AGRICULTURAL AND FOOD SCIENCE

Vol. 17 (2008): 227–239.

Properties and cleanability of new and traditional surface materials in cattle barns – a field study

Risto Kuisma[1], Hanna-Riitta Kymäläinen[1], Maarit Hellstedt[2], Pekka Jauhiainen[2], Jenni Määttä[1],
Anna-Maija Sjöberg[1*]

[1] *Department of Agrotechnology, PO Box 28, FI-00014 University of Helsinki, Finland*

[2] *MTT Agrifood Research Finland, Animal Production Research, Vakolantie 55, FI-03400 Vihti, Finland*

[*] *e-mail: anna-maija.sjoberg@helsinki.fi*

In this study surface properties and cleanability of new and traditional surface materials in cattle barns were examined in a field test. The concrete and plastic-coated samples were placed on a walking path on the floor and on a feeding table in a cattle barn. The surfaces were characterized using colorimetric and gloss measurements and determination of topography. In most cases, the colour of the surfaces placed on the floor darkened during the one year study period, whereas the colour changes of the samples placed on the feeding table did not show a similar trend. However, in both locations the plastic-coated surfaces were generally the easiest to clean, and the highest colour changes indicating soil residues were detected on the uncoated and silane-impregnated concrete surfaces. The difference between the locations was also seen in the gloss values, which increased in the samples placed on the floor during the one-year test period but varied considerably between the different materials on the surfaces placed on the feeding table. This field study confirmed the observation from earlier laboratory studies that plastic coatings improved the cleanability of concrete cattle barn surfaces. Silane impregnation was not functionally competitive with the plastic coatings. In general, the cleanability results were in accordance with the results of previous laboratory experiments but the field study provided practical information about the behaviour of the surface materials examined.

Key-words: cleanability, cattle barn, flooring, colorimetric method, gloss, profilometry, SEM

Manuscript received March 2008

Introduction

Material choices in agricultural environments affect animal welfare, hygienic condition of surfaces and products, and the working environment of the personnel. The durability and cleanability of surfaces are aspects affecting the choice of flooring material for cattle barns (Hörndahl 1995). The importance of this subject is emphasized in large animal buildings, which are nowadays common in many countries.

Concrete is a very generally used floor material in agricultural buildings. The floors of dairy cattle houses are almost exclusively made of concrete, because it can be textured to provide a slip-resistant, non-abrasive surface or finished with a smooth surface to aid drainage and cleaning (Barnes 1989). Although concrete is often very suitable for agricultural environments, it is affected by many environmental hazards, e.g. wear caused by animals and vehicles and chemical load caused by feeds, milk and manure (Nilsson 2005). Both chemical substances and mechanical impact on floorings cause corrosion and wear that may promote injuries to animals. In addition it may make cleaning difficult, thus promoting the spread of diseases (De Belie 1997, De Belie et al. 2000b). Therefore, the use of coatings to protect the surface of concrete against wear is of interest. Polyurethane is an example of materials which have been used in cattle barns and horse stables, but their use in animal floorings is not widespread (Kymäläinen et al. 2008). Recent material research has focused on searching for new materials with potential for use in animal houses. A floor surface which is too rough causes rapid wear of animal hooves and causes grazes on other parts of the body (De Belie 1997). Floors with an initially ideal surface may become too rough or slippery because of degradation (De Belie 1997). A summary of earlier studies concerning cleanability of different kinds of agricultural surfaces and methods is presented in Table 1 (Määttä 2007).

In our earlier laboratory studies, new surface materials for use in floors and feeding tables in cattle barns were developed. In these studies, surface properties and cleanability of several new and traditional surface materials were examined as new (Määttä et al. 2008a) and when chemically and mechanically worn (Määttä et al. 2008b). The materials examined were basic cement paste, both uncoated and treated with inorganic sealants or with fluorochemical coatings of concrete including epoxy, polyurethane, polyester and acrylic, and three different jointing materials.

There is some evidence from public office buildings that despite the fact that numerical results of laboratory experiments may not straightforward correlate with the values obtained from field experiments carried out in use conditions, materials can be compared and ranked according to both laboratory and field experiments (Kuisma et al. 2008).

The aim of the present study was to examine the surface properties and cleanabilities of new and traditional surface materials in a field test and to compare these results with the results of the earlier laboratory experiments (Määttä et al. 2008a,b). The surface material samples were selected to this study according to the results of the laboratory experiments and placed on a feeding table and walking path in a cattle barn. A colorimetric method was used for evaluating cleanability. The surface properties were examined by determining surface roughness parameters and gloss.

Materials and methods

Laboratory-made and commercial surface materials

The materials evaluated are presented in Tables 2 and 3. Epoxy, polyester, polyurethane, acrylic, substances containing oil, and plaster were used as surface coatings. In addition, asphalt and concrete without any coating or extra treatment were examined. The surface materials were selected to this study according to previous laboratory experiments (Määttä et al. 2008a), with exceptions as mentioned in Table 2. In all experimental materials, the basic concrete was laboratory-made, whereas commercial versions of the other materials were examined. However, not all

Table 1. Cleanability studies concerning agricultural surfaces (mostly according to Määttä 2007)

