WHITE PAPER

The Hygienic Design of Food Industry Brushware

- the good, the bad and the ugly

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INTRODUCTION:

Cleaning is a critical step in the management of food safety. Consequently, the correct selection of cleaning equipment by the food manufacturing and food service industries is essential to minimise the risk of product contamination, and aid compliance to relevant regulatory, guidance and standard requirements.

Thanks to organisations like the European Hygienic Engineering Design Group (EHEDG), and 3-A Sanitary Standards Inc. (3-A SSI), many food manufacturers already appreciate the benefits of using hygienically designed production equipment. Hygienically designed equipment is quicker and easier to clean, and minimises the risk of product contamination by microbes, allergens, foreign bodies etc. This in turn maximises food safety and quality, reduces the risk of expensive product rejection or recall, and minimises food waste. However, when it comes to the equipment used to clean food production equipment, very few cleaning tools are developed with good hygienic design in mind. Consequently, their use can jeopardise all of the above.

Cleaning equipment are recognised as a major 'collection' point for the isolation of pathogens. Unpublished data from Campden BRI, used to establish guidance on 'Effective microbiological sampling of food processing areas'[1], showed that *Listeria monocytogenes* was rarely present on food processing equipment, 17% of the swabs taken from floors and 25% of those taken from drains were positive for *L. mono*, maybe not unexpectedly, but more surprisingly and worryingly, 47% of the cleaning equipment sampled was positive for the organism *(pers comm. Holah, 2015).*

Once contaminated, the cleaning equipment itself can then become a 'vector' of contamination, i.e. it can spread the contamination around the environment, increasing the subsequent risk of cross-contamination to the food.

Additionally, equipment that is likely to come into contact with food and food contact surfaces should be constructed of materials that do not pose a risk to the consumer. This includes the risks posed by the migration of harmful chemicals and that from foreign bodies. It is therefore essential that cleaning equipment is made of food safe materials and constructed in such a way so that these risks are minimised.

Investigations conducted by Vikan indicate that much of the cleaning equipment currently used in the food industry is of poor hygienic design, therefore increasing the risk of cross-contamination. Clearly the application of good hygienic design criteria would help minimise this risk.

The importance of using cleaning equipment of good hygienic design has been recognised for some time now by two of the largest Global Food Safely Initiative (GFSI) benchmarked schemes, i.e., BRCGS and FSSC 22000.

BRGCS: Sections 4.11.6 & 8.5.3
'Cleaning equipment (including that used for cleaning in high-care and high-risk areas) shall be:- *hygienically designed* & fit for purpose,...' [2]

FSSC 22000: ISO/TS 22002-1:2009, Part 1. Section11.2 Cleaning and sanitizing agents and tools - 'Tools & equipment shall be of *hygienic design*....' [3]

This paper provides a summary of information, with regard to hygienic equipment design criteria, and illustrates, thorough the use of examples, good and bad hygienic design of food industry brushware.

HYGIENIC DESIGN CRITERIA:

European Hygienic Engineering Design Group (EHEDG) hygienic equipment design criteria

Founded in 1989, the EHEDG is a consortium of equipment manufacturers, food industries, research institutes and public health authorities that aims to promote hygiene during the processing and packing of food products. The principal goal of EHEDG is the promotion of safe food by improving hygienic engineering and design in all aspects of food manufacture. For more information please visit URL:http://www.ehedg.org.

EHEDG actively supports European legislation, which requires that handling, preparation processing, and packaging of food is done hygienically using hygienic machinery, in hygienic premises (EC Directive 2006/42/EC for Machinery [4], EN 1672-2 [5] and EN ISO 14159 [6] Hygiene requirement).

