Hygiene of environmental surfaces in a cattle barn

Hanna-Riitta Kymäläinen*, Risto Kuisma

(*Department of Agricultural sciences, PO Box 28 (Koetilantie 5), FI-00014 University of Helsinki, Finland*)

Abstract: Microbiological dipslides are widely used e.g. in food production facilities for HACCP (hazard analysis & critical control points) measurements and hygiene monitoring surveys, as well as for other cleanability studies. In this study the suitability of microbiological dipslide methods to measure the hygiene level of the environmental surfaces in a cattle barn was tested. A total of 1112 measurements were carried out during five measurement days. When evaluating the rooms by combining the results of the individual sampling sites and different dipslide types (total microbes, enterobacteria and β-glucuronidase-positive organisms, yeasts and moulds), the corridor and personnel rooms had the highest hygiene status. The office and personnel kitchen and the milk room were generally the next cleanest, depending on the evaluation criteria. The poorest hygiene level was observed in the barn and the second dirtiest in the washing room. It was demonstrated that the hygiene level of cattle barn surfaces with no excessive amounts of visible soil can be measured using microbiological dipslides. The results provided preliminary reference values for future studies and constitute an information source for training and self-monitoring systems.

Keywords: cattle barn, bioenvironment, hygiene, microbiological dipslides

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1 Introduction

The hygienic status of environmental surfaces and the various hygienic measures carried out in cattle barns are important because bioenvironmental hygiene can affect milk quality (de Koning et al., 2003; Hanus et al., 2004; Skrzypek, 2006; Trevisi et al., 2006; DeVries et al., 2012). More generally, surface hygiene can also affect animal health (Noordhuizen and Cannas da Silva, 2009; Hovinen and Pyörälä, 2011), behaviour and welfare (DeVries et al., 2012), and safety of the attending personnel (Kymäläinen et al., 2009). Air pollutants in animal houses also affect the safety of the environment, as well as the welfare and performance of workers and animals (Hartung and Schulz, 2011).

Cattle barn environments include a combination of different rooms and levels of hygiene physically often close to each other. For example, milking systems have relatively high hygienic requirements, whereas other sections in the barns are often covered with a macroscopic level of soil, such as manure on the floors. Different methods are used in cleanability research of animal houses (Kymäläinen et al., 2009), but only some of them are suitable to be used in field studies and practical investigations. In order to obtain an overview of the hygiene of environmental surfaces, hygiene monitoring including the use of e.g. microbiological methods and rapid hygiene tests has earlier been used in different types of buildings and different production sectors, such as slaughterhouses and the meat industry (Suihko et al., 2002; Gudbjörnsdóttir et al., 2004), the fish industry (Miettinen et al., 2001) and vegetable processing (Lehto et al., 2011). These monitoring methods are the most suitable for surfaces with no excessive amounts of visible soil. The aims of this study were to investigate the suitability of microbiological dipslides method for monitoring the bioenvironmental surfaces of a cattle barn, provide new methodology and guidelines for bioenvironmental hygiene determination in cattle barns,

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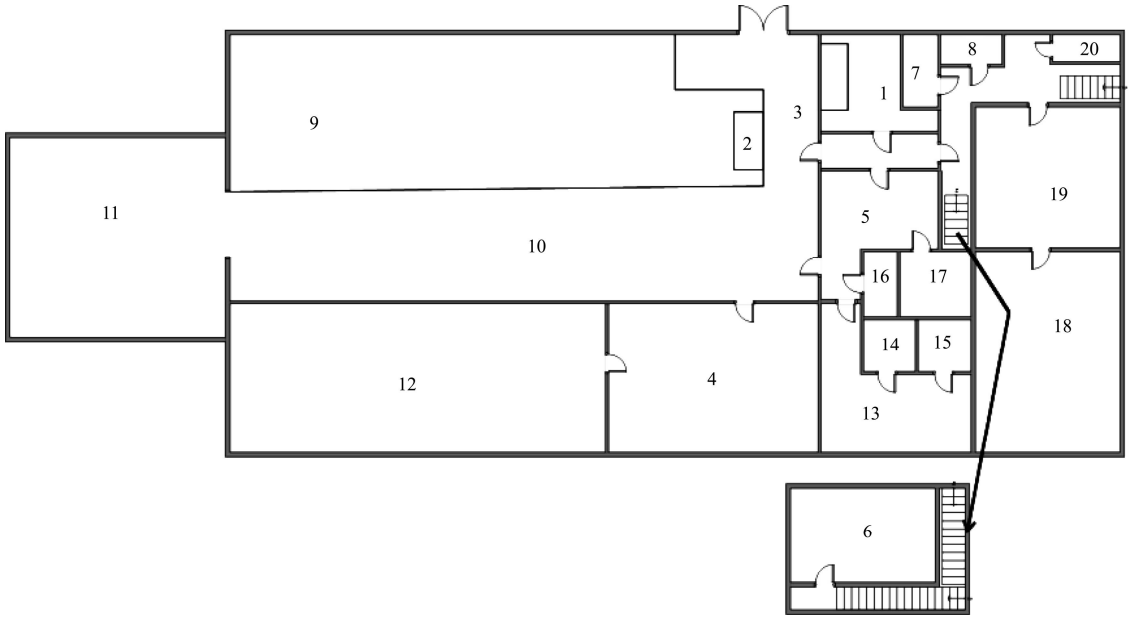
* **Corresponding author: Hanna-Riitta Kymäläinen,** Department of Agricultural sciences, PO Box 28 (Koetilantie 5), FI-00014 University of Helsinki, Finland. Email: hanna-riitta.kymalainen@helsinki.fi