Materials	Soil	Methods	Results	Reference
Concrete, ceramic, steel, aluminium, wood, glass, plastics, asphalt, rubber	Manure (cow, pig)	Visual, microbiological	Pig manure was removed more easily from surfaces than cow manure	Sundahl 1974
Concrete, plastic coatings	Artificial soil	Visual	Coatings improved cleanability	Puumala and Lehtiniemi 1993
Asphalt, concrete	Manure (cow)	Visual	Smooth surfaces were cleaned more easily than rough ones	Hörndahl 1995
Concrete, timber, rubber, aluminium	Organic wastes	Microbiological	The optimal temperature for liquids used in cleaning and disinfection was 40°C	Böhm 1998
Concrete, wood	Manure (pig)	Microbiological	The main findings were that cleanliness was improved by regularly cleaning and soaking of the pens with water before cleaning	Larsson 2000
Rubber solid floor, solid stall floor	Manure (cow)	Visual, scoring cleanliness and health of cows	Cows that used standings with rubber-slatted floor were cleaner than those on fully solid rubber mat	Hultgren and Bergsten 2001
Concrete, epoxy-coated concrete	Manure (pig)	Microbiological	Epoxy-coating improved cleanability	Pelletier et al. 2002
Concrete, plastic, wood, metal	Manure (pig)	Visual sensor system, Spectral characterisation	The determination method was able to locate dirty areas	Braithwaite et al. 2005
Concrete, plastic, wood, steel	Manure (pig)	Visual and optical	The determination method was able to locate dirty areas	Zhang et al. 2006
Concrete, several plastic coatings	Manure (pig), coloured saw-dust mixture	Colorimetric, radiochemical	Coatings improved cleanability of concrete	Kymäläinen et al. 2008
Concrete, surface treatments, plastic coatings, joint materials	Partly radiochemically labelled model soils based on manure (cow), feed, chemical compounds	Radiochemical, biochemical	Coatings improved cleanability of concrete	Määttä et al. 2007
		Radiochemical	Mechanical wear decreased cleanability of all materials, particularly in the case of joints.	Määttä et al. 2008a

Table 2. Codes and compositions of the evaluated surface materials and their use in the cattle barn in the study.

Code	Components		Experimental material (E) or material already in use (U)	Site	
	Substrate	Surface coating or treatment		Floor	Feeding table
C1	Concrete	None	U	X	X
C2	Concrete	Plaster and silane	E	X	X
Co1	Concrete	Acrylic coating	U	X	X
Co2	Concrete	Polyurethane coating	U	X	X
Co3	Concrete	Epoxy coating	U	X	X
Co4	Concrete	Polyester coating	U	-	X
Co5*	Concrete	Oil based coating	E	X	-
Co6*	Concrete	Oil based and rubbercoating	E	X	-

-not suitable

* Not included in the laboratory study.

Table 3. Manufacturing and formulation of substrates and surface coatings or treatments.

Code	Manufacturing of components			
	Substrate		Surface coating or treatment	
	Type	Manufacturing	Type	Manufacturing
C1	Concrete	Components (kg m^{-3}): Rapid cement 333.6, sand 1836.1, water 183.5, VB-Parmix(=plasticizer) 1.33.	Trowelled	-
C2	Concrete	See Co3	Cement-based coating (7–10 mm) and silane treatment (StoFinexter)	StoCryl CP -primer+ StoCrete VM Hard-cement based coating + StoCryl HP 200 -hydrophobic impregnation (primer and impregnation agent were applied by brushing, coating was trowelled
Co1	Concrete	See Co3	Acrylic coating (5-6 mm) (Nanten)	Primed with acryl; acryl DC 305, Sand addition (7 kg m^{-2}, granule size 0.6–1.2 mm)
Co2	Concrete	See Co3	Polyurethane coating (3 mm) (Nanten)	Primed with thinned PU 710 sand addition (0.5 volume-% of amount of polyurethane, grain size 1 mm), paint rolling of PU 710
Co3	Concrete	Same composition as in C1. Surface was sand blasted and vacuum cleaned before coating.	Epoxy coating (2 mm) (DeLaval)	Mixture of transparent epoxy and sand (3 kg m^{-2}, granule size 0–0.9 mm), spread with a spatula
Co4	Polyester concrete	Prefabricated element	(DeLaval)	No information available
Co5	Concrete	See Co3	Oil-based SE Biomassa (1.4 mm) (Suomen Elektrodi)	Priming with thinned SE Biomassa (plastic:hardener = 50:100). Coating with SE Biomassa (plastic:hardener = 70:100). Spreading of quartz granules (0.8–1.2 mm)
Co6	Concrete	See Co3	Primer SE Biomassa, coating SE Biomassa and rubber (0.7 mm) (Suomen Elektrodi)	Priming with thinned SE Biomassa (plastic:hardener = 50:100). Coating with SE Biomassa (plastic:hardener = 70:100) containing quartz grains (0.2 mm) and rubber grains (0.7 mm)

- no surface coating

the materials are used in animal houses or marketed for that use at present (Table 2). The coded samples as three replicates were placed in a metal frame in random order and fastened on the floor (sorting gate) and feeding table.

Cleanability experiments and characterization of surfaces

The experimental design of determination of cleanability and surface properties is presented in Fig. 1. Cleanability was examined using a colorimetric method. A similar method was also used in the study by Kymäläinen et al. (2008), which focused on flooring materials for use in piggeries. Surface properties were examined using a laser profilometer, a scanning electron microscope (SEM) and a gloss meter. The similar SEM measurements were carried out as in the earlier laboratory studies for the same surface materials as unused (Kymäläinen et al. 2008) and worn (Määttä et al. 2008b). Topography, colour and gloss of the samples were measured *in situ* at 3-month intervals between March 2006 and November 2007.

