

The soluble to the insoluble era: the evolution of hydrocolloid skin barriers through super-absorbent polymers

ABSTRACT

There are many hydrocolloid skin barriers (HSBs) available to ostomy patients, making it difficult to determine the differences among ostomy products and offerings. The materials that are used to formulate the HSB is one perspective to classify different HSB types. Here, I classify HSBs, (traditional, infused, insoluble), based on their materials. Specifically, I focus on the use of the super absorbent polymer (SAP) in the HSB, by measuring fluid management and durability properties. This was conducted by comparing three different HSB products from two different companies. The results show the differences in performance for two different types of SAP, soluble and insoluble (iSAP). I further show how formulating with an iSAP can be optimised with an additional property, such as pH balancing, to create an HSB formulation defined as an iSAP+.

Keywords ostomy product, hydrocolloid skin barrier, super absorbent polymer, classification

For referencing Defante AP. The soluble to the insoluble era: the evolution of hydrocolloid skin barriers through super-absorbent polymers. WCET® Journal. 2025;45(3)28-36.

DOI <https://doi.org/10.33235/wcet.45.3.28-36>

ABBREVIATIONS

CMC – carboxymethylcellulose

FAC – fluid absorption capacity

GATS – gravimetric absorption testing

HSB – hydrocolloid skin barrier

iSAP – insoluble super absorbent polymer

iSAP+ – an HSB formulation comprised of an insoluble, super-absorbing polymer with pH buffering

KOH – potassium hydroxide

MARSI – peristomal medical adhesive-related skin injury

PMASD – peristomal moisture-associated skin damage

PSC – peristomal-skin complications

SAP – super absorbent polymer

TEWL – transepidermal water loss

INTRODUCTION

Living with a stoma presents numerous challenges, and maintaining healthy peristomal skin is among the most critical. Peristomal-skin complications (PSCs) contribute substantially to discomfort, appliance leakage, and diminished quality of life. Reported PSC incidence ranges from 36% to 73%¹ and a

13-country survey of 4227 people with stomas found that 73% experienced a PSC within six months.² These data underscore the need for proactive preventive care, timely stoma care nursing support and evidence-based selection of skin barriers.

Two mechanisms drive most PSCs: Peristomal Medical Adhesive-Related Skin Injury (MARSI) and Peristomal Moisture-Associated Skin Damage (PMASD).^{3,4}

MARSI occurs when the adhesive bonds of ostomy products adhere more strongly to the skin than the cohesion of skin cells to one another.³ This can lead to skin stripping, blisters and tears. Repeated removal of skin barriers may strip away microscopic layers of skin, disrupting the stratum corneum and leaving it vulnerable to further damage.

PMASD develops when moisture, whether from perspiration, transepidermal water loss (TEWL), or stoma output (faecal or urinary) comes into contact with the skin.⁴ The outermost layer of the epidermis, the stratum corneum, maintains an acidic pH of around four, forming an acid mantle that protects skin integrity and defends against bacteria and irritants. However, stoma output is alkaline (pH ~8) and contains digestive enzymes that disrupt this acid mantle, raise skin pH, and damage the epidermis, ultimately leading to PSCs.⁵

Central to contemporary ostomy care is the evolution of hydrocolloid skin barriers (HSBs) designed to protect and preserve skin integrity. HSBs are formulated for their fluid management and adhesive properties by incorporating

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hydrocolloids, including, most recently, super-absorbent polymers (SAPs). SAPs are capable of absorbing and retaining significant amounts of fluid. These materials offer enhanced protection against moisture-induced skin damage. By effectively managing excessive moisture and promoting optimal skin hydration, SAP-integrated hydrocolloid barriers promise improved clinical outcomes, reduced incidence of PSCs and enhanced overall patient experience.

The performance of these absorbent materials plays a vital role in managing peristomal skin health. SAPs have been a foundational material used in the formulation of skin hydrocolloid.^{6,7} These polymers are capable of absorbing large amounts of fluid, 30X to 1000X, relative to their weight. SAPs broadly have the ability to absorb fluid, but there are differences in fluid absorption rate, capacity, and solubility due to SAP type. Taking advantage of these material differences has led to the development of distinct types and generations of HSBs. This paper categorises HSBs according to SAP type origin, capacity and solubility and systematically compares their fluid management, durability and skin health properties. By linking polymer science to clinical performance, we aim to inform evidence-based barrier selection and promote ongoing innovation in ostomy technology.

MATERIALS IN HYDROCOLLOID SKIN BARRIERS

The beginnings of materials solutions for ostomy care

George Deppy, Queen Caroline of Brandenburg-Ansbach, and Margaret White are among the earliest documented individuals to live with a stoma.⁸ In the absence of specialised products, options for managing stomal output were extremely limited. From the 1700s to the 1940s, people often relied on improvised waste collection devices, such as washcloths, metal containers, bags, or sponges, secured with elastic bands.⁹⁻¹¹

One of the first polymeric materials used for skin adherence in ostomy care was gum karaya—a naturally occurring polymer derived from the sap of the *Sterculia urens* tree. Originally used in denture fixatives, gum karaya was introduced to ostomy care in 1952 by Dr Rupert Turnbull, often regarded as the father of enterostomal therapy.¹²⁻¹⁴ Turnbull recognised its absorbent properties as beneficial for managing stomal output. However, karaya’s weak skin adhesion required it to be combined with other polymeric materials (CMC), Poly (methyl vinyl ether-co-maleic anhydride), polyisobutylene) to be effective.¹²

The growing availability of synthetic polymers, driven by mass production in the mid-20th century, enabled the development of more advanced and reliable materials. This innovation marked a turning point in the development of HSBs, explicitly engineered to meet the specific needs of individuals living

with a stoma. Some early examples of HSB formulations using synthetic polymers, such as Stomahesive™, appeared in the 1970s.^{15,16}

Figure 1 shows the evolution of ostomy technology. Solutions to manage life with a stoma consisted of do-it-yourself remedies, using available materials not intended for ostomy care. Today, the design of ostomy care technology mostly consists of an HSB and a waste collection system. The application of polymers has fundamentally changed the development of ostomy care technology, enabling scientists and engineers to design materials with intentional functions.

