheese in the farm dairy.

Description of the prototype

The machine (*Figure 1*), with all stainless steel structure, operates vertically: the separated solids of dry content around 33 to 35% are loaded in from above and the partially dried, sanitized material is unloaded from the bottom. During transition the biomass is constantly mixed with vanes of a specially designed geometry, rotating around a robust vertical central shaft. Mixing is combined with forced aeration from the exterior using a fan that blows air into the central shaft and from there into the vanes: the air exits through nozzles distributed along the vane profile. The air input provides the oxygen required for the oxidation process (highly exothermic) and as it moves upwards it becomes saturated with H2O, partially drying the biomass. The drying effect is proportional to the air input volume. The cooling of the biomass resulting from ventilation is offset by a heat recycling system for the outlet air as it is extracted from the top of the HBC, making it possible to raise the temperature of the input air. It is important to note that the untreated input material never comes into contact with the material in the lower layers that has already undergone the sanitization process.

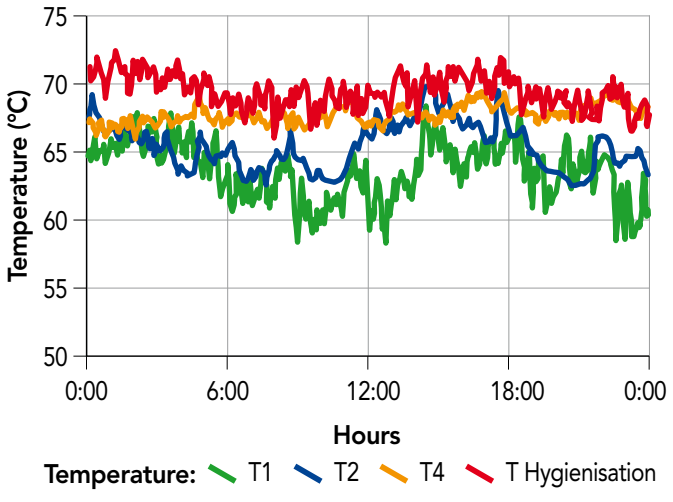
The process is monitored using temperature and weight transducers suitably distributed to provide constant feedback on the quantity of material present and the degree of sanitization and drying. The transducer signals are processed by a PLC, which modulates air input. A computer program can manage the entire separation and sanitization plant. The HBC management system is designed to guarantee sanitization of the unloaded material, with unloading being disabled if the required sanitization conditions have

DIAGRAM 1 - Schematic diagram of the HBC biocell control system



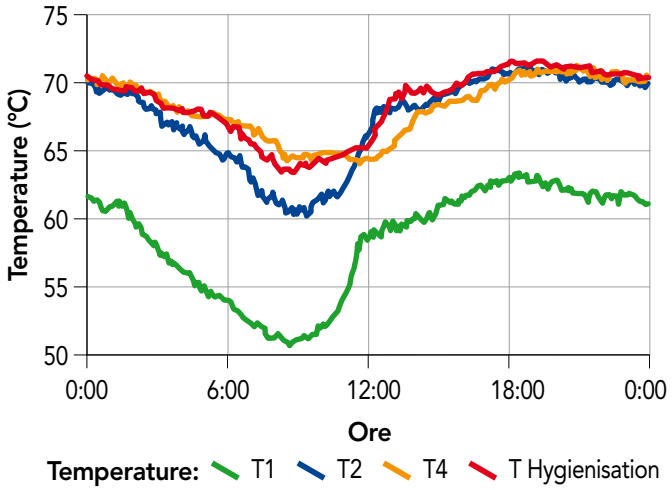
The main page of the management software displays all the components of the HBC separation system with continuous updating of the process data (temperature, weight, air input)

CHART 1 - Temperature variation of the mass inside the biocell with retention time of 2 days (January 2015)



Low winter temperatures make it more difficult to achieve the sanitization temperature (red line), but by adjusting the unloading rate and air input it is still possible to achieve the required conditions.

CHART 2 - Temperature variation of the mass inside the biocell with a retention time of 1 day (April 2015)



It is easier to maintain the process temperature during the spring, but the increased temperature range produces oscillations in the process controls.

not been achieved (the reference parameter is residence at 70°C for 1 hour).

