# Waste management systems of dairy cattle farms in Japan

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**Abstract** Recently, the size of livestock farms in Japan has been expanding and the pollution from farm wastes has become a serious problem in rural areas. Therefore it is necessary to design treatment strategies and improve the recycling of livestock manure for sustainability of agriculture in Japan. The dairy cattle waste management systems were studied at dairy farms in Aomori prefecture and in Hokkaido, Japan. The four farms, typical for the respective regions in Japan, were investigated on the basis of the land and livestock size, housing, overall farm and waste management, type of machinery and a farm labour force. A statistical comparison was made for housing, milking and waste handling systems of dairy farms. One of the waste handling strategies was aerobic slurry treatment and land irrigation of the treated liquid fraction. Such methods began to solve some of waste management problems created since 1967 in grassland farming areas of Hokkaido. The irrigation system supplies water fertiliser and organic material to land as well as shortening the spreading times. It recycles livestock resources, increases the soil fertility and rationalises the farm management.

**Keywords** Aerobic slurry treatment; dairy cattle; irrigation; land application; livestock waste management

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## Introduction

Recently, the size of livestock farms in Japan has been expanding and the pollution from farm wastes has become a problem in rural areas. Therefore it is necessary to design correct treatment strategies and improve the recycling of livestock manure to enhance the sustainability of agriculture (Burto, 1997; Haga, 1998). One of the strategies is the aerobic slurry treatment and a consequent land irrigation of the treated liquid fraction, which can be diluted with water. The irrigation system supplies water, fertiliser and organic material to the land as well as it shortens the spreading times. It recycles livestock resources, increases the soil fertility and rationalises the farm management (MAFF, 1983; Shima *et al*., 1990). In Japan some sections of the UK MAFF Codes of Good Agricultural Practice (MAFF, 1998) were translated to Japanese and are used in form of booklets whilst a Japanese equivalent of the code is expected to be published shortly.

Livestock waste management has been researched and developed continuously by many researchers and scientists, e.g. Svoboda and Jones (1999) discussed in their paper the waste management plan, including storage volumes and slurry treatment for hog farms. An estimate of volumes and exposed surface areas of stored animal manure and slurries in England and Wales were studied by Nicholson and Brewer (1997), clearly showing that the majority of diluted livestock slurry, accounting for an estimated 15.5 $Mm^3$ was stored in earth-banked lagoons. The quantities of slurry from housed animals on farms in Scotland and Northern Ireland were estimated and, by relation to the size and type of slurry and manure store, the surface areas were calculated in "Slurry/manure collection in relation to the type of housing was examined for different livestock types" by Baines *et al*. (1997) to provide a basis for calculation of gaseous emissions from wastes. Various types of cattle housing and waste disposal facilities and their relationship with types of fodder and manure produced on dairy farms in south-west Scotland were examined by Brownlie and Henderson (1984).

Dairy production systems, management of resources and the use of dairy wastes in small holder dairy farms in Thailand were surveyed by Skunmun *et al.* (1998). The utilisation of cow dung on rice fields in Bangladesh were researched by Bala *et al.* (1992). Manure collection, manure storage, land application and property of dairy cattle slurry for irrigation systems in Japan have been studied by Shima (1998). Mayer *et al.* (1997) described the development and implementation of research to improve the utilisation of manure and to minimise the adverse impacts on the environment. Production and characteristics of urine and faeces from dairy cows were published by Morse *et al.* (1994). Fulhage (1997) considered many factors required for expansion of dairy herds and Van Horn *et al.* (1994) described the design components of dairy manure management systems including manure production and the potential for manure processing.

The objective of this paper is to explain the characteristics of waste management systems on dairy cattle farms in Japan. Types of machinery, capacity of storage tanks, times required for spreading and costs of machinery including the specific costs and times required for spreading are studied at the Japanese dairy cattle farms.

## Materials and methods

### Study areas

There were two areas in Japan which were investigated in order to select four farms for this more detailed study. The areas studied were: a) Shibecha district in Hokkaido-North Japan and b) Tonamigaoka district in Aomori prefecture in the northern part of Honshu, Northern Japan. The Shibecha district has 107 farms from which 15% use the more effective, modern, slurry irrigation system in contrast to the remaining 85% of farms which use the older application systems with tankers. The two farms described here were chosen from those using the irrigation system. The Tonamigaoka district in Aomori prefecture has 20 farms, neither using irrigation, although 20% of farms produce mostly slurry. The remainder of 80% produces slurry and farm yard manure (FYM). Two farms, one from each waste producing systems, were studied and are described in this paper. The Shibecha district is in Kushiro region, Hokkaido. The mean daily ambient temperature in January is –6.1°C in July is 15.3°C and the annual average is 5.7°C. The total rainfall is 1,104 mm/year and the snow lies on average for 132 days per year. The altitude of this region varies between 60 to 300 m, with the topography of hilly areas and flat land. There is the Kushiro moorland plain at the lower stretches of the Kushiro river. The soils are volcanic ash soil of Mashuu type and deposit (accumulative) soil at the riverside. The land use is grassland (76%), forage corn fields (14%) and forest (10%). The average farm at Shibecha district holds 83 dairy cattle with dairy cattle stocking density of 0.98 head/ha. The Shibecha district is in one of the most popular dairy farming regions in Japan.

