

Review

Traditional to Modern of *Aloe* Application in Industry, A Review

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Abstract. Many of the traditional uses of *Aloe* species have been confirmed by scientific studies. These days, a lot of companies are industrializing a range of goods made from *Aloe*. *Aloe* species serve as a foundation for a number of formulations, such as suntan lotions and moisturizers, which are humectants in skin preparations. In modern days, researchers are trying to confirm the scientific way of using these plants in both *in vitro* and *in vivo* trials for the therapeutic efficacy, responsible bioactive compounds, toxicology and dosages. Currently, incorporating *Aloe* extracts to the raw material of food industry is used to manufacture functional foods, nutraceutical foods, edible coating/films and antimicrobial agent foods. The study examined the effects of spraying *Aloe vera* extract and using organic fertilizer on the chemical composition, seed yield, oil yield and vegetative growth of plants *Aloe* species extract have been used to achieve high yields. Because *Aloe* species have a naturally occurring colour, they are used as thickening agents and in biotechnology applications for textile pretreatment and colouration. Taking into account their numerous health benefits and valuable chemical composition, the *Aloe* species could be regarded as economically significant matrices for the cosmetics, pharmaceutical, food, beverages, agricultural chemicals, printing and dye industries. As a result, controlled research will be needed in the future to demonstrate the *Aloe* species efficacy in a variety of settings while maintaining the species. In summary, *Aloe* species extracts are used to boost the efficacy of modern industrial inputs for various products by combining them with other useful materials.

Keywords: *aloe* species, phytochemicals, chemical composition, biological activities, industrial applications

Introduction

People have long used *Aloe* plants for traditional and popular purposes. Several commercial applications have resulted from the multipurpose traditional medicine of *Aloe* species. Many different ailments have been treated with *Aloe* plants as a folk remedy. The plants have been used for food and medicine for thousands of years. Because their preparations, instructions, practices, skills and knowledge are profitable, traditional medical systems all over the world have a significant role in modern development. Many of the traditional uses of *Aloe* species have been confirmed by scientific studies (Akaberi *et al.*, 2016; Chen *et al.*, 2012). *Aloe* species are commonly used in the production of bioactive compounds, traditional medicine and commercial food products (Baskaran *et al.*, 2015). Aloes are produced as lovely plants and contain a wide range of chemical compositions that can be used to make pharmaceutical, personal hygiene and cosmetic products, as well as

medical and beauty products (Grace *et al.*, 2008). The plant's fleshy leaves, gel and latex are primarily used commercially in the food, cosmetics and pharmaceutical industries as pills, jellies, creams, drinks, liquid, sprays, ointments and lotions (Datta *et al.*, 2012).

Aloe gel processing from the plant's leaf pulp has become a significant global industrial raw material due to its applications in the cosmetics, pharmaceutical, food and beverage industries (Nejatzadeh-Barandozi *et al.*, 2012; Chang *et al.*, 2011). Mesophyll, or "gel," is a colourless, spongy substance derived from the leaves of *Aloe* plants. It is used as a natural product ingredient in foods, household goods, topical medications and cosmetics, with a significant global market (Grace *et al.*, 2013). These plants are used industrially for a variety of purposes, including beverages, ice cream, food supplements and more products (Hamman, 2008). Several species of *Aloe* have recently been included in a range of skin and hair care products (Habtemariam and Medhanie, 2017). Numerous products, such as lotions, creams, soaps, shampoos, ointments, pills and

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capsules, are made with *Aloe* gel moisturizing and excipient qualities (Ray *et al.*, 2013). *Aloe vera*, for instance, is frequently used in toothpaste, mouthwash, shaving creams, deodorants, moisturizers, cleansers, sun lotions and shampoos in the toiletry and cosmetic industries (Christaki and Florou-Paneri, 2010). These days, a lot of companies are industrializing a range of goods made from *Aloe* extracts. However, there is a lack of thorough data illustrating the incorporation of *Aloe* extracts into manufactured goods. The *Aloe* species have various value added applications in the marketplace today which are used for food production, medicine and cosmetics sectors. These are verifications of traditional applications of *Aloe* species for industrial applications. The study also used gather information on how prepare *Aloe* extracts and chemical compositions of *Aloe* species. Therefore, the current objective is dependent upon the incorporation of *Aloe* species extracts into raw materials of industrial products.

Preparation of *Aloe* extracts. Every *Aloe* plant treatment involves getting ready for the extraction process. An extract can be made from plant material directly or from plant material in solvents. To make the leaf extracts, mature, healthy and large leaves of *Aloe* species are selected and gathered. The collected leaves are washed with water to remove impurities (Ahmed and Hussain, 2013; Joseph and Raj, 2010). If each of the three leaf portions (leaf peel, leaf gel or leaf latex) is needed separately, the leaves are then cut transversally near the base and stacked concentrically around a plate or container to extract the leaf latex. To create the gel, cut the leaf's peel/skin and edge with a sterile, sharp knife or blade (Fig. 1). Next, gel is chopped in order to expedite the drying process. After that, the gels are powdered. Although the techniques for drying and powdering may differ, other components of the *Aloe* plants such as root and flower, are also dried and ground up for additional processing (Abdissa *et al.*, 2017; López *et al.*, 2013). The powdered plant samples may be analyzed solely without solvents or extracted with solvents based on the target of analysis or application.

