Assessing the Effect of Mechanical Cleaning on Surface Cleanability

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Summary

Introduction
Mechanical cleaning of food contact surfaces (FCSs) is thought to impact surface cleanability through wear. Historically, measurements of surface topography have been used to assess surface cleanability.

Ultimately, this suggests that wear from use/abuse of FCSs over time reduces the smoothness of surfaces and would result in a reduction in cleanability.

Purpose
The aim of this study was to investigate any change in surface cleanability and topography following repeated abraision of selected FCSs by brushes with different bristle stiffness', in wet and dry conditions, and to determine any correlation between the two.

Conclusions
Overall, the results of this study indicated no significant impact on cleanability for any surface related to bristles stiffness, and no strong correlation between surfaces cleanability and topography ($R_2 < 0.62$).

The cleanability of PP improved, but this did not relate to changes in surface topography. Dry brush abraision did, in general, show greater impact on surfaces. There was no clear relationship between surface cleanability and any investigated surface characteristics.

Significance
These study findings suggest that the selection of wet or dry cleaning method, and bristle stiffness can be focused on soil type removal rather than concerns about the future cleanability and wear of FCSs.

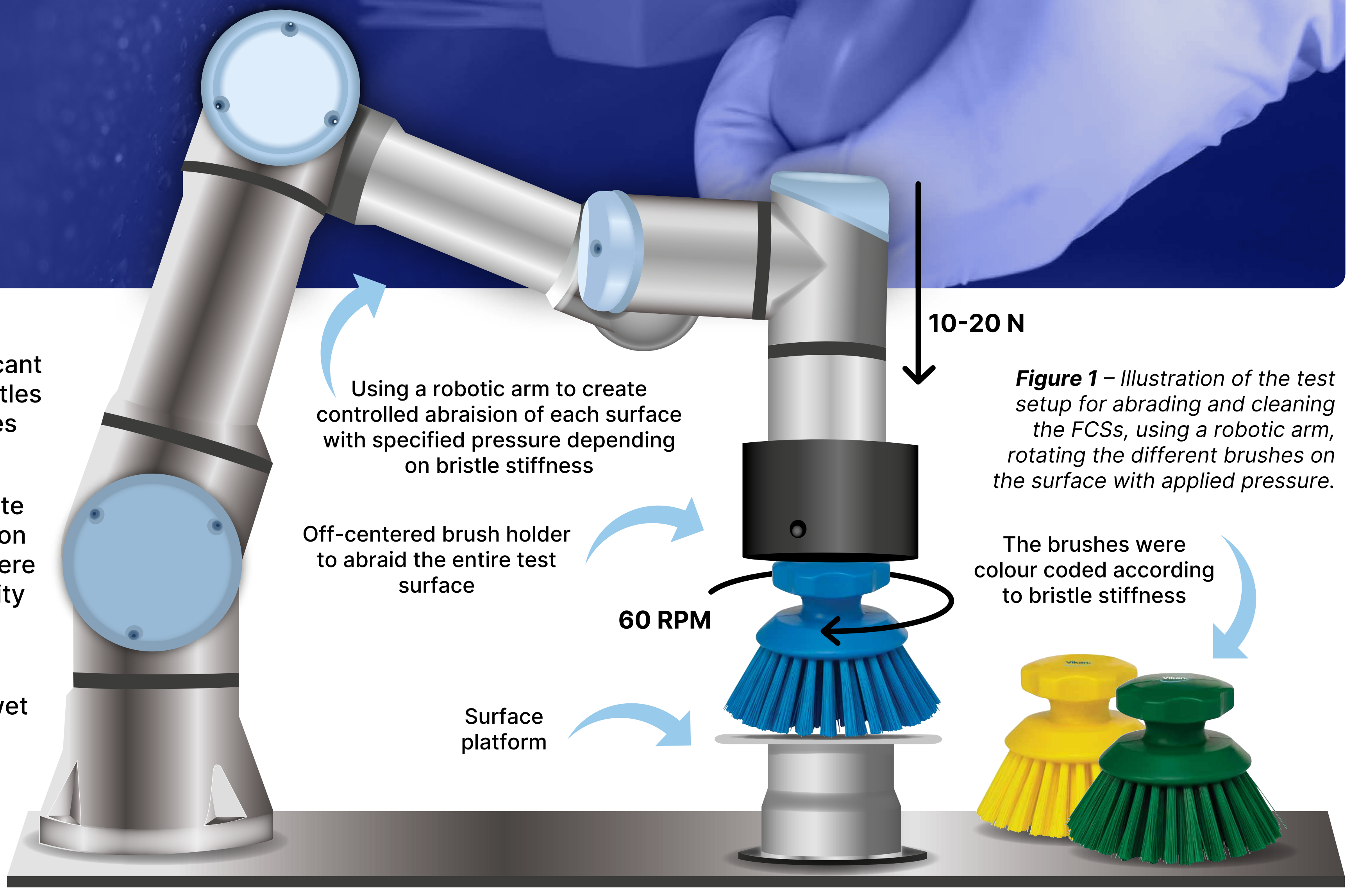


Figure 1 – *Illustration of the test setup for abrading and cleaning the FCSs, using a robotic arm, rotating the different brushes on the surface with applied pressure.*

Methods

Materials
FCSs Stainless steel (SS, EN 1.4301, AISI 304) with 2B surface treatment; and Polyproylene (PP) and High-Density Polyethylene (HDPE), both provided by Laude, CZ, with one side treated according to the manufacturers surface finish acceptance criteria.

Surface Abraision
Surfaces were abraided using a UR3e robotic arm fitted with brushes of various different bristle stiffness as illustrated in Figure 1. The brushes were offset 2.5 cm from the centre to ensure total coverage of the test surface. Surfaces were abraded either dry or with the addition of demineralised water.

Surface Topography
Surface roughness profile (S-L plane) was measured by 3D optical microscopy with 3 evaluations per surface. Evaluation lengths ([lambda symbol]c): 0.8 µm or 25 µm. The surface roughness profile is illustrated in Figure 4. All measurements were performed across the visible layer direction.

