Development of advanced sanitary materials with the use of probiotic paste

Olivera Sauperl1, Andrej Zabret2 and Lidija Fras Zemljič1

Abstract
Cotton sanitary towels were functionalized by probiotic paste with incorporated Lactobacillus L. fermentum LN99, L. rhamnosus LN113, and L. gasseri LN40 in order to reduce the possibility of infection or inflammation during menstruation and to develop a friendlier product. These towels were characterized through elemental composition using attenuated total reflectance Fourier transform infrared spectroscopy, determination of the pH of aqueous extract, water retention, capillary properties, determination of absorption capacity, and microbiological testing, to assess the antimicrobials’ function and stability of lactic bacteria paste as a coating for sanitary towels. The results of the used methods show that the physical–mechanical properties of towels functionalized by probiotic paste are not significantly different if compared to non-treated ones. Attenuated total reflectance Fourier transform infrared spectroscopy set the successful functionalization of sanitary towels with probiotic paste due to the occurrence of typical probiotics paste peaks. The pH of the probiotic-functionalized sanitary towels was reduced in comparison to the reference material to an acidified region of pH = 5.6, which is an ideal environment for maintaining physiological pH. The decrease in water retention of towels after functionalization is relatively low (8.48 %). The sorption behavior of towels was worse by up to 15 % regardless of the reference material, which is still acceptable from a practical point of view and internal standards of the included company Tosama d.o.o. The probiotic-functionalized sanitary towels absorb synthetic blood faster than the reference ones, due to compatibility of the paste with synthetic blood. Moreover, towels obtain functionalities such as good condition for lactobacilli growth with simultaneous pH adjusting, as well as introducing of Staphylococcus aureus reduction. Functionalization of sanitary towels with probiotic paste showed a commercial potential to reduce the probability of infection during the menstruation cycle, as well as being a more customer-friendly product.

Keywords
Probiotics, cellulose, functionalization, sanitary material, antimicrobial

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Introduction
As is well known, a modern lifestyle requires the increasing use of tampons and sanitary towels, which opens the possibility of their extended use in the field of gynecology. Today, tampons and sanitary towels not only provide protection during the menstrual cycle, but their function is also to take care of physiological or pathological vaginal discharge. In general, women’s intimate areas are protected against infection by a low pH value (below 5) of the vaginal flora. Even a small increase in pH above normal inhibits the development of harmful microorganisms, as it is difficult for them to be reproduced in an acidic environment.1,2

1University of Maribor, Maribor, Slovenia
2Tosama d.o.o., Domžale, Slovenia

Corresponding author:
Olivera Sauperl, University of Maribor, Smetanova ulica 17, SI-2000 Maribor, Slovenia.
Email: olivera.sauperl@um.si
The normal vaginal flora in healthy women are highly colonized by *Lactobacilli*. The lactic acid produced by these organisms maintains the constant acidity of the vagina. Infections can occur if the balance of natural protection breaks. Natural balance disorders can occur as a result of treatment with antibiotics or antimycotics, during hormonal changes, menstruation, pregnancy, or menopause, in diabetes, taking oral hormone contraception, a weakened immune system, or excessive hygiene of intimate areas with inadequate care products. In this case, the mucous membrane becomes more susceptible to infection as the vaginal pH increases.1 This gives pathogen microorganisms favorable conditions for reproduction, which can result in inflammation in the vaginal flora. In women treated for infections in the vaginal flora (including bacterial vaginosis and fungal infection), the positive effect of a particular type of probiotic bacteria has been identified in the treatment of these problems.3,4 Dosing of such probiotics into the vaginal mucous membrane during the menstrual cycle can act preventively, while, at the time of inflammation, it is also curative.