EHEDG Guideline Document 8 'Hygienic Equipment Design Criteria'[7], and Document 32 'Materials of construction for equipment in contact with food'[8] provide some hygienic equipment design criteria, i.e. equipment should be/have,

- free of crevices and contamination traps e.g. use of smooth welds, absence of small holes, recesses, and sharp internal angles
- a smooth surface finish (R_a < 0.8µm)
- easy to clean (and dry) e.g. quick and easy to dismantle/re-assemble, or of one piece construction, or with easy access to all areas for cleaning and disinfection
- made of food safe materials e.g. no wood or glass, non-toxic
- well constructed e.g. durable, no foamed materials, not painted or coated
- non-absorbent
- appropriately temperature and chemical resistant.

The EHEDG logo.

3-A Sanitary Standards, Inc. (3-A SSI)

The 3-A Sanitary Standards organisation is the more senior American equivalent to EHEDG, with the first 3-A Sanitary Standards for the advancement of food sanitation and hygiene being developed in the late 1920s. 3-A Sanitary Standards, Inc. (3-A SSI) was incorporated into the organisation in late 2002. The five Founding Members include the American Dairy Products Institute (ADPI), the International Association of Food Industry Suppliers (*IAFIS) the International Association for Food Protection (IAFP), the International Dairy Foods Association (IDFA), and the 3-A Sanitary Standards Symbol

Administrative Council. Additionally, leadership of 3-A SSI includes the Food & Drug Administration (FDA), the U.S. Department of Agriculture (USDA), and the 3-A Steering Committee. *IAFIS is now the Food Processing Suppliers Association. For more information please visit URL:http://www.3-a.org/.

This non-profit organisation encourages the development of voluntary standards and accepted practices with regard to hygiene within food manufacturing. It also oversees the 3-A Symbol, used to identify equipment manufactured to 3-A Sanitary Standards, as part of its Third Party Verification (TPV) program.

The mission of 3-A SSI is to enhance product safety for consumers of food, beverages, and pharmaceutical products through the development and use of 3-A Sanitary Standards and 3-A Accepted Practices. The criteria used by 3-A for hygienic design are similar to those stated by EHEDG.

The Symbol of Assurance

The 3A logo.

The European Brushware Federation (FEIBP) Charter

In 1995 the FEIBP established a Professional Hygiene Brush (PHB) Working Group to formulate an FEIBP Charter defining criterias for Professional Hygiene Brushware (PHB).

All brushware bearing the FEIBP PHB logo (Figure 1), which is officially registered as an EU collective trademark under no. 010919132, are manufactured to the criteria set out in the FEIBP Charter [9] (see Appendix 1 for the relevant parts of the Charter with regard to this study).

Figure 1. The FEIBP PBH charter logo.

HYGIENIC DESIGN ASSESSMENT OF FOOD INDUSTRY BRUSHWARE:

There are currently four established manufacturing processes for brushware commonly used by the food industry - Drilled and stapled; resin set; drilled and stapled resin set; and fused bristle. In 2015 Vikan introduced a fifth option, it's Ultra Safe Technology (UST) brushware. Vikan has investigated these five brushware options, with regard to hygienic design, using microscopy and Ultra Violet (UV) sensitive lotion (as a contaminant). The samples were also assessed against established hygienic equipment design criteria.

Methods

Drilled and stapled, drilled and stapled resin set, and UST samples were investigated using a Leica M80 stereo-microscope and a Zeiss Evo 60 scanning electron microscope (courtesy of Campden BRI; Gloucestershire, UK).

Additionally, drilled and stapled, resin set, and fused brushware samples were smeared with UV reactive lotion. Figures 2a shows a drilled and stapled brush 'contaminated' with UV lotion. Figure 2b shows the same 'contaminated' brush as seen under UV light.

Figure 2a. 'Contaminated' brush.

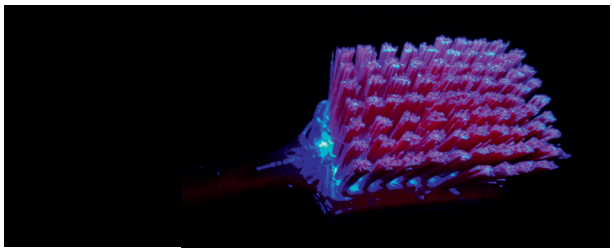

Figure 2b. 'Contaminated' brush as seen under UV light.