Chemical components of *Aloe* species. Proximate and mineral composition of *Aloe* species. A quantitative chemical technique for determining and communicating a food nutritional value is called proximate analysis. As a percentage of dry fuel weight, it presents the fuel's moisture content, ash (minerals), crude fibre, crude fat and crude protein (total nitrogen) (Haque *et al.*, 2014). Proximate analysis, also known as "conventional

analysis," is a method of nutrient investigation that identifies the gross components as opposed to the specific nutrients, such as monosaccharides, fatty acids



Fig. 1. Separation of the leaf gel of *Aloe fleurentinorum* (Moni *et al.*, 2021).

and amino acids (Onyeike and Osuji, 2003). Moisture content, crude protein, crude fibre, crude fat, ash content and carbohydrate make up the proximate composition. *Aloe* species have been found to be high in fat, protein and carbohydrates in literature, which suggests that *Aloe* species have nutritional value (Yadeta, 2022).

Aloe species are rich in minerals such as potassium, sodium, phosphorus, magnesium, zinc, iron, manganese, copper, lead and so forth, as the mineral analysis revealed (Adesuyi *et al.*, 2012). Determining the amount of ash and minerals in food helps evaluate its nutritional value. It involves identifying the components and confirming whether the food contains certain minerals in amounts that are harmful to the consumer's health, whether those minerals are naturally occurring or have been added to processed, preserved, or other food items (Jain and Gupta, 2005).

Phytochemical reports of *Aloe* species. Phytochemical screening determines whether secondary metabolites are present or absent in the in the extract. Basic characteristics of phytochemical screening include (1) plant parts such as leaves (gel, latex, or skin), roots, or flowers; (2) weather and soil type; (3) harvesting period; (4) extraction solvent (methanol, ethanol, ethyl acetate, chloroform, hexane, etc., or their ratio); (5) other factors that determine whether phytochemicals are present or absent even for the same plant (Steenkamp and Stewart, 2007). To display the reports of the phytochemical screening, some *Aloe* species and the part of the plant are taken into account (Table 1).

Isolated compounds from *Aloe* species. Several bioactive compounds which are classified into chromone, anthraquinone, flavonoids, phenylpropanoids, coumarins, phytosterols, naphthalene analogs, lipids and others have been isolated from *Aloe* species, Fig. 2 (Kahramano-glu *et al.*, 2019). The chemical components of *Aloe* have been analyzed using a variety of techniques, including capillary electrophoresis, thin layer chromatography, size exclusion chromatography, gas chromatography, gas chromatography-mass spectrometry, high performance liquid chromatography, liquid chromatography/mass spectrometry, atomic absorption spectrometry and counter current chromatography. In addition to chromatographic techniques, spectroscopic instruments used to characterize the structure of the isolated compounds (López-Cervantes *et al.*, 2018; Nejat-zadeh-Barandozi *et al.*, 2012; Grace *et al.*, 2008).

Relationship between phytochemicals, biological activities and applications of *Aloe* species. Phenolic compounds, carbohydrates, proteins, lipids, minerals, vitamins, enzymes, hydrocarbons, fatty acids, indoles, pyrimidines, aldehydes and ketones, dicarboxylic acids, alkaloids and others are among the active chemical constituents found in *Aloe* species. The phytochemicals are what give *Aloe* species their biological activities. *Aloe* species are known for their biological activities, which include anti-inflammatory, anti-cancer, anti-inflammatory, gastrointestinal, hepato-protective and antimicrobial properties. They are also known for their beneficial effects on skin conditions like wounds and other infectious diseases (Yadeta, 2022; Akaberi *et al.*, 2016; Mukherjee *et al.*, 2014; Chen *et al.*, 2012). Because of this, *Aloe* plants have a wide range of applications due to their numerous chemical constituents and biological activities.

Many researchers are currently interested in conducting studies on *Aloe* and related fields of study. For this interest, the three primary elements that are interconnected are: (1) *Aloe* species chemical composition; (2) *Aloe* species biological activity; (3) *Aloe* species applications. This indicates that the active chemicals found in aloe species are abundant and are in charge of a variety of biological processes. *Aloe* species have a wide range of uses as a result of their diverse biological activities. *Aloe* species are of interest to researchers due to their many applications. Thus, the *Aloe*-research cycle is made up of these connected points. In general, it can be summed up as follows: the more biological activities and applications a plant has, the more active constituents it has (Fig. 3).

***Aloe* extracts for industrial products. Cosmetics industry.** *Aloe* species are used in the preparation of traditional hair washing shampoos which are transformed to preparation of industrial in cosmetic and personal care products today (Sbhatu *et al.*, 2020). Aloes ability to penetrate the epidermis, dermis and hypodermis, expelling grease and bacteria from pores and inducing new cell production, which speeds up healing, is why the plants used in cosmetics (De Rodriguez *et al.*, 2006). *Aloe* gel is added to cleansers, moisturizers, shampoos, suntan lotions and sunburn screens in the cosmetics industry. Aloesin has potential as a pigmentation-altering agent for cosmetic and medicinal uses because it inhibits tyrosinase competitively, which modulates melanogenesis (Iwu, 2014). *Aloe vera* gel is widely used in cosmetics,