Polymers in barrier formulation

The two primary attributes of ostomy barrier performance are adhesion to the skin to support a waste collection system and the management of bodily fluids, specifically absorption. To achieve this performance, HSBs are composed of a mixture of hydrophobic and hydrophilic polymers. Hydrophobic polymers are polymers that have poor affinity for water. They mainly provide adhesion to the skin and durability during wear. Polyisobutylene, styrene block copolymer derivatives, and rubbery polymers are examples of hydrophobic polymers used in the formulation of HSBs.^{7,17} Hydrophilic polymers are polymers that have a high affinity for water. They give the HSB the ability to absorb stomal output and manage skin moisture. Most polymers used are derived from natural sources, such as tree sap, wood pulp, or fruit peels. Karaya gum, CMC) and pectin are more specific examples of hydrophilic polymers used in HSBs.^{6,7,17}

Super-absorbent polymers

The hydrophilic polymers used in HSBs can also be called super-absorbent polymers (SAPs). SAPs can be categorised by origin, fluid capacity, or solubility. Figure 2 demonstrates the material properties of two SAPs: CMC and sodium polyacrylate, showing they can absorb large amounts of fluid relative to their weight. SAPs in ostomy care can be sourced from natural sources mentioned previously or produced synthetically. Sodium polyacrylate, polyvinyl alcohol, polyvinylpyrrolidone, and ethylene maleic anhydride are examples of synthetic SAPs.¹⁸

The two fluids used for testing water and 0.9% saline represent the range of ionic strength or salinity that might be found in stoma effluent.¹⁹ CMC absorbs large amounts of water and the type of fluid does not influence its absorption capacity. Sodium polyacrylate absorbs more water compared to saline. This is because the ions in saline can disrupt their ability to bond with water molecules, diminishing their absorption capacity. CMC, therefore, has a lower fluid absorption capacity and range compared to sodium polyacrylate. SAPs can also be categorised

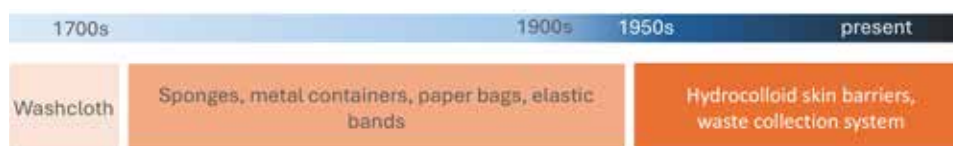


Figure 1. The progression of ostomy care technologies.

by solubility. From these results, SAPs can be characterised by their fluid absorption capacity and versatility.

SAPs can be categorised by their solubility. Solubility is the ability of a polymer to dissolve in a fluid. Soluble SAPs can dissolve, whereas insoluble SAPs (iSAPs) do not. This is due to the chemical crosslinks of iSAPs, which prevent dissolution. Figure 3 shows the visual difference between soluble and insoluble SAPs when dispersed in fluid. The turbidness [e.g. cloudiness or milkiness] of sodium polyacrylate indicates it is an iSAP.

In contrast, the clarity of the CMC placed in a fluid indicates that this polymer dissolves in the fluid. Differences in how much fluid these materials absorb and whether they dissolve (solubility) reveal the differences in the performance of super-absorbing polymers. Different types of hydrocolloid skin barriers are formulated based on variations in these material properties, such as absorption capacity and solubility.

MATERIALS AND METHODS

Materials: Three different brands of HSBs were tested: Nova™ and TRE™ (manufactured by Dansac A/S) and SenSura Mio™ (manufactured by Coloplast A/S). To account for performance and manufacturing variability, three production lots of each brand were tested.

The study selected HSBs differentiated by SAP type to compare within a single brand and between two different brands. This allowed for comparison of the same materials, same brand and comparison of same materials for two different brands. This allowed for comparison of two different materials, different brands.

Methods

Gravimetric Absorption Testing (GATS): 50mg of polymer powder was placed on a glass frit. Fluid was passed through the frit from a reservoir connected to a balance. As absorption occurred, changes in the weight of the fluid source were monitored over time to assess the absorption rate.