During the menstrual cycle, the physiological pH of the vagina is usually disrupted; therefore, the introduction of probiotic bacteria such as *Lactobacilli* may provide the necessary (between 3.8 and 4.5) pH.5 Most of these commercial products exist in the form of capsules or gels.6 For tampon and sanitary towel users, it is essential for such products to assure comfortable hygienic protection during menstruation and to prevent potential inflammation.7 Probiotic tampons exist on the market as a medical product supplying the vagina with beneficial probiotics of *Lactobacilli*, but many users have concerns about the use of tampons due to the possible drying-out of the vagina, as well as the possible toxic shock syndrome, which is the reason that some women use mainly sanitary towels during the menstrual cycle.8,9 In recent years, several hygiene product were developed, such as a sanitary towel, diaper, pant liner, tampon, incontinence guard, and hygiene tissue, with included diverse probiotic compositions. Hydrocolloid plasters, including viable probiotic strains of *Lactobacillus spp.* and used for various types of wounds, infected wounds, dry wounds, and deep wounds were also developed. Among these products of big interest is also functionalization of towels and pads in order to eliminate unpleasant odor and to reduce possible infections. Although some of the pads already exist on the market (INTIMEA Micci ProBioc pads), they are still many challenges, while the final response of these tampons depends on bacterial strains that differ in quantity and productions in lactic acid, as well as in adjustment into specific vaginal flora.10,11

Functionalization of sanitary towels with novel probiotics or novel probiotic compounding is, therefore, challenging for maintaining a healthy vaginal flora, and to offer users the added value of the sanitary materials in the sense of health and environmentally friendly products,2,12–16 such as microbial inhibition.

For this reason, the presented research is oriented at functionalization of sanitary towels with the patented probiotic paste, which until now was not used as a towel adsorbent, in order to activate the lactic acid bacteria present in the external core of the functionalized sanitary towel. This part of the towel is extremely important, while presenting a contact cone at the interface with vaginal mucous membrane. In this way, *Lactobacilli* could penetrate into the vagina, and, by maintaining healthy vaginal flora, may reduce the risk of vaginal disorders during the menstrual period.

Regarding the targeted research problem, the influence of the used probiotic paste applied onto cotton hygienic towels on selected physicochemical properties. The aim of the research was to determine whether the sanitary towels with the applied probiotic paste can assure that the vaginal pH will be suitable for maintaining a healthy vaginal flora during the use of this product. Together with this, the sorption ability of probiotic-functionalyzed sanitary towels was estimated in comparison to the untreated ones. The research itself was carried out based on tracking and controlling the input parameters, currently defined by tampon producers as the most important ones for successful application. Functionalization of sanitary towels with the probiotic paste was confirmed by attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy. Using standard microbiological techniques, the antimicrobial efficiency of functionalized sanitary towels was checked; special attention was paid to the analysis of the probiotic functionalization stability and activity.

**Experimental**

**Materials**

Hundred percent cotton daily hygiene towels manufactured by Tosama d.o.o. were used for the experiment. For functionalization, a lactic acid bacteria probiotic paste supplied by Tosama d.o.o. was used within the experiment. In the paste, three patented lactic acid bacteria strains mix are presented (*L. fermentum* LN99, *L. rhamnosus* LN113, and *L. gasseri* LN40 ≥ 108 CFU/g).

**Methods**

**Functionalization of towels.** Sanitary towels were functionalized by probiotic paste in a microbiological laboratory of Tosama d.o.o. For optimal application, the probiotic paste of a high density was liquefied at a temperature of about 24.5°C, and then applied (1 mL) onto the surface of the sanitary towels using a pipette and further roll on technique...
using a small roller. A small volume (1 mL) of paste was applied onto an area of 3.5 cm × 15 cm; this means a surface area of 52.5 cm².

The paste consists of the following components: hydrogenated Coco-glycerides, Caprylic/Capric Triglyceride Cetyl alcohol, sucrose, Trehalose, and calcium chloride with incorporated *Lactobacillus* (*L. fermentum* LN99, *L. rhamnosus* LN113, and *L. gasseri* LN40 ≥ 10⁸ CFU/g). Functionalized sanitary towels were then stored in a refrigerator for subsequent testing by a selected test method, as pointed out above.

**ATR-FTIR spectroscopy.** A Perkin Elmer Spectrum GX NIR-FT spectrophotometer with associated software was used within the experiment. Samples were recorded in the wavelength range of 4000 cm⁻¹ to 650 cm⁻¹ with 16 scans at a resolution of 4 cm⁻¹ and an interval of 1.0 cm⁻¹.

**pH of aqueous extract (ISO 3071).** Following ISO 3071, 2 g of the sample was poured with 100 mL of deionized water, and treated for 1 h in accordance with the procedure prescribed by the standard. The purpose of the method was to check the changes in pH of the aqueous extract after functionalization of sanitary towels in comparison to the reference using a pH-meter SevenCompact™, producer Mettler Toledo. The given value is an average of three measurements.