Table 1. Phytochemical screening reports of *Aloe* species

<i>Aloe</i> species	Part of Pant	Phytochemicals Present	Ref
<i>Aloe elegans</i> <i>Todaro</i>	Leaf gel	Anthraquinones, flavonoids, saponins and tannins	(Sbhatu <i>et al.</i> , 2020)
<i>Aloe vera</i>	Leaf gel	Tannins, saponins phlobatannins, flavonoids, anthraquinones, terpenoids, steroids, alkaloids, carbohydrates and glycosides	(Jha <i>et al.</i> , 2019)
<i>Aloe gilbertii</i>	Root	Alkaloids, anthraquinones, terpenoids and flavonoids	(Jemal <i>et al.</i> , 2018)
<i>Aloe elegans</i>	Root	Anthraquinones, terpenoids, phenols, saponins, tannins and glycosides	(Habtemariam and Medhaniet, 2017)
<i>Aloe elegans</i>	Leaf gel	Saponon, glycosides, tannins, terpenoids, phenols and flavonoids	(Chaithanya, 2018)
<i>Aloe adigratana</i> <i>Reynolds</i>	Leaf gel	Alkaloids, flavonoids, tannins, terpenoids, saponins, steroids and glycosides,	(Sbhatu <i>et al.</i> , 2020)
<i>Aloe tormentorii</i>		Phenols, saponins, tannins, alkaloids, anthraquinones, terpenes, coumarins and flavonoids	(Ranghoo-Sanmukhiya <i>et al.</i> , 2010)
<i>Aloe arborescens</i>	Leaf	Flavonoids, terpenoids and aromatic compounds	(Bisi-Johnson <i>et al.</i> , 2017)
<i>Aloe arborescens</i>	Leaf	Alkaloids, terpenoids, steroids, flavonoids, tannins and reducing sugars	(Gauniyal and Teotia, 2014)
<i>Aloe ferox</i>	Leaf	Flavonoids, condensed tannins and gallotannins	(Fawole <i>et al.</i> , 2010)
<i>Aloe ferox</i>	Leaf	Phenols, flavonoids, flavonols, proanthocyanidins, tannins, alkaloids and saponins	(Wintola and Afolayan, 2011)
<i>Aloe striata</i>	Leaf	Flavonoids, terpenoids and aromatic compounds	(Ranghoo-Sanmukhiya <i>et al.</i> , 2010)
<i>Aloe vera</i>	Leaf	Steroids, terpenoids, carotenoids, anthraquinones, catechin and tannins	(Kammoun <i>et al.</i> , 2011)
<i>Aloe vera</i>	Leaf	Alkaloids, glycosides, reducing sugars, phenolic compounds, steroids, terpenoids, flavonoids, tannins and saponin glycosides	(Kumar <i>et al.</i> , 2017)
<i>Aloe turkanensis</i>	Whole plant	Tannins, anthraquinones, terpenoids/ steroids, saponins and alkaloids	(Muthii <i>et al.</i> , 2015)
<i>Aloe perryi</i>	Flower	Glycosides, phytosterols, proteins and amino acids, flavonoids, phenols and carbohydrates	(Kedarnath <i>et al.</i> , 2012)
<i>Aloe vera</i>	Leaf	Tannins, saponins and flavonoids	(Kumar <i>et al.</i> , 2017)
<i>Aloe pulcherrima</i> G. and S.	Leaf latex	Anthraquinones, flavonoids, saponins, glycosides, tannins, phenols and alkaloids	(Amare <i>et al.</i> , 2020)

where it is now a key component in product sales. It serves as a foundation for a number of formulations, such as suntan lotions and moisturizers, which are humectants in skin preparations (Eshun and He, 2004). Because *Aloe vera* has beneficial moisturizing and calming properties, its gel and powder are used in a wide range of cosmetic products, including cleansers, shampoos and moisturizing creams. One benefit of *Aloe*

vera-based prepared soaps is that they don't irritate skin or leave it feeling parched. *Aloe* extracts are also included in some shaving lotions and creams in the USA and Asia to speed up the healing of shaving wounds. In shaving creams, *Aloe vera* gel's mucilaginous quality aids in its ability to act as a barrier of defense between the skin and beard (Maan *et al.*, 2018; Lad and Murthy, 2013).

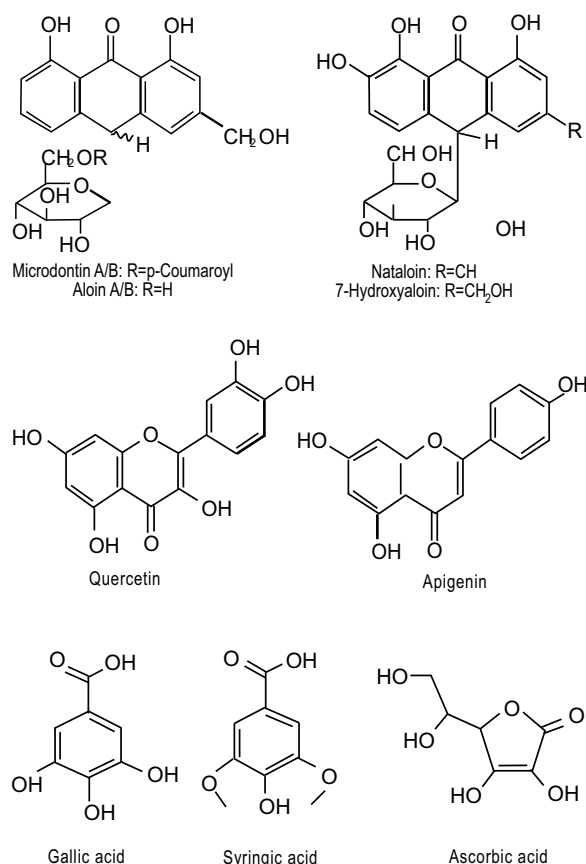


Fig. 2. Some compounds isolated from *Aloe* species.

