

## **Estimate of manure present in compost dairy barn systems for sizing of manure storage**

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**Abstract.** Milk production is increasingly modernized as a result of the growing demand for food around the world. Improvements in livestock facilities are observed, with a large increase in the use of feedlot systems such as the Compost Dairy Barn. Increasing milk production in confinement systems has also raised concerns such as the management of wastes (water, faeces and urine) from the system, which has become one of the most important issues in the intensive dairy farms. The aim of this work was to estimate the amount of manure present in compost dairy barn systems in order to size the manure storage. The study was conducted at four compost dairy barns in southern Minas Gerais, Brazil. These compost barns had different bedding materials and dimensions. In each farm, data on milk yield and quality (daily production, fat and protein content), animal weight and amount of feed ingested by the animals were collected. Total-day manure delivered by the cows in the feeding alley and milking parlour was piled up together and weighed. Based on the results, it was observed that, in the compost dairy barns, only part of the total manure produced per day was delivered in the milking parlour (1.6 and 2.0%) and in the feed alley (27.6 to 49.3%). These results are very important for designers for the proper manure management system design of the dairy farms.

**Key words:** animal facility, compost-bedded pack barn, dairy farming, manure, organic wastes.

### **INTRODUCTION**

The performance improving in dairy farms is related to a large increase in herd confinement, using intensive housing systems such as freestalls and compost barns. Producers tend to look for more pure breed animals with better production rates and increasingly efficient nutrition.

With the increase of milk production in feedlot systems, concerns such as the management of wastes (water, faeces and urine) from the facilities have become one of the most important issues in intensive dairy farms.

In the Compost Dairy Barns (CB) system animals are housed in an open bedding area that allows them to move freely without barriers inside the resting area (Leso et al., 2019). The bedded pack (made up of organic material and cattle excreta) should often be cultivated over to incorporate the excreta into the organic material of the pack to promote the aerobic composting process (Leso et al., 2020). In this confinement system manure waste can be found mainly in the bedding area, feed alley and milking parlour.

Considerable quantities of dirty water, composed of milking parlour wash-water, milk spillages, runoff from cattle yard areas and effluent from silage and manure are produced on dairy farms (Martínez-Suller, 2010). Waste from milk production is produced daily while washing the floor of the facilities. Rinsing waters from milking parlour and milk tanks may also be part of the waste. The amount of waste produced daily will depend on the type of production system, the way the facility is washed and the quality of the workforce. The manure delivered by the herd represents the largest amount of the total waste produced in the dairy farms. Daily manure production of the animals is estimated from 9.0–12.0% of the live weight of the herd (Campos et al., 2002).

The discharge of untreated wastes into the soil, lakes, rivers causes serious environmental problems: groundwater and surface water pollution, soil pollution, proliferation of flies and gas emissions. However, several management and treatment alternatives have been developed and tested to mitigate the effects on the environment (Freitas, 2008).

For the dairy producers, an appropriately sized manure pit storage system gives several advantages, such as: reduction of effluent movement tasks daily, flexibility in the use of manure as fertilizer and more effective utilization of nutrients and water present in the manure.

Thus, estimating the amount of manure produced in dairy cattle facilities allows the correct sizing of manure storage, which is a low cost alternative to prevent the manure percolation or leaching through the soil.

The manure management system requires a correct project design, based on the potential scale of the dairy farm, as well as the potential environmental and climatic issues and the technical and productive management issues. A right sizing of volume and time of storage is related to all these aspects. Therefore, the global investment for CB has to consider the presence of a concrete feeding alley and the manure removal system. The manure storage should be sized to store all the farm wastes according to the waiting period needed for the application of the treated waste in the soil based on the current legislation. Enough flexibility has to be considered in order to use the manure in the best period of the crops. For Brazilian conditions, Freitas (2008) recommends at least 30 days of storage volume.

In the CB facilities manure pit store usually is built to receive the manure that the cows deliver in the feeding alley while they are standing up eating the ration or drinking water. As part of the dejections is kept in the bedded pack and is composed in the bed, it is enough to manage the part of excreta released in feeding alley. Therefore the manure storage must be sized according to the amount of manure (faeces plus urine) released in the feeding alley. The ratio between manure released in the feeding alley and in bedded pack is the main question when the design of the barn is starting. In fact it is important

to calculate with good precision the storage size. Janni et al. (2007) cited that farmers estimated about 25% to 30% of manure released in the feeding alley, and used a mini pit to store manure for about 2–3 days. However the right sizing of the manure storage has to be based on technical criteria.