**Water retention (DIN 53814).** Water retention of the functionalized and non-functionalized (reference) sanitary towels was performed using the procedure (three repetitions) of the Standard DIN 53814 and was calculated using equation (1)

\[
WR = \frac{Mc - Mad}{Mad} \times 100\%
\]

where WR is the water retention (%), Mc is the mass of the centrifuged sample (g), and Mad is the mass of the absolutely dry sample.

**Velocity of soaking water of textile fabrics (method by determining the rising height) (DIN 53924).** A sanitary towel was immersed in deionized water up to the height of 0.5 cm. The rising height for the functionalized and non-functionalized samples was measured at prescribed time intervals (10, 30, 60, and 300 s). Three parallel measurements were done for each experiment.

**Maximal absorption and release (internal method of the producer Tosama d.o.o.)**

**Maximal absorption.** The tested sanitary towel was first weighed (Mm), then, immersed for 30 min in a 0.9 w/v% aqueous solution of sodium chloride (NaCl), left for 5 min in a drainage pad, and, finally, weighed again (Mw). Based on the difference in mass before and after immersion in a test solution, maximum absorption (Amax) was calculated by equation (2)

\[
A_{\text{max}} = M_m - M_w
\]

where Amax is the maximal absorption (g), Mm is the mass of the dry sample (g), and Mw is the mass of the wet sample (g).

Testing of samples during the process of the maximal absorption and release determination is shown in Figure 1.

**Maximal release.** The tested sanitary towel was centrifuged for 3 min at 3000 r/min after being immersed in deionized water (see maximal absorption procedure), and then weighed. Based on the difference in mass before (Ma/g) and after centrifugation (Mc/g), the maximal release (Rmax) was calculated in accordance to equation (3)
where Rmax is the maximal release (g), Ma is the mass of the sanitary towel before centrifugation (g), and Mc is the mass of the centrifuged sanitary towel (g).

**Time of absorption (internal method of the producer Tosama d.o.o.).** A sanitary towel was put in the sensor-active holder, and then 4 mL of synthetic blood was poured over the towel’s center using a pipette. The procedure requires 3× application of the liquid within 10-min intervals. The result is expressed as time/s needed for each sanitary towel to absorb 12 mL of liquid (synthetic blood).

Three repetitions of measurements were performed for both procedures.

**Microbiological testing**

1. Determination of the number of lactic acid bacteria.

A small volume (0.1 mL) of *Lactobacilli* probiotic paste was applied onto the Natura Femina sanitary towels. In order to verify the possible reduction of the *Lactobacilli* presented on the surface of the functionalized pads and to conclude their potential storage usefulness, some samples were stored in a refrigerant at 2°C–8°C, and the other three at room temperature (20°C–25°C). A microbiological test for *Lactobacilli* persistence as described above was performed after 1 week and 1 month of storage, respectively.

Two test solutions were prepared, as follows: (1) PSDF bujun was prepared by suspending 9.5 g of the dehydrated culture medium (peptone (1 g/L), sodium chloride (8.5 g/L), pH 7 ± 0.2) in 1 L of demineralized water. The content was stirred well, followed by a 15-min sterilization at 121°C. (2) De Man, Rogosa and Sharpe (MRS) agar was prepared by suspending 21 g of dehydrated culture medium in 339 mL of demineralized water and was also sterilized for 15 min at 121°C.

Functionalized sanitary towels were then sterile cut and transferred to both culture mediums in order to study the possible reduction of the probiotics in dependence of the time of storage conditions.

2. Determination of antimicrobial properties of the functionalized towels regarding *Staphylococcus aureus* were evaluated by a modified method of ASTM E2149.

This is a quantitative antimicrobial test method performed under dynamic contact conditions. The antimicrobial activity is expressed as the reduction (R = %) of the organism after contact with the test specimen, compared to the number of bacterial cells surviving after contact with the control. Microbiological testing was performed at the National Laboratory for Health, Environment, and Food, Maribor, Slovenia. Three repetitions of measurements were performed for testing.

**Results and discussion**

**ATR-FTIR spectroscopy**

Figure 2 shows the ATR-FTIR spectra of the sanitary towel (black), probiotic paste (light green), both as references, as well as of the two probiotic-functionalized sanitary towels (blue and green) to assure the repeatability. The probiotic paste has typical signals in the ATR-FTIR spectrum at the following wave numbers: 3220, 2918, 2850, and 1741 cm⁻¹. All typical probiotic paste signals were also seen in both ATR-FTIR spectra of the probiotic-functionalized sanitary towels. ATR-FTIR spectroscopy confirmed the successful functionalization of sanitary towels with probiotic paste due to the occurrence of typical probiotics paste peaks.