The samples were then cleaned by vigorous dunking in and out of warm soapy water and then shaking to remove excess water (Figures 3a – c).

Figures 3a – 3c. Brush cleaning by vigorous dunking in and out of warm soapy water.

The samples were then visually examined in a UV cabinet to assess the extent of any remaining 'contamination' (cleanability assessment) and visualise any contamination traps.

The hygienic design features of each type of brushware were compared against EHEDG hygienic equipment design criteria [7], and the FEIBP PHB Charter [9]. Both sets of guidance are written with due regard to the European [10,11,12], and FDA [13] regulatory requirements. Consequently, comparison of the different brush types to this guidance provides a good method by which to assess their overall hygienic design.

RESULTS:

Drilled and stapled brushware

Drilled and stapled brushware, as the name suggests, is constructed by drilling holes into a solid plastic block and then stapling bristles into the holes.
Figure 4a shows the drilled and stapled brush sample. Figure 4b shows an image of the bristle bundles in the drilled and stapled brush when examined under the light microscope.

Figure 4a. Drilled and stapled brush sample.

Figure 4b. Light microscope image of the area where the bristles enter the brush head.

Figures 4c and 4d show images of the bristle bundles when examined using the scanning electron microscope. Figure 4c shows the gap that exist between the brush block and the bristles when the bristles are fixed into the drilled holes. Figure 4d shows the gaps between the bristles, and the depth that these gaps extend to within the brush block.

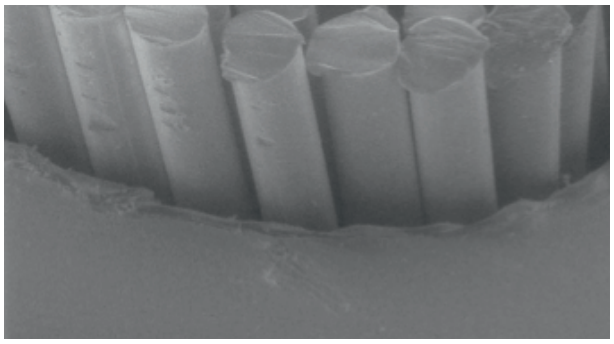

Figure 4c. Scanning electron microscope image showing the gap between the brush block and the bristles.

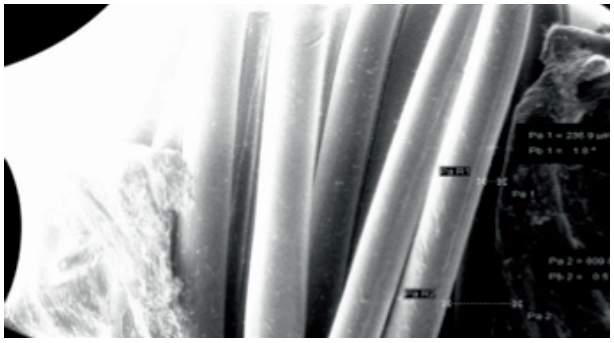

Figure 4d. Scanning electron microscope image showing the gaps between the bristles, and the depth that these gaps extend to within the brush block.

Figures 5a and 5b show the location of UV lotion (contamination) after the drilled and stapled brush had been cleaned. Figure 5a shows UV lotion trapped between the brush block and the bristles in the drilled holes. Figure 5b shows a cross-section of one of the drilled holes revealing residual UV lotion lining the hole within the brush block. Drilled hole depth approximately 10 mm.

Figure 5a. Drilled and stapled brush after cleaning. UV lotion trapped in the drilled holes.