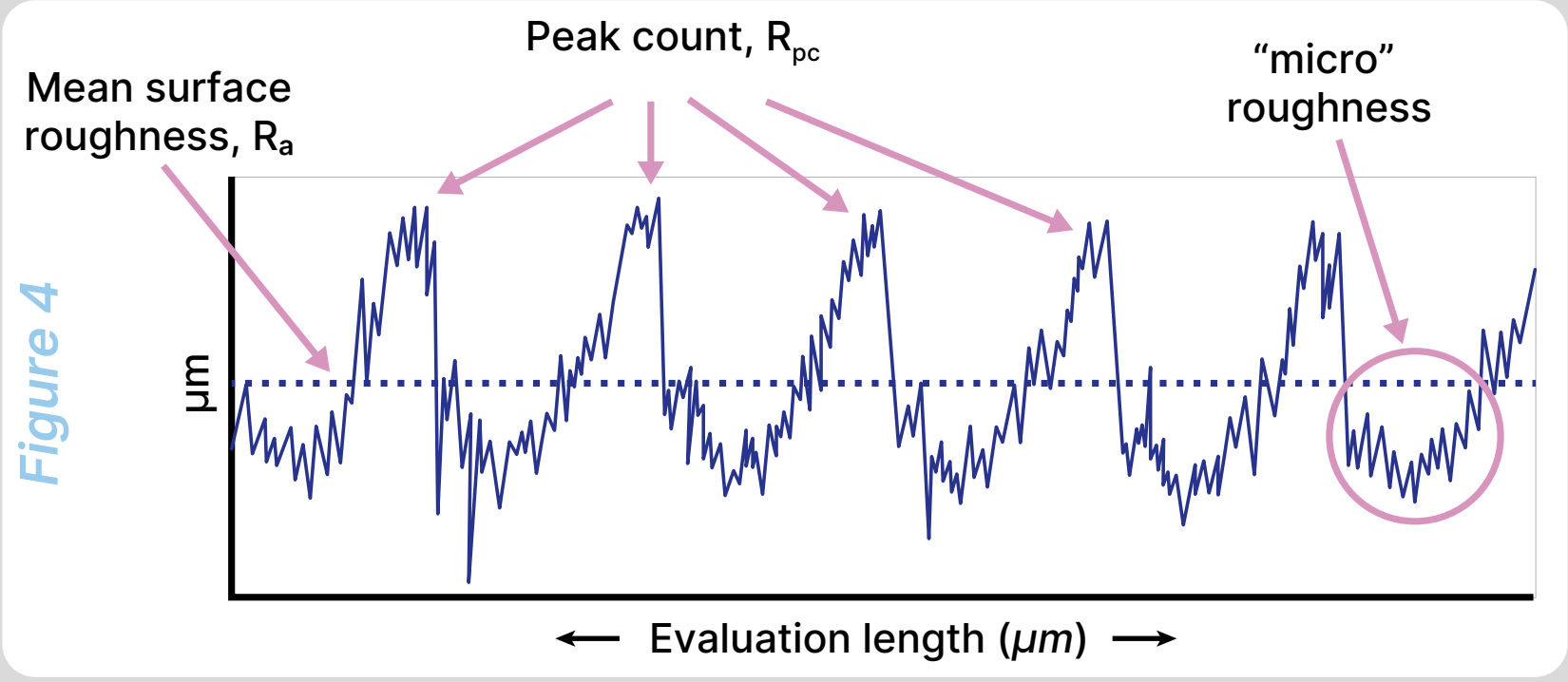