Lotions and sunblocks are used to treat a wide range of skin conditions, including sunburns, flaky or dry skin, hair and scalp issues, psoriasis, stretch marks and dandruff. Because of its high nutritional content and antioxidant qualities, *Aloe vera* is well known for its potent healing activity, even at the epithelial level of the skin. This results in the skin having a protective layer that speeds up healing (Arunkumar and Muthuselvam, 2009). *Aloe vera* is applied before mineral-based makeup to prevent the skin from drying out. It is ideal for oily skin because of its moisturizing properties without leaving a greasy feeling behind. Gibberellin, a growth hormone found in *Aloe vera*, promotes the formation of new cells and promotes skin healing with little scarring. Ayurvedic medications for persistent skin conditions like psoriasis, acne and eczema contain *Aloe vera* (Aburjai and Natsheh, 2003). *Aloe vera* leaves contain antioxidants such as β -carotene, vitamin C and E which help to maintain the skin's moisture balance and natural firmness (Eshun and He, 2004; Mascolo *et al.*, 2004).

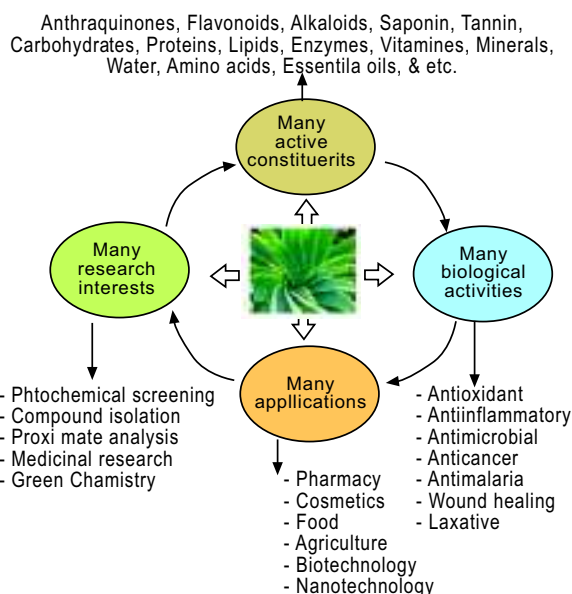


Fig. 2. Relationship between phytochemicals, biological activities and applications of *Aloe* species (Baskaran *et al.*, 2015; Datta *et al.*, 2012; Grace *et al.*, 2008).

Any product that calls for mildness or moisturizing can benefit from the addition of *Aloe vera* gel. However, the gel's compatibility with the product system is essential to the development of such products successfully. *Aloe vera* gel generally works well with non-ionic, cationic and anionic systems. Anionic systems, on the other hand, can only incorporate a limited amount of gel where quinones can react with the base to discolour the product. Furthermore, the product system may become neutralized if the gel's natural pH is added in a concentration greater than 30% (Mpiana *et al.*, 2020).

Pharmaceutical industry. Traditionally people used *Aloe* species for impotence in men, malaria, stomach ache, fire burn, caught, gonorrhea, swollen foot, strain, ascariasis, anthrax, internal parasite, wound, asthma, psychiatric disease, sprain, diabetes, liver disease and eye ailments. In modern days, researchers are trying to confirm the scientific way of using these plants in both *in vitro* and *in vivo* trials for the therapeutic efficacy, responsible bioactive compounds, toxicology and dosages. That means *Aloe* in one form or another is a common domestic medicine and is the basis of most pharmaceutical preparations which lead to drug delivery (Salehi *et al.*, 2018; Oda and Erena, 2017). *Aloe* species phytochemical traits and pharmacological qualities have been thoroughly investigated and assessed (Surjushe

et al., 2008). A variety of therapeutic activities for gastrointestinal disorders, burns, skin regeneration, inflammation, kidney infections, bladder conditions, asthma, bronchitis and arthritis have been reported for more than 200 compounds derived from *Aloe vera* (Canche-Escamilla *et al.*, 2019).

A patent composition for oral administration that aims to reduce appetite and manage weight includes *Aloe* as a main ingredient (Buchwald-Werner, 2008). Aloin, which is extracted from the yellow exudate of leaves, is utilized by certain pharmaceutical industries to make diacerein, a medication that is prescribed for the treatment of osteoarthritis (Bartels *et al.*, 2010). Pharmaceutical companies produce acemannan, a polysaccharide derived from the *Aloe* species (Sierra-García *et al.*, 2014). Because of its proven medicinal qualities, studies have given *Aloe vera* more significance and it is now used to make pharmaceutical products like ointments, tablets and capsules (Eshun and He, 2004). After gathering, the *Aloe* leaves are thinly sliced, the bitter sap is extracted, sun-dried and then ground into a powder (known as whole leaf powder). The powder is mixed into the formulation in a ratio of 30–70%, and the remaining portion is made up of bentonite or kaolin. The mixture is then formed into granules or tablets (Chen *et al.*, 2012).