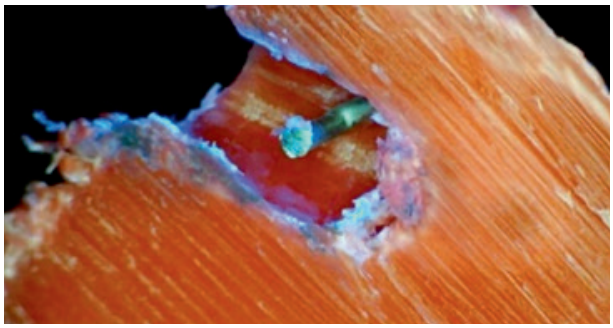

Figure 5b. Vertical cross-section of a drilled hole containing residual UV lotion after brush cleaning.

Resin set brushware

Resin set brushware is constructed by setting bundles of bristles into a liquid epoxy resin. The resin is usually formed by mixing two component chemicals that then react to cause the resin to set. The mixed liquid resin is poured into a well in the brush head and the bristles are then inserted and held in position until the resin has set.

Figure 6a shows the resin set brush sample and the potential contamination traps created by the ridges and wells of the brush construction. Figure 6b shows a vertical cross-section of the resin set brush showing the way the bristles are fixed into the resin and how the resin sits within the hollowed out brush block.

Figure 6a. Resin set brush sample with potential contamination traps.

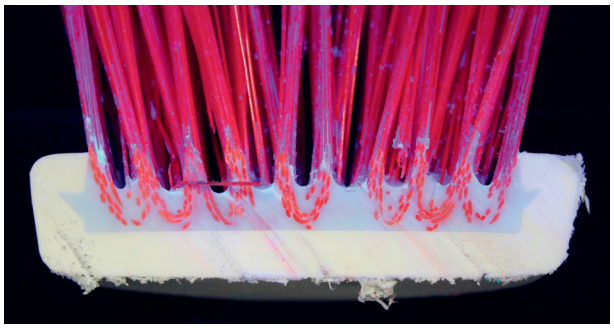

Figure 6b. Vertical cross-section of resin set brush showing how the bristles are fixed and how the resin sits within the brush block.

Figure 6c shows the location of the UV lotion remaining on and in the brush block after the brush has been cleaned. Figure 6d is an image of a resin set bristle bundle. It can be seen that the resin forms a good seal around the bristles, thus preventing 'contamination' ingress into the resin, but that the way the bristles are set in the resin forms a contamination trap where the UV lotion has been retained even after brush cleaning.

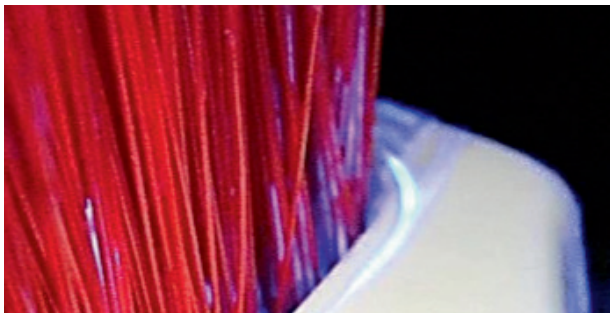

Figure 6c. UV lotion remaining on and in the brush block after brush cleaning.

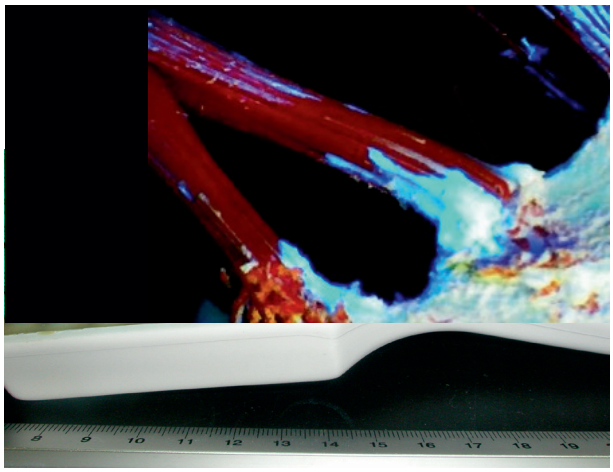

Figure 6d. Image of 'contaminated' resin set bristle bundle after brush cleaning.

