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DAIRY COMPOSTING BARNS CAN IMPROVE PRODUCTIVITY, ENHANCE COW WELFARE AND REDUCE ENVIRONMENTAL FOOTPRINT: A SYNTHESIS OF CURRENT KNOWLEDGE AND RESEARCH NEEDS

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Abstract

Dairy composting barns, developed overseas, involve innovative technologies that collectively address dairy farm productivity, cow welfare and environmental footprint, with transformational potential for New Zealand dairy while still retaining pasture-based grazing systems. The underlying principle is that dung and urine combine with high carbon bedding materials to produce *in situ* composting within loafing barns, and cows rest on this dry compost. Key requirements are appropriate infrastructure design and associated air movement, combined with twice daily tilling by tractor. All liquid is removed by natural evaporation, facilitated by internal compost temperatures of approximately 55 degrees C and dry matter content no less than 50%. The external compost temperature provides a comfortable resting surface, with compost typically replaced once per year.

In New Zealand, there are probably no more than four operational composting barns, but with multiple others planned. They are used within controlled duration pasture-grazing systems. Compared to most other bedding systems, and assuming appropriate management, cows remain remarkably clean and healthy. This facilitates barn-use for lactating cows, with usage determined by seasonal grazing rules and weather-related conditions.

We have been monitoring two such farms, both designed with cow welfare and productivity paramount, and with minimal focus on leaching. As such, it is notable that although enhanced animal welfare and markedly improved productivity criteria have been met, there remains considerable scope for reducing nitrogen leaching without further radical farm-system change.

A cautionary note is that *in situ* composting within barns has not been successful on some New Zealand farms. The reason has been farmer failure to understand fundamental elements of composting-barn systems, including both structure design and management.

If dairy composting barns are to become mainstream in New Zealand, then R&D investigations are needed. Investigations need to span the farming system, but with particular focus on composting processes and outcomes using a range of bedding materials, and in different geographical locations. Also, investigations are needed of nutrient loss within the compost, together with the effect of adding composted nutrients to soils at different C:N ratios, and across different soil types. Monitoring of commercial farms can provide major insights but structured investigations are also needed within more formal R&D settings. Accordingly, this paper is a call to action.

Introduction

The purpose of this paper is to communicate the key principles of dairy composting barns. We contend that these barns and the associated farming systems have transformational potential for New Zealand dairying by reducing environmental footprint and enhancing animal welfare, while also offering potential for improved physical and economic productivity within pasture-based grazing systems. However, there is a need for a structured R&D program to quantify the biological processes and to optimise farming systems for New Zealand conditions.

Composting barn technologies have been developed initially in the USA and subsequently in Europe and applied predominantly within confinement-farming systems. However, they have particular applicability within controlled-duration grazing systems where they provide off-paddock high-quality shelter which meets animal welfare standards at considerably lower capital cost than free-stall systems, and without the animal welfare constraints associated with hard surface off-paddock systems.

Given the developing state of knowledge, specific parameters should be taken as indicative only.

The essence of composting barns for New Zealand

The key feature of these farming systems is that cows spend their resting hours in a well ventilated barn (Figure 1) in which the bedding is organic material initially high in C:N ratio, and that composting of dung and urine occurs *in situ* within the barn. The composting material remains relatively dry, driven by the composting warmth and moisture evaporation. If working well, there is no liquid effluent – there is only compost to be removed. In a well-managed system, the compost only needs to be removed once per year. However, specific ventilation parameters need to be met, and aeration of the compost with twice-daily tractor tilling (Figure 2) is fundamental to success.

Figure 1. Cows resting in a New Zealand composting barn

Infrastructure

The key infrastructure is an open-sided roofed barn structure with a roof slope of at least 18 degrees. Open side walls should be at least 4.6 metres high and the roof should have an open channel of at least 1.5% of the barn width to create a chimney effect. In an efficient composting system, rain is unlikely to enter though this air vent because of the positive air pressure effect, but if a cap is added, then it must still allow air to flow upwards rather than sideways. Fans may be useful under specific environmental conditions.

Figure 2. Tilling the compost bed in a New Zealand composting barn

Under New Zealand conditions, the preferred system in many situations will be where off-paddock feeding occurs within the composting barn with feed troughs along the side, but with drinking troughs outside the barn area and surrounded by concrete.

When cows are feeding inside the shed, it is best that they are on a hard surface, perhaps 2 metres wide. Dung and urine falling on this pad can be spread into the compost, and this is facilitated if the pad is wide enough for a small tractor with appropriate manure sweeping equipment. If cows are urinating directly into the compost when they are feeding, then this area is likely to become wet.

As a general rule, each composting bay within the barn should be designed for no more than 200 cows to optimise cow behaviour.

The area of bedding per cow will be influenced by the proportion of the time cows spend in the barn, particularly during winter. Under American conditions, nine square metres of compost area, and with a depth of at least 600 mm is often considered appropriate. Under New Zealand climatic conditions, and within controlled-duration grazing systems, this area but not the depth may typically be reduced somewhat. Specific requirements depend on the proposed farming system.

Animal Welfare and Animal Health

Dairy composting barns are able to meet all realistic animal welfare requirements as long as the compost remains appropriately warm and dry. The open loafing barn structure facilitates normal cow behaviour, linked both to freedom of animal movement and secure footing. When in the barn, cows that are not feeding typically choose to lie down.