and to specify limit and reference values of the colony-forming unit. Another aim was to obtain information concerning the hygiene level of different cattle barn rooms.

2 Material and methods

The study was carried out in a loose housing cattle barn (Figures 1 and 2) in southern Finland. Measurements were made similarly on five Mondays: (I) on 26th March, (II) 16th April, and (III) 4th June 2012, and (IV) on 28th January and (V) 11th February 2013, between 9:00 a.m. and 1:00 p.m. The milk room and the automatic milking system and its surroundings in the barn were examined on each of the five days. The individual sampling sites were measured in total three to five times depending on the various normal operations in the barn and thus on the availability of the surfaces for measurement. In 2012, washing rooms, office, corridors and personnel rooms were also measured. Three replicate measurements were made for all sampling locations in these rooms.



1. Milk room 2. Milking robot 3. Sink 4. Barn 5. Washing room 6. Office and personnel kitchen (second floor) 7. Personnel room (men) 8. Personnel room (women) 9. Free stall barn 10. Feed alley 11. Feed storage 12. Calving stalls 13. Laboratory 14. Cold room 15. Freezer room 16. Compressor room 17. Storage 18. Technical room 19. Engine room 20. Washing/shower room

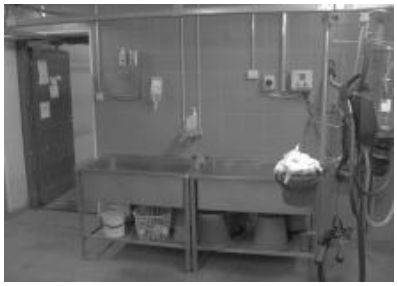
Figure 1 The cattle barn lay-out

a. Milk room

b. Milking robot

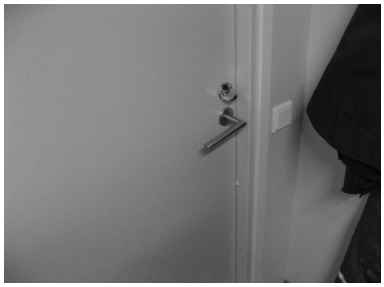
c. Sink in the barn

d. Barn



e. Washing room

f. Office and personnel kitchen



g. Personnel room

Figure 2 Typical measurement places in the cattle barn building

The numbers of total microbes on surfaces were measured using Hygicult® TPC contact slides (9.4 cm^2, Orion Diagnostica, Finland) by pressing the dipslide on the examined surface. Yeasts and moulds were sampled using Y&F-Hygicult® contact slides. Both sides of the slides were examined and the mean was presented as the final result. The Enterobacteriae and β-glucuronidase-positive bacteria were sampled similarly using Hygicult® E/β-Gur contact slides. One side (E) of the slide promotes the growth of Enterobacteriaceae. The other side (β-Gur) is used to test for the presence of β-glucuronidase-positive organisms (e.g. *Escherichia coli*). In the barn and for the milking robot, all dipslide types were used for all sampling locations. In the milk room, washing room, main corridor, personnel rooms, office and personnel kitchen all dipslide types were used for surfaces with an appreciable area in order to allow many samplings. In these rooms, for small sampling locations such as handles, only the enterobacteria and β-GUR were sampled. These bacteria group types were evaluated to be the most indicative for the hygienic status of these sites. Dipslides were incubated for 2-3 days at 20-25°C as in the study by Lehto et al. (2011). The Hygicult contact slides were interpreted by calculating the number of colonies or according to the manufacturer's chart models.

