



COMPARISON OF PHYSICAL AND MICROBIOLOGICAL CHARACTERISTICS OF SELECTED CLINICAL SWABS

Kathryn Harry, Julie C. Turner, Denene Lofland, and Kunapuli T. Madhusudhan
CET, LLC., Winston-Salem, NC USA

Katie Harry, M.S.
CET, LLC
101 N. Chestnut St., Suite 101
Winston-Salem, NC 27101
336-397-1900 (Main)
336-397-1911 (Fax)
khharry@cleanearthtech.com

Abstract

Introduction: Diagnostic sensitivity varies with the number of cells collected and released by swabs as the swab fibers are in direct contact with the organisms. An ideal swab system has the ability to absorb organisms from the infection site and release them into the test system. The purpose of this study is to determine the physical and microbiological characteristics of Nylon Flocked, Rayon Flocked, HYDRA flock and Macrofoam swabs of Puritan Medical Products and the Nylon Flocked swab of Copan Diagnostics.

Methods: Whole swabs were placed in water or a protein solution and the weight gain determined to compute percent absorption. The absorption of swab-tip material was determined to evaluate if absorption was the result of material alone. Ability of swabs to collect and release bacteria was evaluated in a model system by immersing swabs in a polystyrene bead suspension with or without washing. The ability of swabs to collect and release microorganisms was studied by using suspensions of *S. aureus*, *S. pneumoniae*, *S. pyogenes*, *H. influenzae*, *N. gonorrhoeae*, *B. fragilis*, and *P. anaerobius*.

Results: Water and protein absorption capacities of whole swabs ranged from 14% to 21% with the HYDRA flock swab exhibiting the highest absorption capacity. Highest water absorption capacity of swab tip material was seen with Macrofoam followed by Rayon Flocked. HYDRA flock swabs collected beads more efficiently in the simulation study, although the fractional release of beads was comparable to or less than other swabs. Statistical analysis (ANOVA) of the recovery of all bacterial species demonstrated the highest recovery with the HYDRA flock swab (69%), followed by Macrofoam (62%), Rayon Flocked (60%), Nylon Flocked (57%), and Copan's Nylon Flocked (53%). The recovery of all Gram-negative bacteria was significantly higher than Gram-positive bacteria.

Conclusions: The results of the study demonstrated the overall superiority of Puritan Medical Products' HYDRA flock swab over other swabs and its potential to increase the diagnostic sensitivity of clinical tests by collecting and releasing a significantly larger number of bacteria.

Materials and Methods

Swabs

Puritan Medical Products	Copan Diagnostics
Nylon Flocked	Nylon Flocked
Rayon Flocked	
HYDRA flock	
Macrofoam	

Absorbance studies

Water and protein absorption of entire swab

- Swab (N=3) was immersed in 1 mL of distilled water or 22% bovine serum albumin for 15 sec and percent water or protein absorption was determined after weighing the wet swab.

Water absorption of swab head material

- Using a scalpel blade, swab head material was removed from the swab shaft (N=8), transferred into a pre-weighed 1.7 mL tube and 1 mL of distilled water was added. To facilitate water absorption, tubes were shaken for 1 min at room temperature.
- To remove the unbound water, tubes were centrifuged and excess water was removed to determine percent water absorption.

Scanning electron microscopy (SEM) measurements

To simulate the collection of bacteria

- Swab tips were placed in a 1% polystyrene bead suspension (Microbead, 1 µm), then removed and air-dried.
- To measure the release of bacteria in the same model system, swab tips adhering polystyrene beads (as before) were placed in 2 mL of distilled water, vortexed at high speed for 10 sec, and air-dried. SEM images of untreated swabs were also done to record the surface morphology.
- A Hitachi S-3200 Variable Pressure SEM was used to obtain electron micrographs after each sample was subjected to critical point drying and gold-palladium sputtering, using a DC plasma sputtering machine (Pathan *et al.*, 2008).