Land reclamation, drainage and water irrigation systems and improvements of farm roads were carried out intensively since 1978 in the Shibecha district. The farmers here greatly benefited from the state grants. The Tonamigaoka district is situated at Mutsu City, near the Mutsu bay, in Aomori prefecture. The district mean daily ambient temperature during January is –1.8°C and in July is 0.9°C with annual average of 9.7°C. The long term mean total annual rainfall is 1,407 mm and there are in average 162 days a year with land snow cover. The altitude of this area varies from 20 to 250 m. The soil is a volcanic ash soil of kuroboku type. The Tonamigaoka district is in one of the most intensive dairy farming regions in the Northern Japan. The land use (average of 20 farms) is: grassland (55%), corn fields (40%) and forest (5%). The average size farm stocks 45 dairy cattle with the density of 4.07 head/ha. The agriculture enterprise in Tonamigaoka district is managed by 20 farmers who formed a co-operative society in 1942.

#### Investigated dairy farms

A large number of farms visited and investigated in Northern Japan provided a good basis for a detailed study of two farms (S1 and S2) in Shibecha district and another two (T1 and T2) in the Tonamigaoka district (Table 1). The major difference between farms of the two districts is the size of farms. At the Shibecha district the farms are larger than in the Tonamigaoka district. The dairy cattle stocking density on S1 farm is 1.05 head/ha and on S2 farm 1.57 head/ha at the Shibecha district, while on farms T1 and T2 it is 4.38 head/ha and 6 head/ha respectively at the Tonamigaoka district. A larger number (2.5 and 3), by about 50%, of farm workers is required to manage larger herds in the Shibecha district than in the Tonamigaoka district.

#### Farm investigation methods

The four studied farms, typical for the respected regions in Japan, were compared on the basis of the land and livestock size, housing, overall farm and waste management, type of machinery and a farm labour force. The values of specific areas, specific time spent on discrete actions and specific costs were then calculated.

## Results and discussion

#### Statistics of housing type, milking systems and waste management on dairy cattle farms in Japan

Statistical data, extracted from Japanese sources (MAFF 1994), about the management on Japanese dairy farms are shown in the Table 2. These data clearly indicate the differences and similarities in the management strategies on farms.

#### Housing types and milking systems

This is reflected in a small percentage of free stall barns (cubicles), 4% of the total, used in Japan. This type of Japanese housing is therefore more suitable for less costly but more labour intensive milking systems like bucket (39%) or pipeline milking (58%).

#### Waste management

Only relatively a small percentage (20%) of Japanese dairy farms collects the dairy faeces and urine in a form of slurry (Table 2) and the rest of farms stores farm yard manure. The dairy slurry is stored mostly in lagoons and other stores (79%). FYM produced on Japanese farms is stored preferably in concrete middens (70%). Although FYM and compost made

**Table 1** Characteristics of Japanese farms

| Farm | S1 Hokkaido | S2 Hokkaido | T1 Aomori | T2 Aomori |
|---|---|---|---|---|
| Livestock (number | | | | |
| Milking cattle | 46 | 70 | 34 | 48 |
| Dairy young stock | 42 | 70 | 23 | 30 |
| Total | 88 | 140 | 57 | 78 |
| Land area (ha) | | | | |
| Grazing and silage | 37 | 89 | 8 | 6.5 |
| Crop | 6 | 0 | 5 | 6.5 |
| Total | 43 | 89 | 13 | 13 |
| Livestock density (head/ha) | 2.05 | 1.57 | 4.38 | 6.00 |
| Number of farm staff | 2.5 | 3 | 2 | 2 |
| Number of dairy cattle/Number of farm staff | 18 | 23 | 17 | 24 |
| Livestock building | | | | |
| Type of stall | Tie stall | Tie stall | Tie stall | Tie stall |
| Bedding | Yes | No | Yes | No |
| Manure removal | Barn cleaner | Barn cleaner | Barn cleaner | Barn cleaner |

