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

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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.

## 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$^{-1}$ day$^{-1}$) and 37 HMY (23.7 kg head$^{-1}$ day$^{-1}$). In CB2, 53 cows were housed, 18 LMY (22.1 kg head$^{-1}$ day$^{-1}$) and 35 HMY (27.2 kg head$^{-1}$ day$^{-1}$). In CB3 58 cows were housed, 22 LMY (20.8 kg head$^{-1}$ day$^{-1}$) and 36 HMY (25.4 kg head$^{-1}$ day$^{-1}$). In CB4 68 cows were housed, 28 LMY (25.8 kg head$^{-1}$ day$^{-1}$) and 40 HMY (29.2 kg head$^{-1}$ day$^{-1}$). In all CB the cows were milked twice a day and fed once a day.
The CB facilities have different dimensions. The bedding area is 832.32 m$^2$ (54.4 x 15.3 m) in CB1, 700 m$^2$ (50.0 x 14 m) in CB2, 681.6 m$^2$ (48 x 14.2 m) in CB3 and 825 m$^2$ (55 x 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.
Equation 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.

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

Where: $D_{total}$ is the mass of total manure (manure excretion by cow per day); $P_{Milk}$ is milk production by cow (kg of milk head$^{-1}$ day$^{-1}$); $C_{MS}$ is the dry matter intake (kg of dry matter by head$^{-1}$ day$^{-1}$); $G_{Milk}$ is the fat in milk (g $g_{milk}^{-1}$); and $PT_{Milk}$ is the protein in milk (g $g_{milk}^{-1}$).

For sizing of the manure storage, the volume ($V_{est,}$ in m$^3$) of tanks must be calculated using equation 2 (Palhares, 2019).

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

Where: $T_a$ is the storage time (days); $V_{res}$ is the total volume of waste produced per day (m$^3$); 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). It was also considered that the manure has a density of 600 kg m$^{-3}$ (Freitas, 2008) and that a storage time of 30 days is required.

## Results

Table 1 shows the Milk yield (L – low and H – high), values of body weight average (BW), milk protein ($PT_{milk}$), fat in milk ($G_{milk}$), dry matter intake ($C_{MS}$) and total mass of total manure ($D_{total}$) evaluated in this study.

**Table 1**. Amount of manure delivered in different places of the facilities (milking parlour, feeding alley and bedding area).

| CB | Milk yield | BW kg cow$^{-1}$ | $PT_{Milk}$ g $g_{Milk}^{-1}$ | $G_{Milk}$ g $g_{Milk}^{-1}$ | $C_{MS}$ kg cow$^{-1}$ day$^{-1}$ | $D_{total}$ kg cow$^{-1}$ day$^{-1}$ |
|---|---|---|---|---|---|---|
| 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$^{-1}$; $PT_{Milk}$ is the milk protein (g $g_{milk}^{-1}$); $G_{Milk}$ is the fat in milk (g $g_{milk}^{-1}$); $C_{MS}$ is the dry matter intake (kg of dry matter cow$^{-1}$ day$^{-1}$); $D_{total}$ is the total mass of total manure (kg of manure by cow per day).*

Table 2 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.

**Table2**. 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$^{-1}$ day$^{-1}$ | Feeding alley kg cow$^{-1}$ day$^{-1}$ | Bedding area kg cow$^{-1}$ day$^{-1}$ |
|---|---|---|---|
| L | 0.93±0.25 | 16.90±0.16$^a$ | 32.92±11.24 |
| H | 1.01±0.21 | 22.52±1.35$^b$ | 32.05±10.23 |

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

Table 3 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 3**. 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$^{-3}$, water contribution factor ($F_t$) = 1.2.

| MY | Variable | Feeding alley (kg cow$^{-1}$ day$^{-1}$) | $V_{res}$ (m$^3$ day$^{-1}$) | $V_{est}$ (m$^3$) | $V_{total}$ (m$^3$) |
|---|---|---|---|---|---|
| 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 1, 2 and 3, it was observed that the lowest portion of the manure produced per day (Vres) was delivered in the milking parlor and the highest in the in the feeding alley and bedding area (up to ~50%).

## 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 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 m3 cow$^{-1}$ on average, but it ranges from 1.014 m3 cow$^{-1}$ for the lowest value measured for the low milk yield (LMY) to 1.446 m3 cow$^{-1}$ for the highest value measured for the high milk yield (HMY). 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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