Microorganisms isolated and antimicrobial treatments applied at different stages of leather processing

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Leather due to the substances it contains is an ideal nutrient source for micro-organisms. Various types of bacterial and fungal species have been isolated from hides/skins and leather at various stages of the leather manufacturing processes. Micro-organisms can cause damages or problems as smells, oil leaching, spoiling of the leather and colour irregularities removal of which is hard or sometimes impossible. In this chapter, microorganism species identified on leather through its processing and antimicrobial effects of biocide and fungicide or operations applied on leather to prevent them are presented.

Keywords: Bacteria, Fungi, Leather, Antimicrobial, Microbicide

1. Introduction

Leather, because of the substances it contains, is an ideal nutrient for micro-organisms. It consists of 50% carbon, 25% oxygen, 7% hydrogen, 17.8% nitrogen and 0.2% minerals. Raw leather consists of 64% water, 30% protein, 3% carbohydrate, 2% fat, 0.5% minerals and 0.5% other materials [1].

Because of its protein and lipids, leather provides a suitable substrate for many organisms [2]. From the moment it is removed from the animal or flayed and throughout the various preservation processes in the tannery, the raw leather is under threat from micro-organisms. In spite of such processes as pickling, vegetable tanning and chrome tanning, which are intended to prevent damage from micro-organisms, treated leathers, crust and even finished leathers constitute a source of nutrients for micro-organisms [3, 4].

In the processes before tanning, problems are caused mostly by bacteria, while in tanning and later processes, it is fungi which cause the most problems. In leathers which have been damaged by micro-organisms, removal of such problems as smells, oil leaching, spoiling of the leather and colour irregularities is sometimes impossible [3].

2. The microorganism species identified through leather processing

2.1 Bacteria Species Isolated from Skin, Hide and Leather

Raw hides and skins may be contaminated with a variety of microorganisms. Researchers have found that bacteria such as *Staphylococcus aureus*, *Corynebacterium pyogenes*, *Escherichia coli* and *Pseudomonas aureginosa* are part of the normal flora of leather [5, 6]. Various Gram-positives (such as *Staphylococcus spp. and Corynebacterium spp*.) and Gram-negatives (such as *Micrococcus spp., Proteus spp., Agrobacterium spp. and Shewanella spp.*) were isolated from cattle hides [7]. It was stated that raw hides and soaking baths offer conditions for abundant bacterial growth such as *Bacillus subtilis, E. coli, Proteus vulgaris* and *P. aeruginosa* [8].

Staphylococcus spp., Micrococcus spp., Corynebacterium spp., Bacillus spp., Escherichia coli and *Pseudomonas spp.* were the predominant microorganisms isolated from raw hides and skins which were delivered without treatment to the tannery. Histological examination of the putrefied areas showed that the epidermis became thin without cellular structure and appeared ribbon-like and detached from the dermis whilst the dermis became loose. The bacterial damage was clear and had lesions of putrefaction with *St. equorum*, *St. gallinarum*, *Dermacoccus nishinomiyaenesis*, *Gardnerella vaginalis* being isolated from putrefied hides and skins for the first time [9].

Curing is carried out by several chemical, biocidal and physical methods. The salt curing system is the most popular animal skin preservation method adopted globally [10]. The studies below revealed that the salt-pack curing method is not quite efficient or adequate in preserving the raw skin and hides. It was even recommended to modify the salt-pack curing method due to its inefficiency to inactivate Gram-positive and Gram-negative bacteria.

It was found that the various bacterial species isolated from fresh calf skins had the ability to withstand a high level of salt (NaCI) concentrations (1.5-9% w/v). The isolated bacterial species included *Bacillus coli, B. megatherium, B. mycoides, B. proteus, B. subtilis, Staphylococcus albus, S. aureus, Sarcina lutea* and *Micrococcus roseus. B. subtilis* and *B. mycoides* was found to have survived in a dormant state at a high salt concentration (20% w/v) [11].

In the salted hides, the pH values of all samples (pH 6-9) and moisture content (49-66%) in 28% of the samples were found to be appropriate for bacterial growth. Despite the salt-curing of hides, proteolytic and lipolytic mesophilic bacteria were isolated from the hides in high numbers. Proteolytic and lipolytic extremely halophilic bacteria were

observed in the most samples of salt and salted hides. It was determined that this hide preservation method was not adequate to inactivate bacterial activity [12].

