



New Approaches of utilization Aloe vera in Wet Processing of Textiles

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Abstract

The application of aloe vera in textile processing is gaining worldwide detection as one of the hopeful approaches to pollution issues and cost reduction. Aloe vera gel possesses some biological activities and unique properties such as colorless, transparent, and viscosity which meet the using as a printing thickener, mordant, antimicrobial for different fabrics and dyes. Aloe vera is used in pre-treatment such as scouring, desizing, softening, and printing due to its succulent enzymatic and gummy characteristics. Aloe vera gel also contains a salty substance that allows its use in natural, eco-friendly dyeing. Aloe vera gel also is an alternative to synthetic antimicrobial agents. This state of art highlights the novel approaches of application of aloe vera in the textile coloration and industry covering both current types of research and pilot application.

Keywords: Aloe vera; antimicrobial; ecofriendly; textile wet processing; thickener; pre-treatment; printing; dyeing; finishing; microencapsulation.

1. Introduction

Textile wet processing utilizes a huge amount of water, dyes and chemicals, and other auxiliaries for processes. It can be considered as having three stages, pretreatment (or preparation), coloration (dyeing or printing) and finishing.

Textile wet processing industry is one of major cause of environmental pollution. Because it is included a toxic, hazardous, and less bio-degradable compounds which is a major source of effluents and pollution. Searching for ecofriendly alternatives is a main concern of most researchers.

Natural resources are gaining global recognition because of their nontoxic and eco-friendly characteristics with the increasingly important requirements for textile manufacturers to reduce pollution in textile production.

Historically, Aloe vera is one of the oldest medicinal natural plants in human history. Many ancient works, including the Bible, refer to the use of aloe. 6000 -year-old carvings of the aloe plant have been discovered in Egypt. [1] Aloe vera as an herbal preparation, was mentioned in the papyrus no fewer than 12 times. [2]

Aloe vera has been used for medicinal purposes in several cultures for thousands of years: Egypt, India, Greece, Mexico, Japan, and China. [3] Egyptians called Aloe vera a “Plant of Immortality” [4]. It was presented as a burial gift for deceased pharaohs [1]. Egyptian history refers to Aloe as favorite herb in Cleopatra’s bath, and Egyptian queen Nefertiti used it as part of her regular beauty regimes. [5]

Today, the Aloe vera plant has been used for various purposes. Aloe gel is proving to be essential, with its natural, biodegradable, and eco-friendly products that are safe for our health. There is no denying the fact that it is loaded with nutrients. However, as they say, excess of anything is bad. There are chances that aloe vera may not suit your body, skin, or hair, which can further lead to side effects. Most people can be allergic to the aloe vera gel, causing skin allergies, redness in the eyes, skin rashes, irritation and burning sensation. [6]

Aloe was previously considered in family Liliaceae, but now it has been placed in its own family Aloaceae. [7]

Geographically, Its origin dates to the South and East Africa as well as in the Mediterranean regions. It

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Receive Date: 13 July 2021, Revise Date: 07 August 2021, Accept Date: 11 August 2021

DOI: 10.21608/EJCHEM.2021.85303.4158

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has more than 400 species and is found all over the world but grows mostly in subtropical regions.



Fig (1) Aloe vera plant

Aloe vera is a perennial plant with green leaves (color varies from bright green to gray) arranged in a rosette pattern at the stem. Each plant usually has 12-16 leaves and can be harvested every 6 to 8 weeks by removing 3 to 4 leaves per plant. Its leaves are triangular and fleshy with serrated edges, which have a high-water holding capacity which enables the plant to survive in harsh conditions such as long periods of drought and warm dry climate. [8]

Aloe vera is considered as the most important types of aloe species, because of their leaves are the source of various organic acids, enzymes, phenolic compounds, minerals, and vitamins. Similarly, polysaccharides, lignin, pectin, hemicellulose, and cellulose are present in the rind. [9]

2. Composition of Aloe vera

Aloe vera is a tender plant containing a high-water content (99 – 99.5%). Solid contents range from (0.5 – 1%) and consist of a variety of active components such as fat, water soluble minerals, vitamins, simple/complex polysaccharides, organic acids, enzymes, and phenolic compounds. [10] as shown in Fig (2) the leaf of aloe vera consists of three layers: rind, latex, and gel.

- **Rind or epidermis** : is the outer thick layer consisting of 15 – 20 cells which gives protection to gel matrix and helps in the synthesis of carbohydrates and proteins. (photosynthesis takes place here with sap) [8] and [11]
- **Latex**: is the middle layer containing bitter yellow exudate which contains 1, 8 dihydroxy anthraquinones derivatives, and glycosides. Also called The mucilage (container) layer. [10]
- **Gel**: Inner layer consisting of soft, clear, moist, colorless, and slippery tissues having large parenchyma cells storing the leaf gel which contains water (99%) with an average pH of 4.5., glucomannans, amino acids, lipids, sterols, enzymes, vitamins and inorganic compounds and small organic compounds in addition to a variety carbohydrate.