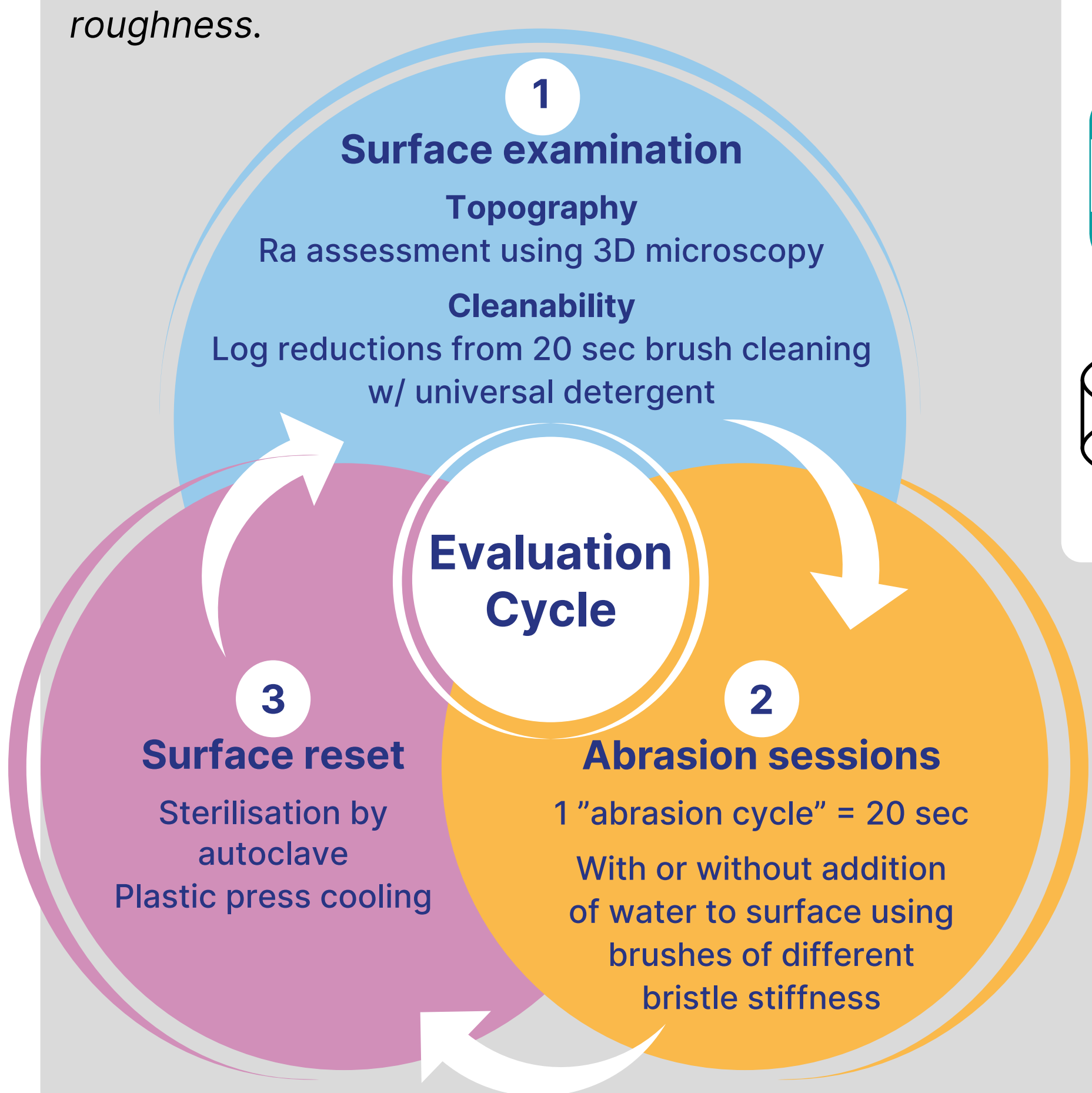