Measurement of cleanability using the colorimetric method

The cleaning efficiency was measured with a Minolta Chroma Meter CR-210 colorimeter (Minolta Co Ltd), equipped with Standard Illuminant D65 as described previously (Pesonen-Leinonen et al. 2003, Redsven et al. 2003). In this study the L* (lightness) value was used for assessing the soiling and cleaning properties of the plastic surfaces. Measurements were performed after the cleaning, which was made using running water and a scrubbing brush. The results were expressed as soil residues, calculated from the means of the L* values of the sample:

Soil residue $\Delta L^*_R = L^*_{unsoiled} - L^*_{cleaned}$

Gloss measurements

The gloss of plastic surfaces was measured using a three-angle glossmeter Picogloss 503. The main principle of this device is based on measuring the amount of reflected light directed to a surface at a specified angle from its normal. The amount of light reflected from the surface under investigation is divided by the amount of light reflected from the surface of a reference smooth black glass plate (de-

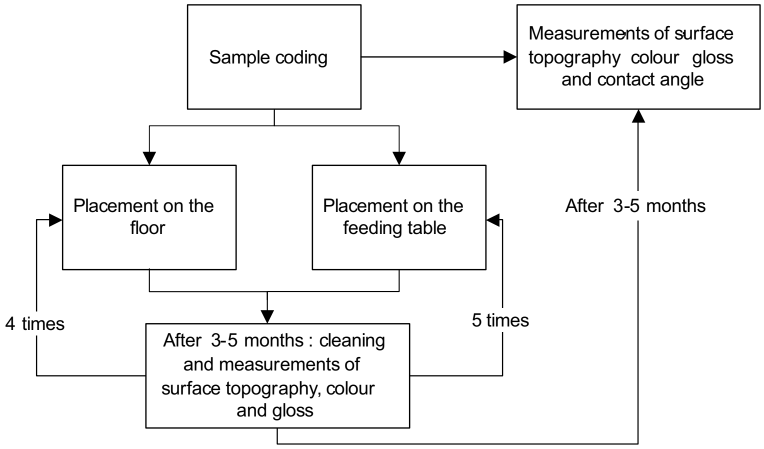


Fig.1. Experimental setup of the study: procedures and measurements in the cattle barn.

livered by the manufacturer of the glossmeter) and the specular gloss is obtained by multiplying this intensity ratio by 100. The readings are expressed in GU (gloss units). All the measurements were carried out using an incidence angle of 85º. Measurements were performed after the cleaning.

Topography assessment

The roughness of new and worn surface materials was measured using a laser profilometer (Micro-Epsilon ILD1400-100) by running it four times for 100 mm over the tested surfaces, varying the scan location. The data analysing method was the same as presented by Kymäläinen et al. (2008). The results are averages of all scans of the studied material as new and during the test (3, 6, 9 and 12 months). Change due to wear was calculated from the results of 9 months (floor) or 12 months (feeding table) of use. One image at each magnification was recorded and from each image five line profiles were measured. The high spot count (HSC) and peak average height values (Rpm) were derived from the line profiles. In addition, images of the surfaces were taken using a scanning electron microscope (JEOL JSM-840, USA) at 100×, 500× and 1500× magnifications. The magnification 500× illustrated the surface best and was used for each material.

Results

As can be seen in the colorimetrically determined soil residues in Fig. 2a, C1 (30–50%), C2 (15–30%) and Co4 (10–25%) showed the greatest colour changes, indicating soil residues on the feeding table.

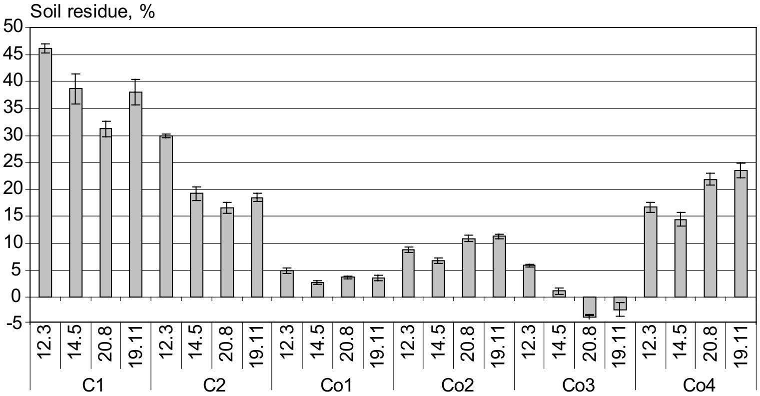


Fig. 2a. Cleanability as soil residue of the surfaces placed on the feeding table as estimated by colorimetric methods. The results are expressed as means (columns) and standard errors of means (±SE, bar) of five replicates. The codes of surfaces are presented in Table 3.

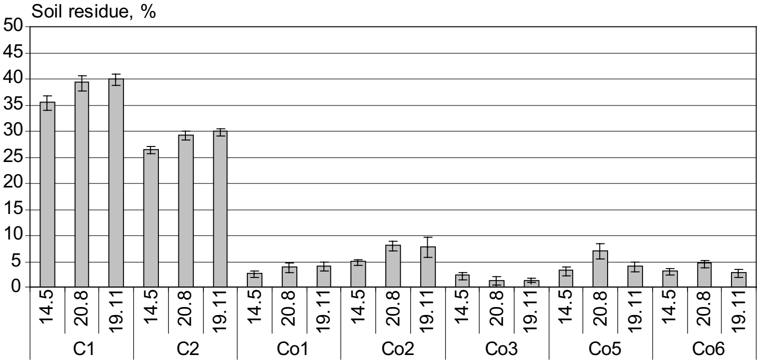


Fig. 2b. Cleanability as soil residue of the surfaces placed on the sorting gate on the floor as estimated by colorimetric methods. The results are expressed as means (columns) and standard errors of means (±SE, bar) of five replicates. The codes of surfaces are presented in Table 3.