A total of 1112 surface samples were taken from the barn rooms using a sampling plan prepared in advance. Here one sample means one side of a Hygicult contact dipslide, and so a total of 556 Hygicult dipslides were used. From the milk room 420 samples, from the barn and milking robot 270 samples, from the office and personnel kitchen 198 samples, from the main corridor and personnel rooms 144 samples and from the washing room 80 samples were taken. Since the timing of cleaning was not constant and varied at different locations in the barn, it could not fully be taken into consideration when selecting the measurement time. Thus the results present the hygienic status of the surfaces during normal operation on different days, not in all cases after cleaning as is the normal practice in hygiene monitoring (e.g. Lehto et al., 2011).

Results were collected in a database and evaluated using the criteria presented in Table 1. There are no existing limit values intended specifically for cattle barn rooms. The proposed limits in Table 1 were collected and modified from the literature from other fields of application, and also from the instructions of the detection kits. The reference values from good to poor for total microbes were taken from a Finnish guide book, in which this scale was intended for the meat processing industry. The scale from good to poor for yeasts was taken from a Finnish master's thesis by Hakala (2001). The scale from good to poor for moulds (Orion Diagnostica, 2009a), enterobacteria (Orion Diagnostica, 2011) and β-GUR (Orion Diagnostica, 2009b) was taken from the instructions of the manufacturer of the dipslides. All these three-step scales were also used e.g. in the study by Lehto et al. (2011) examining processing plants of fresh vegetables. For total microbes, yeasts, enterobacteria and β-GUR a fourth class of "very poor" was created for the results of the present study. For moulds the three-step scale was evaluated to be sufficient, since heavy contamination with moulds (+++) appeared as almost full growth on the dipslide.

Table 1 Surface hygiene guidelines for total microbes, yeasts, moulds, enterobacteria and β-glucosidase-positive bacteria used in the present study

Microbial group, cfu/cm^2	Classification of the results				References
	Good	Moderate	Poor*	Very poor**	
Total microbes	<2	2-10	11-49	>50	Rahkio et al. (2006),
Yeasts	<1	1-5	6-25	>25	Hakala (2001),
Moulds	-/+ (light)	++ (moderate)	+++ (heavy)	Not included	Orion Diagnostica (2009a)
Enterobacteria	<0.1	0.1-1.1	1.2-5	>5	Orion Diagnostica (2011)
β-glucosidase-positive bacteria (β-GUR)	<0.1	0.1-1.1	1.2-5	>5	Orion Diagnostica (2009b)

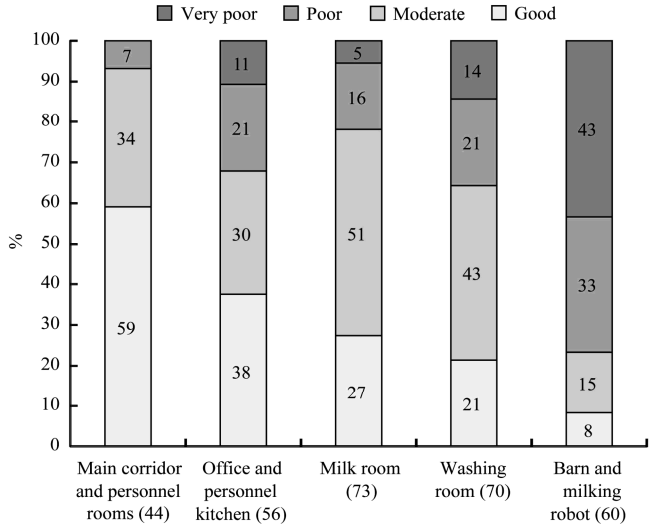
Note: * In the original references this class was the poorest (i.e. total microbes >10) and was described as "unacceptable";

** A limit value not included in the references given.

The limit values are modifications from the original sources.

3 Results and discussion

The total shares of good, moderate, poor and very poor results in the rooms examined are presented in Figure 3. As a whole the measurement sites in the corridors and personnel rooms were the cleanest. The share of the clean results was the second greatest in the office and personnel kitchen and the third greatest in the milk room, but on the other hand the share of poor and very poor results was smaller in the milk room compared to that in the office and personnel kitchen. The greatest share of very poor results and the smallest share of good results were detected in the barn sampling targets, the washing room being the second dirtiest when examining the same shares. Detailed results in the different rooms and individual sampling targets are presented in Tables 2-6 and in the following.