Although salt-pack curing is the most widely used method to preserve hides, it was not sufficient to inactivate both Gram-positive and Gram-negative bacteria. A total of 396 Gram-positive bacteria comprising from 12 different genera (*Aerococcus, Aneurinibacillus, Bacillus, Brevibacillus, Enterococcus, Geobacillus, Kocuira, Lactococcus, Paenibacillus, Streptococcus, Staphylococcus and Virgibacillus*) and 47 bacterial species were isolated and identified from the hides. The most common Gram-positive genera on the salted hides were *Staphylococcus* (115 isolates), *Bacillus* (111 isolates) and *Enterococcus* (75 isolates) [13].

A total of 256 Gram-negative bacterial isolates containing 21 different genera (*Acinetobacter, Aeromonas, Alcaligenes, Burkholderia, Citrobacter, Comamonas, Edwardsiella, Enterobacter, Escherichia, Hafnia, Klebsiella, Mannheimia, Pasteurella, Proteus, Pseudomonas, Salmonella, Serratia, Sphingomonas, Stenotrophomonas, Vibrio* and *Yersinia*) and 46 different bacterial species were isolated and identified from the salt-pack cured hide samples. The most common Gram-negative genera on these hides were *Enterobacter* (66), *Pseudomonas* (59) and *Vibrio* (32) [14].

The study revealed that salted sheep skins can be contaminated by preservation salt containing different species of mostly extremely halophilic archaea. According to comparative partial 16S rRNA gene sequence analysis, *Acinetobacter johnsonii, Alkalibacillus halophilus, A. salilacus, Pseudomonas halophila, Salimicrobium salexigens, Marinococcus luteus and Staphylococcus equorum subsp. equorum* belonging to moderately halophilic bacteria; and *Halorubrum tebenquichense, H. saccharovorum, H. kocurii, H. terrestre, H. lipolyticum, Halococcus dombrowskii, H. qingdaonensis, H. morrhuae, Halostagnicola larsenii, Haloterrigena saccharevitans, Natrinema pellirubrum,* and *N. versiforme* belonging to extremely halophilic archaea were isolated from the sheep skins. Hair slip, red and yellow discolorations, slimy layers and bad odor were detected on the skin samples examined. Therefore, antimicrobial applications during brine curing of skins suggested to be applied to overcome halophilic microbial damage on the salted skins [15].

Multidrug-resistant *Enterobacteriaceae* were common on both salted cattle hide and sheep skin samples. Therefore, effective antibacterial applications during salt curing of hides and skins in the leather industry were suggested to eradicate these multidrug-resistant bacteria [16].

If leather is not properly protected from the first stages of processing, proteolytic and lipolytic bacteria and fungi could damage the leather.

Various bacterial species including proteolytic and nonprotolytic bacteria were isolated from fresh hides before and after a soaking process. Proteolytic bacteria are thought to be responsible for the putrification of hides/skins [17].

In a study to determine the number of bacteria and fungi in the processes before tanning, Bilgi (2007) reported the development of aerobic spores along with the total of aerobic mesophyll, proteolytic and lipolytic bacteria. At the same time it has been shown that proteolytic and lipolytic fungi are also present in tanning bath [18].

Kayalvizhi *et al*. (2008) isolated various Gram-positive and Gram-negative bacteria from goat and sheep skins. Most of the identified bacteria (78.7%) were Gram-positive. The isolated bacteria were identified as *B. cereus, B. subtilis, B. megaterium, Lactobacillus casei, L. acidophilus, L.s fermentum, Micrococcus luteus, Neisseria f1avescens, N. sicca, Proteus mirabilis, Proteus spp. Pseudomonas spp. Staphylococcus luteus, S. aureus, S. epidermis* and *Streptococcus faecalis.* Besides, it was found that the Gram-positive *Bacilli* and *Cocci* with proteolytic activity are responsible for degradation of goat and sheep skins [19].

Shede *et al*. (2009) isolated various bacterial species with proteolytic and/or lypolytic activity, such as *Acinetobacter caviae, B. cereus, B. sphaericus, Brevibacterium luteolum, B. otitidis, E. coli, Proteus mirabilis, P. penneri, P. vulgaris, Myroides odoratimimus, Staphylococcus sciuri, Vagococcus species* and *Weeksella virosa.* It was observed that the appreciable release of hydroxyproline, tyrosine and free fatty acids was the cumulative effect of bacterial metabolic activity [20].