Food and beverage industry. The gel and flowers of *Aloe* species are eaten as cooked or raw vegetables traditionally in various parts of the world. The study evaluated the nutritional value of *Aloe* species and their possible use as a food. Nowadays, incorporating *Aloe* extracts to the raw material of food industry is used to manufacture functional foods, nutraceutical foods, edible coating/films and antimicrobial agent foods (Yadeta, 2022). Due to the nutritional components of *Aloes*, which include proteins, carbs, lipids, vitamins, minerals, amino acids and active enzymes that combine to produce these beneficial and biological effects, *Aloes* are also utilized as a food product and beverage ingredient. Because it is a new source of bioactive components, *Aloe* species is currently one of the most important ingredients in the food industry. Owing to its advantageous characteristics in managing conditions like constipation, coughs, diabetes, headaches, arthritis and immune system deficiencies, the gel's possible application in the food industry is primarily concentrated on the creation of functional foods (Minjares-Fuentes *et al.*, 2016). Several species of edible *Aloes* are mentioned in the literature for their applications as

cooked vegetables, snack foods, famine foods and preserves ingredients. That does not imply that all *Aloe* species are edible, though (Steenkamp and Stewart, 2007). Because *Aloe* species contain nutrients, a lot of commercial food product manufacturers have increased the use of *Aloe* juice or gel in one way or another (Lad and Murthy, 2013). The gel is used in the nutraceutical industry as a supplement in other food products and as a mineral source for a range of functional foods that are used to make different health drinks and beverages (Ray *et al.*, 2013).

Because the gel from *Aloe* species is used in the food industry, its processing from the plant's leaf pulp has grown to be a significant global industry (Chang *et al.*, 2011). It is used by the food industry to produce functional goods, particularly yogurt, cranberry, orange, grape, raspberry, pineapple and strawberry beverages, as well as jam and jelly and health drinks (El-Sayed and El-Sayed, 2020). Additionally, its gel is used in the preparation of other food products like ice cream, milk, confections, etc. as a food preservative and flavoring (Chowdhury *et al.*, 2020). Therefore, *Aloe* species appears to hold promise as a safe, all-natural and environmentally friendly substitute for traditional synthetic preservatives because it has no effect on the taste or appearance of food.

To extend the safety and quality of fresh products, *Aloe vera* gel can be applied as an edible coating (Serrano *et al.*, 2006). *Aloe* gel-coated table grapes considerably slowed down the breakdown of useful substances like ascorbic acid and total phenolic. It does, in fact, prevent food spoilage and the growth of microorganisms that cause foodborne illnesses in humans or animals (Feily and Namazi, 2009; Eshun and He, 2004). The FDA in the US has authorized gel's internal use as a "dietary supplement." It is permitted to be used by the feed industry as a sensory additive functional group known as "flavoring compounds" by the European Commission (EC) in Annex I of Regulation No. 1831/2003 in order to improve the smell or palatability of feeding materials (Franz *et al.*, 2007; WHO, 1999).

Agricultural chemicals. Natural plant extracts can be used to enhance and promote the growth of other plant species because they are a rich source of plant hormones. One of these is an extract made from *Aloe vera* plant leaves. *Aloe* leaf extract has been used as a natural plant growth regulator in *Majorana hortensis* and *Salvia officinalis*, as well as to enhance the vegetative growth

of *Abelmoschus culentus*, *Oenothera biennis* and *Majorana hortensis* (El Sherif, 2017). The study examined the effects of spraying *Aloe vera* extract and using organic fertilizer on the chemical composition, seed yield, oil yield and vegetative growth of the caraway plant, *Carum carvi* L. *Aloe vera* extract has been used to achieve high yields. Fertilizers containing *Aloe* serve as transporters for good bacteria that supply nutrients to the roots of plants, promoting long-term growth. *Aloe* species are abundant in vitamins, minerals, amino acids, enzymes and other components. *Aloe* extracts can be added to other substances to fertilize soil (Khater *et al.*, 2020; Akaberi *et al.*, 2016).

The *Aloe vera* plant can make an excellent addition to pest repellents for crops due to its resistance to insect infestation. According to a recent study, *Aloe adigratana* Reynolds leaves were utilized in the cotton fabric industry to prevent cotton plant infections with *Staphylococcus aureus* (Chaithanya, 2018). Extracts from *Aloe vera* may prove to be a promising new organic insecticide and preventive measure against insect-caused damage. It can be utilized even more profitably in the integrated pest management program due to the low input cost, increased gross benefits and net turnover in pest control treatment, as well as the financial savings connected with the use of *Aloe vera*. *Aloe vera* gel is abundant in inorganic nutrients and healthy organic compounds. *Aloe* species contain chemical combinations that have antiviral, antifungal and antibacterial qualities. This provides resistance or immunity to certain harmful microbes, fungi, yeast, mold, blight and other substances, thereby aiding in the protection of plants. Therefore, plant extracts are utilized to make agricultural chemicals like as herbicides, pesticides and etc. (Sarwar, 2013).

Printing industry. Natural plant-based thickeners are safe, economical, environmentally benign and do not cause fabric stiffness. The technical viability of employing *Aloe vera* polysaccharide as a thickener for printing on cotton, wool and polyester fabrics has been investigated in the literature. The paste preparation used in textile printing is made up of thickeners, binders (for pigment printing) colouring materials (dyes and pigments) and additional ingredients. Thickeners regulate the rheology or flow behavior, of the print formulation. This regulates the printed colour's presentation and resistance to migration, guaranteeing crisp print definition and a well-defined design. Because *Aloe vera* and *Aloe debrana* have a naturally occurring colour, they are used as thickening agents and in biotechnology

applications for textile pretreatment and colouration. To improve *Aloe vera* polysaccharide gel's rheological performance as a thickener in textile printing, alginate, carboxymethyl cellulose and DELL thickener P were combined with it (Saad *et al.*, 2021; Amanuel, 2017; Awoke *et al.*, 2013). In order to avoid the negative effects of synthetic thickeners and dyes, *Aloe vera* gel, which is viscous and colourless, can be used as a thickening agent in conjunction with natural dyes (Zarkogianni *et al.*, 2019).