Note: The results for total microbes, enterobacteria, β-GUR, yeasts and moulds are included

Figure 3 Shares of good, moderate, poor and very poor mean results in the measured cattle barn rooms (the number of mean results is presented in parentheses)

In general, in food processing facilities different hygiene areas are separated from each other in order to prevent cross-contamination (Maller, 2011). In this study clear differences were observed between the total average cleanliness levels of the rooms examined in the barn building. Similar studies were not found in the literature to allow comparison. In earlier studies including measurement of cleanliness of animal buildings, visual and qualitative methods have dominated (Kymäläinen et al., 2009). Microbiological detection methods have been used in a few studies in cattle barns (Lorentzon, 2005; De Palo et al., 2006), but their content and focus differ from that of the present study. The detection methods used in this study are commonly used in food processing factories, as was presented in the introduction, but probably not currently in cattle barns. The dipslide methods were also observed to be suitable for the cattle barn building environment, although the most contaminated surfaces such as floors with faeces were excluded from the measurement plan. Surfaces with a high level of soil are not suitable for microbiological dipslide methods.

Most results (73%) of total microbes in the milk room were on the poor level, whereas the majority of the enterobacteria (75%) and β-GUR (60%) results were on the moderate level (Table 2). Only a few very poor results were detected: two of them on shoe-contact surfaces (grating of floor, step of ladder) and two on a light switch inside the room. Slightly more than half (55%) of both the yeast and mould results were good, the rest (36%) being mainly moderate and only one (9%) was poor for both these microbe types. Except for the one light switch mentioned, all results of the door handles and light switches were at the moderate or good level. Of the surfaces of the milk tank the step of the ladder was the most contaminated and the evacuation tap the second most contaminated.

According to the measurements of total microbes, enterobacteria (with the single exception of one result of a drinking trough) and β-GUR, the average cleanness of all measured surfaces in the cattle barn was poor (33%) or very poor (64%) (Table 3). However, variation between the measurement days was in many cases considerable: for example the number of total microbes on the teat brushes and teat cups of the milking robot varied from 0-1.5 cfu/cm^2 to 80-90 cfu/cm^2, and the results of β-GUR from 0-0.1 cfu/cm^2 to 5-30 cfu/cm^2. The results for yeasts and moulds of the teat brushes and teat cup of the milking robot were good or moderate, whereas those of the sink varied between moderate and very poor and the results of the drinking and feeding dishes and troughs from good to very poor.

Table 2 Hygiene results of surfaces in the milk room

Sampling target	N	Total microbes/cfu cm^{-2}		Enterobacteria/cfu cm^{-2}		β-GUR/cfu cm^{-2}		Yeasts/cfu cm^{-2}		Moulds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Door handle 1, outside the room	5	*	*	0	0	0-1.9	0.6	*	*	*	*
Door handle 2, outside the room	5	*	*	0-0.2	0.1	0-0.1	0	*	*	*	*
Door handle 3, inside the room	5	*	*	0-1.5	0.3	0-1.0	0.2	*	*	*	*
Door handle 4, inside the room	5	*	*	0-1.0	0.4	0-2.8	0.6	*	*	*	*
Light switch 1, outside the room	5	*	*	0-2.2	0.5	0-1.5	0.4	*	*	*	*
Light switch 2, outside the room	5	*	*	0-0.6	0.3	0-0.4	0.1	*	*	*	*
Light switch 3, inside the room	5	*	*	0-45	9	0-45	9	*	*	*	*
Control panel	5	0-24	10	0-0.3	0.1	0-0.5	0.1	0.1-0.5	0.3	-…+++	++
Milk tank: knob	5	*	*	0-0.3	0.1	0-0.1	0	*	*	*	*
Milk tank: evacuation tap	5	1.6-100	31	0-0.4	0.1	0-2.1	1.5	0-6	1.4	-…++	+
Milk tank: milk tube	5	0-25	6	0	0	0-0.2	0	0-0.1	0	-…+	-
Milk tank: hand rail of ladder	5	0.1-41	14	0-0.2	0	0-0.2	0.1	0-0.8	0.2	-…++	+
Milk tank: step of ladder	5	3.0-100	68	0.2-0.6	0.4	0-23	5	0.6-1.2	0.8	++…+++	++
Fridge: handle	5	*	*	0-2.0	0.4	0-0.2	0.1	*	*	*	*
Thermometer (loose)	5	1.5-90	30	0-0.3	0.1	0-0.4	0.1	0-2.0	0.6	+…+++	+++
Teat bucket	5	0.1-73	32	0-1.4	0.4	0-0.1	0	0.1-6	1.4	-…+++	+
Teat bucket: lid	5	2.6-45	22	0-1.4	0.4	0-0.4	0.2	0-23	4.7	+…+++	++
Tap for washing of the room	5	0.9-100	30	0-0.1	0	0-2.2	0.6	0.2-0.9	0.4	-…+++	+
Cleaning brush	5	0.7-80	42	0-0.3	0.1	0-0.9	0.3	0-5	1.1	-…+++	+
Floor: grating	5	1.2-80	35	0-2.7	0.8	0-45	10	0-25	10	-…+++	++