Drilled and stapled resin set brushware

Drilled and stapled resin set brushware utilise a combination of the drilled and stapled and resin set methods described above.

Figure 7a shows the drilled and stapled resin set brush sample. Figure 7b shows two of the bristle bundles in this brush when examined under the light microscope. Figure 7c shows the scanning electron microscope image of one of these bristle bundles.
It can be seen that the resin forms a good seal around the bristles on the outside of the bundle.

Figure 7a. Drilled and stapled resin set brush sample.

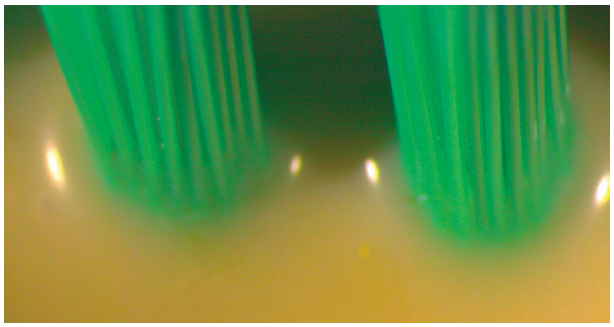

Figure 7b. Light microscope image of the area where the bristles are fixed into the brush head.

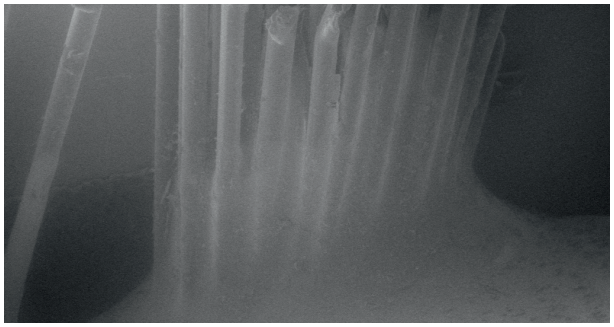

Figure 7c. Scanning electron microscope image of a drilled and stapled resin set bristle bundle. The resin forms a good seal around the bristles on the outside of the bundle.

Figure 7d is a light microscope image of a vertical cross-section of a drilled and stapled resin set bristle bundle. This image clearly shows that the resin fails to seal the bristles at the centre of the bundle and that the incorporation of a staple generates a channel into the brush head that is a potential contamination trap. Channel depth approximately 6 mm.

Figure 7d. Light microscope image of a vertical cross-section of a drilled and stapled resin set bristle bundle showing a potential contamination trap.

Fused bristle brushware

It was not possible to determine exactly how the fused bristle brushware is constructed however it appears that the bristles are heat fused into a bundle which is in then either inserted in to or over-moulded with a foamed plastic block.

Figure 8a shows the fused bristle brush sample. Figure 8b shows a close up image of the area where the bristles are fixed into the brush block and the resultant potential contamination traps.

Figure 8a. Fused bristle brush sample.

Figure 8b. Image of the area where the bristles enter the brush head.

Figure 8c shows an image of the back of the brush, which has a poor surface finish. Closer inspection of the brush surface shows the presence of numerous surface defects all of which are potential contamination traps (Figure 8d).

Figure 8c. Back of the fused bristle brush, poor surface finish.

Figure 8d. Close up image of the surface of the fused bristle brush - potential contamination traps.

Figure 9a shows the UV lotion remaining on the fused brush product after brush cleaning. Contamination traps at the base of the bristle bundles, and around the areas where the bundles are fused into the brush block are clearly evident. Much of the UV lotion has also been retained by the surface of the brush due to the poor surface finish (Figure 9b).