Aloe vera gel has been utilized as a thickener in printing recently and because of its high water content, it is said to exhibit shear-thinning properties based on its rheological behavior. Thus, successful 3D printing of the lattice structures using the direct ink writing (DIW) technique was made possible by the intrinsic shear-thinning behavior and excellent viscoelastic properties of *Aloe vera* and 2,2,6,6-tetramethylpiperidin-1-oxyl-oxidized cellulose nanofibers (TEMPO-CNFs or TOCNFs) hydrogels (Baniyadi *et al.*, 2021). Certain *Aloe* species, like *A. megalacantha* Baker and *A. confusa* Engl., have been used for their capacity to produce dyes and inks (Tom, 2004).

Protection and future trends. *Aloe* species extracts are known to have a variety of industrial uses, both alone and in conjunction with other raw materials. There are a plethora of additional uses for *Aloe* besides industrial ones. Owing to these many uses, *Aloe* plant transportation has received more attention from the business community than any other. As a result of using them exclusively for commercial purposes, the genus became endangered. Thus, in order to protect the genus and continue using *Aloe* plants in more products, afforestation and reforestation are essential. To use, transport and trade the plants all applicable national and international regulations must be followed. The acquisition and use of traditional knowledge and natural resources are governed by a number of signed national and international agreements. These agreements were formalized by the convention on biological diversity (CBD), which at least 52 African nations have ratified. The three primary goals of the CBD are the preservation of biological diversity, the encouragement of sustainable resource use and the fair distribution of benefits resulting from the use of genetic resources. South Africa passed the bioprospecting law in 2008, which mandates that anyone conducting applied research or engaging in the commercial trade of medicinal plants obtain a research permit (Juliani *et al.*, 2009).

The second is raising awareness of the benefits and drawbacks of the species' presence and absence, respectively. These principles govern local and household users, traders and businesses, protecting the genus in the process. Government oversight of the *Aloe* species processing industries is necessary to verify that the products contain the beneficial bioactive chemicals that the manufacturers claim. The safety and toxicological properties of *Aloe* species products intended for food applications must also be investigated by regulatory bodies. Verified and approved clinical trials data should back up any claims made about the medicinal benefits of *Aloe* products. It is assumed to mention the many nutraceutical claims made by the manufacturers of *Aloe* products (Ahlawat and Khatkar, 2011).

Conclusion

Giving readers a forward-looking perspective on the subject would involve discussing current research or potential trends pertaining to the use of *Aloe* species gel in the printing industry, such as enhancements in formulation techniques, investigation of new uses or integration with cutting-edge technologies like 3D printing. By addressing these issues the sections on printing and agricultural chemicals would be improved and a more thorough grasp of the possible uses and effects of *Aloe* species into industrial products based on the traditional applications as these will expand the field of study on *Aloe* species and technology stack such as drug discovery, nano biotechnology and etc. Thus, taking into account its numerous health benefits and valuable chemical composition, the *Aloe* species could be regarded as economically significant matrices for the cosmetics, pharmaceutical, food, beverages, agricultural chemicals, printing and dye industries. As a result, controlled research will be needed in the future to demonstrate the *Aloe* species efficacy in a variety of settings while maintaining the species. In summary, *Aloe* species extracts are used to boost the efficacy of modern industrial inputs for various products by combining them with other useful materials.

Conflict of Interest. The authors declare they have no conflict of interest.

References

- Abdissa, N., Gohlke, S., Frese, M., Sewald, N. 2017. Cytotoxic compounds from *Aloe megalacantha*. *Molecules*, **22**:1136.
- Aburjai, T., Natsheh, F.M. 2003. Plants used in cosmetics. *Phytotherapy Research*, **17**: 987-1000.
- Adesuyi, A.O., Awosanya, O.A., Adaramola, F.B., Omeonu, A.I. 2012. Nutritional and phytochemical screening of *Aloe barbadensis*. *Current Research of Journal Biological Science*, **20**: 4-9.
- Ahlawat, K.S., Khatkar, B.S. 2011. Processing, food applications and safety of *Aloe vera* products: a review. *Journal of Food Science and Technology*, **48**: 525-33.
- Ahmed, M., Hussain, F. 2013. Chemical composition and biochemical activity of *Aloe vera* (*Aloe barbadensis* Miller) leaves. *International Journal of Chemical and Biochemical Sciences*. **3**: 29-33.
- Akabeti, M., Sobhani, Z., Javadi, B., Sahebkar, A., Emami, S.A. 2016. Therapeutic effects of *Aloe* species. in traditional and modern medicine: A review. *Biomedicine and Pharmacotherapy*, **84**: 759-72.
- Amanuel, L. 2017. Textile bio processing using *Aloe* gel. *Industrial Engineering Manage*, **6**: 1-5.
- Amare, G.G., Meharie, B.G., Belayneh, Y.M. 2020. Evaluation of antidiabetic activity of the leaf latex of *Aloe pulcherrima* Gilbert and Sebsebe (Aloaceae). *Evidence-Based Complementary and Alternative Medicine*, **2020**: 1-9.
- Arunkumar, S., Muthuselvam, M. 2009. Analysis of phytochemical constituents and antimicrobial activities of *Aloe vera* L. against clinical pathogens. *World Journal of Agricultural Sciences*, **5**: 572-6.
- Awoke, S., Adugna, Y., Jihad, R., Getaneh, H. 2013. The importance of *Aloe debrana* plant as a thickening agent for disperse printing of polyester and cotton in textile industry. *Journal Textile Science Engineering*, **4**: 1-4.
- Bartels, E.M., Bliddal, H., Schöndorff, P.K., Altman, R.D., Zhang, W., Christensen, R. 2010. Symptomatic efficacy and safety of diacerein in the treatment of osteoarthritis: a meta-analysis of randomized placebo-controlled trials. *Osteoarthritis and Cartilage*, **18**: 289-96.
- Baskaran, P., Kumari, A., Naidoo, D., Van Staden, J. 2015. *In vitro* propagation and biochemical changes in *Aloe pruinosa*. *Industrial Crops and Products*, **77**: 51-8.
- Bisi-Johnson, M.A., Obi, C.L., Samuel, B.B., Eloff, J.N., Okoh, A.I. 2017. Antibacterial activity of crude extracts of some South African medicinal plants against multidrug resistant etiological agents of diarrhoea. *BMC Complementary Alternative*