**pH of the aqueous extract**

One of the very useful standardized methods in the field of textile materials’ treatment is to measure the pH of the aqueous extract, which gives an answer to whether the treatment used results in alkaline, neutral, or acidic pH. It was expected that the functionalization of the sanitary towels using probiotics would assure acidic pH of the aqueous extract, as probiotics are known to provide or regulate such (acidic) pH. The results of the pH of the aqueous extract (ISO 3071) shows the reference (non-functionalized sanitary towel) has an average pH of 7.4, so in this case we can conclude on a nearly neutral product. In the case of probiotic-functionalized sanitary towels, the average pH (three repetitions of measurements) of the aqueous extract was acidic that is pH = 5.6. This pH of the aqueous extract confirmed successful probiotic functionalization, while the pH of the probiotic paste was 5.4–5.8. To decrease the pH of the reference sample to an acidic scale, it is extremely important as acidic pH maintains vaginal physiological pH. In this case, we can conclude on a promising result, since the purpose of functionalizing is to achieve effective release of lactic bacteria from the surface of functionalized sanitary towels, as well as to maintain physiological pH. Healthy pH of the vagina is slightly acidic, but can be neutralized during the outflow of the neutral blood. With *Lactobacilli* facilitated by the production of lactic acid and decreased acidic pH, it is therefore possible to maintain physiological pH, thus preventing inflammatory processes during the menstrual period. By this method, the release of the paste from the surface was confirmed by the results. According to the American Association for Clinical Chemistry, the average value for urine pH is 6.0, which is almost the same as the pH of the used distilled water in which the desorption experiments were done. So, the experiment may approach the real-life situation for the average value of urine. The variations of
pH with a lower limit of 5 to a higher limit to 7.5 were not considered.
The STDEV of three repetitions of measurements was small (in both cases 0.06) and can therefore be concluded on as highly reproducible results.

Sorption properties

Water retention. Using the water retention method, it is possible to see whether the probiotic-functionalized sanitary towels still provide adequate and enough water retention in comparison with the untreated/reference ones. The results show a decrease in the ability of the functionalized samples to retain water (22.83 %) if compared to the reference (31.31 %) and good reproducibility of results. The decrease in water retention value by introduction of *Lactobacilli* may be due to the conformation of the paste attached onto the fiber’s surface. When paste is bound onto fibers, the packing density of fibers may increase, and, thus, sorption capacity could be lowered. Moreover, the paste has a more hydrophobic character, which contributes to the higher fiber contact angle (from the hydrophilic character of the reference material hydrophocity is introduced) and, thus, lower sorption capacities and affinity for water retention. STDEV was evaluated after three repetitions of measurements and was 1.43% for the reference and 1.68% for the functionalized sanitary towel. However, water retention in the case of a probiotic-functionalized sanitary towel was still satisfactory in accordance with the internal quality and control Standard of Tosama d.o.o., that is, decrease in water retention was relatively low (8.48%).

Velocity of soaking/capillarity. Results of velocity of soaking (deionized water rise) are summarized in Table 1.
The results collected in Table 1 show higher capillarity of the reference at all time intervals (10, 30, 60, and 300 s) if compared to the probiotic-functionalized sanitary towels. At a time of 10 s, the height of the wetting (i.e. velocity of soaking) for the reference is 50% better when compared to the probiotic-functionalized sanitary towel. Exactly the same trend was seen at a time interval of 30 s. After 60 s, the height of wetting of the reference was 67% higher if compared to the probiotic-functionalized sample. In addition, the same trend also applied at the final time of 300 s, where the height of the wetting of the reference was 56% better when compared to the probiotic-functionalized sanitary towel. As already mentioned, it is obvious that a thick film of probiotic paste closes the pores or dense fiber packaging of the material for adsorption of liquids a bit; however, the remaining adsorption capacity is still in the limits.
(internal Standard of Tosama d.o.o.) needed for application for sanitary towels. This was also proved by preliminary measurement of the contact angle (by water drops). It has been shown that the reference towel had a contact angle of 65°, while with coating of probiotic paste, the contact angle increased by 28° (i.e. to 93°). This is because, the viscous and more hydrophobic probiotic solution covered the surface of the towel in the form of a thick film (“seen visually”), which worsened the accessibility to material pores.