Rind and gel make up a significant portion of the whole leaf's weight (20 - 30% and 70 -80%, respectively).

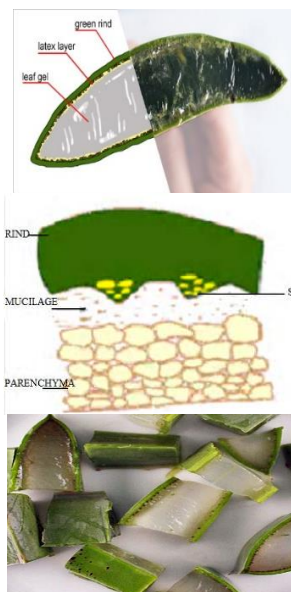


Fig (2) A cross sectional view of Aloe vera leaf showing inner, middle and outer layers. [12]

On a dry matter basis the gel consists of 55% polysaccharides, 17% sugars, 16% minerals, 7% proteins, 4% lipids, 1% phenolic compounds and a variety of vitamins including vitamin A, C, E, B1, B2, B12, niacin, choline and folic acid. Fig (2) [13]

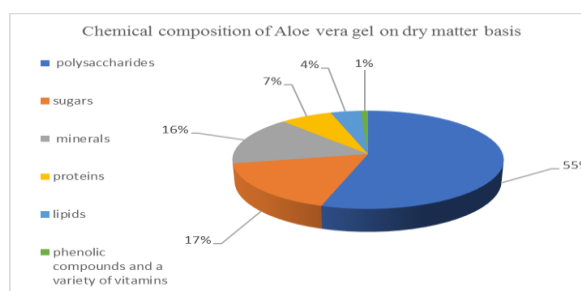
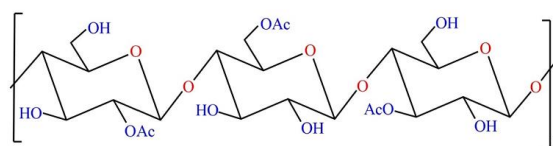


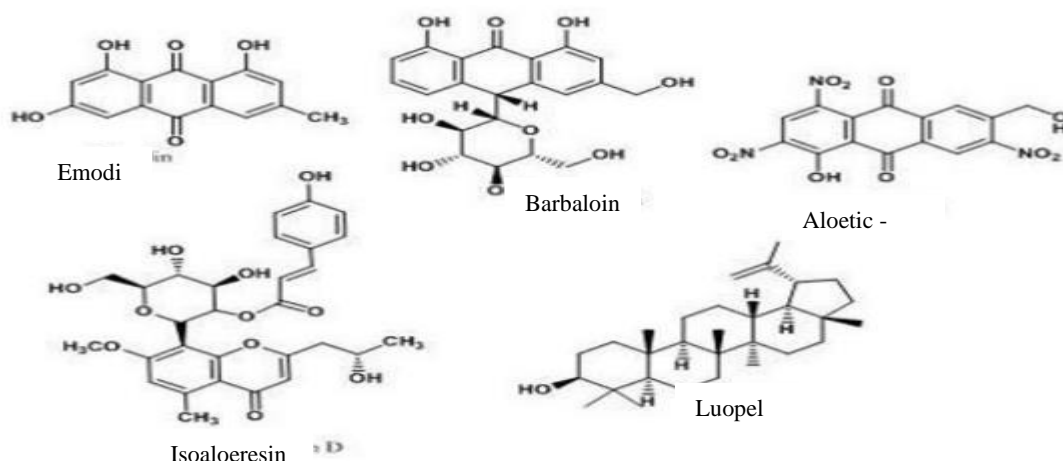
Fig (3) chemical composition of Aloe vera gel on dry matter basis [14]

Carbohydrates: consist of mono and polysaccharides including glucomannans, xylose, rhamnose, galactose and arabinose. [13]

Monosaccharide and polysaccharide sugars which combine into acemannan, polymannose glucose, cellulose, mannose, pectic substances, acetylated glucomannan and mannan. The chemical structure of acemannan is shown in Scheme (1) Aloe vera consists of more than 200 active ingredients, Its bioactive molecules are given in Scheme (2).