Changes during the 12 month test period varied. Only a minor amount of soil, with soil residues below 5%, was detected on Co3 and Co1 surfaces on the feeding table (Fig. 2a).

As in the case of the feeding table, the greatest soil residues on the flooring were detected on C1 (35–40%) and C2 (25–30%) (Fig. 2b). On the floor, Co3, Co1 and the Co5 had the lowest soil residues, below 5%, and that of Co2 was not much greater (<10%). Particularly on the C1 and C2 concrete samples, the soil residues had a slightly increasing trend during the 9 month test period.

In most cases the mean gloss of the surfaces placed on the floor increased during the one-year test period (Fig. 3b), whereas the gloss changes of the surfaces placed on the feeding table varied considerably between the different materials (Fig. 3a).

Surfaces of two replicate samples of the rubber-coated concrete (Co6) were totally worn out between 6 and 9 months of use. Wear caused varying changes in roughness for other floor and feeding table surfaces (Tables 4 and 5). In most cases the number of HSC increased on the feeding table, although the variation between the materials was great, from 5% (acrylic coating) to over 800% (silane-impregnated concrete) (Table 4). The magnitude of changes was similar for the feeding table and floor samples, with the exception of Co2, on which HSC increased on the feeding table but decreased at the sorting gate. The effect of wear on surface roughness was lowest on the acrylic coating. Changes in the Rpm of the surfaces varied, and only weak correlation between HSC and Rpm was observed (r = 0.424 for all samples, statistically significant at the 0.01 level).

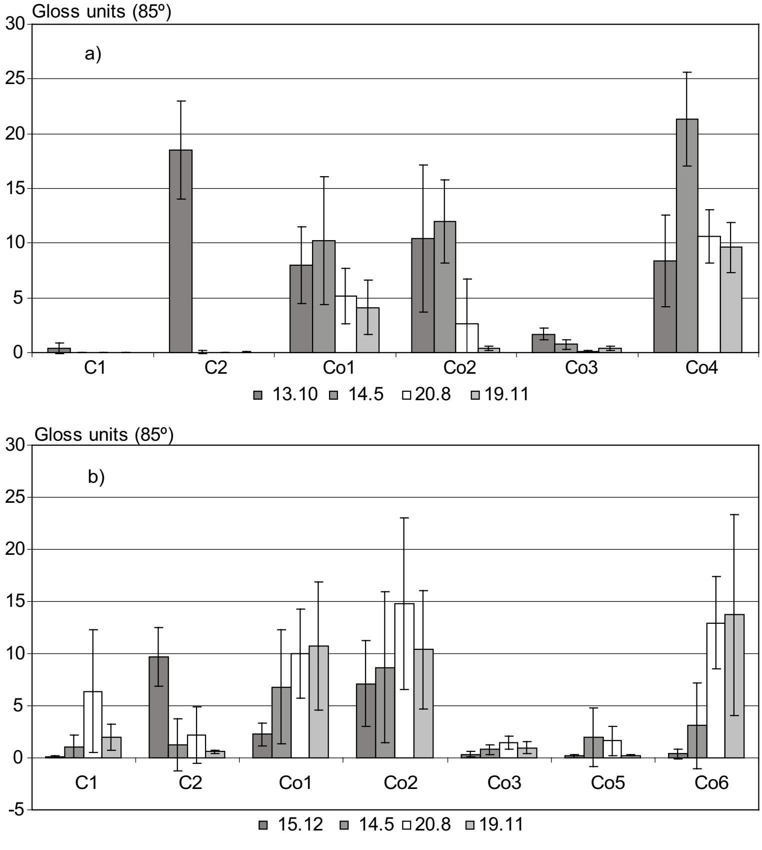


Fig. 3. Gloss of the samples placed on the feeding table (a) and on the floor (b). Results are means of the gloss values (as gloss units, 85° measurement angle) of five measurements (column) and standard errors of means (±SE, bar). The codes of surfaces are presented in Table 3.

Table 4. Mean roughness of new and used surface materials on the feeding table. The codes of surfaces are presented in Table 3.