Culture studies

- The CLSI document M40-A (CLSI, 2003) served as a guide for culture studies.
- Bacterial cell suspension equivalent to 0.5 McFarland in 0.85% sterile saline was prepared and diluted to ~10⁷ CFU/mL.
- The test swabs (N=10) were immersed in the diluted bacterial suspension, and cultured on appropriate media after necessary dilutions to obtain recovery.

$$\text{Recovery (\%)} = \frac{\text{Dilution Factor} \times A}{\text{Dilution Factor} \times B \times C \times D} \times 100$$

A = Number of bacteria recovered (CFU/mL)
B = Number of viable organisms in the starting culture (CFU/mL)
C = Average water absorption capacity of the swab (mL)
D = Average dry weight of swab (g)

Materials and Methods (continued)

Table 1. Summary of organisms, media, and culture conditions used in the study.

Organism	Culture Medium	Culture Conditions
<i>Staphylococcus aureus</i> (ATCC 25904) <i>Streptococcus pneumoniae</i> (ATCC 6305) <i>Streptococcus pyogenes</i> (ATCC 19615)	5% Sheep blood agar	37°± 1° C for 18-24 h, 5% CO ₂
<i>Hemophilus influenza</i> (ATCC 49247) <i>Neisseria gonorrhoeae</i> (ATCC 43069)	Chocolate agar	37°± 1° C for 18-24 h, 5% CO ₂
<i>Bacteriodes fragilis</i> (ATCC 25285)	5% Sheep blood agar	37°± 1° C for 18-24 h, anaerobic
<i>Peptostreptococcus anaerobius</i> (ATCC 27337)	5% Sheep blood agar	37°± 1° C for 48 h, anaerobic

Data Analysis

- Statistical analysis of data collected was done by using JMP-7 (SAS Institute, Cary, NC).
- One-way Analysis of Variance (ANOVA) was used to test the equality of several means and to establish the test of significance. The *p*-values were computed and then the test of significance was applied ($\alpha = 0.05$).
- Tukey-Kramer Honestly Significance Different Test ($p \leq 0.05$) was applied to determine which means are significantly different from one another.

Results

Table 2. Absorbance characteristics of swabs.

	Copan	HYDRA flock	Macrofoam	Nylon flocked	Rayon flocked
Water absorption of swab	19.7%	21.5% *	19.8%	19.0%	17.1%
Protein absorption of swab	16.5%	19.6% *	13.6%	18.4%	16.1%
Water absorption of fibers	486%	624%	662% *	606%	558%

* Swab with the highest absorption

HYDRA flock swab exhibited the highest capacity to absorb both water and protein (Table 2). The weight of fibers or macrofoam of the swabs is a small fraction of weight of the swab (<1%), and therefore, water absorption of the whole swab is not a true measure of the physical property. This is evidenced by differences in water absorption profiles between whole swabs and separated swab fibers or foam. Macrofoam swab head material had the highest water absorption capacity (Table 2).