Note: * = no measurements;

N = number of measurements, β-GUR = β-glucuronidase-positive organisms.

The scale for moulds is explained in Table 1.

Table 3 Hygiene results of surfaces in the barn and milking robot

Sampling target	N	Total microbes/cfu cm^{-2}		Enterobacteria/cfu cm^{-2}		β-GUR/cfu cm^{-2}		Yeasts/cfu cm^{-2}		Moulds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Milking robot: teat brushes	5	0-80	22	0-3.3	4.6	0-30	6.9	0-23	4.6	-…++	+
Milking robot: teat cup	4	1.5-90	35	0.2-3.1	1.6	0.1-5	2.6	0-5.2	1.6	-…++	+
Sink	4	80-100	88	1.4-100	33	0-5.4	2.7	0.9-80	33	+…+++	++
Sink: soap dispenser	4	45-90	65	0.2-45	8	0-4.6	1.9	0-24	8	+…+++	+++
Sink: soap dispenser	4	45-90	74	0-5	24	0-5	3.7	2.3-45	24	+…+++	++
Sink: hand towel dispenser	4	73-90	81	0.5-5	24	2.9-80	27	3.6-45	24	+…+++	+++
Drinking trough 1	5	23-100	51	0.1-45	11	0.1-80	16	0.1-5	1.5	-…+++	+
Drinking trough 2	3	25-63	44	0-1.0	0.4	0-5	1.7	1.2-2.3	1.9	-…++	+
Drinking dish	3	1.3-100	64	0-1.6	1.2	1.3-45	30	0.3-0.8	0.5	++…+++	+++
Drinking dish: hose	3	63-100	81	0-45	30	0-45	30	1.6-25	10	++…+++	+++
Feeding trough 1	3	45-100	78	0-80	27	5-100	50	0.7-45	30	+…++	++
Feeding trough 2	3	1.2-100	55	0-100	34	0-4.6	1.5	0.2-45	30	+…++	++

Note: N = number of measurements, β-GUR = β-glucuronidase-positive organisms.

The scale for moulds is explained in Table 1.

The cleanest sampling targets in the washing room, consisting of only good or moderate mean results, were both door handles outside the room and one door handle inside the room, both light switches, the lower horizontal surface of the cabinet, the soap dispenser, the switches of the washing machine and the teat cloths (Table 4). The dirtiest sampling targets, including one or several very poor mean results, were the horizontal surfaces, a vertical

surface and the tap of the sinks, the work surface of the cabinet, the filling hatch of the washing machine and a door handle inside the room. However, in the case of all very poor mean results the range of the results was very wide, e.g. for enterobacteria it was from 0-1.7 cfu/cm^2 to 45-80 cfu/cm^2. Poor yeast and mould results were detected only from the work surface of the cabinet. The washing room was located next to the barn (Figures 1 and 2) and also allows walking through the room to the corridor and laboratory (not examined in this study). In addition, this washing room had no regular responsible intervals or persons for cleaning, in contrast to e.g. the corridors and personnel rooms. These facts may partly explain the relatively poor results in this room. However, there were washing facilities for hands and boots in the barn.

Most results in the main corridor and personnel room surfaces examined were good (60%) or moderate (34%) (Table 5). Only three results (hand rails, 7%) of total microbes were on the level of poor.