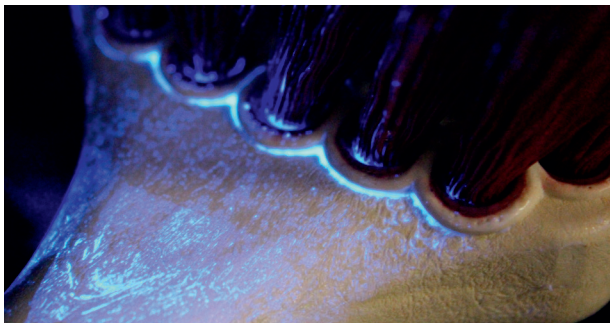

Figure 9a. UV lotion remaining on the fused brush product after brush cleaning.

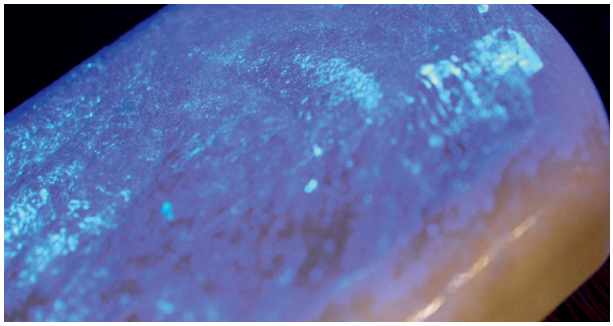

Figure 9b. UV lotion retained by the brush surface - poor surface finish.

Vikan Ultra Safe Technology (UST) Brushware

Most recently Vikan have launched a series of new food industry brushware products that have been developed using good hygienic design principles including; being of fully moulded construction - to minimise the presence of crevices; having a smooth surface finish with no acute internal angles – to aid cleanability; and utilising a new way of securing the bristles – to minimise the risk of foreign body contamination. An example of this 'Ultra Safe Technology' (UST) brushware is shown in Figure 10a.

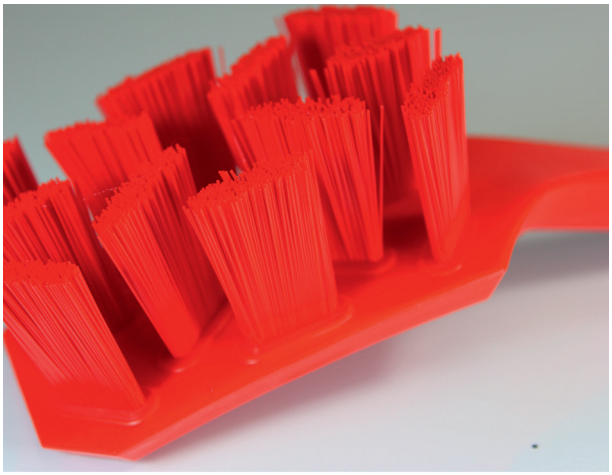

Figure 10a. Vikan UST hand scrub brush.

Figure 10b shows a light microscope image of the area where the bristles enter the brush head.

Figure 10b. Light microscope image of the area where the bristles enter the brush head.

Figure 10c shows a scanning electron microscope image of the area where the bristles enter the brush head. The construction of the UST brush minimises the gap between the bristles and the brush block where they enter the brush head, in contrast to those seen for the drilled and stapled, and fused bristle brushes.

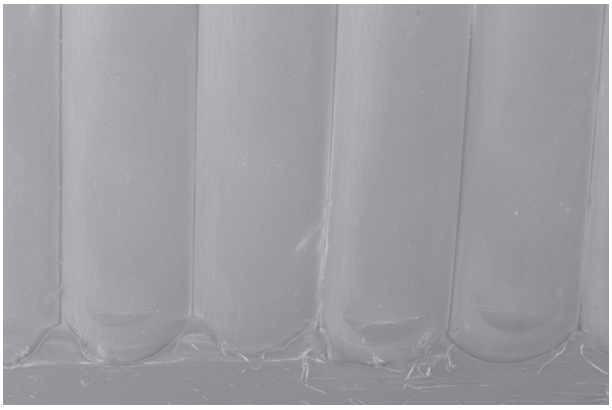

Figure 10c. Scanning electron microscope image of the area where the bristles enter the head of a UST brushware product.