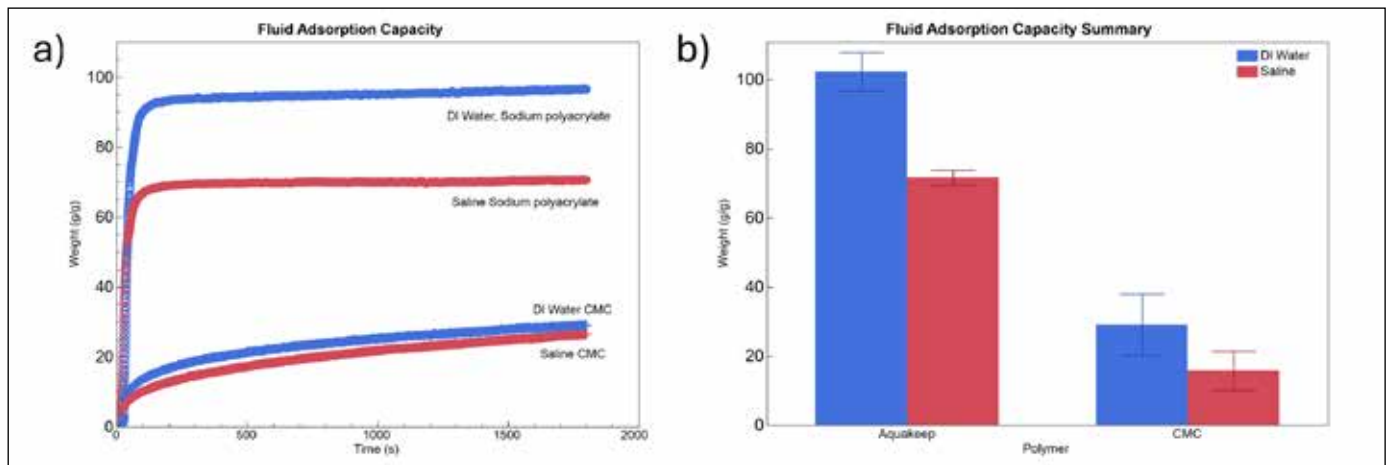


Figure 2. Fluid adsorption capacity measurements showing the uptake behavior of a) Two fluids and b) The summary of fluid capacity for two different polymers.

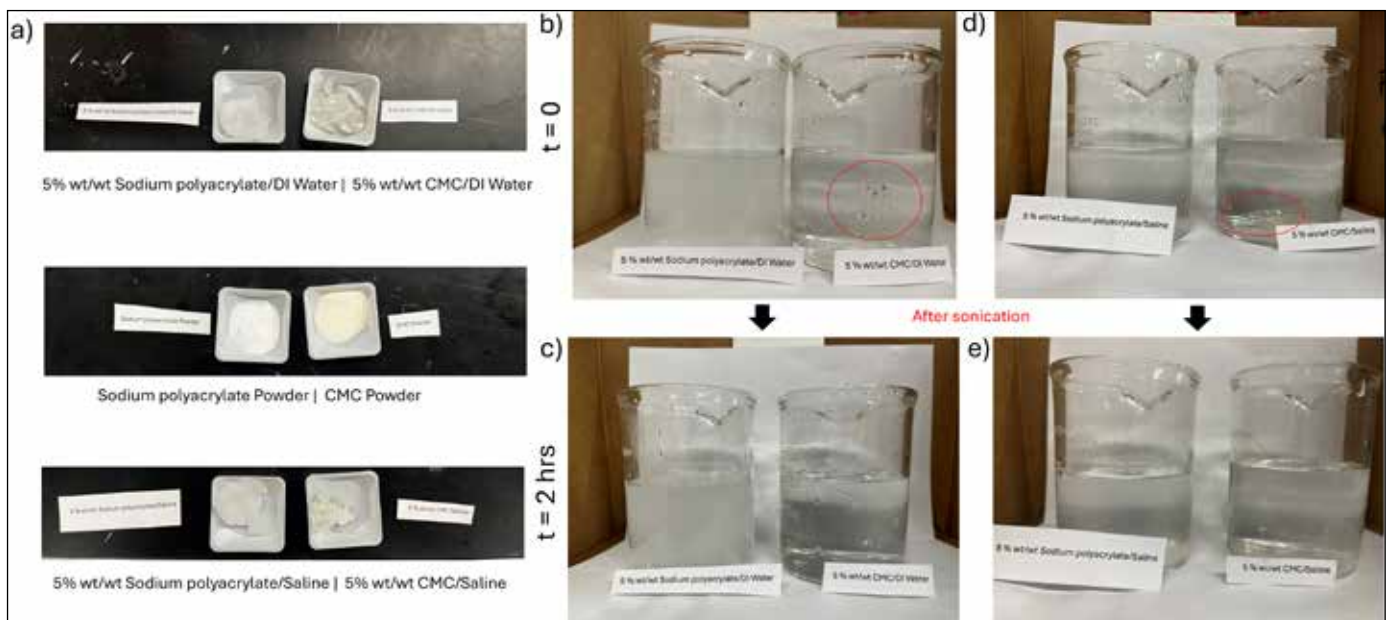


Figure 3. a) Dry and wet form of super absorbing polymers b) Visual representation of dissolution behavior between a soluble and insoluble super absorbing polymer.

Surface absorption rate and surface dryness: To measure the rate of fluid absorption, a 100 μ L droplet of fluid was applied to the adhesive side of a 20mm diameter test disc (the side designed to contact the skin). The barrier's backing film faced downward on a level surface. The droplet was intentionally larger than the surface area of the disc.

Barriers were weighed with their release liners before fluid application. The release liners were also weighed after removal. Tests were conducted under controlled conditions (temperature: 21–25°C; relative humidity: 30–50%).

An image of the droplet was captured every five minutes for 60 minutes using a JAI Go-5100C camera with a FUJINON HF12.5SA-1 lens. After 60 minutes, Whatman 1 filter paper was placed over the disc to absorb any fluid remaining on the surface of the barrier. A 100-gram weight was placed on top of the filter paper for 60 seconds to ensure consistent pressure was applied.

The droplet height was measured using ImageJ software. The fluid absorption rate was calculated as the percentage change in droplet size over time.

The volume of fluid absorbed into the barrier was calculated as the differential change in the test sample: $m_{absorbed} - m_{dry} - m_{release}$.

The volume of fluid remaining on the surface was calculated by the differential change in the weight of the filter paper: $m_{absorbed} - m_{dry}$.

Fluid Absorption Capacity: Fluid absorption capacity was measured in accordance with ISO 12505-1:2014. In brief, a disc of the test material was weighed before and after exposure to a fluid reservoir. Samples were placed in an environmental chamber set at 37°C for 24 hours to simulate body temperature conditions. After incubation, samples were drained of excess fluid for 15 minutes before their final weight was recorded. The difference in weight before and after exposure represented the material's fluid absorption capacity.

Swelling ratio: The swelling ratio was determined by measuring the change in the barrier's height before and after 24 hours of fluid exposure (absorption testing).