The presence of proteolytic and lipolytic mesophilic bacterial populations in high numbers in the main soak liquors showed that the recommended concentration of the bactericide (0.4 g/l) was not effective to control bacterial populations. Based on these results, the recommended concentration of the bactericide in the main soaking process was doubled (0.8 g/l) and it was observed that this concentration was considerably effective in controlling the bacterial growth. It was recommended to test periodically the dose of commonly used bactericides in main soaking process to inactivate various bacterial populations [21].

Various types of bacterial and fungal-species have previously been isolated from hides/skins and leather at various stages of the leather manufacturing processes. Beamhouse processes, tanning and post-tanning processes are carried out in water. Water, humidity and organic material involved in the process of leather manufacture, all favouring the growth of micro-organisms. Due to different pH values which are predominant during the different steps of leather production various populations of microbe species are responsible for the trouble [8].

It has been reported that after the chrome tanning, retannage, drying and finishing processes, the number and variety of bacteria have been observed to decrease, although *Bacillus* species continued to live commonly in the form of spores, and that bacterial development was inhibited because the pH was low [22].

A large number of bacteria species have been found to exist on leather at different stages of production and on finished leather. For instance, such bacterial types as *Bacillus*, *Micrococcus* and *Staphylococcus* have been identified

not only on salted leathers but also at the liming stage bacteria with spores have generally been identified. Bacteria such as *B. brevis, B. cereus, B. firmus, B. laterosporus, B. licheniformis, B. megaterium, B. pumilis, B. sphaericus, B. subtilis, S. aureus, S. epidermidis, M. candidus, M. luteus, M. rubens, Kurthia variabilis* and *P. aureginosa* have been isolated and identified not only from raw leathers but also from leathers at various production stages and even from finished leathers [23, 24].

Bacteria mainly cause putrefaction the sign of which is bad smell, later on hairslip. This deterioration may result in considerable loss of substance, loose grain and holes [25]. The causes and control of various types of microbial damage to hides, skins and leathers are well defined in a study where the microbial biodeterioration of leather before and after tanning are given in detail [2].

Microorganisms, present on the raw hides and skins are able to degrade protein and consequently the degraded raw materials may produce inferior quality leather [26, 19]. Therefore, on most occasions the concern related to microorganisms in the leather industry is the quality of leather production [27]. Depending on the pH, supply of nutrients and water content micro-organisms can grow and cause damage in several processes or states of the product [25].

Thus, in the used shoes such organisms as *Staphylococcus aureu*s, *S. epidermidis*, *Streptococcus faecalis*, *Micrococcus flavus*, *Gaffkya tetragena*, *Sarcina citrea*, *Aerobacter rectii*, *Bacillus cereus*, *B. fusiformis*, *B. megaterium*, *B. pyocyaneus, B. subtilis* and *B. tumescens* were isolated and identified. It was reported that foot infections could be passed on by shoes [28].

In another study, micro-organisms isolated from leather shoes worn by healthy people and diabetes patients were compared. The micro-organism species isolated from the shoes worn by the healthy people were *E. coli, S. aureus, B. subtilis, Proteus vulgaria* and *Candida albicans*, while the bacterial species isolated and identified from the leather shoes worn by the diabetes patients were mostly *Bacillus cereus, B. fusiformis, B. subtilis, Stenotrophomonas maltophilia, Enterobacter hormaechei subsp. oharae, Mycobacterium mucogenicum, Klebsiella* sp.*,* and *Acinetobacter* sp.*,* and also the yeasts *Cryptococcus albidus* and *Rhodotorula mucilaginosa* [29].

13 strains of bacteria were isolated from 12 shoes that were worn by children aged 6 to 12 for more than half a year. Through morphological observation, physiological and biochemical measurements, as well as 16SrRNA sequence analysis, the bacteria were identified as follows: *Bacillus licheniformis, Bacillus subtilis* (5 subspecies)*, Bacillus spore* (3 subspecies)*, Bacillus anthracis, Staphylococcus aureus, Bacillus amyloliquefaciens* and *Bacillus thuringiensis.* The results may contribute to the selection of efficient antimicrobial agents for children's shoes and insole [30].