- Medicine*, **17**: 1-9.
- Baniasadi, H., Ajdary, R., Trifol, J., Rojas, O.J., Seppälä, J. 2021. Direct ink writing of *Aloe vera*/cellulose nanofibrils bio-hydrogels. *Carbohydrate Polymers*, **266**: 118114.
- Buchwald-Werner, S. 2008. Compositions of Extracts of *Aloe* for Oral Administration. *United States patent* No. 12,045,225, 9th November, 2008.
- Canche-Escamilla, G., Colli-Acevedo, P., Borges-Argaez, R., Quintana-Owen, P., May-Crespo, J.F., Cáceres-Farfan, M., Puc, J.A., Sansores-Peraza, P., Vera-Ku, B.M. 2019. Extraction of phenolic components from an *Aloe vera* (*Aloe barbadensis* Miller) crop and their potential as antimicrobials and textile dyes. *Sustainable Chemistry and Pharmacy*, **14**: 100168.
- Chaithanya, K.K. 2018. Phytochemical screening and *in vitro* antioxidant activities of ethanolic gel extract of *Aloe adigratana* Reynolds, *Journal of Pharmaceutical Research*, **12**: 13-19.
- Chang, X.L., Chen, B.Y., Feng, Y.M. 2011. Water-soluble polysaccharides isolated from skin juice, gel juice and flower of *Aloe vera* Miller. *Journal of the Taiwan Institute of Chemical Engineers*, **42**: 197-203.
- Chen, W., Van Wyk, B.E., Vermaak, I., Viljoen, A.M. 2012. Cape Aloes—A review of the phytochemistry, pharmacology and commercialisation of *Aloe ferox*. *Phytochemistry Letters*, **5**: 1-12.
- Chowdhury, M.A., Sultana, T., Rahman, M.A., Saha, B.K., Chowdhury, T., Tarafder, S. 2020. Sulphur fertilization enhanced yield, its uptake, use efficiency and economic returns of *Aloe vera* L. *Heliyon*, **6**: 1-8.
- Christaki, E.V., Florou-Paneri, P.C. 2010. *Aloe vera*: a plant for many uses. *Journal of Food, Agriculture and Environment*, **8**: 245-249.
- Datta, A.K., Mandal, A., Silva, J.A., Saha, A., Paul, R., Sengupta, S., Dubey, P.K., Halder, S. 2012. An updated overview on *Aloe vera* (L.) Burm. F. *Medicinal and Aromatic Plant Science and Biotechnology*, **6**: 1-10.
- De Rodriguez, D.J., Angulo-Sanchez, J.L., da Silva, J.A., Aguilar-Gonzalez, C.N. 2006. Review of *Aloe* species' medicinal properties and bioactive compounds. In: *Floriculture, Ornamental and Plant Biotechnology: Advances and Topical Issues*, Vol. **IV**, pp. 460-471, Global Science Books, UK.
- El-Sayed, S.M., El-Sayed, H.S. 2020. Production of UF-soft cheese using probiotic bacteria and *Aloe vera* pulp as a good source of nutrients. *Annals of Agricultural Sciences*, **65**: 13-20.
- El Sherif, F. 2017. *Aloe vera* leaf extract as a potential growth enhancer for populus trees grown under *in vitro* conditions. *American Journal of Plant Biology*, **2**: 101-5.
- Eshun, K., He, Q. 2004. *Aloe vera*: a valuable ingredient for the food, pharmaceutical and cosmetic industries—a review. *Critical Reviews in Food Science and Nutrition*, **44**: 91-6.
- Fawole, O.A., Amoo, S.O., Ndhlala, A.R., Light, M.E., Finnie, J.F., Van Staden, J. 2010. Anti-inflammatory, anticholinesterase, antioxidant and phytochemical properties of medicinal plants used for pain-related ailments in South Africa. *Journal of Ethnopharmacology*, **27**: 235-41.
- Feily, A., Namazi, M.R. 2009. *Aloe vera* in dermatology: a brief review. *Giornale italiano di dermatologia e venereologia: organo ufficiale, Societa italiana di dermatologia e sifilografia*, **144**: 85-91.
- Franz, C., Bauer, R., Carle, R., Tedesco, D., Tubaro, A., Zitterl-Eglseer, K. 2007. Study on the assessment of plants/herbs, plant/herb extracts and their naturally or synthetically produced components as 'additives' for use in animal production. *EFSA Supporting Publications*, **4**: 1-297.
- Grace, O.M., Dzajic, A., Jäger, A.K., Nyberg, N.T., Önder, A., Rønsted, N. 2013. Monosaccharide analysis of succulent leaf tissue in *Aloe*. *Phytochemistry*, **93**: 79-87.
- Grace, O.M., Kokubun, T., Veitch, N.C., Simmonds, M.S. 2008. Characterisation of a nataloin derivative from *Aloe ellenbeckii*, a maculate species from East Africa. *South African Journal of Botany*, **74**: 761-3.
- Gauniyal, P., Teotia, U.V. 2014. Phytochemical screening and antimicrobial activity of some medicinal plants against oral flora. *Asian Pacific Journal of Health Science*, **1**: 255-63.
- Habtemariam, M., Medhanie, G. 2017. Screening of biologically active constituents from leaves of *Aloe elegans* and their antimicrobial activities against clinical pathogens. *African Journal of Microbiology Research*, **11**: 366-71.
- Hamman, J.H. 2008. Composition and applications of *Aloe vera* leaf gel. *Molecules*, **13**: 1599-1616.
- Haque, M.Z., Islam, M.B., Jalil, M.A., Shafique, M.Z. 2014. Proximate analysis of *Aloe vera* leaves. *Journal of Applied Chemistry*, **7**: 36-40.
- Iwu, M.M. 2014. *Handbook of African Medicinal Plants*,