Erosion Rate: Erosion rate (mg/hr) was calculated by measuring the rate of weight change of each sample before and after 24 hours of exposure to falling fluid droplets, delivered at a rate of 3.1mL/min. Droplet size was controlled using 22GA blunt-tip nozzles, with flow regulated by constant gravity-driven hydrostatic pressure. The test area had a diameter of 13mm, and barrier thickness varied by manufacturer. All samples were conditioned in a desiccator for a minimum of two hours prior to testing.

pH Titration: A Mettler Toledo T50 titrator with a DGi115-SC electrode was used to measure the acid value. Each 25mm diameter barrier sample was placed in 50mL of 0.9% saline in a beaker. The sample's initial weight was recorded and entered into the instrument. After equilibrating at 37°C for 24 hours, the

solution was titrated with 0.1N potassium hydroxide (KOH) to reach a neutral pH of seven. The titrator recorded the volume of KOH consumed, the acid value (mg KOH/g sample), and the starting pH.

Data Analysis: Data were summarised using standard descriptive statistics for continuous variables (such as means and standard deviations). All graphical error bars represent ± 1 standard deviation from the mean. Temporal patterns were evaluated using both linear and sublinear trend analyses, with the latter modeled as a square root function of time, to assess changes over time.

RESULTS AND DISCUSSION

The core function of a hydrocolloid skin barrier (HSB) is to provide skin adherence and manage fluids. This study specifically focused on fluid management facilitated by the SAPs within the barrier. We did not assess adhesion performance, as hydrophobic polymers primarily impact this aspect. This paper compares fluid management, durability and the potential to support advanced skin health functionality across three hydrocolloid skin adhesives formulated with two different types of SAPs.

Fluid management

Fluid management consists of the ability of an HSB to remove fluid from an interface, such as the skin, and the amount of fluid it can hold.

Figure 4 shows the absorption rate of a fluid droplet on a hydrocolloid barrier over 60 minutes, simulating fluid removal from the skin surface. The absorption patterns differ noticeably between water and saline. To evaluate the rate of absorption, we applied a linear model, with steeper negative slopes indicating faster uptake. To assess the water absorption rate of the TRE barriers, we used a Fickian diffusion model. These results demonstrated that TRE had the highest absorption rate among all tested HSBs and fluids.

Across all three hydrocolloid barriers, water was absorbed more rapidly than saline. This difference can be attributed to saline's ionic strength, which limits water bonding to the SAP, thereby slowing absorption.²⁰ Among the HSBs, Sensura Mio and Nova exhibited similar rates for both saline and water, whereas the TRE barrier showed a markedly faster uptake of water than saline. This difference suggests that the TRE barrier offers greater versatility in handling fluids of varying ionic strengths, such as those commonly excreted from a stoma, enhancing its ability to remove moisture efficiently from the skin surface.

Figure 5 shows the amount of residual fluid remaining on the surface after 60 minutes of absorption into the hydrocolloid barrier. This complements the absorption rate data presented in Figure 4, as faster fluid uptake is expected to result in less fluid remaining at the skin-barrier interface. Figure 5b confirms that fluid volume was conserved across all tested systems.

For water, we observed that the TRE barrier absorbs the most, leaving the least residual surface fluid. Nova and Sensura

Mio show progressively lower water uptake. For saline, the Nova barrier leaves less fluid on the surface than both the TRE and Sensura Mio barriers. Notably, after 60 minutes, the Sensura Mio barrier absorbs the least amount of both fluids. The dry-to-touch results for the TRE barrier suggest that this HSB effectively removes a broader range of fluids with varying ionic strengths from the skin-barrier interface.

Figure 6 shows the amount of fluid each hydrocolloid barrier absorbed after 24 hours. This test focused on the capacity of fluid absorbed into the barrier when exposed to a saturated fluid environment. Sensura Mio absorbed similar amounts of water and saline, indicating fluid-independent performance. In contrast, both the Nova and TRE barriers show fluid-dependent absorption. Nova absorbed approximately 20% more saline