The aim of this work was to estimate the amount of manure present in compost dairy barns in order to size properly the manure storage.

## MATERIALS AND METHODS

The study was conducted in four compost dairy barns (CB) in southern Minas Gerais, Brazil. In each farm two herds, one with high milk yield (HMY) and one with low milk yield (LMY) were evaluated. In CB1 62 cows were housed, 25 LMY (18.2 kg head<sup>-1</sup> day<sup>-1</sup>) and 37 HMY (23.7 kg head<sup>-1</sup> day<sup>-1</sup>). In CB2, 53 cows were housed, 18 LMY (22.1 kg head<sup>-1</sup> day<sup>-1</sup>) and 35 HMY (27.2 kg head<sup>-1</sup> day<sup>-1</sup>). In CB3 58 cows were housed, 22 LMY (20.8 kg head<sup>-1</sup> day<sup>-1</sup>) and 36 HMY (25.4 kg head<sup>-1</sup> day<sup>-1</sup>). In CB4 68 cows were housed, 28 LMY (25.8 kg head<sup>-1</sup> day<sup>-1</sup>) and 40 HMY (29.2 kg head<sup>-1</sup> day<sup>-1</sup>). In all CB the cows were milked twice a day and fed once a day.

Some characteristics of the four CB are shown in Table 1.

**Table 1.** Main characteristics of Compost Dairy Barn (CB) evaluated in this study

CB	Herd Production	Milk Yield (kg head <sup>-1</sup> day <sup>-1</sup> )	Number animals	Length (m)	Bedding area		Stocking density (m <sup>2</sup> head <sup>-1</sup> )
					Width (m)	Feeding alley Width (m)	
1	Low	18.2	25	54.5	15.3	4.0	13.4
	High	23.7	37				
2	Low	22.1	18	50.0	14.0	4.0	13.2
	High	27.2	35				
3	Low	20.8	22	48.0	14.2	3.8	11.7
	High	25.4	36				
4	Low	25.8	28	55.0	15.0	4.2	12.1
	High	29.2	40				

The CB facilities have different dimensions. The bedding area is 832.32 m<sup>2</sup> (54.4×15.3 m) in CB1, 700 m<sup>2</sup> (50.0×14 m) in CB2, 681.6 m<sup>2</sup> (48×14.2 m) in CB3 and 825 m<sup>2</sup> (55×15 m) in CB4. As bedding material, CB1, CB2 and CB3 used sawdust and CB4 used wood shavings.

In all the four CB the feeding alley is 4.0 m width, and the surface floor made of concrete.

In each CB the following data were collected: milk yield (litres for herd divided by the total number of cows), milk quality (bulk tank fat and protein content), animal weight (weight of the animals of the herd), amount of feed ingested by the animals (kg of dry matter offered less the refusal dry matter for total herd). The amount of manure produced by LMY and HMY cows over a 24-hour period was measured. All the manure delivered by the cows in the feeding alley and milking parlour was piled up, placed in plastic buckets and weighed with digital scales. Before collecting the manure from the floor of

the feeding alley, scraping was performed to remove solid manure present from the previous day.

Eq. 1 was used to estimate the amount of total manure produced by cow per day (ASAE, 2005). The amount of manure delivered in the bedding area was calculated by subtracting from the total manure the manure collected and weighed in feeding alley and in milking parlour.

$$D_{\text{total}} = (P_{\text{Milk}} \cdot 0.172) + (C_{\text{MS}} \cdot 2.207) + (G_{\text{Milk}} \cdot 171.83) + (PT_{\text{Milk}} \cdot 505.31) - 8.17 \quad (1)$$

where  $D_{\text{total}}$  is the mass of total manure (manure excretion by cow per day);  $P_{\text{Milk}}$  is milk production by cow (kg of milk head<sup>-1</sup> day<sup>-1</sup>);  $C_{\text{MS}}$  is the dry matter intake (kg of dry matter by head<sup>-1</sup> day<sup>-1</sup>);  $G_{\text{Milk}}$  is the fat in milk (g g<sub>milk</sub><sup>-1</sup>); and  $PT_{\text{Milk}}$  is the protein in milk (g g<sub>milk</sub><sup>-1</sup>).

For sizing of the manure storage, the volume ( $V_{\text{est}}$ , in m<sup>3</sup>) of tanks must be calculated using Eq. 2 (Palhares, 2019).

$$V_{\text{est}} = T_a \cdot V_{\text{res}} \cdot Ft \quad (2)$$

where  $T_a$  is the storage time (days);  $V_{\text{res}}$  is the total volume of waste produced per day (m<sup>3</sup>); and  $Ft$  is the value of the factor dependent on the type of water diversion system (rain, sprinkler and water cooler) that exists in the facilities (feeding alley).