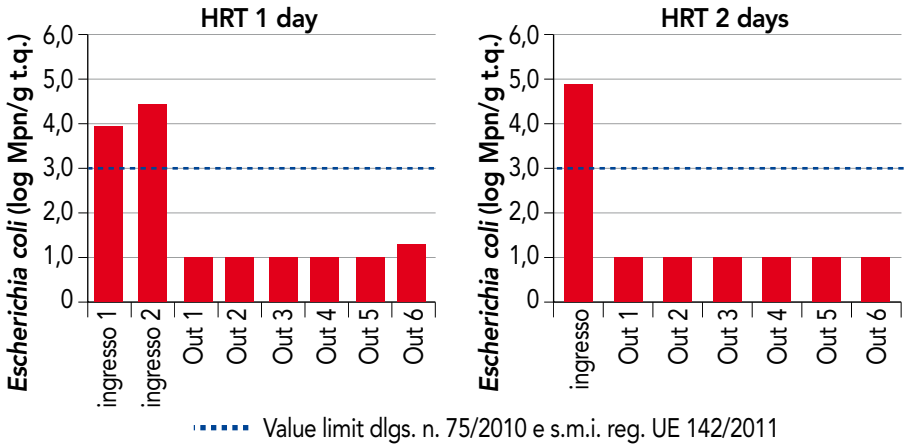
The HBC biocell can also be programmed to vary the residence time of the material (HRT retention time): the unloading of material can be stopped, slowed down, or speeded up. The dimensions of the HBC biocell are 2.7 m x 2.7 m, and height 4.5 m. It is equipped with electric motors for mixing the biomass, unloading the sanitized material, blowing in air, and for expelling vapour. The total power consumption is 6.5 kW. The system for accumulating sanitized material downstream of the HBC biocell and completing the plant also has to be considered (screw conveyor or belt, indicatively 1.5 kW), while for the separation system a 5.5 or 7.5 kW machine is considered necessary, together with a loading pump of 4 kW and a mixer for homogenizing the slurry in the tank sized according to the volume (5.5 to 18.5 kW). Obviously the energy costs of this equipment are already borne by the company, if they are currently separating the slurry.

Production performance

The control and management system supporting the mechanical assembly made it possible to constantly record the process temperatures at different points in the biocell, and the weight of product loaded and unloaded. Monitoring continued for about 9 months from the summer of 2014 until the end of spring 2015. **The possibility of controlling the input air flow and residency time at the sanitization temperature makes the machine very easy to operate.** The process was tested by simulating different material retention times inside the biocell, from 5 days to 1 day: in all the cases analysed the temperature always remained higher than the set threshold of 70 °C for at least one hour. *Charts 1* and 2 show examples of the variations recorded in different seasonal conditions and with different retention times (1 day and 2 days).

The production of sanitized material by the machine model described was tested up to 8 tons per day with a retention time of 1 day. The process, obviously, makes it possible to evaporate a quantity of water directly proportional to the retention time and the volume of warm input air in order to oxygenize the bacterial consortium. At maximum production capacity capable of ensuring general product sanitization, the retention time was reduced to 24 hours and the reduction in weight was less than 2 to 3 per cent. In summer conditions with a retention time of 5 days the weight reduction easily reached 20 to 25% of the quantity processed in the biocell. In order to guarantee the success of the process, a solid/liquid separator was used with an elongated filter and at an high average operating pressure, capable of producing separated solids with an average concentration of 335 ± 35 g/kg.

CHART 3 . Microbiological parameters with a retention time of 1 day and 2 days



Mpn = Most probable number. **t.q.** = solid manure.

From a health and hygiene perspective the absence of Salmonella spp. was always confirmed along with an obvious reduction in the level of Escherichia coli.