All results of total microbes except the moderate results of the office table were poor or very poor (Table 6). The most contaminated target measured in the office and personnel kitchen was the cleaning cloth on the sink: the results of total microbes, enterobacteria and β-GUR were very poor, whereas the result of yeasts was poor and that of moulds was moderate. In addition to the cleaning cloth, the results of total microbes of the kitchen table and the horizontal and vertical surface of the sink were very poor. After the cleaning cloth, the surfaces secondly most contaminated with enterobacteria and β-GUR were the horizontal and vertical surfaces and the tap of the sink. Except on the cleaning cloth, all results of yeasts were on a good level. Low or moderate amounts of moulds were detected in this room.

Table 4 Hygiene results of surfaces in the washing room

Sampling target	N	Total microbes/cfu cm^{-2}		Enterobacteria/cfu cm^{-2}		β-GUR/cfu cm^{-2}		Yeasts/cfu cm^{-2}		Moulds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Door handle 1, outside the room	3	*	*	0-0.4	0.2	0-0.2	0.1	*	*	*	*
Door handle 2, outside the room	3	*	*	0-0.3	0.2	0.6-1.7	0.9	*	*	*	*
Door handle 3, inside the room	3	*	*	1.7-45	17	0-1.8	0.9	*	*	*	*
Door handle 4, inside the room	3	*	*	*	0.3	0-0.7	0.2	*	*	*	*
Door handle 5, inside the room	3	*	*	0-4.8	1.7	0.1-3.1	1.3	*	*	*	*
Light switch 1	3	*	*	0-0.1	0	0-1.0	0.4	*	*	*	*
Light switch 2	3	*	*	0-0.6	0.2	0-0.3	0.1	*	*	*	*
Cabinets, lower, horizontal surface	3	2.0-5	3.9	0-0.1	0	0-0.2	0.1	0-0.3	0.1	++…+++	++
Cabinets, upper, horizontal surface	3	0-45	16	0-0.1	0	0.1-0.4	0.2	0-0.4	0.2	+…+++	++
Cabinet: work surface	3	25-90	65	1.4-1.8	1.6	0.1-3.7	1.6	1.4-24	9	+++	+++
Sink: horizontal surface 1	3	43-80	56	0-80	27	0.5-45	16	0.3-1.6	1.0	+…++	+
Sink: horizontal surface 2	3	1.3-45	16	0.2-45	15	0.6-5	2.6	0.5-1.0	0.8	++…+++	++
Sink: inner vertical surface	3	2.8-90	40	0-0.7	0.2	0.2-3.5	1.5	0.1-2.5	1.0	+…++	+
Sink: inner vertical surface	3	8.6-45	26	0-45	15	0.1-1.8	0.9	0-0.5	0.2	+…++	+
Sink: tap	3	*	*	0-1.1	0.5	0.1-45	15	*	*	*	*
Sink: soap dispenser	3	*	*	0.2-0.6	0.4	0-0.3	0.4	*	*	*	*
Washing machine: switches	3	*	*	0-2.1	1.0	0.1-1.1	0.6	*	*	*	*
Washing machine: filling hatch	3	24-73	53	0-1.4	0.5	0-80	27	0-0.2	0.1	+…++	+
Teat clothes	3	1.0-2.2	1.7	0-0.1	0.1	0.1-0.5	0.4	0-0.3	0.1	-…+	+
Plastic gloves	3	5-45	25	0.2-2.7	1.3	0.6-4.6	2.7	0.5-3.7	1.7	++…+++	++

Note: * = no measurements;

N = number of measurements, β-GUR = β-glucuronidase-positive organisms.

The scale for moulds is explained in Table 1.