Scheme (1) (Acemannan) antimicrobial ingredients of aloe vera [15]



Scheme (2) Active agents of aloe vera [16]

Enzymes: Sixteen distinct enzymes have been found in Aloe vera, include catalase, amylase, oxidase, cellulase, lipase, carboxypeptidase, catalase, superoxide dismutase, cyclooxygenase, anthranol, barbaloin, alkaline phosphatase, smodin, phosphoenolpyruvate carboxylase, chrysophanic acid, and brad-kinase. The above-mentioned enzymes are widely employed as anti-bacterials, anti-fungals, antivirals, anti-inflammatory agents and analgesic agents. [17, 18]

As **mineral** composition: Aloe Vera contains Potassium and chloride are present in excessive amounts whereas sodium, calcium, magnesium, copper, zinc, chromium, and iron are present in small amounts. [19]

A series of **glycosides** (anthraquinones) are present in Aloe gel with aloin A and aloin B being the most prominent. Anthraquinones and their derivatives are potent antimicrobials and analgesic agents. Around 20 amino acids are present in Aloe vera gel among which seven are essential amino acids. [13]

In addition, lectin (a protein), present in Aloe vera, is reported to promote cell proliferation.



Fig (4): Components of Aloe vera plant

3. Rheological behavior of Aloe vera gel

Aloe vera gel generally exhibits elastic behavior which can be attributed to the network of polymeric fibrous chains. Viscosity decreases with increasing shear rate (exhibiting shear thinning behavior); however, above certain critical value (100 S^{-1}) viscosity becomes constant. Such rheological behavior is attributed to the structural decomposition and

rearrangement of weak network of polymeric fibers. [20]

Rheology of any formulation such as paste depends upon the combination of individual components as well as their mutual interactions. The addition of Aloe vera gel to different products can lead to complex rheological behaviors, developing from its interactions with product ingredients as well as process conditions.

However, the rheological properties of Aloe vera can be tuned to meet product requirements. Moreover, it can also be used as a rheology modifier for various products. [19]

In the refrigerator, the aloe vera gel can last for up to 6 months. [21, 22]

Aloe vera is used in pre-treatment and printing due to its succulent enzymatic and gummy characteristics. Aloe gel also contains a salty substance that allows its use in natural, eco-friendly dyeing and finishing.

This review considers the many actual and potential applications of Aloe vera in textiles wet processing field.

4. Eco-friendly utilization of Aloe vera in Wet Processing of Textiles.

To meet customer demand, A huge amount of inorganic chemicals are used in textiles pretreatment, dyeing, printing, and finishing.

Since, the use of these chemicals produces a huge amount of effluent but causes water pollution, researchers have been trying to use eco-friendly products like Aloe vera instead of inorganic chemicals for these purposes to protect the environment from this pollution.

Aloe vera is suitable for such pretreatment because it contains many enzymes, salt and gummy substances which are essential for textile wet processing.

4.1. Bio Scouring with aloe vera

Scouring process was used to remove the non-cellulosic impurities from the cotton to have a uniform

absorbency. Highly alkaline chemicals like caustic soda, soda ash, silicate, acetic acid, and soaping agents are used for scouring, but destruction of cotton structure may be happened also attack the cellulose leading to heavy strength loss and weight loss in the fabric.

moreover, the need for intensive rinsing and more acid to reutilization the cotton, which leads to a large volume of effluent.

Jothi D. [23] worked on bio-scouring of 100% cotton knitted fabric with lipase enzyme extracted from Aloe deberena plant at various concentration (1%, 3% and 5%) at various temperature (40°C, 60°C and 80°C) for various time (30, 45, and 60 min) and various pH (5.5, 7.0 and 8.5). The properties of bio scoured fabrics are compared with these of conventional scoured one after bleached and dyeing with reactive dye.

Optimum condition of bio scouring with enzyme, requires treatment with concentration 5% at pH 5.5 at 80°C for 1 hour. Bio-scoured fabrics, using the Aloe vera extract, showed better dye levels, dye uptake, light fastness, wash fastness, and rubbing fastness for medium and dark reactive colors than did conventionally scoured fabric. Bio-scouring saved a substantial amount of thermal energy (50%) and electrical energy (40%). Bio-scouring wastewater has 40–50% less COD and 60% fewer TDS than conventional-scouring wastewater does.

Bio scouring with enzyme is corresponding with a significant role in minimizing the demand of energy, water, chemicals, time and therefore costs. After bio scouring, fabric can be dyed directly without bleaching, which also reduces additional cost in this step. But in this process, light-colored shades cannot be produced or very difficult match. [24]

Enzymatic Desizing with aloe vera:

For the improved and uniform wet processing of the fiber, starch-based size is needed to be removed prior to dyeing and printing, this is known as desizing, which is the key action of the pretreatment. As converts the water insoluble starch in to the soluble one which is washed away from the fabric during washing and enhances the performance of the fabric. [25]

Since enzymes are widely used in desizing which called Enzymatic desizing. These enzymes catalyze the breakdown of the starch chain without damaging the support material as their action is specific to starch.