**Maximal absorption and release.** Testing of samples during the process of the maximal absorption and release determination is shown Table 2.

From the results collected in Table 2, the maximum absorption of the reference sample (75.72 g) is approximately 14% higher if compared to the probiotic-functionalized sanitary towel (64.82 g). These results are in trend with the results of the capillary rise, which means that the deterioration in absorption in the case of probiotic-functionalized samples is proved again. All of this means that probiotic functionalization influences the sorption properties of probiotic-functionalized towels, consequently, having lower maximum absorption in comparison to the untreated one. Such phenomenon is expected, since probiotic paste is adsorbed onto the towel’s surface, so the liquid (i.e. 0.9 w/V% NaCl solution) has lower affinity to penetrate into the sanitary towel due to the increased contact angle after functionalization. Nevertheless, the 14% reduction in maximum absorption compared to the reference does not mean a dramatic deterioration of the sorption properties of probiotic-functionalized sanitary towels; therefore, in the case of functionalization, in spite of the lower sorption, the positive effects of the probiotic-coating are likely to be predominant. The release is greater in the case of the reference sample (5.24 g), since the absorption in this case is also higher than in the case of the probiotic-functionalized sample. Release means the amount of fluid that has drained from the sample after being soaked with deionized water.

**Time of absorption.** Results of the time of synthetic blood absorption are seen in Table 3.

Synthetic blood absorption was measured at 10-min intervals (10, 20, 30 min) to see the difference in synthetic blood absorption ability between the probiotic-functionalized towels and the reference. Results show that the probiotic-functionalized sanitary towels absorb synthetic blood much faster when compared to the reference, regardless of the added volume of the synthetic blood (Table 3). After 10 min and addition of 4 mL of the synthetic blood, the difference in the rate of synthetic blood absorption is in favor of the probiotic-functionalized sanitary towel and was 4.27 s; after 20 min and addition of 12 mL of the synthetic blood the difference (in favor of the probiotic-functionalized sample) was 2.37 s, and after 30 min and addition of 12 mL of synthetic blood (in favor of probiotic-functionalized sample) the difference was 14.45 s, respectively. Probiotic functionalization, therefore, proved to be favorable in terms of increasing the absorption of probiotic-functionalized sanitary towels after treatment with *Lactobacilli* as a physiological fluid that is, synthetic blood in the presented case. Obviously in this case, there is a certain relationship between the surface tension of the probiotic applied (hydrophobic character) to the sample and the synthetic blood, which is manifested in the faster absorption of the synthetic blood when compared to the reference ones, which was especially pronounced in the case of the highest volume of synthetic blood added (12 mL).

**Microbiological test**

The results of the number of *Lactobacilli* after 1 week and 1 month of storage of the probiotic-functionalized sanitary towels at different temperatures are collected in Table 4.

Table 4 shows the proportion of *Lactobacilli* of probiotic-functionalized sanitary towels after a certain storage time at different temperatures (2°C–8°C and 20°C–25°C). Results show a relatively small proportion of *Lactobacilli* (2.3 × 10^6) after 1 week of storage in a refrigerator (2°C–8°C) when compared to samples stored in the refrigerator for 1 month (4.6 × 10^6). Obviously, these conditions are ideal for *Lactobacilli* growth, which is positive for practical use when it is expected that the product will have to be stored for a relatively longer time relative to the production time itself to avoid spoiling of the product. The opposite trend is seen with samples stored at room temperature (20°C–25°C), where the proportion of *Lactobacilli* dropped significantly (92.8) after 1 month of storage if
Microorganisms like lactobacilli can produce other antimicrobial peptides such as bacteriocins, bacteriocin-like substances, and biosurfactants, and promote autophagy (engulfment and degradation) of intracellular bacteria, viruses, and protozoa. Hence, through these mechanisms, lactobacilli inhibit the growth of other potentially pathogenic endogenous vaginal bacteria and prevent the acquisition of exogenous bacteria. For these reasons, a lactobacilli-dominated vaginal microbiota has been described as healthy and necessary for the overall well-being of women.