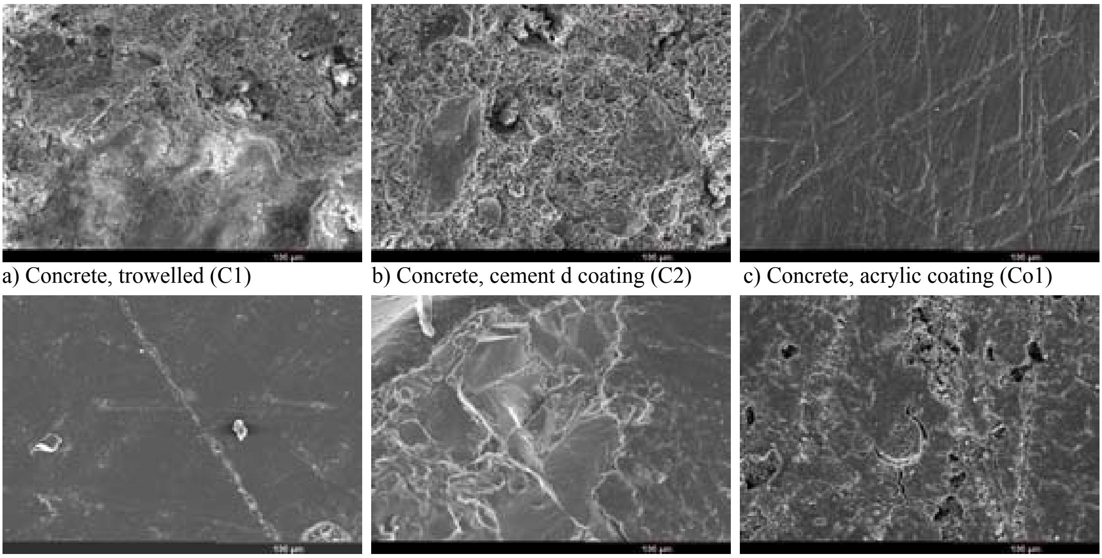
Code	High spot count per 100 mm			Peak average height, mm		
	New	12 months in use	Change due to use for 12 months, %	New	12 months in use	Change due to use for 12 months, %
C1	8.8	26.8	206	0.3	0.4	43
C2	1.3	12.0	856	0.2	0.4	86
Co1	22.3	23.5	5	0.4	0.4	-1
Co2	11.2	13.3	19	0.6	0.4	-38
Co3	54.2	38.0	-30	0.6	0.4	-29
Co4	1.4	7.0	400	0.4	0.4	1

Table 5. Mean roughness of new and used floor materials at the sorting gate. The codes of surfaces are presented in Table 3.

Code	High spot count per 100 mm			Peak average height, mm		
	New	9 months in use	Change due to use for 9 months, %	New	9 months in use	Change due to use for 9 months, %
C1	4.5	9.1	100	0.2	0.3	31
C2	0.2	4.5	1808	0.1	0.1	75
Co1	17.3	17.9	4	0.4	0.4	-18
Co2	10.7	4.1	-62	0.6	0.2	-71
Co3	34.4	15.4	-55	0.6	0.3	-49
Co5	3.7	11.2	206	0.3	0.1	-58
Co6[1]	26.3	20.9	-20	0.4	0.6	61

[1] From two test pieces the surface treatment had worn out between the measurement of 6 months and 9 months in use. For these materials, the numeric results are for 3 (or 5) replicate samples.

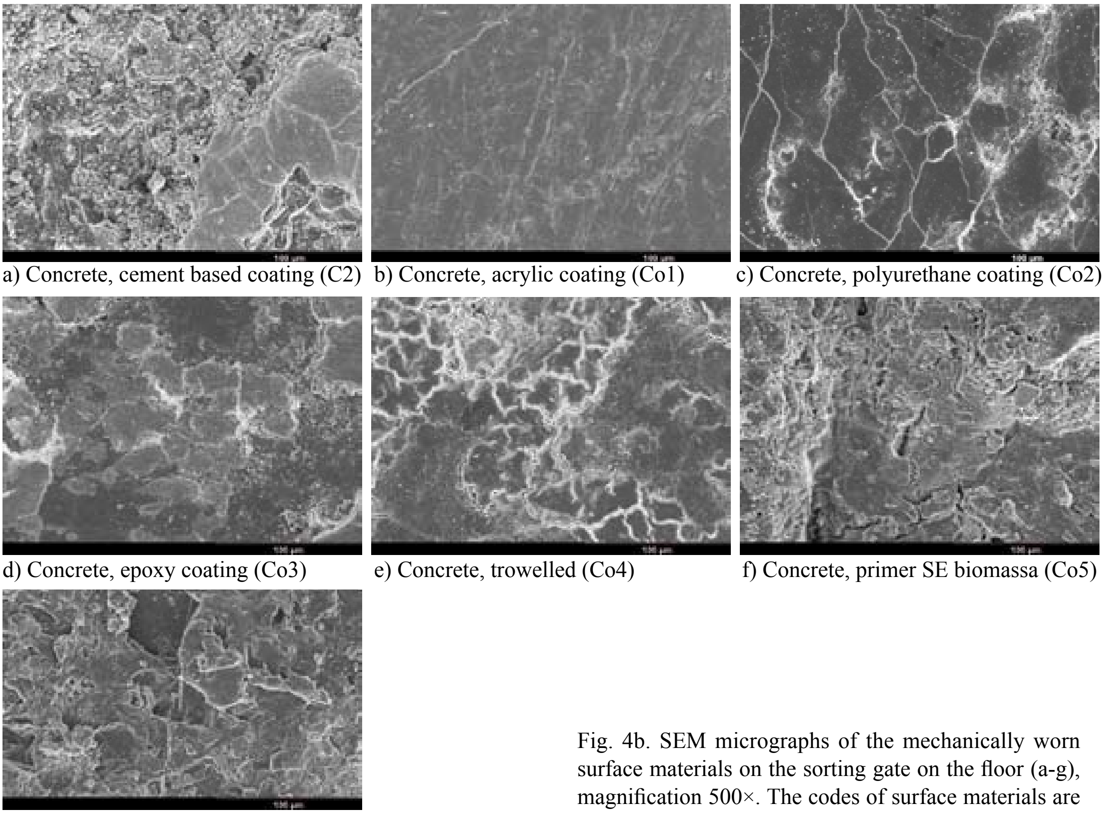
Qualitative SEM micrographs of different types of feeding table and sorting gate floor surface materials are presented in Fig. 4a and 4b. The most typical images were selected from the replicate measurements of magnification at 500×. When compared with the new surfaces (Määttä et al. 2008a), clear changes due to wear were observed on all surfaces (Fig. 4a and 4b). As new the plastic coatings (Co1–Co4) were among the smoothest surfaces (Määttä et al. 2008b), but after wearing only the acrylic coating (Co1) on the floorings and acrylic and polyurethane (Co2) coatings on the feeding table were ranked as smooth (Fig. 4b) according to the SEM pictures. There were some differences between the effect of wear in the two locations: Co2 was worn more on the flooring than on