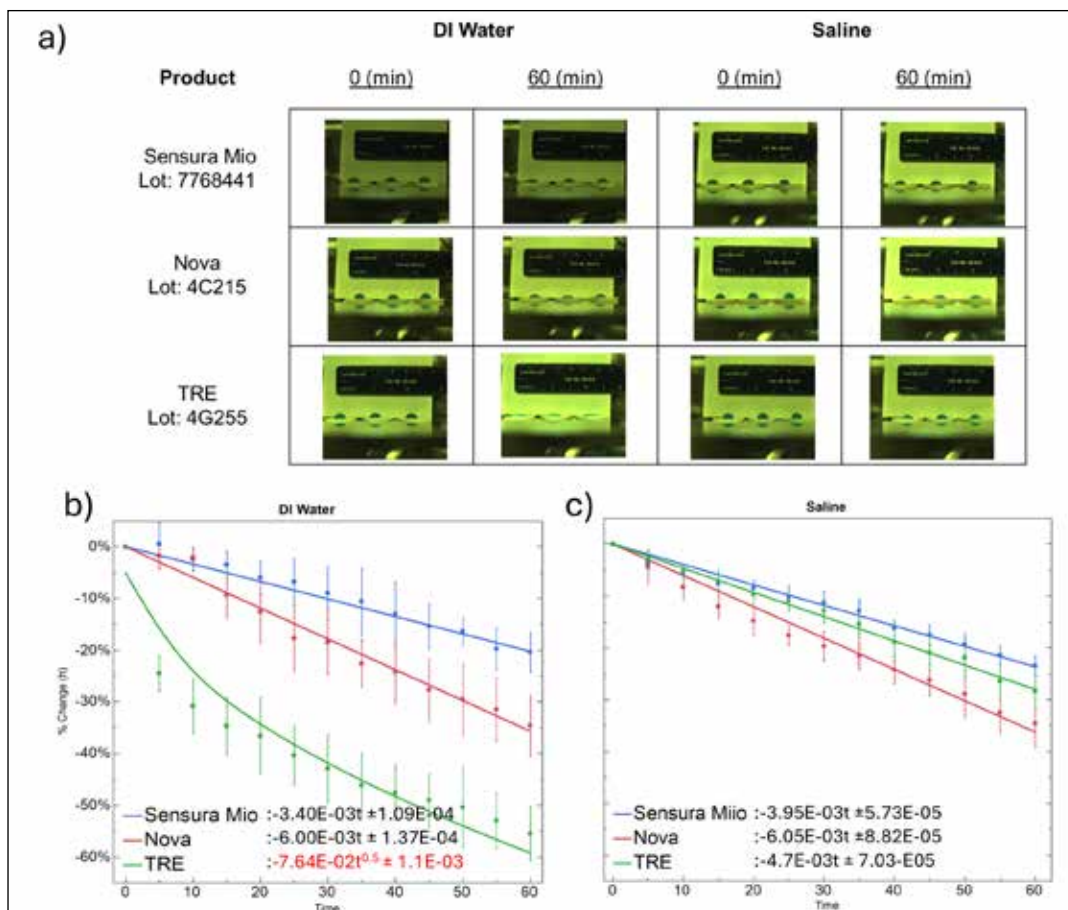


Figure 4. a) The absorption behavior of fluid droplets on three different hydrocolloid skin barriers at time 0 minutes and 60 minutes. b) and c) % change of droplet height over time with a summary of the absorption rates. All hydrocolloid skin barriers follow a linear behavior, except for TRE.

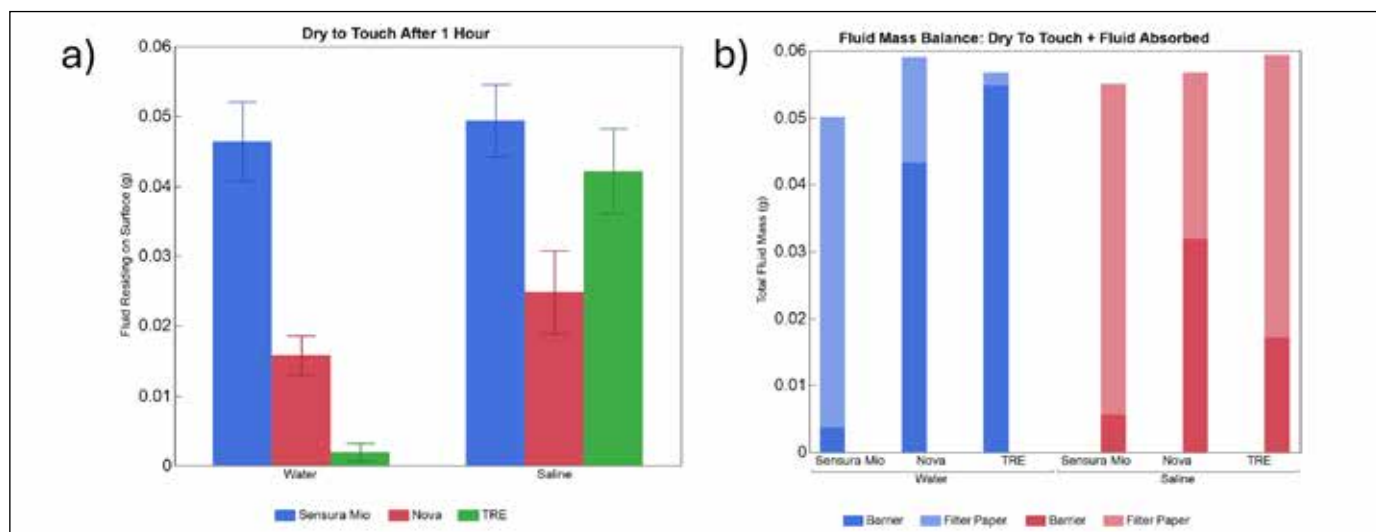


Figure 5. a) Dry touch measurements characterising the amount of fluid residing on the surface after 60 minutes. b) Mass balance of unabsorbed and absorbed fluid.

than water, while the TRE barrier absorbed approximately 240% more water than saline. Both Nova and TRE barriers absorbed marginally more saline than the Sensura Mio, but the TRE barrier demonstrated the highest overall water absorption across the tested HSBs.

Figure 6c presents the swelling ratio of each barrier. A swollen barrier provides a physical cue that fluid is being absorbed and retained in the barrier. Sensura Mio and Nova showed similar swelling behaviour in both fluids, aligning with their consistent absorption profiles. The TRE barrier, however, swelled significantly more in both water and saline, reflecting its higher absorption. This pronounced swelling may offer a clearer visual or tactile signal to the end user that the barrier is actively absorbing and managing fluid at the skin surface.

Erosion resistance serves as a quantitative measure of barrier durability and is indicative of wet integrity. The following results highlight how the incorporation of SAPs influences the structural resilience of hydrocolloid barriers under simulated use conditions.

Durability

Figure 7 presents erosion resistance results for each hydrocolloid barrier after 24 hours of exposure. It measures

barrier integrity when simultaneously absorbing fluid and undergoing mechanical stress due to the impact of fluid droplets.

While this test simulates a more extreme scenario than typical clinical use, it serves as a proxy for the physical stress that barriers experience during patient movement, particularly when saturated with fluid. Erosion rates are reported in milligrams per hour (mg/h).

Among the barriers tested, the Nova barrier exhibited the highest erosion rates in both water and saline exposure, indicating the lowest resistance to degradation over time. In contrast, TRE and Sensura Mio demonstrated lower erosion rates in water, with similar values for both materials when tested in saline.