In another study 13 strains of fungi were isolated from 12 shoes worn by children aged 6 to12 consisting of 5 strains of yeasts and 8 strains of molds. Through morphological observation and 18SrDNA sequence analysis, the 5 strains of yeasts were identified as follows: *Cryptococcus neoformans, Candida albicans, Cryptococcus albidus, Rhodotorula mucilaginosa* and *Candida utilis* [31].

Numerous of researches on the microbial contamination of the leather product indicated that the predominant species of fungi are species of the following genus: *Penicillium, Aspergillus, Alternaria, Cladosprium, Trichoderma, Fusarium, Aureobasidium, Scopullariopsis* and actinomycetes of the genus *Streptomyces* [32].

Microbial destruction of tanned leather is mainly caused by the action of filamentous fungi. Moulds can penetrate through the entire thickness of the skin, causing the breakdown of fat and other substances. This interferes of the dyeing process, the effect of which is white blooms. Cover the surface of the skin by mycelium significantly reduces the aesthetic and functional leather value.

2.2 Fungi Species Isolated from Skin, Hide and Leather

The fat, protein and other materials contained in leather form an ideal nutrient environment for the growth of fungi. Humidity, pH and temperature levels in places where leather is stored and during production are close to the ideal values determined for the growth of fungi, and this is a constant problem for the leather industry. One of the most important factors for the growth of fungi is a sufficiently humid environment.

It is known that humidity levels of 40-60% are enough for fungal development in pickled and chromed leathers, while 13-25% is enough for finished leathers. During leather production, the stage at which fungal development is most often observed is when semi-finished leathers are stored after tanning [33].

It is reported that the species of fungus most commonly seen in leather production are from the genus *Aspergillus* [34]. While Birbir *et al*., (1994) listed some fungus types encountered in leather processing as follows: *Penicillium, Absidia, Acremomium, Aspergillus, Basipetospora, Byssochlomys, Chrysonilia, Cladosporium, Emericella, Eupenicillium, Euratum, Fusarium, Monoscus, Paecilomyces, Mucor, Moniliella, Neosortorya, Phialophora, Scopulariopsis, Stachobotrys, Trichoderma, Trichosporon* and *Verticillium* [35]. It was stated that primary biodeteriogens are fungi such as *Mucor, Rhizopus* and *Aspergillus* species [36].

An environmental mycological survey was carried out by Nigam (1994) at the liming section of the Tannery and Footwear Corporation at Kanpur, India. Auhtor isolated and identified 33 fungal species, among which *Aspergillus* spp. and *Penicillium spp*. were the two predominantly isolated fungal species. The other isolated species were *Alternaria* spp.*, Cephalosporium* spp.*, Chaetomium* spp.*, Cladosporium* spp.*, Cunningham ella* spp.*, Curvularia* spp.*, Drechslera* spp.*, Fusarium* spp.*, Mucor* spp.*, Phoma* spp.*, Rhizopus* spp. and *Trichoderma* spp [37].

In the tannery, the growth of fungi normally occurs on pickled skins, since fungi are capable of growing at a lower pH [38, 39]. Growth of fungi also occurred on vegetable tanned, chrome tanned and finished leather. *Aspergillus spp., Penicillium spp.* and *Paecilomyces spp.* were the most common type of fungi isolated from leather and may be responsible for the discoloration on the skins or leathers. *Aspergillus terreus, A. niger, A. fumigatus, Penicillium restrictum, P. citrinum, Altemia spp.* and *Cladosporium spp.* were isolated from salted sheep skins [40].

Tannage takes place in an acidic medium. The tanned hides (wet blues) are therefore especially sensitive to the growth of mould fungi. Different studies determined that moulds as *Aspergillus niger*, *Mucor* spp., *Paecilomyces* spp., *Penicillium funiculosum, Trichoderma viride, Chaetomium globosum, Aureobasidium pullulans, Rhizopus* spp., *Cladosporium* spp., *Fusarium* spp. and yeasts as *Candida albicans, Torula rubra, Saccaromyces cerevisiae, Rhodotorula* spp. may attack leather [8, 23, 25, 35].

Various fungal species such as *Penicillium* spp., *Aspergillus* spp., *Alternaria* spp., *Scopulariopsis* spp. and *Cladosporium* spp. were isolated from 14 tanneries in Istanbul, Turkey. *Penicillium* spp. was found to be the most commonly isolated fungal species followed by *Aspergillus* spp. [41].