a) Concrete, trowelled (C1) b) Concrete, cement d coating (C2) c) Concrete, acrylic coating (Co1)

d) Concrete, polyurethane coating (Co2) e) Concrete, epoxy coating (Co3) f) Polyester concrete (Co4)

Fig. 4a. SEM micrographs of the mechanically worn surface materials on the feeding table (a-f), magnification 500×. The codes of surface materials are given in Table 3.



a) Concrete, cement based coating (C2) b) Concrete, acrylic coating (Co1) c) Concrete, polyurethane coating (Co2)

d) Concrete, epoxy coating (Co3) e) Concrete, trowelled (Co4) f) Concrete, primer SE biomassa (Co5)

g) Concrete, oil-based SE biomassa (Co6)

Fig. 4b. SEM micrographs of the mechanically worn surface materials on the sorting gate on the floor (a-g), magnification 500×. The codes of surface materials are given in Table 3.

the feeding table, whereas in the case of Co3 and Co1 no clear differences in the SEM figures taken from the two locations were observed. Changes were also observed on the surfaces C1 and C2, but it is difficult to say how much these were caused by wear and how much by the absorption of soil into the surface.

Discussion

Soil residue has been considered to be the most valuable parameter calculated from the L*-value because it indicates whether the surfaces can be cleaned easily and economically. The surface colour offers an easy way to compare the cleanability of agricultural surfaces, but does not necessarily correlate with the absolute amount of soil attached to the surfaces. Cleanability of agricultural surfaces has earlier been examined with radiochemical methods in the laboratory (Kymäläinen et al. 2008, Määttä et al. 2008a). Measuring the amount of soil on the surface with radiochemical methods would provide quantitative information useful for studying different cleanability performances. However, in field studies it is not possible to use radiochemical methods and colorimetric method was a promising alternative.

The soil residue results show that in general the best cleaned surfaces were the plastic coatings. This is in accordance with previous studies by Puumala & Lehtiniemi (1993), Kymäläinen et al. (2008) and Määttä et al. (2008a). Most of the best cleaned surfaces in this study were non-porous, in contrast to the uncoated and silane-impregnated concrete. On the feeding table polyester (Co4) coating could not be kept as clean as the other plastic coatings. This difference can be seen in the SEM pictures, showing that the Co4 coating was more porous than the other plastic coatings. Considering the other materials, the differences in cleanability could be explained by differences in their roughness observed from the SEM pictures but could not be explained by the HSC and Rpm roughness parameters. In our previous study the contact angles of uncoated concretes were low or even unmeasurable due to porosity or brittleness of the materials (Määttä et al. 2008a). According to these results the differences in cleanability of surfaces may be partly explained by the absorptivity or repellency of the surface to soil. Furthermore, coatings sealed and smoothened surfaces thus improving their cleanability.

The average peak height (Rpm) of the trowelled concrete (C1) and polyurethane coating (Co2) measured from new surface is in accordance with those measured in the study by Norring et al. (2006). Surface properties of new and worn floors in production buildings have earlier been studied with profilometric measurements by Kymäläinen et al. (2008). The artificial wear induced in that study was very mild. Therefore comparison between the two sets of results is rather difficult. However, Rpm of epoxy (Co3) and polyurethane (Co2) coatings both on the feeding table and on the sorting gate decreased similarly in both locations.

It is evident that consideration of the durability of building materials and components is an important aspect of design (De Belie et al. 2000a). In this study the laboratory experiments prior to the field test for pre-selecting surfaces to resist mechanical and chemical wear were shown to be valuable. Table 6 shows the order of superiority of the surface materials according to the colorimetric results in this study and to the radiochemical results from the previous laboratory studies (Määttä et al. 2008a,b). It can be seen that the results showed similarity between the laboratory and field experiments. Accordingly, when the materials were ranked in order of superiority according to the soil residues, the order was exactly the same according to both the feeding table and sorting gate floor surfaces (Table 6). In a comparison of colorimetric results in non-agricultural buildings it was similarly observed that plastic flooring materials could be ranked in the same order according to both laboratory and field experiments (Kuisma et al. 2008). However, the wear, soiling and cleanability methods differed from the methods used in the present study.

Similar changes in colour and gloss were observed on the flooring, but not on the feeding table. This could be explained by the dominating role of manure soil in the colour measurements on the

Table 6. Cleanability of the surface materials listed in order of superiority according to the colorimetric soil residues in the present field study (C) and previous radiochemical laboratory studies (R) (based on sums of all radiochemical soils, Määttä et al. 2008a,b). The smaller the number, the better the cleanability. Only the five materials that were included in all three studies are ranked here. The codes of surfaces are presented in Table 3.