Table 5 Hygiene results of surfaces in the main corridor and personnel rooms

Sampling target	N	Total microbes/cfu cm^{-2}		Enterobacteria/cfu cm^{-2}		β-GUR/cfu cm^{-2}		Yeasts/cfu cm^{-2}		Moulds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Hand rail 1, metal	3	1.2-3.2	2.4	0-0.1	0.1	0-0.1	0	0-0.4	0.1	+…++	++
Hand rail 2, metal	3	3.6-24	11	0	0	0-0.1	0	0-0.2	0.1	-…++	+
Hand rail 3, wooden	3	5-45	25	0	0	0-0.1	0	0-0.1	0	-…++	+
Hand rail 4, wooden	3	2.8-63	23	0-0.2	0.1	0	0	0	0	-…+	+
Light switch 1	3	*	*	0-0.5	0.2	0-0.2	0.1	*	*	*	*
Light switch 2	3	*	*	0-0.1	0.1	0	0	*	*	*	*
Light switch 3	3	*	*	0	0	0-0.2	0.1	*	*	*	*
Light switch 4, clothing room	3	*	*	0	0	0-0.1	0	*	*	*	*
Light switch 5, clothing room	3	*	*	0	0	0-0.1	0	*	*	*	*
Door handle1, washing room	3	*	*	0-0.3	0.1	0-0.2	0.1	*	*	*	*
Door handle 2, washing room (inside)	3	*	*	0	0	0	0	*	*	*	*
Door handle 3, clothing room	3	*	*	0-0.1	0	0	0	*	*	*	*
Door handle 4, clothing room	3	*	*	0-0.1	0.1	0-0.3	0.1	*	*	*	*
Door handle 5, clothing room (inside)	3	*	*	0	0	0	0	*	*	*	*
Door handle 6, clothing room (inside)	3	*	*	0.1	0.1	0-0.1	0	*	*	*	*
Guest book: pen	3	*	*	0-0.3	0.1	0.3-0.6	0.5	*	*	*	*

Note: * = no measurements;

N = number of measurements, β-GUR = β-glucuronidase-positive organisms.

The scale for moulds is explained in Table 1.

Table 6 Hygiene results of surfaces in the office and personnel kitchen

Sampling target	N	Total microbes/cfu cm^{-2}		Enterobacteria/cfu cm^{-2}		β-GUR/cfu cm^{-2}		Yeasts/cfu cm^{-2}		Moulds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Light switch	3	*	*	0	0	0	0	*	*	*	*
Door handle 1, outside the room	3	*	*	0-0.1	0	0-0.4	0.1	*	*	*	*
Door handle 2, inside the room	3	*	*	0-0.2	0.1	0-2.0	0.7	*	*	*	*
Office table	3	2.4-5	4.1	0-0.2	0.1	0	0	0-0.7	0.3	++	++
Chair	3	2.7-63	30	0-0.1	0.1	0.1-0.2	0.2	0-0.5	0.2	+…++	+
Telephone	3	2.1-63	30	0-0.5	0.4	0-0.4	0.2	0-0.2	0.1	+…++	++
Kitchen table	3	24-80	68	0.1-1.8	0.9	0-2.9	1.0	0.1-1.4	0.5	+	+
Kitchen chairs	3	2.8-3.4	35	0.1-0.5	0.3	0-1.3	0.6	0-0.2	0.1	+…++	++
Sink: horizontal surface	3	45-80	63	0.4-1.9	1.2	1.3-5	2.5	0.1-0.3	0.2	+	+
Sink: inner vertical surface	3	45-63	57	0.5-2.6	1.4	0.3-5	2.7	0.4-1.4	0.7	+	+
Sink: tap	3	25-63	44	0.3-5	2.0	0.5-5	2.2	0.1-0.3	0.2	-…+	+
Sink: hand towel dispenser	3	2.6-45	17	0-0.1	0	0	0	0-0.1	0	-…+	-
Sink: cleaning cloth	3	80-100	90	4.8-100	38	11-80	45	0.9-25	9	+…++	++

Note: * = no measurements;

N = number of measurements, β-GUR = β-glucuronidase-positive organisms.

The scale for moulds is explained in Table 1.

In the case of the milking robot, the interval between cleaning and measurement was minimal since the robot cleans the teat cups with vapour and the brushes with water and detergent immediately after each milking. In addition both are washed thoroughly three times a day, and the brushes are changed and disinfected daily. By contrast, the cleaning interval for the milk room was not constant. Checkpoints in the cleaning procedures can be included in Good Dairy Farming codes of practice, presented by FAO (Noordhuizen et al., 2008). In addition to the cleaning procedure of the teat brushes made by the robot, the cleanliness of the cows affects the cleaning results of the teats and probably also has an effect on how well the brushes can be kept clean.

Several factors affect the cleanliness of the animals, e.g. air humidity, type of housing, stall dimensions, material and construction of the floors, use and amount of bedding, manure consistency, maintenance of the floors and cleaning of the animals (Ruud et al., 2011; Hauge et al., 2012). Silage is one potential source of contamination in cattle barns (Driehuis, 2013). In the present study, it is understandable that the feeding troughs and drinking bowls were rather highly contaminated due to the contact with animals and silage.