Figure 4 – *Simple illustration of the surface roughness profile and how the mean surface roughness (R_a) and Peak count (R_{pc}) are calculated. These values were also evaluated on a smaller scale, referred to as "micro" roughness.*



Evaluation Cycle

1 **Surface examination**
Topography
Ra assessment using 3D microscopy
Cleanability
Log reductions from 20 sec brush cleaning w/ universal detergent

2 **Abrasion sessions**
1 "abrasion cycle" = 20 sec
With or without addition of water to surface using brushes of different bristle stiffness

3 **Surface reset**
Sterilisation by autoclave
Plastic press cooling

Surface Cleanability
The evaluation of surface cleanability was adapted from the in the EHEDG Doc. 2 method to an absolute evaluation, in order to assess any significant correlation between the cleanability and surface roughness profile characteristics.

The FCSs were soiled, with inoculated butter milk (Geobacillus stearothermophilus (GB) spores), dried, cleaned and incubated according to (Figure 5). Brush cleaning setup was the same as for abrasion (Figure 1). Positive control plates was soiled with a 100-fold dilution in PBS.

Following the first incubation the agar was extracted from all surfaces , re-melted, solidified in sterile petri dishes, and incubated O/N at 58°C. Visible colonies of GB spores were counted, and transfer loss was calculated by difference to calculated applied spores on positive controls.