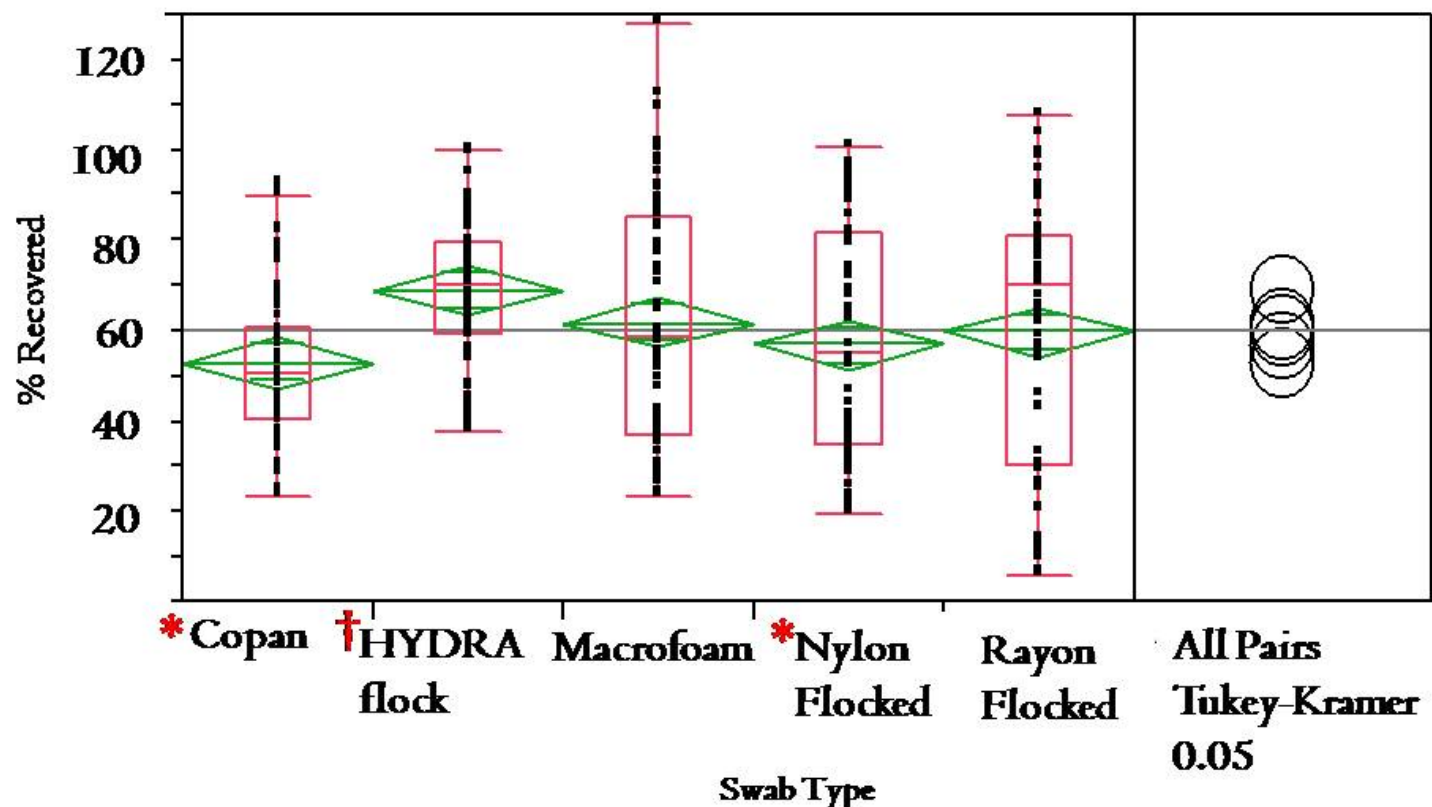
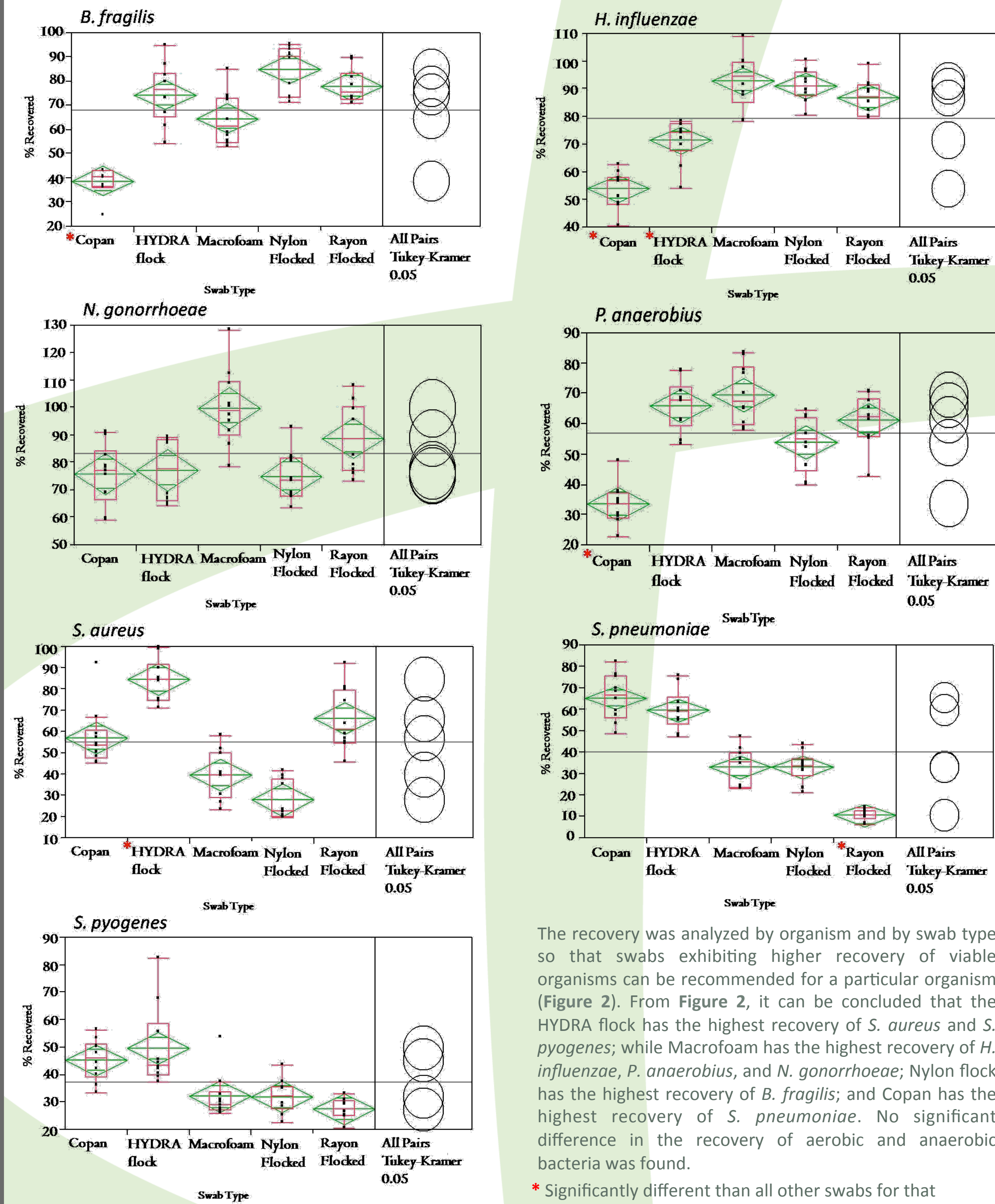