The cleaning cloth on the sink in the office and personnel kitchen was the most contaminated item measured in that room. Cleaning cloths have also been observed to be contaminated in hospitals (Kuisma et al., 2012; Kymäläinen et al., 2012) and are in general potential vehicles for spreading contaminants (Toiviainen-Laine et al., 2013). Considering all the rooms in the barn building, shoes, hands, animals, wheels and air should also be taken into account when considering potential vehicles for cross-contamination.

The function of the corridor, which in this study was observed to be rather clean, differs considerably from that of the other rooms measured. This is probably one reason for the good results obtained for this area. In addition the main corridor and personnel rooms were cleaned regularly on Monday mornings before the measurements, which may partly have led to the superiority of the cleanliness of these sites compared with the other rooms. In a study in hospitals (Kymäläinen et al., 2012) it was shown that cleaning of patient rooms and personnel rest rooms increased the share of good results by 8%-27% units when using similar measurement methods to those of the present study. In dairy environments it has been observed that not all cleaning systems are effective (Wirtanen et al., 1997). In contrast to the barn examined, in many food production plants measurements can be carried out immediately after cleaning since often there is a daily period with no production and/or the rooms are cleaned according to a fixed timetable. Deviations were in many cases great and therefore it is essential to make replicate samplings. The amount of measurement data was sufficient to allow conclusions, although not all the sites could be measured on all five sampling days.

Selecting the scale when grouping the results as good, moderate or poor is an essential step in evaluating the results of hygiene monitoring. In barns the probability of manure contamination is high and therefore the scales that are used e.g. in slaughterhouses should be considered critically. In the present study the scale used in other studies was expanded with the class “very poor”. In a study by Lehto et al. (2011) many of the bacterial counts measured in vegetable processing plants were unacceptable when using the general surface hygiene guidelines as criteria. However, in their study the authors also noted that the results must be viewed in the context of the type of production and the stage of operation. In some stages of vegetable processing, e.g. in washing of root vegetables, soil (ground) is a normal contaminant, as is manure in some parts of cattle barns.

Dipslides are useful in hygiene monitoring as they are convenient, simple to use and cost effective. Some types of dipslides, e.g. the Hygicult® TPC (total microbes) and E (enterobacteria and β-GUR) dipslides used in the present study have been validated against swabbing and control plate methods and the results have been observed to be at the same level (Salo et al., 2000). However, in some cases the accuracy of the dipslides may be limited e.g. because of the limited area of the dipslide.

It was known in advance that some clearly visibly dirty surfaces in the barn are probably not optimal for measurement with the detection methods used. This is because when a surface, e.g. those of the feeding troughs in the barn, is normally covered with visible soil (feed, animal saliva etc.); it is most probable that the dipslides sampled from these sites will be full of microbes. The dirtiest surfaces such as floors in the barn were therefore not measured. However, since the aim was to obtain an overall view of the differences between the hygiene status of different rooms in the building, different kinds of rooms and surfaces were measured. The differences between the rooms with different hygiene levels were demonstrated. On the other hand it was shown that variation of the results within a single measurement site was sometimes great. In the case of possible problematic disorder situations e.g. in the spreading of

diseases (Noordhuizenet al., 2008), information concerning the most contaminated surfaces is valuable. Hygiene monitoring is often used to identify sites in need of improvement. In the EU, adoption of HACCP-like (hazard analysis and critical control points) programs has also been suggested for farmers, including dairy farmers (Noordhuizenet al., 2008). However, the implementation of HACCP at dairy farms has been observed to depend to a great extent on the active participation of the farm workers (Vilar et al., 2012). Based on the results of the present study, the need for separating the different areas in a barn in order to enhance hygiene was demonstrated. In addition to this, other procedures to prevent cross-contamination should be created and followed. All rooms should be cleaned regularly and there should be responsible persons to implement the cleaning plans. The present study provided preliminary reference values for future studies, training of agricultural students and personnel, and possible risk evaluations.

4 Conclusions

As a whole, the corridor and personnel rooms were the cleanest rooms investigated in the barn building. The next best total cleanliness was observed in the office and personnel kitchen or in the milk room, depending on the points of view of evaluation. The overall dirtiest results were observed in the barn, the washing room being the second dirtiest as a whole. It was shown that although the hygiene of cattle barn surfaces has traditionally not been measured using microbiological dipslides they can in fact be used for this purpose, particularly in the case of surfaces with no excessive amounts of visible soil. The results for the barn sites can be used as preliminary reference values for use in further studies, for training and in hygiene monitoring in cattle barns e.g. as a part of self-monitoring systems.

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