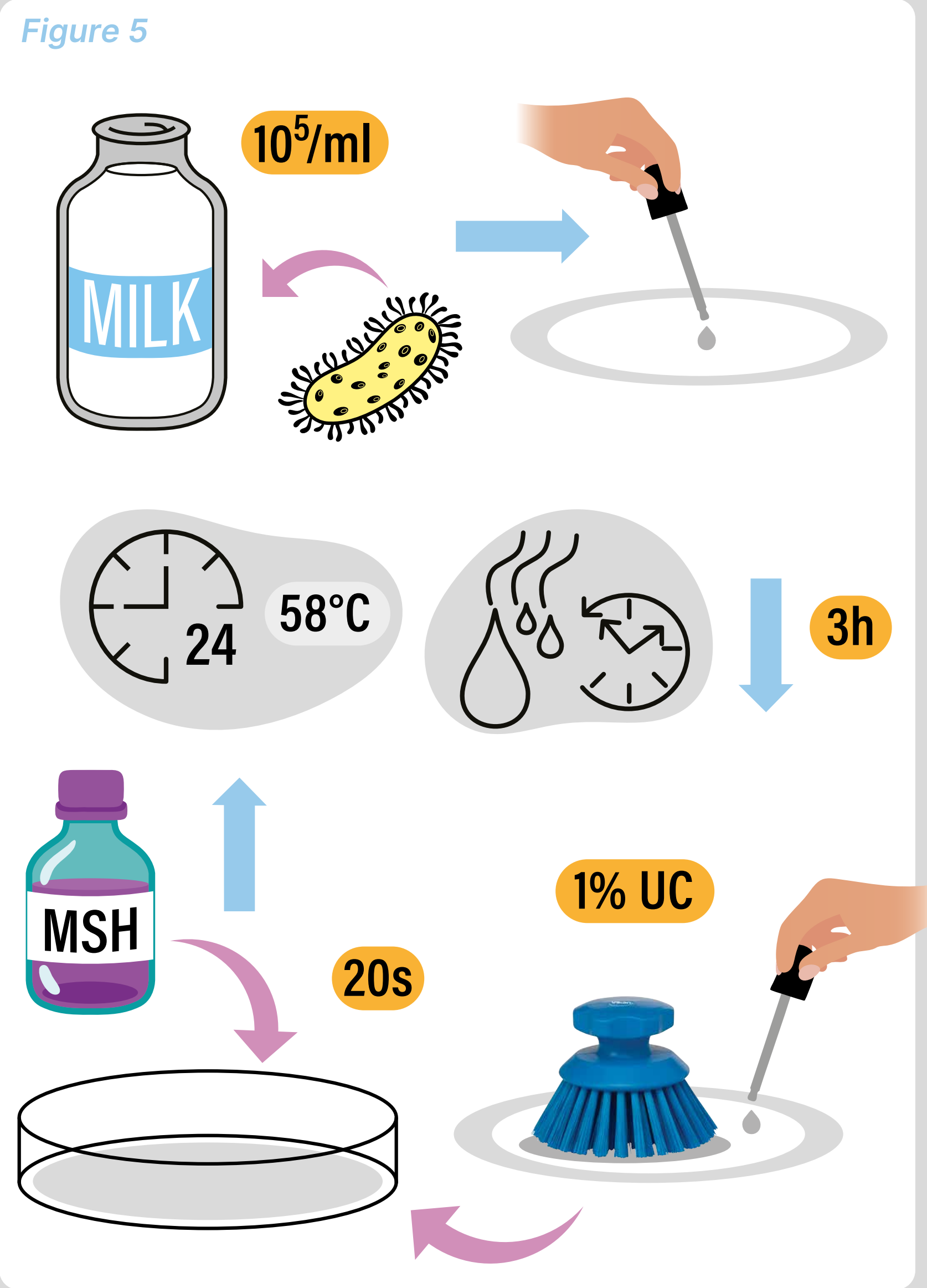


Figure 5 – *Procedure for evaluating cleanability, by soiling FCSs with innoculated buttermilk (Geobacillus stearothermophilus, GB, spores), drying for 3 hours and brush cleaning for 20s with detergent (1% universal cleaner, UC). Cleaned FCSs were incubated in Modified Shapton Hindes (MSH) agar overnight at 58°C.*

Results & Discussion

FCS cleanability and surface roughness measurements indicated the same trend when new; SS had the highest and lowest values, respectively; PP was the opposite to this, and HDPE was in between, or near one of the two (Figure 2). Evaluating change in cleanability between new and used surfaces (1 vs. 90 abraisions), the results indicated a significant loss in cleanability of stainless steel, a significant increase for polypropylene, and no significant change in cleanability of high-density polyethylene (Figure 3).

Surface Cleanability Results
The results in Figure 2 indicate that only dry abraision of stainless steel surfaces significantly decreased the cleanability as well as the peak density within the evaluated period of abraision and that PP surfaces were more significantly impacted by dry abraision. HDPE did not seem to be affected and all surfaces showed no change in standard surface roughness. These results suggest that dry abraision potentially impacts surfaces more than wet abraision, but further analysis over a longer period of abraision would need to be conducted to make any firmer conclusions.