Amanuel L and Teferi X [26] discuss the desizing process using Aloe vera gel instead of inorganic chemicals. Since Aloe gel contains many important enzymes and organic components like peroxidase, carboxypeptidase, amylase, and alkaline phosphatase. The aloe gel has been showed outstanding results for desizing with controlled temperature and pH.

The aloe gel treated fabric was exhibited high desizing efficiency. This is due to key-Lock

mechanism of enzymes presents in the aloe gel Fig (5). When we compare the desizing efficiency of synthetic enzyme and aloe gel enzyme (natural enzyme amylase) the weight loss is greater that means the weight loss in synthetic enzyme desizing is 7.9% and in aloe gel case it is 11.02% so it has good desizing efficiency but aloe gel desizing have side effect of coloring salt.

These aloe vera enzymes have active centers, which fits into a particular substrate molecule. Then the substrate forms a complex with the enzyme. Later the substrate molecule is converted into the product and the enzyme itself is regenerated Fig (6). The process continues until the enzyme is poisoned by a chemical bogie or inactivated by extremes of temperature, pH.

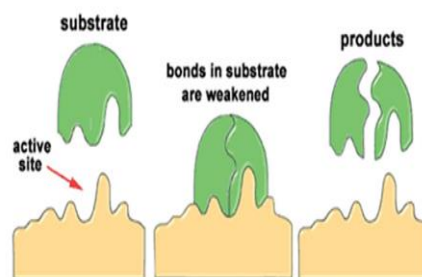


Fig (5) Aloe vera's enzyme key-Lock mechanism desizing

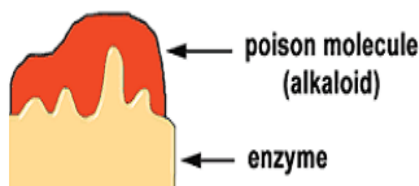


Fig (6) Active side by enzyme blocked by chemical bogie

4.2. Dyeing with aloe vera

Srivastava A. and Singh T. [11] worked on using aloe vera leaf as a natural dye and mordanting agent. Aloe vera's dye was extracted by churned leaves into a mixer then extracted by two ways using water boiling or solution containing 60% ethanol and 40% water. Then A solution of fresh aloe leaves was used for dyeing of cellulose and protein fabrics in presence of nitric acid, the dye obtained 'chrysammic acid' is acid dye.

On protein (silk and wool) fabrics, it rendered beautiful golden yellow color when using with outstanding wash fastness, due to cationic groups in the form of protonated amino groups. On cellulosic fabric (cotton): because cotton contains an anionic group, so a cationization process must be carried out before dyeing. In presence of different mordants to achieve different colors varying from yellow, pink, khaki to brown.

Amanuel L and Teferi X [27] worked on Aloe vera gel which used instead of salt in a reactive dyeing process.

Since aloe vera consists of salt, acid, enzymes, and many components that are essential to the dyeing process, aloe gel have been used to present sodium ion on dyeing cotton with reactive dye without salt. Aloe gel treated cotton fabrics, was dyed with different types of reactive dyes without addition of sodium chloride with different concentration of aloe gel. Treated sample was compared with normal dyed untreated sample. The fabrics treated with 100% aloe gel have good and highest shade depth, 80% aloe gel treated fabrics has medium, while the 60% aloe gel treated fabrics have lowest. increasing the concentration aloe gel led to increase the amount of sodium ion and therefor increase dye bath exhaustion so the dye uptake of the fabrics is higher. on a high concentration of Aloe vera contains more salt than dye does. Treatment of cotton fabric with aloe gel increases dye uptake of cotton at low salt condition without decreasing the wash fastness.

Some reports discuss using Aloe vera as a mordant for dyeing of turmeric powder on cotton and silk fabric. Fig (7) [28]



Fig (7): Cotton (left) and silk (right) fabric dyed with turmeric by using aloe vera mordant

4.3. Aloe vera gel as thickening agent on Printing:

Printing is most important process used to decorate textile materials. Textile printing is localized dyeing in definite patterns.

A successful print involves correct color, sharp-line, levelness, good hand, and efficient use of dye; all these factors depend on the type of thickener used. [29]

Thickening agents usually high molecular weight polymeric substances that give the necessary viscosity of the color printing paste under high pressure, without distortion. Textile thickeners either natural (e.g., Arabic gum, guar gum, alginate, starch, etc.) or man-made (i.e., based on modified natural polymers or wholly synthetic polymers, or emulsion).