The erosion resistance of a hydrocolloid barrier is influenced by its formulation, particularly the balance of water-soluble and water-insoluble components. Water-soluble materials tend to dissolve upon exposure to fluid, thereby reducing barrier integrity. In contrast, insoluble materials, such as hydrophobic polymers, contribute to wet strength by maintaining structural cohesion. A low erosion rate is typically associated with a high proportion of insoluble materials.

The TRE barrier is formulated with an insoluble SAP (iSAP). This unique polymer is capable of absorbing fluid while maintaining integrity. As observed in the previous test methods, the iSAP enables TRE to achieve a balance between high fluid absorption and low erosion—properties that are often mutually exclusive in conventional hydrocolloid barrier systems.

Notably, the erosion rate of the TRE barrier appears elevated in water compared to saline and relative to Sensura Mio. This is due to the high swelling ratio of the TRE barrier in water, which can cause the material to expand and spill into adjacent wells during testing (Figure 7b). While this may affect the precision of the erosion measurement, the test samples remained structurally intact upon removal, suggesting that the TRE barrier retains functional durability under saturated conditions.

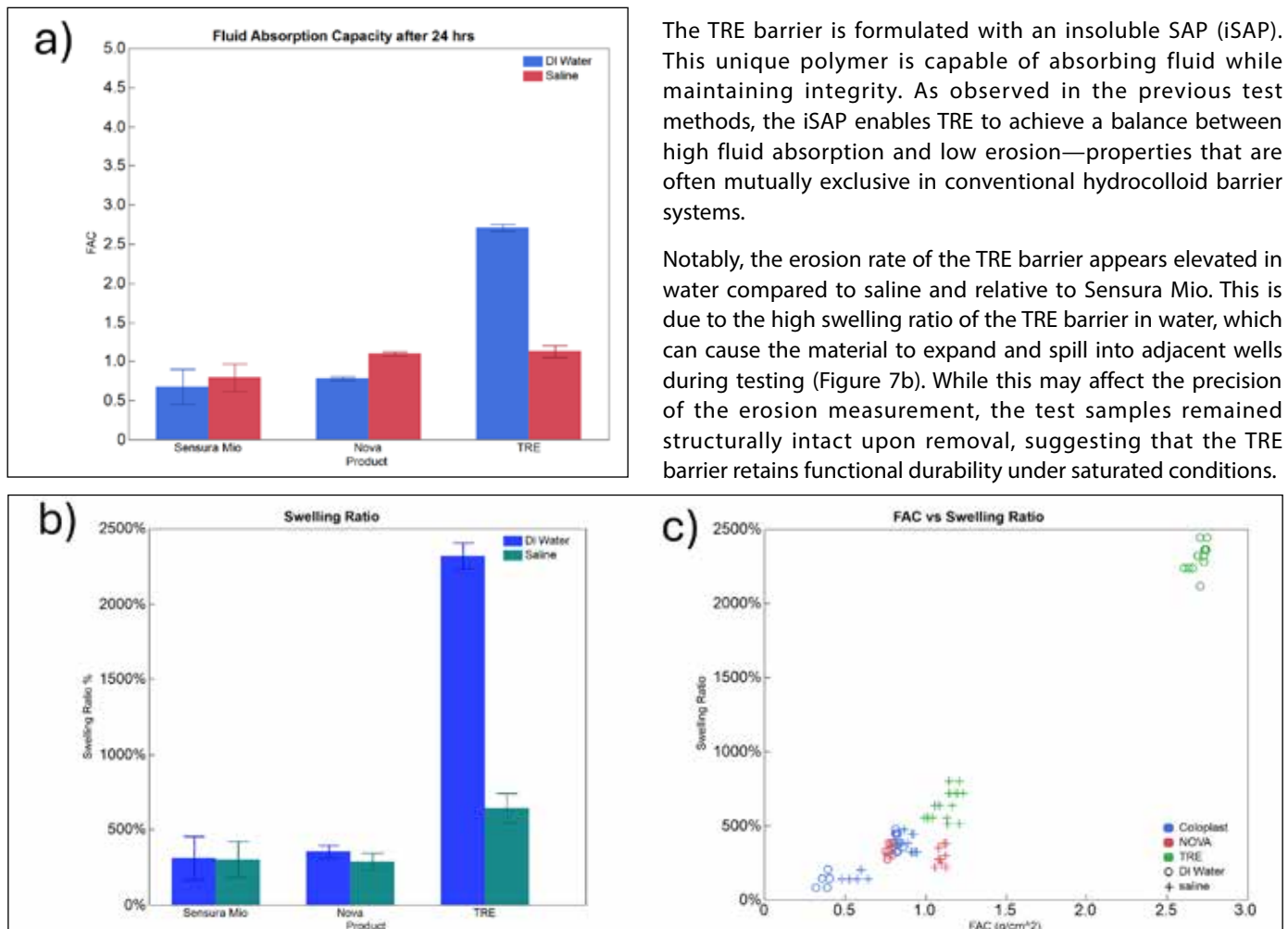


Figure 6 Data for fluid property measurements a) Fluid absorption capacity b) Swelling ratio and c) Relationship between fluid absorption capacity and swelling ratio.

Skin health

The following results demonstrate that an iSAP can be effectively formulated into a hydrocolloid barrier that supports skin health while maintaining fluid management performance and structural durability.

Figure 8 illustrates the acid value, a measure of the hydrocolloid barrier's buffering capacity. This parameter reflects the ability of the hydrocolloid to help maintain the skin's acid mantle when exposed to alkaline (caustic) or enzyme-rich stoma effluent.²¹ Maintaining a slightly acidic pH at the skin surface is critical to preserving skin integrity.

In the visual assessment shown in Figure 8a, each HSB was exposed to a pH-sensitive indicator for 30 minutes. The indicator solution initially appears blue, reflecting an alkaline environment. Over time, the fluid colour shifted to yellow, indicating a more acidic environment. Among the tested barriers, the TRE hydrocolloid produced the most rapid and intense colour change, suggesting a strong buffering response.