### Conclusion

Within this research, hygienic sanitary towels were functionalized by probiotic paste with the aim to introduce new functionalities of towels. The adsorption of Lactobacilli paste onto the towels’ surfaces was proved by ATR-FTIR spectroscopy. The pH of the probiotic-functionalized sanitary towels was reduced to the acidified region of pH = 5.6 in comparison to the reference material, which is an ideal environment for maintaining physiological pH, that is, extremely important during the menstrual cycle. The decrease of towel pH after functionalization is also provident for successful adsorption of probiotic paste into the towel. The sorption behavior of towels was worsened by up to 15% regardless of the reference material, which is still acceptable from a practical point of view and internal Standards (for quality and control) of the producer Tosama d.o.o., that were included into this research. Interestingly, the probiotic functionalization proved to be favorable in terms of increasing the absorption of synthetic blood of probiotic-functionalized sanitary towels after treatment with Lactobacilli.

Regarding the following of Lactobacilli growth in intervals of 1 month and different temperature conditions, it is possible to give an appropriate recommendation regarding the storage of probiotic-functionalized sanitary towels in a refrigerator because storage at lower temperatures proved to be very effective. At room temperature after 1 month, the number of Lactobacilli was reduced by 4.599.999.907.2.

With our approach, towels obtain functionalities such as good conditions for Lactobacilli growth with simultaneous pH adjusting and very important introducing of gram-positive S. Aureus reduction which causes serious vaginal infections. Results are very promising for potential development of user-friendly, probiotic-effective sanitary towels for everyday use, and even for medical applications.

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**Table 3.** Time of absorption.

|                  | Time of absorption after 10 min (4 mL of synthetic blood)/s | Time of absorption after 20 min (8 mL of synthetic blood)/s | Time of absorption after 30 min (12 mL of synthetic blood)/s |
|------------------|-------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Reference        | 8.02                                                        | 10.09                                                       | 38.39                                                       |
| Probiotic-functionalized sample | 3.75                                                        | 7.72                                                        | 23.94                                                       |

**Table 4.** Number of Lactobacilli after 1 week and 1 month of storage.

| Temperature      | Number of Lactobacilli after 1 week of storage | Number of Lactobacilli after 1 month of storage |
|------------------|-----------------------------------------------|-----------------------------------------------|
| 2°C–8°C          | 2.3 × 10⁹                                      | 4.6 × 10⁹                                      |
| 20°C–25°C        | 4.3 × 10⁷                                      | 92.8                                          |

Compared to the samples after 1 week of storage at room temperature (4.3 × 10⁷). This amount of Lactobacilli when compared to other commercial products such as commercial probiotic creams and capsules (e.g. capsules Lactobacillus acidophilus) are very low, and may, due to their reduced quantity, be too low for successful function. On the basis of the results of the number of Lactobacilli and its comparison within an interval of 1 month, it is possible to conclude an appropriate recommendation regarding the storage of probiotic-functionalized sanitary towels, where storage at lower temperatures (e.g. in a refrigerator) is necessary. The results are consistent with some other studies explaining that the survival of probiotics was strongly dependent on the storage temperature, and remarkable viability loss occurred at room temperature. Moreover, the antimicrobial test also showed that probiotic paste introduces antimicrobial properties to towels. The R (pointed out by Standard test ASTM E2149) in % for Staphylococcus aureus for the reference material was 6%, and, for the functionalized towel, 57%. For gynecological sanitary material, it is extremely important to introduce the inhibition capacity for S. aureus. S. aureus is known as the most prevalent vaginal pathogen (57.33%), followed by Escherichia coli (25.33%). It is the main reason for bacterial vaginosis. The mechanism of antimicrobial action is due to the Lactobacilli activity. It has been reported by Amabebe and Anumba that Lactobacilli produce hydrogen peroxide (H₂O₂), which inhibits the growth of catalase-negative anaerobic organisms by production of hydroxyl free radicals. They can also bind to the surface of vaginal epithelium and prevent other microbes from attaching to and infecting the cells competitively. Lactobacilli can produce other antimicrobial peptides such as bacteriocins, bacteriocin-like substances, and biosurfactants, and promote autophagy (engulfment and degradation) of intracellular bacteria, viruses, and protozoa. Hence, through these mechanisms, lactobacilli inhibit the growth of other potentially pathogenic endogenous vaginal bacteria and prevent the acquisition of exogenous bacteria. For these reasons, a lactobacilli-dominated vaginal

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ORCID iD
Olivera Sauperl https://orcid.org/0000-0002-9919-5076

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