The use of synthetic thickeners causes harmful effects in the environment, to reduce and avoid this effect an eco-friendly thickener can be used.

Aloe vera gel possesses some unique properties such as colorless, transparent, and viscous which meet the using as a printing thickener for different fabrics and dyes.

4.3.1. Aloe vera gel as thickener with reactive dye on cotton

Since the conventional thickeners such as starch, CMC, guar gum contains free -OH groups, are not suitable for printing cotton with reactive dyes. because of these free hydroxyl groups which competes with the free hydroxyl group of cellulose toward dye. whereas Sodium alginate is suitable because it is free from free -OH groups. the same trend in aloe vera which contains (glactouronic acid) important used as thickener because which is free from -OH groups. Many attempts to use aloe vera as thickening agents had been reported.

Ferede E. [30] worked on using aloe vera gel in combination with sodium alginate as a thickener to suit printing cotton fabric with reactive dyes.

Three different types of thickeners combination, aloe vera gel (AG), Sodium alginate (SA) and Mixture of aloe vera gel and sodium alginate (AGSA), was applied directly on cotton using manual screen-printing method to gaining best result.

using mixture of thickener (20 gm aloe vera and 2.5 gm sodium alginate), cotton printed fabrics had good characteristics include washing fastness, high color yield, softness and hand feeling properties, with medium viscosity and washing easily removed the extra chemicals.

Aloe vera can be applied to cotton as a new thickening agent in reactive printing, achieving increased thickening efficiency as well as better depth and stability properties for printed samples.

Pradhan et al. [21] found that printing cotton samples with Aloe vera gel exhibited excellent results (wash and lightfastness) when using 4gm reactive dye concentration.

4.3.2. Aloe vera gel as thickener with direct dye on cotton

Pradhan et al. [22] found that aloe vera thickener was successfully applied on cotton fabrics with 3gm direct dye. When using after treatment with 10% vinegar for 5 minutes gave best result.

4.3.3. Aloe vera gel as thickener with pigment on cotton

In printing with pigments, the use of a low-solids thickener is required, as it remains with the fabric after printing.

zero-solids emulsion thickeners become quite prohibited in recent years owing to problems such as emission of volatile organic compounds (VOCs) into the atmosphere during the drying and curing stage, flammability or explosion risk, wasteful use of energy, and ever-increasing cost.

because aloe vera gel contains a very low solids content, allowing most of its constituents to be evaporated during curing treatment. For the same reason, a sample printed with higher aloe vera shows

a better comfort property in terms of vapor permeability.

poor sharpness of the printed sample and less color yield were observed when only Aloe Vera gel was used as thickener, followed by an improvement in color yield with Sodium Alginate addition.

Islam et al., [30] discuss possibility of aloe vera gel as thickener for printing of cotton fabric with pigment, in combination with sodium alginate, to enhance the properties of the printed fabric (sharpness, color yield, overall fastness properties, softness, and water vapor transmission) which are dependent on the percentage of Aloe vera gel in the thickener combination, the concentration of printing auxiliaries, and the curing conditions.

Optimum printing properties were achieved by using a printing paste containing 80% Aloe vera 20% sodium alginate (700 g/kg), pigment (50 g /kg), binder (145 g /kg), fixer (10g/kg), and ammonium sulfate (5 g /kg), followed by drying at 85 ° C for 5 min and curing at 150 ° C for 3 min.

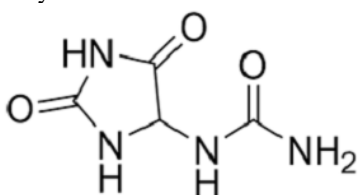
4.3.4. Aloe vera gel as thickener with natural dyes on cotton

Zarkogianni et al. [31] worked on adding aloe vera into printing paste as a part of the thickener when printing with natural dyes and examine its effect on the printed fabric and on the fabric sew-ability.

Printing pastes as expected lower the fabrics sew-ability, due to the additional printed film over the fabric surface, that the needle must penetrate through.

knitted and woven cotton fabrics was printed with two different thickening agents (sodium alginate and acrylic thickener) with natural dyes turmeric, annatto and Saffron. aloe vera was added to sodium alginate to enhance fabric properties.

With curcumin paste aloe vera showed best results in fastness properties specially rubbing wet properties and sew-ability.



Scheme (3): Curcumin present in turmeric [14]

NB: it is known that the force developed is related to the ease of the sewing process, which is called "sew-ability". Fabrics with needle high penetration tend to cause needle heating, breakage, and problematic processing. [32]

4.3.5. Aloe vera gel as thickener with disperse dyes on polyester

Awoke et al. [33] discuss broadly the technical feasibility of using Aloe debrana gel as thickener for printing polyester or cotton with disperse dyes.