Leather without preservation or treated with insufficient of antimicrobial agent to prevent fungal contamination showed changes in the structure, loss of protein material, a reduction in physical and mechanical properties as well as the presence of stains that may compromise the quality of the final product [42].

Although the majority of the isolated microbial species are non-harmful and do not cause infections to humans [7, 43], studies also show that some species in the genera *Bacillus, Staphylococcus, Pseudomonas, Klebsiella, Aspergillus* and *Candida* are considered to be pathogens or potential pathogens [43, 44].

3. Antimicrobial materials and treatments utilized in leather processing

Among all the beamhouse processes, the soaking process is the most significant in which bacterial threat to raw material is high. In order to inhibit the bacterial growth in soaking various bactericides are used. Bactericides need to be effective in a neutral to weak alkaline medium only for a short period of time (1-2 days). They must not have an adverse effect on the hide or the activated sludge in effluent treatment plants [25].

Some attempts were performed on the research of the antibacterial effectiveness of different chemicals such as 2-Bromo-2-nitropropane-1,3-diol and potassium dimethyl dithiocarbamate against mix population of Gram negative (*Enterobacter cloacae, Vibrio fluvialis* and *Pseudomonas luteola*), Gram positive (*Staphylococcus cohnii and Enterococcus faecium*) and Gram positive endospore forming bacteria (*Bacillus pumilus*) and the test agent were proven to be fairly effective against the mix population of test bacteria [45, 46].

Researchers have determined that when leathers were soaked in a mixture of 2-Octyl-4-isothiazolin-3-one, the main ingredient in the commercial biocide known as Kathon biocide, and a solution of glutaraldehyde, it had an antibacterial effect against *S. aureus*. When 2-Octyl-4-isothiazolin-3-one was used alone, a 1 cm inhibition zone was formed around the leather, and when the mixture was used, a strong antibacterial effect was observed against both *S. aureus* and *colibacillus* [47].

As an alternative to these chemical based bactericides which are lethal to bacteria may also be harmful to the environment and human health, the possible use of ozone - which is used as an antimicrobial agent in various industries - in the leather industry is investigated. Comparing to the effect of a sodium dimethyl dithiocarbamide based bactericide, 15 minutes of ozone application has been found to be effective on bacterial growth prevention [48].

As a new attempt, chrome-tanned goatskins were dyed with pigments obtained from various fungi and they observed to have a greater antibacterial effect against Gram negative bacteria than against Gram positive bacteria. Among the pigments used, it was reported that those of *M. purpureus* (red) and *P. purpurogenum* (yellow) (6% owf) showed the greatest percentage reduction in the number of bacteria on the leather [49].

The synergistic effect of a combined electric current treatment using both 1.5 A direct and 2.0 A alternating electric currents, followed by 1 g/L of bronopol on mixed culture of Gram positive and Gram negative hide bacteria was examined in a soaking liquid medium. After the electric current treatment the reduction of bacteria was observed and the damaged bacteria were killed easily by bronopol in 5 hours [50].

In order for finished leather to gain antimicrobial qualities, biocides used in the leather industry are generally applied during the production process [51]. Various researchers have reported the addition of biocides at different processing stages such as soaking, pickling, tanning and dyeing in order to protect the leathers from the effects of micro-organisms.

The biocides used till now were mercury salts, mercaptobenzothiazole, DDT (dichloro diphenyl trichloroethane), HCH (hexachloro cydohexane), chloroacetamide, octylisothiazolinone, quaternary ammonium salts, chlorinated cresols and derivatives of benzothiazole. The use of the latter substances is said to be increasing due to the prohibition of pentachlorophenol, e.g., in Germany [52].

There are certain biocides, which can be used for a shorter period preservation. Several biocides were investigated of which biocides based on bigunanidine hydrochloride and benzothiozole derivatives along with boric acid are found to be effective. Even though these methods are comparatively less polluting, there are certain limitations such as cost effectiveness, not being effective for longer duration etc. which make the salt indispensable as curing agent till today [53].

Biocides, although killing the microorganisms, may not necessarily inactivate their hydrolytic enzymes [36]. Besides, the use of some biocides has been forbidden because of the danger they pose to the environment and human health, and the use of some fungicides has been limited in the production of environmentally friendly leathers [54].