Figure 10d shows a vertical cross-section through a Vikan UST brush bristle bundle. Bristle recess depth approximately 2.5mm. It also shows the UST brushes fully moulded construction.

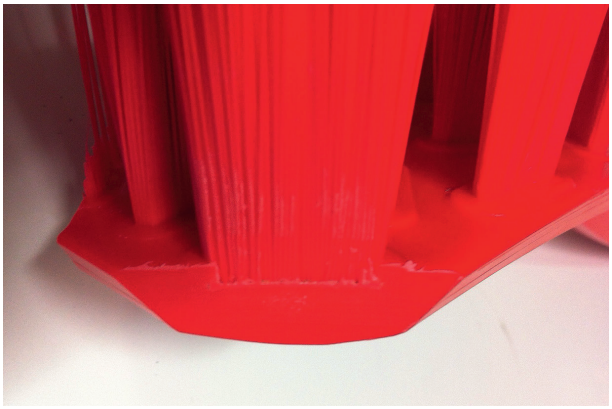

Figure 10d. Vertical cross-section through a UST bristle bundle showing its fully moulded construction.

ASSESSMENT OF BRUSHWARE AGAINST EHEDG HYGIENIC EQUIPMENT DESIGN CRITERIA AND THE FEIBP PHB CHARTER:

The hygienic design features of each type of brushware were compared to the EHEDG and FEIBP PHB guidance. The results of these comparisons, when taken together with the results of the microscopic and UV lotion investigations, enabled the different brushware to be ranked with regard to their overall hygienic design, see Table 1.

Table 1. Sample overall hygienic design ranking.

Sample	Overall hygienic design ranking	Compliance to EHEDG hygienic equipment design criteria [7], and the FEIBP PHB Charter [7]. (See Key below)
UST brushware	1	*1, **2, 3, ***4, 5, 6, 7, 8, 9, 10, 11, ****12 *fully moulded, no sharp internal angles, minimal number and depth of crevices. **R_a < 0.8µm. ***all components FDA and EU compliant. ****In-mould food grade labeling. Scratch, flake, chemically and thermally resistant.
Drilled and stapled brushware	2	**2, ***4, 5, 6, 7, 8, 9, 10, 11, *****12 ** R_a < 0.8µm. *** all components FDA and EU compliant *****Plasma printed using food grade inks. Scratch, flake, chemically and thermally resistant.
Drilled and stapled resin set brushware	3	2, ******4, 5, 6, 7, 8, 9, 10, 11,12 ****** Resin component FDA compliant only 'to the best of (the manufacturers) knowledge'.
Resin set brushware	4	2, 5, 6, 7, 8, 9, 10, 11
Fused bristle brushware	5	4, 6, 7, 8, 9, 10, 11

KEY

1 - 5 EHEDG criteria 4, 6 & 7 EHEDG criteria and FEIBP PHB Charter 8 - 12 FEIBP Charter

1. free of crevices and contamination traps e.g. use of smooth welds, absence of small holes, recesses, and sharp internal angles
2. a smooth surface finish R_a < 0.8mm
3. easy to clean (and dry) e.g. quick and easy to dismantle/re-assemble, or of one piece construction, or with easy access to all areas for cleaning and disinfection
4. made of food safe materials e.g. no wood or glass, non-toxic
5. well constructed e.g. durable, no foamed materials, not painted or coated
6. non-absorbent
7. appropriately temperature and chemical resistant
8. components must not contain chlorine
9. additives, inc. colourants, must be food grade of a recognised standard and must not contain lead, mercury, or cadmium
10. no hollow or flagged fibres allowed
11. brush filling material retention must be by means of oxidation-proof wire, recognised food grade standard epoxy resin, or through fused construction
12. product markings must use the best technical and hygienic methods possible.

DISCUSSION:

Based on these investigations it is evident that drilled and stapled, resin set, drilled and stapled resin set, and fused bristle brushware all have hygienic design issues.