**Table 2** Housing type, milking systems and waste handling in Japan

| | (%) |
|---|---|
| Housing type | |
| Free stall barns (cubicles) | 4 |
| Stanchion or tie stalls barns | 85 |
| Other | 11 |
| Total | 100 |
| Milking systems | |
| Byre with bucket | 39 |
| Byre with pipeline | 58 |
| Milking parlour | 3 |
| Total | 100 |
| Waste handling | |
| Slurry | 20 |
| Solid manure (FYM) | 80 |
| Total | 100 |
| Waste storage | |
| Slurry | |
| Lagoon, tanks | 79 |
| Other | 21 |
| Total | 100 |
| Farm yard manure (FYM) | |
| Concrete pad, field heap | 70 |
| In house | 30 |
| Other | – |
| Total | 100 |

Source: MAFF (Japan) (1994)

from FYM on Japanese dairy farms are mostly used on the grassland, frequently they are exported to the rice paddy fields and to the vegetable upland fields. The dairy farmers use rice straw and hay for bedding. Dairy slurry, usually after separation and dilution is irrigated on the farm grassland.

#### Case studies of management of dairy cattle waste

The waste management on the two farms studied in the Shibecha district was aimed primary for slurry irrigation. The flow diagram of dairy cattle waste management at the first farm is shown in the Figure 1. The dairy waste was, after removal from the barn by a barn cleaner, separated by a mechanical separator into solid and liquid fraction. Solids were stored in the open midden and then, using a manure spreader, applied on the corn field in early spring or in autumn.

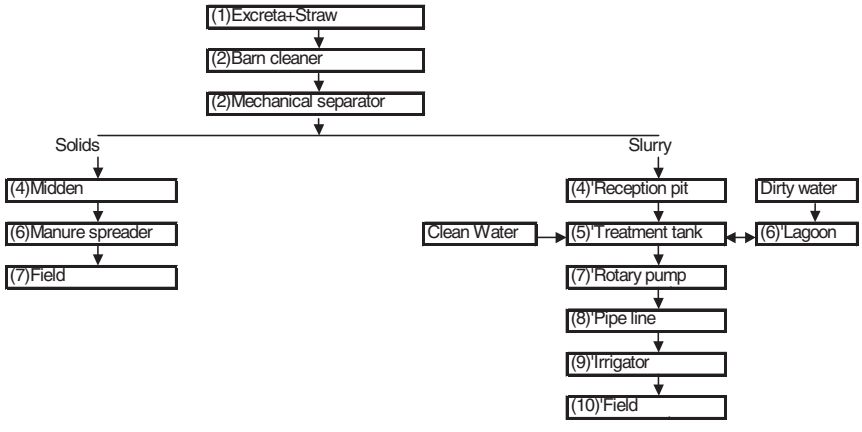


**Figure 1** A flow diagram of the dairy cattle waste management on the S1 farm at the Shibecha district

The liquid fraction was firstly stored in a reception pit and then aerated with compressed air for four hours daily in the treatment tank for approximately 2 weeks, and then it was transferred to and stored in a lagoon for between 2 to 4 months. Then when required, an appropriate volume of slurry was transferred back to the treatment tank from where, after continuous aeration and dilution with water, slurry was pumped through a pipeline to a travelling irrigator and applied to the grassland.

On the second farm, S2, in the Shibecha district, only dairy slurry was collected because the cattle were housed without bedding. Slurry was therefore removed from the barn by a scraper to a reception pit and aerated in the treatment tank, four hours daily, for 2 weeks. The main storage was a lagoon where slurry and collected farm dirty water were mixed and stored for two to four months. This diluted treated slurry was then applied onto the grassland using a high pressure displacement pump and travelling irrigator.

A flow diagram of the dairy cattle waste management on the T1 farm at the Tonamigaoka district is shown in Figure 2. Dairy cattle on this farm was bedded on hay therefore mostly FYM was produced. It was removed from the passages by a scraper/barn cleaner. Since FYM was scraped over partially perforated floor at the end of the scraped passage, the liquid part of FYM seeped out and was collected separately. The solid fraction of manure was stored in a midden and used similarly as at the Farm S1. The liquid fraction was stored in an underground tank and applied to grassland by a vacuum tanker three times a year after the grass cuts for either hay or silage.

On the Farm T2 predominantly slurry was produced. It was scraped into a reception pit and then stored in an underground tank which was used as a cold anaerobic digester. The digested slurry was applied to a corn field in early Spring and in the Autumn, and on grassland after the grass cuts for silage or hay making.

#### Characteristics of dairy cattle waste management

Waste management and particularly total and specific farm characteristics were assessed (Table 3) on dairy farms described in this paper.

Slurry irrigation was used on farms S1 and S2. Two farms S1 and S2 had large total storage capacities, which, on farms S1 and S2 were required to store additional water for slurry dilution (farm dirty water and clean water). The storage capacity on farm T1 and T2 were smaller due to a smaller herd and small rain water collecting areas. The specific capacity of slurry storage tanks on farms S1 and S2 was 19.4 and 27.9$m^3$ per dairy cattle head respectively. On farm T2 it was smaller with 5.6 $m^3$/head and even smaller on the farm T1 with 8.9$m^3$/head.