Polyester and cotton have different nature chemically. Cotton has hydrophilic end chemical nature and it is not expected to have good interaction with hydrophobic dyes (disperse dyes) however using the Aloe debrana thickener with disperse dyes showed very good interaction with cotton and printing was carried out with good performance.

Different thickener agent Aloe debrana gel, Alginate and emulsion and their mixture (Aloe gel - Alginate or Aloe gel -Emulsion) were applied on 100% polyester and 100% cotton woven fabrics using flat screen technique. fresh Aloe debrana and preserved gel was also compared.

A natural preservative lemon juice has high potential to preserve the gel more than two months. The results showed that no significant difference between fresh gel and preserved gel.

Aloe debrana as a thickening agent in disperse printing results in good thickening efficiency as well as better depth and fastness properties of the obtained prints in comparison with the Alginate and Emulsion thickener.

El-Zairy E. [34] found that the optimum conditions for printing disperse dyes on polyester fabric using Aloe vera gel as a thickener as follows: 30 g/kg disperse dye, 50 g/kg urea, 15 g/kg citric acid, 500 g/kg Aloe vera thickener and 50% drying at 100°C for 3 min followed by steam fixation at 180°C for 6 min.

4.4. Textiles Finishing

In order to impart desired, specified, and desired functional properties to the fabric, this can be done by subjecting the material to various types of physical and chemical treatments.

Textile finishing refers to any process performed after dyeing the yarn or fabric to improve the look, performance, or hand feel of the finished textile or clothing.

4.4.1. Antimicrobial Finishing Methods

Coating, Exhaust, Pad-dry-cure, Spray & foam techniques, Synthesize Zinc Nano particles stabilization, or Fiber spinning method.

Pad dry method was the best way to give greater antibacterial properties which also made the fabric soft. [35]

The antimicrobial finishes are generally applied by following means to the textile substrate:

- Absorption or Surface Treatment
- Chemical Bonding
- Micro-encapsulation.

4.4.2. Antimicrobial

The use of antimicrobials dates to ancient Egypt where these were used in the procurement of mummies.

After the COVID-19 pandemic, antimicrobial textiles have gained a lot of attention and popularity in the market and in daily life. The antimicrobial finishes protect not only to the wearer but also to the fabric itself.

The main factors that promote the growth of microbes on textiles are the moisture content and the large surface area.

The attachment of microorganisms to fabrics is dependent upon the type of organism and the physio-chemical characteristics of fabric substrate.

The types of micro-organisms include different kinds of organisms such as virus, bacteria, unicellular plants and animals, certain algae, and fungi. Classification in bacteria family is "gram positive, gram negative, spore bearing or non-spore bearing type". Some of the bacteria are of pathogenic nature that may cause infections to human. [36] A microbe (such as bacteria and fungus) normally protected with an outer cell wall that is composed of polysaccharides.

The antimicrobial finish can be applied by physical and chemical methods, and by adding functional agents on to textile fibers. Such functional finishes can be of two main types, i.e., temporary antimicrobial finish and durable antimicrobial finish which done by wet process by bounding the biocide to fiber of fabric surface which release slowly and deactivate bacteria. [37]

The antimicrobial finishing process imparts the ability to textile substrate to inhibit the growth or kill at least some types of microorganisms.

A term that is adopted to indicate the textile fibers with activity against microorganism's growth is "bioactive fibers"

Types of Antimicrobial Finish

- Organic antimicrobial agents such as quaternary ammonium compounds (QACs)
- inorganic antimicrobial agents such as metal oxides, copper and zinc, titanium, magnesium, silver, and gold
- Eco-Friendly Antimicrobial Agents (Natural Plant and Fruit Extracts) aloe vera, Neem andso on.

Although the synthetic antimicrobial agents are very effective against a range of microbes and provide a durable effect on textiles, they are a cause of concern because of the associated side effects and ecological problems such as water pollution. Aloe vera possesses antifungal, antibacterial, and antimicrobial properties, which can be exploited for medical textile applications, such as wound dressing, suture, bioactive textiles, etc.

4.4.3. Antimicrobial applications of aloe vera on textiles

Selvi B.T. et al. [38] worked on preparing an ecofriendly natural antimicrobial finished cotton fabric, using Aloe vera gel combined with citric acid.

After the gel drained out, followed by air dried and soaked in acetone for four days. These were filtered and evaporated to dryness. The extract was dissolved in sterile water and used for the antimicrobial finishing by directly applied on 100% cotton fabric by pad-dry-cure method, at 60°C for 15 minutes.