Figure 1. One-way ANOVA (by swab type) of recovery of all bacteria.

The recovery of all bacteria by swab type is shown in Figure 1. One-way ANOVA showed the highest recovery of all viable bacteria with HYDRA flock and the lowest recovery with Copan's Nylon Flocked swab. Macrofoam swab ranked in second place.

* and † are significantly different from each other

Figure 2. One-way ANOVA of recovery of bacteria analyzed by organism.



The recovery was analyzed by organism and by swab type so that swabs exhibiting higher recovery of viable organisms can be recommended for a particular organism (Figure 2). From Figure 2, it can be concluded that the HYDRA flock has the highest recovery of *S. aureus* and *S. pyogenes*; while Macrofoam has the highest recovery of *H. influenzae*, *P. anaerobius*, and *N. gonorrhoeae*; Nylon flock has the highest recovery of *B. fragilis*; and Copan has the highest recovery of *S. pneumoniae*. No significant difference in the recovery of aerobic and anaerobic bacteria was found.

* Significantly different than all other swabs for that organism

Figure 3. One-way ANOVA of recovery of bacteria analyzed by Gram-reaction.

The study consisted of three Gram-negative (*N.gonorrhoeae*, *H.influenzae* and *B. fragilis*) bacteria and four Gram-positive (*P. anaerobius*, *S. aureus*, *S. pneumoniae*, and *S. pyogenes*) bacteria. The results showed that Gram-negative bacteria had significantly higher recovery than Gram-positive bacteria (Figure 3).