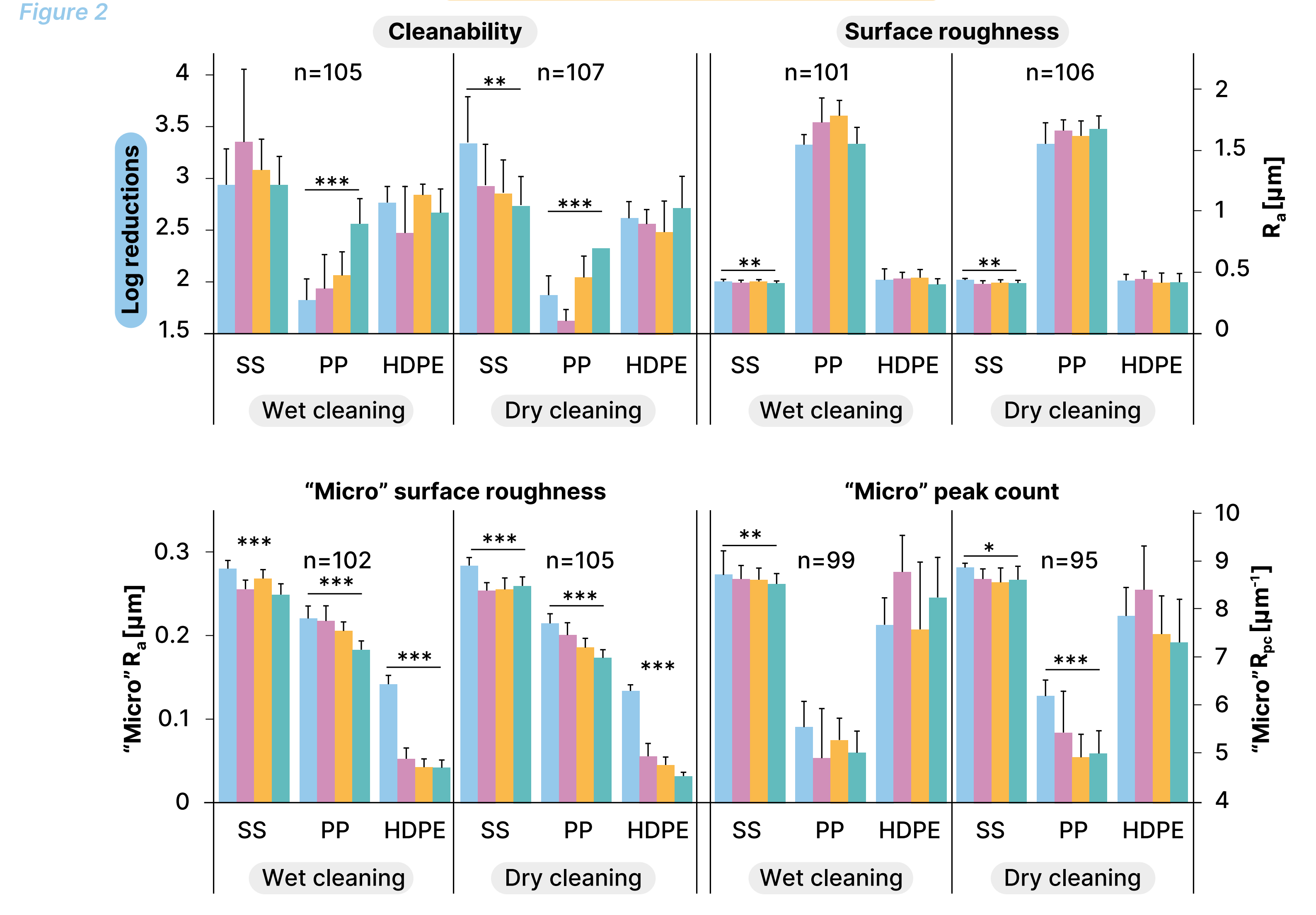


Figure 2 – *Presentation of cleanability and surface roughness (R_a) at 0.8 µm evaluation length (λc), as well as "micro" R_a and peak density (R_{pc}) with narrowed λc of 25 µm of the tested Food Contact Surfaces (FCSs) during the abraision period (1 , 30, 60, 90 brush rotations) as bar plot with associated standard deviation, divided by dry/wet abrasion between evaluations (*: p<0.05, **: p<0.01, ***: p<0.001). SS: Stainless steel, AISI 304, 2B treated; PP: Poly-propylene; HDPE: High-Density Polyethylene.*

R_a Assessment
The results from "micro" surface roughness clearly indicate that brush abraision does have an abrasive effect on the surfaces, especially for HDPE, but this does not affect other measured surface characteristics. Surface roughness (R_a) ends up with a slightly stronger negative correlation (R_a) of -0.67, compared to "micro" peak count (R_{pc}) with positive R^2 of 0.62. This does support the current believe that lower R_a correlates with higher cleanability, though not enough to support it being the primary cause.

Figure 3 highlights the partial correlation between surface cleanability and surface roughness, but also how this correlation differs between the tested FCSs, with opposite correlations for SS & HDPE and PP. The results show no clear correlation between bristle stiffness and change in surface characteristics.

Multiple linear regression was also performed (data not shown). Evaluating the overall model fit, the combination of variables did significantly improve the overall correlation to cleanability with an adjusted R^2 of 0.62. However, the residual standards error of 0.13 indicates that predicted values of cleanability using this model are attached with an uncertainty of ± 0.92 log reductions (95 % CI), which significantly limits the value of the model presented.