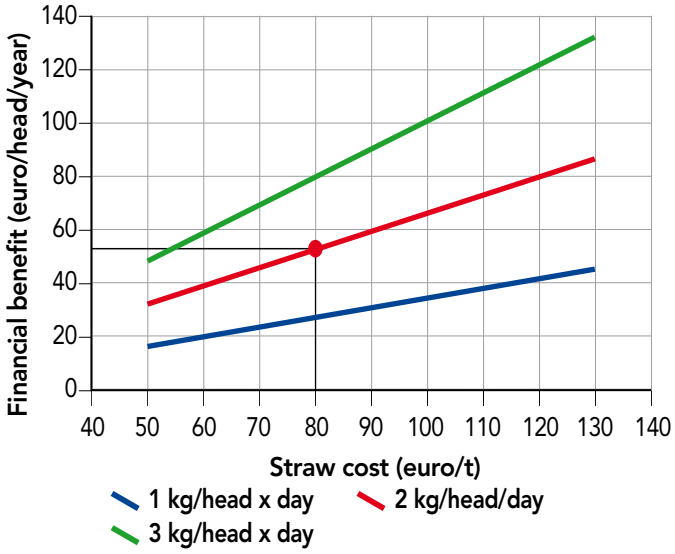
Health and hygiene

In order to check the effective improvement in the sanitary features of the treated solid fraction, repeat test measuring programmes were con-

Figure 2 Sanitized separated solids distributed in the stalls of the shed used for the trial

ducted for the microbiological indicator parameters (Salmonella and Escherichia coli). Both these parameters are foreseen in Leg. Decree N. 75/2010 and subsequent amendments, for the free marketing of composted products, and by EU Reg. 142/2011 for by-products of animal origin subject to pasteurization.**The absence of Salmonella can be observed both in input and output with a marked reduction in the Escherichia coli parameter** (*Chart* 3). It should also be noted that the threshold value imposed by the above cited regulations to ensure a high standard of sanitization is 1,000 MPN/g. In all the cycles conducted during the monitoring of the biocell (5 sessions) this objective was achieved every time.

CHART 4 - Financial benefits, gross of financial costs and maintenance, achievable using the HBC sanitizing biocell



Assuming a cost of straw at 80 euro/t and a consumption of 2 kg/head/day, the financial savings are estimated in the order of 50 euro/head/year.

Financial and energy aspects

In established practice the farm used about 2 to 2.5 kg/head/day of straw. Following the start up of experimentation and production of sanitized separated solids the material was found to be good quality and was used to substitute the dry stall straw for the cows. The average quantities of separated solids used to substitute the straw, during 3 different months of monitoring scattered through the year, were 4.8 to 5 kg/head/day (*Figure* 2). On the basis of the results from the first trial months, the farm decided to extend use to the rest of the herd, considering the results to be satisfactory according to their internal monitoring plan. However, a full assessment of the validity of the new bedding material must include a study of any induced effects in various areas, like the well-being of the animals (foot lesions, grade of cleanliness of mammary glands, etc.), and the quality of the milk (total bacterial load, somatic cells).

As regards energy costs, it is noted that a recent CRPA investigation (2012), conducted as part of the "Re Sole" project, established the average annual consumption of electrical energy in dairy cow farming as around 510 kWh/cow. On the basis of annual electrical costs effectively sustained it was possible to extrapolate a kilowatt hour cost of 0.2 euro/kWh, with 69% of companies bearing a cost of between 0.1 and 0.2 euro/kWh. The average annual energy cost was thus 102 euro/cow.

Considering a company cost of electrical energy at 0.2 €/kWh and an energy consumption of around 25 to 28 kWh/t, the sanitized product obtained using the prototype generates a cost of 4.5 to 5 euro/t (2 to 2.5 c€/head/day). **In terms of average company energy costs this represents and increase of 7 to 9%.** The cost of distribution of the separated solids can be considered equivalent, as an initial approximation, to that of straw, while since the separated solids are produced and consumed continuously, space previously required for storing bedding would be freed. **Against a similar cost for the handling and distribution of the separated solids to that of straw, net of energy costs, the direct financial benefit to the farm is represented by the eliminated cost of buying straw.** Hypothesizing a straw purchase price varying between 50 and 130 €/t and a consumption of between 1 and 3 kg/head/day, the graph of *Chart* 4 illustrates the financial benefits that can be achieved using the HBC biocell. **On average the cost of straw is 80 €/t with a consumption of 2 kg/head/day, so the savings can be estimated at around 50 euro/head/year. Among the indirect benefits there is also a reduced production of effluents deriving from not using straw** (350 to 440 t/year at the company hosting the trial). Obviously, the costs of depreciation and maintenance have to be written off against the financial savings.

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