To quantify this observation, titration was used to calculate the acid value for each product. Consistent with the visual assessment, Sensura Mio and Nova showed minimal buffering capacity. At the same time, the TRE barrier demonstrated a significantly stronger response, with acid values 4–5 times greater than those of the other barriers.

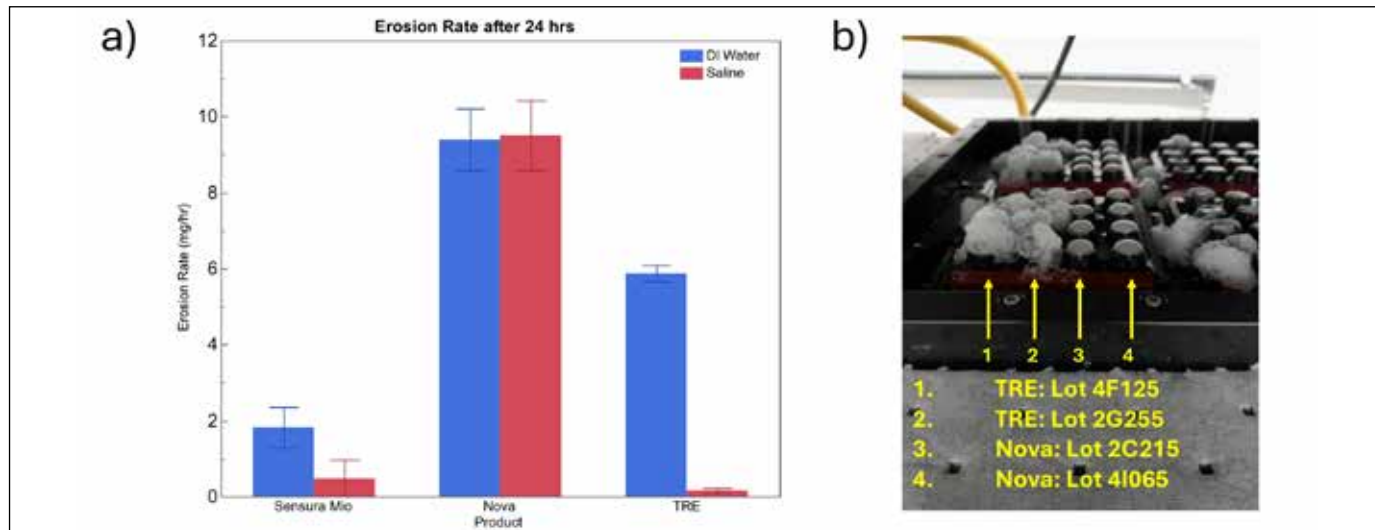


Figure 7. a) Erosion rate for three different HSBs, b) Swollen TRE hydrocolloid aggregating into other test sample spaces compared to minimally swollen Nova.

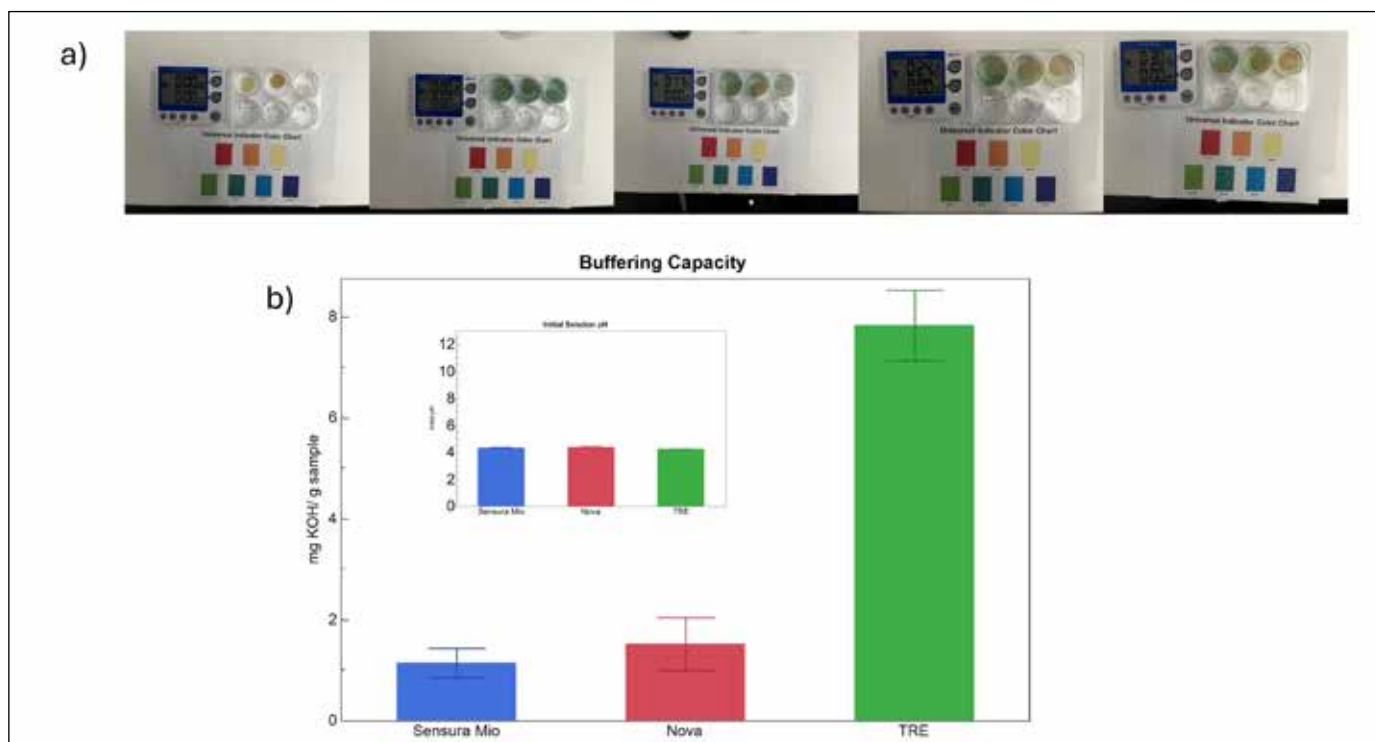


Figure 8. a) Visual comparison and b) Quantitative measurements demonstrating pH buffering capacity.