By using qualitative Antibacterial Assessment of Diffusible Antibacterial (AATTC-147-1993) and quantitative (AATTCC-100-1993) assessment Antibacterial Finishes on Textiles, Aloe vera gel shows antifungal activity. The phenol group and anthraquinone present in Aloe vera gel are binding microbial proteins, inhibiting their growth and exhibit both antibacterial and antifungal activity. [39] The bioactivity was retained up to 15th wash cycles.

Also Hetal Mistry et al. [40] worked on cotton fabric finished with Aloe Vera extract with different solvents (Chitosan and Methanol) for natural antimicrobial finished. The extract was applied by pad-dry-cure method in different parameters (concentrations from 60% -100% for 35-60 mins at 60-80 °C).

The Aloe Vera extract treated cotton fabric exhibited antimicrobial activity against *Escherichia coli* and *Staphylococcus aureus*.

Fabric treated with 100% concentration of Aloe Vera extract, processed for 60 mins at 80 °C showed optimum antibacterial properties as compared to other concentrations. The washing durability was found to be good by this method.

To increase the stability of antibacterial finish methanol and chitosan were used as binding agent in finishing.

Ali S. W. et al., [41] worked on cotton fabrics were finished with Aloe vera gel along with 1,2,3,4-butanetetracar-boxylic acid (BTCA) as a crosslinking agent, and Sodium hypophosphite (NaH₂PO₂,H₂O) was used as a catalyst for carboxylic acid. Using the pad-dry-cure method. After padding, the treated fabric samples were dried at 85 °C for 5 min and cured at 150 °C for 2 min.

The antibacterial property of Aloe vera gel-finished fabric against both gram-positive and -negative bacteria was evaluated.

It was proved by the infrared spectra (FTIR) Fourier transform infrared spectroscopy, that the active ingredients of Aloe Vera are attached with the hydroxyl groups of cotton fabric via carboxylic acid cross linking agent through infrared spectra system.

The mechanism of cell death by Aloe vera gel was evaluated using transmission electron microscopy (TEM). TEM photographs suggested that the cell death is due to the destruction of the bacterial cell wall.

The active ingredients of Aloe vera destroyed the cell walls of both the bacteria. Thus, the cytoplasmic content leaked out from the cells, inhibiting the multiplication for further bacterial growth.

A minimum of 3 % (w/v) Aloe vera gel was found to be effective for obtaining good antibacterial efficacy against both gram-positive and -negative bacteria.

The antibacterial activity of the Aloe vera-finished cotton fabric was retained for up to eight machine washes.

Nadiger V. G. and Shulka S.R. [42] worked on silk fabric was treated with Aloe-Vera using 1,2,3,4-butanetetracarboxylic acid (BTCA) as crosslinking agent and sodium hypophosphite (SHP) as catalyst. The treated fabric with a concentration of 15% of Aloe-Vera showed excellent antimicrobial properties.

Since BTCA was used as a crosslinking agent, crease recovery angle improved with minimal loss in breaking and tearing strength. The mechanism of treatment of Aloe-Vera is found to be chemical binding with silk and not simply of coating or impregnation.

FTIR studies showed that the carboxyl side groups, and short chain amino acids side groups act as sites for BTCA crosslinking inter alia chemical binding of Aloe-Vera.

SEM studies revealed that no coating or tangible impregnation on the surface of the fiber is visible substantiating the chemical binding phenomenon.

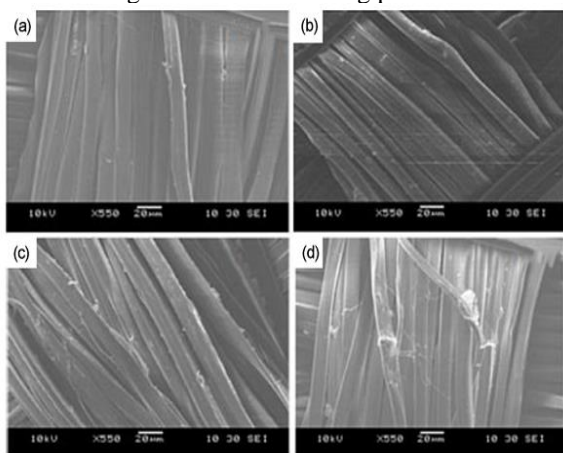


Fig (8) SEM micrographs of (a) control silk fabric, (b) 5 % Aloe-Vera finished silk fabric, (c) 10 % Aloe-Vera finished silk fabric, and (d) 15 % Aloe-Vera finished silk fabric. [42]

4.4.4. The microencapsulation

The microencapsulation of essential oils and its application in textile allows the gathering of various functions to substrates, imparting them antimicrobial properties, UV protection, and others.

The microencapsulation involving essential oils applied to textile substrates enhances the lifespan of this kind of product, avoiding rapid evaporation of it.