Code	Surface and detection method				
	New	Laboratory studies (R) Worn in laboratory		Field study (C) After 1-year field test	
		Chemical	Mechanical	Feeding table	Floor
Co1	1	1	1	2	2
Co2	2	1	3	3	3
Co3	2	3	2	1	1
C1	5	4	broken	5	5
C2	4	-	-	4	4

- Not included in the laboratory study.

flooring, whereas components on the feeding table are less colourful. Chemical loads and wearing were different in the two locations: wear at the sorting gate due to manure and cow claws was more intensive than that at the feeding table caused by fodder and cows licking the surface. Manure contains organic acids (acetic, propionic, lactic etc.), which constitute a severe chemical challenge to the concrete of agricultural structures (Berton et al. 2005). The quality of the concrete used in the floor can be selected to offer the best resistance to organic acids and aggressive conditions (Barnes 1989).

Material selection including corrosion-resistant materials and surface coatings is one means of preventing the formation of biofilms and extending the life-span of barn structures. Other parameters include designing against corrosion and control of aggressive environments (De Belie et al. 2000b). In this study the main focus was on cleanability, but depending on location thermal comfort, softness, friction, abrasiveness, surface profile and contact pressure should also be considered in material selection. However, floors which are hard to clean encourage the transmission of diseases in floors in animal buildings (De Belie et al. 2000c) and cleanability is thus one important factor determining the hygienic properties of surfaces in cattle barns.

Conclusions

This field study confirmed the observation from earlier laboratory studies that plastic coatings improved the cleanability of concrete cattle barn surfaces. Silane impregnation was not functionally competitive with the plastic coatings. The materials were ranked in the same order of superiority acccording to the colorimetric results in this field study and radiochemical results from previous laboratory studies. The field study provided practical information about the behaviour of the surface materials examined.

Acknowledgements: Financial support from the Ministry of Agriculture and Forestry in Finland (project Easy-to-clean surfaces in farm buildings) and the Finnish Cultural Foundation is gratefully acknowledged. DeLaval, Nanten, Suomen Elektrodi and Lujabetoni are acknowledged for providing surface materials. We are grateful to Lippo Sundberg for help in practical work with the samples and measurements and for fruitful discussion during the study.

References

Barnes, M.M. 1989. Update on dairy cow housing with particular reference to flooring. *British Veterinary Journal* 145: 436–445.

Berton, A., Duchesne, J. & Escadeillas, G. 2005. Attack of cement pastes exposed to organic acids in manure. *Cement & Concrete Composites* 27: 898–909.

Braithwaite, I., Blanke, M., Zhang, G-Q. & Carstensen, J. 2005. Design of a visionbased sensor for autonomous pig house cleaning. *Journal on Applied Signal Processing* 13: 2005–2017.

Böhm, R. 1998. Disinfection and hygiene in the veterinary field and disinfection of animal houses and transport vehicles. *International Biodeterioration & Biodegradation* 41: 217–224.

De Belie, N. 1997. A survey on concrete floors in pig houses and their degration. *Journal of Agricultural Engineering research* 66: 151–156.

De Belie, N., Lenehan, J.J., Braam, C.R., Svennerstedt, B., Richardson, M. & Sonck, B. 2000a. Durability of building materials and components in the agricultural environment, Part III: Concrete structures. *Journal of Agricultural Engineering Research* 75: 3-16.

De Belie, N., Richardson, M., Braam, C.R., Svennerstedt, B., Lenehan, J.J. & Sonck, B. 2000b. Durability of building materials and components in the agricultural environment, Part I: The agricultural environment and timber structures. *Journal of Agricultural Engineering Research* 75: 225–241.

De Belie, N., Sonck, B., Braam, C. R., Lenehan, J. J., Svennerstedt, B. & Richardson, M. 2000c. Durability of Building Materials and Components in the Agricultural Environment, Part II: Metal Structures. *Journal of Agricultural Engineering Research* 75: 333–347.

Hultgren, J. & Bergsten, C. 2001. Effects of a rubber-slatted flooring system on cleanliness and foot health in tied dairy cows. *Preventive Veterinary Medicine* 52: 75-89.

Hörndahl, T. 1995. *Slitstyrka och halksäkerhet hos golv i djurstallar, Inverkan av material och utförande*. (Wearing quality and prevention of slipperiness on solid floors in animal houses. Influence of materials and performance). Specialmeddelande 220, Sveriges Lantbruksuniversitet, Institutionen för Jordbrukets Biosystem och Teknologi, Lund, Sweden. 49 p. (in Swedish).

Kuisma, R., Kymäläinen, H.-R. & Sjöberg, A.-M. 2008. Determination of cleanability and wearing of plastic flooring surfaces in field and laboratory conditions. *Construction and Building Materials.* In Press.

Kymäläinen, H.-R., Määttä, J., Joutsen, B.-L., Puumala, M., Kaustell, K. & Sjöberg, A.-M. 2008. Effect of coating on cleanability of concrete as flooring material in piggeries. *Biosystems Engineering* 99: 88–98.

Larsson, K. 2000. *Rengöring av svinstall.* (Cleaning of pig-houses) JTI-rapport Lantbruk & Industri Nr 266, Jordbrukstekniska institutet, Uppsala, Sweden. 49 p. (in Swedish)

Määttä, J. 2007. Modifications of surface materials and their effects on cleanability as studied by radiochemical methods. *MMTEK-Publications* 26. Department of Agrotechnology, University of Helsinki, Finland. Yliopistopaino. 61 p.