About Factor ( $Ft$ ), the following values are used.  $Ft$  equal to 1.0 is used when no water flows into the manure storage, because no sprinklers are placed in the feeding alley and the facility is covered and has gutters on all roofs with a rainwater drainage system that falls to the floor.  $Ft$  is equal to 1.20 when part volume of goes into the manure storage. The environment has gutters on all roofs, but the rain that falls on the floor goes to the pond.  $Ft$  is equal to 1.35 when all water arrives to the manure storage (rain falls on the roofs and is collected in the concrete floors of the barn and sprinklers are placed in the feeding alley).

It was also considered that the manure has a density of 600 kg m<sup>-3</sup> (Freitas, 2008) and that a storage time of 30 days is required.

## RESULTS AND DISCUSSION

Table 2 shows the Milk yield (L – low and H – high), values of body weight average (BW), milk protein ( $PT_{\text{milk}}$ ), fat in milk ( $G_{\text{milk}}$ ), dry matter intake ( $C_{\text{MS}}$ ) and total mass of total manure ( $D_{\text{total}}$ ) evaluated in this study.

Body weight (BW) was from 609.4 to 672.5 kg average cow<sup>-1</sup> (Table 2). According to laboratory analysis, total milk protein ( $PT_{\text{Milk}}$ ) and milk fat ( $G_{\text{Milk}}$ ) ranged from 3.18 to 3.39 g g<sub>milk</sub><sup>-1</sup> and 4.16 to 4.50 g g<sub>milk</sub><sup>-1</sup>, respectively. Dry matter intake per day ( $C_{\text{MS}}$ ) ranged from 7.4 to 20.74 kg cow<sup>-1</sup> day according the estimation results by Eq. 1, the total manure mass ( $D_{\text{total}}$ ) ranged from 35.6 to 66.0 kg head<sup>-1</sup> day<sup>-1</sup>.

Table 3 shows the amount of manure delivered by the cows in the different places of the facilities (milking parlour, feeding alley and bedding area) evaluated in this study for L and H MY levels. No significant differences ( $P < 0.05$ ) in the distribution between MY levels were found.

**Table 2.** Amount of manure delivered in different places of the facilities (milking parlour, feeding alley and bedding area)

CB	Milk yield	BW kg cow <sup>-1</sup>	PT <sub>Milk</sub> g g <sub>Milk</sub> <sup>-1</sup>	G <sub>Milk</sub> g g <sub>Milk</sub> <sup>-1</sup>	C <sub>MS</sub> kg cow <sup>-1</sup> day <sup>-1</sup>	D <sub>total</sub> kg cow <sup>-1</sup> day <sup>-1</sup>
1	L	609.4	3.39	4.16	7.4	35.6
	H	625.7			10.0	42.3
2	L	652.7	3.42	4.50	18.8	62.3
	H	672.5			19.4	64.4
3	L	632.4	3.18	4.25	13.5	48.6
	H	652.3			13.7	49.9
4	L	652.3	3.18	4.25	16.8	56.7
	H	672.4			20.7	66.0

BW is the body weight average cow<sup>-1</sup>; PT<sub>Milk</sub> is the milk protein (g g<sub>milk</sub><sup>-1</sup>); G<sub>Milk</sub> is the fat in milk (g g<sub>milk</sub><sup>-1</sup>); C<sub>MS</sub> is the dry matter intake (kg of dry matter cow<sup>-1</sup> day<sup>-1</sup>); D<sub>total</sub> is the total mass of total manure (kg of manure by cow per day).

The results show that the amount of manure present in milking parlour ranged between 1.6 and 2.0% of the total manure produced per cow per day. In literature the values considered for the effluents produced in milking parlour are between 10 and 15% (Chai et al., 2016; White et al., 2001). However, the effluents comes from teat washing (4%), wash water (86%) and excreta (10%) (Minogue et al., 2015). White et al. (2001) found a high correlation between the time spent in a location and the proportion of manure released on it, and measured 4.6% of the faeces and 3.1% of the total urine produced in the holding area near the milking parlour and in the milking parlour for grazing systems. Most of the manure (84.1% urine and 84.7% faeces) occurred in the paddock, suggesting that the storage capacity and cost of manure handling facilities for pasture-based dairy systems could be greatly reduced.