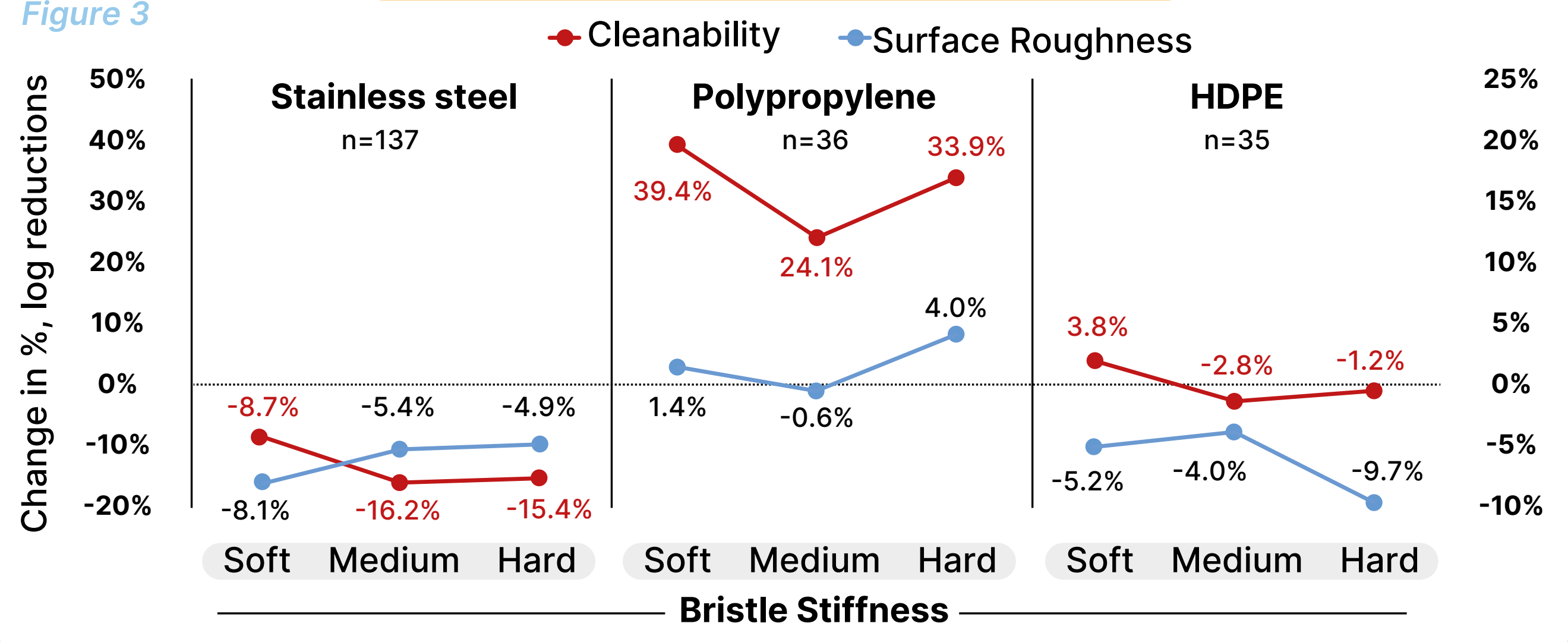


Figure 3 *–*
Presentation of change (%) in cleanability and surface roughness (R_a) of the tested FCSs during the evaluated abraision period (1 vs. 90 abrasion cycles), divided by bristle stiffness. The percentage indicates the change in mean values.

HDPE: High Density Polyethylene.

Conclusions

The study provides valuable insights into the cleanability of food contact surfaces, over repeated abraision cycles. The findings challenge the conventional belief that a lower surface roughness always correlates with higher cleanability, highlighting the complex relationship between surface characteristics and cleanability, and suggests that other unknown factors influence the cleanability of a surface.

The study shows no clear correlations between bristle stiffness and changes in cleanability nor surface roughness for any of the FCSs tested. All brushes show the same degree of abrasion by decrease in "micro" roughness on all FCSs.

Despite no significant changes in surface roughness between wet/dry abraision, cleanabiltiy results indicate that dry cleaning does impact the FCSs more, especially stainless steel.

Surface topography alone cannot predict cleanability While established multiple linear regression models, including both roughness and peak count improved the correlation to cleanability (R^2: 0.62), compared to simple regression, the uncertainty in predicted values highlights one or more missing variables which makes proper predictions on cleanability challenging.

Further work is needed It is recommended to conduct long-term studies with more abraision cycles to better understand the durability and cleanability of different materials. Additionally, investigating other potential factors influencing cleanability, such as chemical composition and environmental conditions, would be beneficial. Finally, examining the impact of different cleaning methods (wet vs. dry) over extended periods would help draw more definitive conclusions.

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