American evidence is that animal health and milk quality are similar to sand-bedded free-stall barns (Eckelkamp *et al* 2016) with sand-bedded barns generally regarded as superior to mattress-bedded free-stall barns. However, there are other issues with sand-bedding and we are not aware of any New Zealand free-stall barns that use sand. On one monitored New Zealand farm with a composting barn, the somatic cell count in the latest year averaged 61,000, demonstrating that exemplary udder health is possible with these systems.

Unlike free-stall barns, no cow-training is necessary for composting barns.

Economics

The economics will depend on the farming system and the ability of the farmer. As with other farming systems, there will be considerable performance variations between farms.

The cost of the roof structure will be about $140 per covered square metre for a high standard permanent structure. Other components, such as sealing of the compost pit and surrounding concrete will depend on individual farm situations.

Once all aspects of the system are considered, including ancillary feeding equipment and feed bunkers, then the overall cost per cow may vary anywhere between $1500 and $3000 per cow. These costs will typically be considerably less than for free-stall barns given the much simpler fit-out and simplified effluent facilities with liquid evaporated naturally. However, costs will be greater than for hard-floor shelters designed for short duration weather events.

However, capital cost per cow is not necessarily a particularly useful metric. More relevant, is the capital cost per additional cost of milksolids. This will depend totally on how the farmer uses the barn. Our initial evidence is that an 'all up' figure of $12 to $15 dollars per kg of additional milksolids is realistic and that this will achieve profitable outcomes.

Neither of the New Zealand farms for which we have data have increased cow numbers consequent to building the barn. Instead, they have focused on increased production per cow and production efficiency. The more intensively monitored farm has increased per cow production from 380kg milksolids prior to barn construction to 544 kg milksolids in the third year of barn (2016/17) and with further increases occurring in the current year. Maize silage is the main feed within the barn. Back calculations within Overseer suggest increased pasture production in excess of 35%. However, in reality this derived number is unlikely to be accurate, with better utilisation of pasture within these systems, together with lower cow maintenance requirements in the barn, not adequately accounted for in the modelling. However, this figure of 35% is indicative of overall pasture feed efficiencies achieved within this system.

This farm has retained a seasonal milking system but is well set up to introduce a 12-month milking system, without further investment. Accounts analysis indicates that the overall cost of production per kg of milksolids has had a tendency to decline, with increased feed costs plus bedding material costs being counterbalanced by fixed costs and most other variable costs declining per unit of production. The overall economics are attractive with capital cost per additional kg of milk solids being approximately $15 per kg milksolids.

The second farm is of high performance Jerseys that produce more than 600 kg milksolids per lactation within a 12-month milking system and with winter premiums. We do not have full cost data for this farm but note that it is the barn which provides the environment for a long-term sustainable winter milking system with winter milk premiums.

Environmental footprint

The environmental benefits from dairy composting barn systems derive from the ability to manage controlled-duration grazing systems and hold animals off-paddock when this is appropriate so as to minimise nitrogen leaching and also to reduce pasture pugging. The current generic evidence with off-paddock systems is that there is an approximate linear equivalence between proportion of hours off-paddock during autumn/ winter and the proportional reduction in nitrogen leaching (Christensen *et a*l 2018a and 2018b)), but this has not been measured directly in composting barn situations. Given that composting barns provide a high-quality animal welfare environment, it is feasible, even in winter grazing situations, to reduce the number of on-pasture hours to no more than about four hours per day.

There is no data that we are aware of for greenhouse gas (GHG) emissions for these composting systems. However, given the biological efficiency of housed cow systems with typically high milk production per kg of liveweight, combined with the controlled return-to-paddock of the compost, there is reason to postulate that these systems will be considerably more GHG efficient per kg of milk or milksolids than traditional New Zealand grazing systems.

Constraints to adoption

Three potential constraints to adoption are insufficient availability of suitable bedding, some failures by early adopters who fail to understand the essential management requirements, and access to finance.

With bedding, the existing supplies of wood-based materials such as sawdust and chips will not meet the necessary demand, currently estimated at three cubic metres per cow per annum. However, there are a number of organic material options, with one option being farmer plantings of long-living perennial Miscanthus grass (Figure 3), which is harvested once per annum (late winter or early spring) when in a woody state.

There is already evidence that some farmers have been unsuccessful in their composting attempts through failure to appreciate the key infrastructure requirements combined with the necessity for twice-daily tilling to maintain the necessary aeration. Such failures can lead to other farmers choosing to be non-adopters, through mistaking management failure for technology failure.

Many New Zealand dairy farmers have high debt and are capital constrained. For these farmers, innovative finance options will be necessary if they are to be adopters.

Figure 3. Miscanthus growing in New Zealand

R&D needs

There is a need for a structured R&D program to assist the early adopters and then communicate the learnings more widely. Investigations need to span the farming system, but with particular focus on composting processes and outcomes using a range of bedding materials, and in different geographical locations. Also, investigations are needed of biological processes and nutrient losses within the composting lifecycle, together with the effect of adding composted nutrients to soils at different C:N ratios and across different soil types, together with greenhouse gas emissions for these systems. More generically, further quantification of N-leaching losses under a diversity of controlled-duration grazing systems and for various soil types is necessary. Although monitoring of commercial farms can provide major insights, structured investigations are also needed within more formal R&D settings.

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