The fused bristle brush is of particularly bad hygienic design, having crevices and contamination traps, but additionally being of foamed plastic construction (less durable and more difficult to clean if damaged due the exposure of the honeycomb-like foamed material inside) and having a very poor surface finish, also making it very difficult to clean.

The resin set brush is of poor hygienic design with regard to the ridges and recesses, created by the construction of the brush head, and the looped configuration of the bristles. All of these features were seen to trap contamination.

The construction of the drilled and stapled brush is much less convoluted, and the relatively large size of the drilled holes allows for easier decontamination, if appropriate cleaning, disinfection and drying methods are used. By contrast the narrowness, depth and inaccessibility of the crevices seen in the drilled and stapled resin set brush could make them more difficult to decontaminate.

Additionally, the drilled and stapled brush is made entirely of materials that are both EU and FDA food contact compliant (specific supporting documentation available), and is all of one colour. The only specific information available at the time of the study, with regard to the food contact compliance of the drilled and stapled resin set brush, was a letter from the manufacturer stating that the resin used in its construction is FDA compliant ‘to the best of (the manufacturers) knowledge’. And, although later

version of this particular brush are now available with matching coloured block and filaments, the resin used still remains 'nude' in colour meaning that its visual detection in food products would be very difficult should it fracture and break off. Other resin-set brushes currently on the market state that 'The two component resin is not approved for direct contact with food'.

The Vikan UST brushware was compliant with all of the listed hygienic design criteria. Consequently, overall, the UST brushware was assessed as being of the best hygienic design, when all of these criteria are taken into consideration.

As previously mentioned poor hygienic design of cleaning equipment can increase the risk of food product cross-contamination by microbes, allergens, and foreign bodies. As a result of the horse-meat scandal in 2013, the Food Standards Agency, UK, established a limit of 0.1% raw pork in raw beef, on a weight for weight (w/w) basis, based on the findings of a project to establish whether carry-over of meat species occurs in UK meat processing plants during the GMP production of minced meat [14]. This precedent may very well be applied to other forms of food residue cross-contamination by, for example, non-halal, or non-kosher foods, GMO foods, meat residues in vegetarian products etc. Additionally, with increased focus and legal requirements related to the control of food allergens, standards of cleanliness in these areas will be under scrutiny. This, together with GFSI scheme requirements for cleaning equipment to be of hygienic design, means that there will be a need to employ effective and hygienically designed cleaning equipment to help maximise removal of contamination and food debris, minimise the risk of cross-contamination, and comply with audit requirements.

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APPENDIX 1:

FEIBP Charter (as relevant to this study)

1. DEFINITION FOR HYGIENE BRUSHWARE

These are products from the brushware sector which are intended for use in any food business (which includes preparation, processing, manufacturing, packing, storing, transportation, distribution, handling or offering for sale or supply, see COUNCIL DIRECTIVE 93/43 ECC 14 th June 1993[14]) or other hygienically sensitive areas such as hospitals, etc. The products are characterised by the fact that they are constructed in such a way, and of such materials, that they will not, in themselves absorb bacteria or contaminate any food stuffs or sensitive areas during their normal use. The materials should be corrosion proof and non-toxic, and the products should be able to withstand sterilisation or disinfection by other processes, including chemical treatment.

2. SPECIFICATIONS OF BRUSHES, HANDLES AND SQUEEGEES

2.1 Brush Components

The brush components must be made of materials resistant to solvents, chemical cleaning agents and temperatures required for disinfection. The components must not contain Chlorine. Any additives/compounds or colourants must be food grade of a recognised standard, and must not contain lead, mercury or cadmium. No hollow or flagged fibres are to be allowed.

2.2 Brush filling material fixing

The brush filling material retention must be by means of either wire (which cannot be attacked or made brittle by oxidisation) and/or by means of epoxy resin, which is made up of food grade components of a recognised standard, or of fused construction.

2.6 Marking/identification

All marking of the products must be carried out by the best technical and hygienic methods possible, prescribed or not.