Some fungi metabolize important substances in leather, causing serious damage such as pigmented stain that is difficult to remove, defects, surface roughness, and loss of physical and mechanical resistance, which affect the quality of the final product [55].

Annamalai *et al*. (1997) reported that fungal growth was a general problem in the leather industry; fungi could appear at different stage in the production process, but they could be controlled by fungicides [56].

Fungicides used in the leather industry can generally be classed under two headings. These are phenolic (CMC (para-chloro-meta-cresol), OPP (ortho-phenylphenol) and TCP (2,4,6-trichlorophenol)) and heterocyclic (TCMTB (2-Thiocyanatemethylthiobenzothiazol), OITZ (2-n-octylisothiazoline-3-one), BMC (2-benzimidazolylmethylcarbamate) and DIMTS (diiodomethyltolyl-sulphone)) compounds. TCMTB based fungicides, organic materials which have been developed over time to protect leathers from fungal damage, today are widely used in the leather industry as wide spectrum antifungal agents, and are employed in the pickling, tanning and crust leather processes.

The fungicides (TCMTB, CMC/oPP (o-Phenylphenol), OITZ) used in the form of their commercial product were investigated and found to be fundamentally suitable for several months preservation of wet blue. The OITZ containing product provided the greatest level of protection of leather [57].

The anti-fungal effects against three different species of fungus on calf leather with 2-amino-6-benzothiazole exchanged for a methoxy group in the form of sulphonic acid was investigated. It was found that a 0.5% benzothiazole based fungicide was enough to protect the leathers from the fungi *Penicillium aurantiogriseum* and *Scopulariopsis brevicaulis*, but that the level of fungicide of 0.5-1% used against the species *A. niger* in the study was insufficient and there was a risk of contamination after seven days [58].

Researchers in another study tested the anti-fungal effects of four different TCMTB based fungicides with methyl, methoxy, chloride and nitro groups in place of the anionic sulphonic group on wet-blue calf leathers against the fungi *A. niger* and *T. viride*, and found that the four fungicides examined were effective only against *A. niger* [59].

In other study the antifungal activity of diiodometil p-tolylsulfone (DIMPTS) and 3-Iodo-2-propynyl butylcarbamate (IPBCT) were compared with conventional fungicides. The greater antifungal capacity of two of the alternative fungicides, DIMPTS and IPBC applied to different processes confirms and ensure the possibility of use them in the leather sector [60].

Recent findings show that TCMTB has negative effects on the environment and human health, and therefore researchers and biocide producers are continuing their work to find more reliable and environmentally friendly fungicides [61].

The need has arisen to re-evaluate the usage rates and conditions of TCMTB based fungicides, to determine the amounts at various production stages and of the finished product using different analysis methods, and thereby to bring them under control.

The amounts of TCMTB in wet-blue sheepskins and their floats treated with five different TCMTB based fungicides sold under different trade names were evaluated using UV spectrophotometry and HPLC analysis methods, and the concentrations of TCMTB in the treated leathers and commercial products were determined. At the same time, the antifungal effect of the amounts of residue was tested against *A. niger*, one of the commonest species of fungi found on leather, according to the tropical chamber and the method ASTM D4576 [62].

The performance of five microbicides conventionally used in the leather industry, against different fungi was evaluated. Microbicides were applied during the tanning process with vegetable tannin in the fatliquoring step. Accelerated microbiological tests (plating and tropical chamber) were performed. The results revealed a low antifungal capacity of selected microbicides when applied at an offer of 0.2% (mass hide base) fungicides. Treatment with OIT+BMC/water at an offer of 0.75% showed satisfactory fungal protection against different fungi tested and proved to be the most suitable for the preservation of vegetable tanned leather [54].

4. Conclusion

Various types of bacterial and fungal species have been isolated from hides/skins and leather at various stages of the leather manufacturing processes. Micro-organisms can cause damages or problems as smells, oil leaching, spoiling of the leather and colour irregularities removal of which is hard or sometimes impossible. It is not less important to determine which species is causing damage and to select and use the specific type of biocide which will inhibit that particular species.

A wide variety of antimicrobial agents can be used to prevent microbial activities in leather making, but many of these have an adverse effect on the environment, and these agents are also the most expensive among the many chemicals employed. Most fungicides used in the leather industry today are dangerous and bad for the environment as well. Therefore, it is important to reveal naturally based compounds with antimicrobial activity which can be used in the leather industry.

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