These findings support that an iSAP can be optimised within a hydrocolloid skin barrier to enhance buffering capacity and promote skin health without compromising fluid absorption or erosion resistance.

Impact of super absorbing polymer technology on hydrocolloid skin barrier development

Figure 9 highlights the evolution of hydrocolloid skin barrier technology, tracing the development of fluid management performance from early karaya-based materials to the integration of modern SAPs. Traditional HSBs were primarily designed to absorb moisture and protect the peristomal skin from effluent, forming the foundational function that defines all subsequent HSB development. Contemporary products such as Sensura Mio, Nova, and TRE barriers exemplify this baseline requirement for fluid handling.

Building on this framework, newer-generation HSBs have introduced enhancements by combining SAPs with ingredients that support skin health. Further differentiation arises from the specific type of SAP used. For example, the iSAP incorporated into the TRE barrier offers broader versatility in fluid management, enabling faster dry-to-touch performance and effective absorption across a range of fluid ionic strengths—capabilities not as prominently observed in Sensura Mio or Nova barriers. Notably, these advantages emerge despite all three products demonstrating comparable total fluid absorption capacity.

An iSAP also contributes to mechanical durability through the polymer crosslinking process. However, durability can also be influenced by the overall formulation, as evidenced by the superior erosion resistance of the Sensura Mio barrier compared to Nova, despite both using conventional SAPs.

Finally, the TRE barrier formulation demonstrates how iSAP-based fluid handling can be integrated with additional functional benefits, such as pH-buffering technology, to support skin health—an HSB formulation comprised of an insoluble, super-absorbing polymer with pH buffering (iSAP+). This added feature distinguishes the TRE barrier from the other barriers tested, marking a significant step forward in the multi-functional design of modern hydrocolloid skin barriers.

CONCLUSIONS

Super-absorbent polymers (SAPs) have played a foundational role in the development of hydrocolloid skin barriers (HSBs) since their introduction in the 1960s. This study highlights how different types of SAPs influence key fluid management characteristics, including dry-to-touch performance, absorption capacity, and swelling behaviour.

Both Sensura Mio and Nova incorporate conventional SAPs, which deliver varying levels of fluid absorption and mechanical durability. In contrast, the TRE barrier formulation incorporates an insoluble super-absorbent polymer with pH buffering (iSAP+), specifically sodium polyacrylate, to create a next-generation HSB that offers versatile fluid management, enhanced durability and skin health support.

The TRE barrier represents an evolution in HSB design, distinguished by its iSAP+ based formulation. Continued advancements in material science, through both polymer innovation and formulation optimisation, will shape the future of ostomy technology, with the potential to improve patient comfort, skin protection and confidence-in-wear performance.

ACKNOWLEDGEMENTS

The author would like to thank Brian Hinsberger, McKenzie Jones and Michael Coen for data collection. Adam Airhart, Nada Ardeleanu, Joel Shutt and Dian Yuan are also acknowledged for reviewing the manuscript.

CONFLICT OF INTEREST

The author is senior lead scientist for breakthrough innovation at Hollister Inc. Dansac, manufacturer of TRE™, is a brand of Hollister Inc.

FUNDING

The author is a salaried employee of Hollister Inc.

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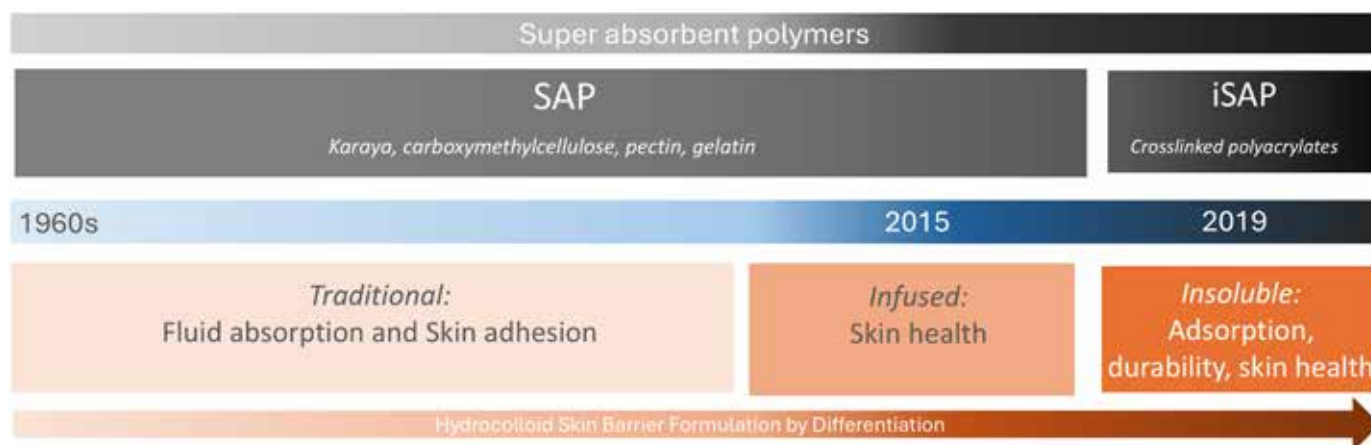


Figure 9. Evolution of the application of SAP technology segmented by super-absorbing polymer type and hydrocolloid skin formulation.

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