The specific spreading times for all waste collected per year (slurry + FYM + dirty water) were expressed as: i) hours required for spreading per head of dairy cattle and year;

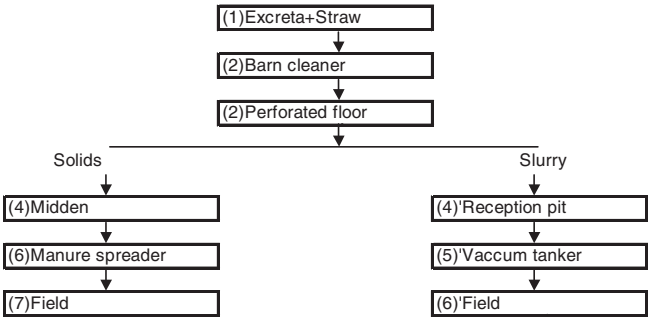


**Figure 2** A flow diagram of the dairy cattle waste management on the T1 farm at the Tonamigaoka district

ii) hours required per hectare of available land and year and were calculated from the farms time-logs (hours spent for waste application).

The cost of fixed and mobile equipment on farms S1 and S2 was rather high, because of more complicated waste systems which included slurry treatment, mixing and storage of dilution water and an automatic irrigation system (Table 4). These costs were reflected in the specific costs per dairy cattle. These farms showed that about twice as much cost was available per head or land area. The remainder of the studied farms, T1 and T2, used a more conventional waste management and application methods, such as slurry tankers and manure spreaders. The farms T1 and T2 held relatively small number of dairy cattle (Table 1) and the land area was also small. With a low rainfall and additional storage for the FYM the slurry stores could be small with small specific storage capacities. The low financial input into the farm machinery was reflected in the low specific investment cost per dairy cattle but, due to the small land areas the specific cost related to the land area was high for T1 and T2.

It is very important to note that the Japanese farmers receive grants which amount to 75% of the waste handling and treatment systems capital cost of which 50% is received from the State and another 25% from the local government. This grant and other grants for animal housing or so, indirectly will allow a relatively high specific labour input on Japanese farms.

The cost of machinery and storage tanks was higher on farms with livestock waste treatment systems. These systems were installed to minimise the waste offensive odour and prevent water pollution (Svoboda *et al.*, 1999, Shima, 1998, Burton, 1997), therefore the increased expenditure was required to improve the relation with neighbouring public and to maintain the high livestock productivity while preventing the environment deterioration.

## Conclusions

The dairy housing, milking and waste handling systems were statistically compared for all dairy farms in Japan. A detailed study was carried out on four dairy farms in Japan. The waste management equipment was assessed and compared among these farms, together with specific costs for waste spreading etc. The results of this study are summarised as follows.

Dairy farms in Japan are on average small or medium sized in land area and cattle numbers.Traditional housing (stanchions and tie stalls) and milking (bucket and pipeline) systems are therefore used more often than the milking parlours. Livestock slurry and FYM are utilised on grassland and arable land and FYM and compost made from the dairy waste

**Table 3** Dairy cattle waste management and costs on the study farms

| Farm | S1 | S2 | T1 | T2 |
|---|---|---|---|---|
| Capacity of storage tanks ($m^3$) | | | | |
| Reception pit | 100 | 593 | 190 | 14 |
| Treatment tank | 191 | 460 | | 412 |
| Lagoon | 600 | 900 | | |
| Slurry store | | | | |
| Total | 891 | 1,953 | 190 | 426 |
| Capacity per number of dairy cattle ($m^3$/head) | 19.4 | 27.9 | 5.6 | 8.9 |
| Capacity per land area ($m^3$/ha) | 20.7 | 21.9 | 14.6 | 32.8 |
| Specific application time | | | | |
| Per number of livestock (hr/head, year) | 1.2 | 1.3 | 0.9 | 0.8 |
| Per land area (hr/ha, year) | 2.5 | 2.1 | 3.9 | 4.6 |
| Cost of machinery and tanks | | | | |
| Total cost (£) | 149,500 | 184,500 | 44,500 | 42,000 |
| Per number of dairy cattle (£/head) | 1,699 | 1,318 | 781 | 538 |
| Per land area (£/ha) | 3,477 | 2,073 | 3,423 | 3,231 |

are exported to paddy fields and hill vegetable farms. There is a rapid development in the use of waste treatment methods in Japan, and the slurry irrigation techniques are now used more frequently. A specific slurry application time per dairy cattle varied between 0.8 to 1.3 hours per year on investigated farms. A specific investment cost of waste handling (Yen/head) was about twice higher on those farms with irrigation. A large financial support for farms allows Japanese farmers to employ effective pollution control methods.



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