Määttä, J., Kymäläinen, H.-R., Hellstedt, M., Mahlberg, R., Kuisma, R., Salparanta, L., Löija, M., Talibachew, A., Hurme, K.-R., Uusi-Rauva, A., Ritschkoff, A.-R. & Sjöberg, A.-M. 2008a. Properties and cleanability of new and traditional surface materials in cattle barns. *Agricultural and Food Science* 17: 210-226.

Määttä, J., Hellstedt, M., Kuisma, R., Kymäläinen, H.-R., Mahlberg, R. & Sjöberg, A.-M. 2008b**.** Effects of chemical and mechanical wearing on cleanability and surface properties of traditional and new surface materials in cattle barns – a laboratory study. *Submitted*.

Nilsson, C. 2005. Use of concrete for floors in livestock buildings. In: Concrete for a suitable agriculture, Agro-aqua and community applications. *Proceedings of the Vth International Symposium on 5–8 June 2005*. San Lorenzo de El Escorial, Spain. p. 25–32.

Norring, M., Valros, A., Munksgaard, L., Puumala, M., Kaustell, K. O. & Saloniemi, H. 2006. The development of skin, claw and teat lesions in sows and piglets in farrowing crates with two concrete flooring materials. *Acta agriculturae Scandinavica. Section A Animal Science* 56: 148–154.

Pelletier, F., DeFoy, C., Marquis, A., Godbout, S., Joncas, R., Gagné, R. & Massé, D. 2002. Effects of different concrete types on gas, odour emissions and sanitation of swine buildings. In: *Concrete for a suitable agriculture, Agro- aqua and community applications. Proceedings of the IVth International Symposium 21-24 April 2002.* Ghent, Belgium. p. 287–294.

Pesonen-Leinonen, E., Redsven, I., Kuisma, R., Hautala, M. & Sjöberg, A.-M. 2003. Cleaning efficiencies of mop cloths on floor coverings. *Tenside Surfactants Detergents* 40: 80–86.

Puumala, M. & Lehtiniemi, T. 1993. *Betonit ja muovit navetan lattiamateriaaleina.* (Concrete and plastic as floor materials in barns) Vakolan tutkimusselostus 67, MTT, Vihti, Finland. 85 p. (in Finnish with English abstract)

Redsven, I., Kuisma R, Laitala, L., Pesonen-Leinonen, E., Mahlberg, R., Kymäläinen, H.-R., Hautala, M. & Sjöberg, A.-M. 2003. An application of a standard proposal for testing soiling and cleanability of resilient floor coverings. *Tenside Surfactants Detergents* 40: 346–352.

Sundahl, A.-M. 1974. *Byggnadsmaterial i djurstallar, Nedsmutsing – rengöring.* (Building materials in animal houses, Soiling-cleaning). Sveriges Lantbruksuniversitet, Inst. för landbrukets byggnadsteknik, Aktuellt 211,Teknik, Uppsala, Sweden. 33 p. (in Swedish)

Zhang, G., Strøm, J.S., Blanke, M. & Braithwaite, I. 2006. Spectral signatures of surface materials in pig buildings. *Biosystems Engineering* 94: 495–504.

AGRICULTURAL AND FOOD SCIENCE

Vol. 17 (2008): 227–239.

SELOSTUS

Uusien ja perinteisten pintamateriaalien ominaisuudet ja puhdistettavuus navetassa - kenttätutkimus

Risto Kuisma, Hanna-Riitta Kymäläinen, Maarit Hellstedt, Pekka Jauhiainen, Jenni Määttä, Anna-Maija Sjöberg

Helsingin Yliopisto ja MTT

Tutkimuksen tavoitteena oli selvittää uusien ja perinteisten pintamateriaalien pintaominaisuuksien vaikutus niiden puhdistuvuuteen kenttäolosuhteissa navetassa. Betoniset ja muovipinnoitetut näytteet sijoitettiin navetan ruokintapöytään sekä lattiaan kulkuväylälle, lähelle lypsyrobottia. Pintojen ominaisuuksista selvitettiin väri, kiilto sekä topografia. Suurin osa lattialle sijoitetuista pinnoista tummui vuoden koejakson aikana, kun taas ruokintapöydälle sijoitetuissa näytteissä ei havaittu samanlaista muutosta. Molemmissa koepaikoissa muovipinnoitetut pinnat olivat yleisesti ottaen helpoimmin puhdistettavia kuin pinnoittamattomat näytteet. Suurimmat värinmuutokset havaittiin pinnoittamattomissa ja silaanilla kyllästetyissä betonipinnoissa. Koepaikkojen välinen ero havaittiin myös kiiltoarvoissa: lattialle sijoitettujen näytteiden kiiltoarvot kasvoivat vuoden koeajanjakson aikana, kun taas ruokintapöydälle sijoitettujen näytteiden kiiltoarvot vaihtelivat eri materiaalien välillä huomattavasti. Tämä kenttätutkimus vahvisti aikaisemmissa laboratoriotutkimuksissa tehdyt havainnot, että muovipinnoitteet parantavat betonin puhdistettavuutta navettojen pintamateriaaleina. Silaanilla kyllästetty pinta ei ollut tässä tutkimuksessa toiminnallisesti kilpailukykyinen muovipinnoitteiden kanssa. Yleisesti ottaen tämän tutkimuksen puhdistuvuustulokset olivat samansuuntaiset kuin aikaisempien laboratoriossa tehtyjen kokeiden tulokset. Kenttätutkimus antoi kuitenkin tietoa tutkittujen pintamateriaalien käyttäytymisestä käytännön olosuhteissa navetassa.