* Significantly different

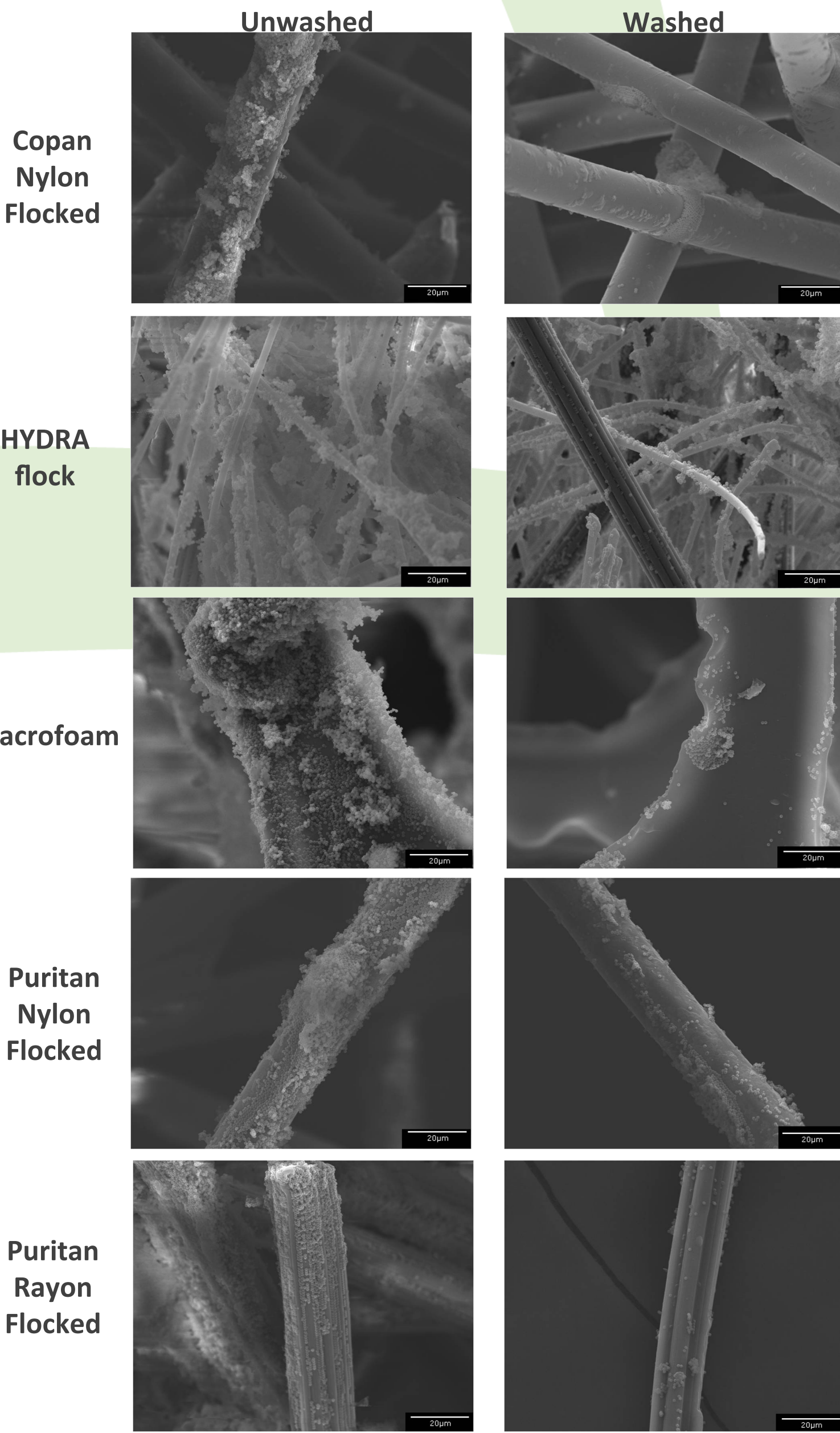


Figure 4. SEM of swab fibers coated in polystyrene beads before and after washing.

SEM measurements

Swabs were dipped in a polystyrene bead suspension and SEM photomicrographs of swab heads were recorded before and after washing (Figure 4) to model capture and release of bacteria. The HYDRA flock demonstrated superior ability to collect beads, although the release of beads was similar to or less than other swabs. The Macrofoam swab was able to release the majority of the beads.

Conclusions

Which swabs performed the best overall?

The **HYDRA flock** swab had the superior performance, based on the following:

- high water and protein absorption capacities
- highest recovery efficiency of various test bacteria

The **Macrofoam** swab was found to recover the second highest amount of test bacteria

How did the swabs rank for recovery of individual test bacteria?

- 1 = lowest amount of recovery
- 5 = highest amount of recovery

	Copan	HYDRA flock	Macrofoam	Nylon flocked	Rayon flocked
<i>B. fragilis</i>	1	3	2	5	4
<i>H. influenza</i>	1	2	5	4	3
<i>N. gonorrhoeae</i>	2	3	5	1	4
<i>P. anaerobius</i>	1	4	5	2	3
<i>S. aureus</i>	3	5	2	1	4
<i>S. pneumoniae</i>	5	4	3	2	1
<i>S. pyogenes</i>	4	5	3	2	1

References

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