**Table 3.** Average and standard deviation of manure delivered in different places of the facilities (milking parlour, feeding alley and bedding area) by MY level

Milk yield	Milking parlour (kg cow <sup>-1</sup> day <sup>-1</sup> )	Feeding alley (kg cow <sup>-1</sup> day <sup>-1</sup> )	Bedding area (kg cow <sup>-1</sup> day <sup>-1</sup> )
L	0.93 ± 0.25	16.90 ± 0.16 <sup>a</sup>	32.92 ± 11.24
H	1.01 ± 0.21	22.52 ± 1.35 <sup>b</sup>	32.05 ± 10.23

L – Low milk yield; H – High milk yield. Different letter between rows shows significant differences ( $P < 0.05$ ).

In the feeding alley, the amount of manure released ranged between 27.6 to 49.3% of the total manure per cow per day. The manure delivered in the bedding area (estimated as total manure per cow per day less milking parlour and feeding alley manure collected) ranged between 49.0 to 70.6% of the total amount of manure produced per cow per day. The amount of manure in the bedding area in LMY of CB2 and LMY of CB4 (70% and 68.3% respectively) was similar to values reported by Janni et al. (2007).

The highest amount of manure delivered in the feeding alley was in the HMY of CB1 (49.3%). Samer (2011) found that in corral systems about 75–80% of the waste is gathered from the feeding places and in free-stalls about 100% of the waste is gathered from the manure canals.

In this study, it was considered that all the manure delivered in the feeding alley would be stored for a period of at least 30 days ( $T_a$ ) in a pit storage system (Freitas, 2008), in order to have good flexibility in the application of manure on the soil (Table 4).

In all the evaluated compost barns, manure and rainwater were deposited in the manure storage. So, considering the design of the four facilities,  $F_t$  was equal to 1.2. Based on these parameters, the total volume of manure produced per day ( $V_{res}$ ), estimated volume of manure produced ( $V_{est}$ ) and total volume of manure produced ( $V_{total}$ ) were calculated.

Table 4 shows the volume for 100 cows with the mean values obtained in the present study for different MY levels. In addition, the maximum value was used to calculate the volume requirement with a security margin.

**Table 4.** Total volume ( $V_{total}$ ) required for 30 days ( $T_a$ ) to store manure of 100 cows by milk yield level (MY) from feed alley of the compost barn. Average manure density ( $D_d$ ) = 600 kg m<sup>-3</sup>, water contribution factor ( $F_t$ ) = 1.2

MY	Variable	Feeding alley (kg cow <sup>-1</sup> day <sup>-1</sup> )	$V_{res}$ (m <sup>3</sup> day <sup>-1</sup> )	$V_{est}$ (m <sup>3</sup> )	$V_{total}$ (m <sup>3</sup> )
L	Mean	16.9	84.5	25.0	101.4
	Maximun	17.1	85.5	30.2	102.6
H	Mean	22.5	112.6	52.4	135.2
	Maximun	24.1	120.5	60.5	144.6

Considering the results showed in the Tables 2, 3 and 4, it was observed that the lowest portion of the manure produced per day ( $V_{res}$ ) was delivered in the milking parlour and the highest in the in the feeding alley and bedding area (up to ~50%). These results are in line with those reported by Priekulis & Āboltiņš (2015), which found that approximately a half, or even more, of the manure from cattle was represented by farmyard manure.

Therefore, based on the estimated and calculated values for 100 cows, it was observed that the total volume of manure ( $V_{total}$ ) ranges between 101.4 to 144.6 m<sup>3</sup> for 30 day of storage.

## CONCLUSIONS

According to the results of this study, it was possible to estimate the amount of manure present in compost dairy barns and how manure is distributed in the different areas of the facility. These data allow to design the appropriate manure storage system. The correct estimation of manure production per day is the key for sizing the manure storage system according the waiting period required by legislation.

The volume of the manure storage for compost dairy barn system is calculated based on the amount of the manure delivered by the cows. On the basis of the results of this study, in the feeding alley the maximum measured value should be considered (49.3%). Considering 30 days as the minimum waiting time period before to apply the manure on the soil, the volume of storage per cow required is 1.209 m<sup>3</sup> cow<sup>-1</sup> on average, but it ranges from 1.014 m<sup>3</sup> cow<sup>-1</sup> for the lowest value measured for the low milk yield (LMY) to 1.446 m<sup>3</sup> cow<sup>-1</sup> for the highest value measured for the high milk yield (HMY).

These values give a very important contribution to the designer of compost barns because the manure storage system is a key part of the facility. A consistent, flexible and safe system of storage allows the strategic use of manure as fertilizer and reduces the risks of environmental impact.

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