The release might happen due to the sensibility of the wall to the pH, heat, mechanical pressure, humidity, and other factors. [43]

The microencapsulation guarantees the protection of the active principle, as well as its controlled release, hence the great interest of its application in textile materials.

Fiedler J.O. et al. [44] worked on the microencapsulation of Aloe Vera with cornstarch using the simple coacervation technique on nonwoven cotton fabric using butane tetracarboxylic acid (BTCA) as a binding agent. FTIR was used to prove the interaction between nonwoven and microcapsule.

Cornstarch was used as encapsulating agent and Aloe vera as active principle. For the formation of the coacervate, a mechanical stirrer was used. The analytical agents used were Acetic Acid (AcOH) 10% v/v, Sodium Hydroxide (NaOH) 1 mol/L for pH correction. Glutaraldehyde ($C_5H_8O_2$) 10% (v/v) was used to stiffen the walls of the microcapsules.

using the pad-dry-cure method. the nonwoven samples were immersed in the bath for 1 min containing 30 g/L of microcapsules dispersed in aqueous solution, 75 g/L of butane tetracarboxylic acid (BTCA) (binding agent), and 45 g/L of sodium hypophosphate ($Na PO_2H_2$) (catalyst)

from Fig (9) note a polydisperse distribution, with irregular shape and sizes varying from 3 μm to 50 μm .

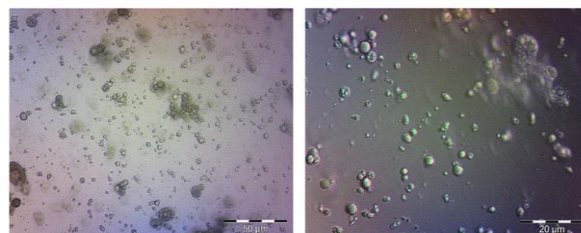


Fig (9) Optical Microscopy of the microcapsules formed via simple coacervation [44]

from Fig (10) there is a significant number of microcapsules that do not have perfect spherical morphology, the cornstarch samples have shown a high proportion of angular granules as well as some rounded granules.

So, the microcapsules of Aloe Vera and cornstarch can be applied to nonwoven bandages used in the treatment of burned skin.

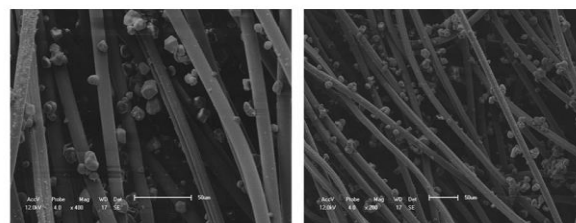


Fig (10) Scanning Electron Microscopy (SEM) for the microcapsules produced via simple coacervation, magnification 1820x. [44]

5. Conclusion

The scope of the current review was to illustrate Aloe vera plant modern usage variants in the field of textiles wet process.

Textile wet processing industry is one of main reason of environmental pollution. As the world began to move towards sustainability, it has become necessary to stop using hazard materials and switch to natural materials.

Aloe gel is proving to be essential, with its natural, biodegradable, and eco-friendly products that are safe for our health.

Aloe vera a "Plant of Immortality", it is a perennial plant containing a high-water content (99%). Solid contents (1%) which consist of a variety of active components such as fats, water soluble minerals, vitamins, simple/complex polysaccharides, organic acids, enzymes, and phenolic compounds. [10]

Due to aloe vera contains lipase enzyme, it can be used in bio-scouring of cotton fabrics, which saved a substantial amount of thermal energy (50%) and electrical energy (40%). Bio-scouring wastewater has 40–50% less COD and 60% fewer TDS than conventional-scouring wastewater does. [23]

Since Aloe gel contains many important enzymes and organic components like peroxidase, carboxypeptidase, amylase, and alkaline phosphatase. The aloe gel has been showed outstanding results for desizing with controlled pH and temperature. [26]

Moreover, Aloe vera can be used as a natural dye and mordanting agent, and gel used instead of salt in a reactive dyeing process, as well. Many attempts to use aloe vera as thickening agent. [11, 26, 27]

Aloe vera gel can be used in combination with sodium alginate as a thickener to suit printing cotton fabric with reactive dyes. [29-31]

Aloe gel has a potential of changing the property of disperse dye to have good interaction with cotton. [33]

Aloe vera possesses antifungal, antibacterial, and antimicrobial properties, so aloe vera gel can be used as an alternative to synthetic antimicrobial agents. This bioactive fabric can be used in hospitals, Sportswear, home textile, carpets, non-woven, protective clothing etc. [38-44]

The future of textile industries is in the production of colored functional fabrics due to its high price and high demand.

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