- 403pp. CRC Press LLC, New York, USA.
- Jain, V., Gupta, K. 2005. Food and nutritional analysis / overview. *Elsevier*, 202-211.
- Jemal, M., Debela, E., Hamza, S., Addisu, D., Endale, M. 2018. Anthraquinones from the Roots of *Aloe Gilbertii* and *Aloe Elegans*. *Journal of Natural Sciences Research*, **8**: 1-7.
- Jha, A., Prakash, Bisht, D. 2019. A phytochemical screening of the ethanolic extract of *Aloe vera* gel. *International Journal of Science and Research (IJSR)*, **8**: 1543-1544.
- Joseph, B., Raj, S.J. 2010. Pharmacognostic and phytochemical properties of *Aloe vera* linn an overview. *International Journal of Pharmaceutical Sciences Review and Research*, **4**: 06-110.
- Juliani, H.R., Simon, J.E., Ho, C.T. 2009. *African Natural Plant Products: New Discoveries and Challenges in Chemistry and Quality*. 537-548pp. Oxford University Press, Washington, DC, New Jersey.
- Kahramanoğlu, I., Chen, C., Chen, J., Wan, C. 2019. Chemical constituents, antimicrobial activity and food preservative characteristics of *Aloe vera* gel (review). *Agronomy*, **9**: 1-18.
- Khater, R.M., Abd-Allah, W.H., El Shafay, R.M. 2020. Effect of organic fertilization and spraying *Aloe vera* extract on the growth and productivity of carum carvi, L. plant under shalateen conditions in Egypt. *Plant Archives*, **20**: 4959-71.
- Kammoun, M., Miladi, S., Ali, Y.B., Damak, M., Gargouri, Y., Bezzine, S. 2011. In vitro study of the PLA2 inhibition and antioxidant activities of *Aloe vera* leaf skin extracts. *Lipids in Health and Disease*, **10**: 1-7.
- Kedarnath, N.K., Surekha, R.S., Mahantesh, S.P., Patil, C.S. 2012. Phytochemical screening and antimicrobial activity of *Aloe vera*. *World Research Journal of Medicinal Aromatic Plants*, **1**: 11-3.
- Kumar, S., Yadav, A., Yadav, M., Yadav, J.P. 2017. Effect of climate change on phytochemical diversity, total phenolic content and in vitro antioxidant activity of *Aloe vera* (L.) Burm. f. *BMC Research Notes*, **10**: 1-2.
- Lad, V.N., Murthy, Z.V. 2013. Rheology of *Aloe barbadensis* Miller: a naturally available material of high therapeutic and nutrient value for food applications. *Journal of Food Engineering*, **115**: 279-84.
- López, A., De Tangil, M.S., Vega-Orellana, O., Ramírez, A.S., Rico, M. 2013. Phenolic constituents, antioxidant and preliminary antimycoplasmic activities of leaf skin and flowers of *Aloe vera* (L.) Burm. f.(syn. *A. barbadensis* Mill.) from the Canary Islands (Spain). *Molecules*, **18**: 4942-54.
- López-Cervantes J, Sánchez-Machado DI, Cruz-Flores P, Mariscal-Domínguez MF, de la Mora-López GS, Campas-Baypoli ON. 2018. Antioxidant capacity, proximate composition and lipid constituents of *Aloe vera* flowers. *Journal of Applied Research on Medicinal and Aromatic Plants*, **10**: 93-8.
- Maan, A.A., Nazir, A., Khan, M.K., Ahmad, T., Zia, R., Murid, M., Abrar, M. 2018. The therapeutic properties and applications of *Aloe vera*: a review. *Journal of Herbal Medicine*, **12**: 1-10.
- Mascolo, N., Izzo, A.A., Borrelli, F., Capasso, R., Di Carlo, G., Sautebin, L., Capasso, F. 2004. *Healing Powers of Aloes: the genus Aloe*. 209-38pp. CRC Press., London, UK.
- Minjares-Fuentes, R., Femenia, A., Comas-Serra, F., Rosselló, C., Rodríguez-González, V.M., González-Laredo, R.F., Gallegos-Infante, J.A., Medina-Torres, L. 2016. Effect of different drying procedures on physicochemical properties and flow behavior of *Aloe vera* (*Aloe barbadensis* Miller) gel. *Lebensmittel-Wissenschaft und Technologie*, **74**: 378-386.
- Moni, S.S., Sultan, M.H., Makeen, H.A., Madkhali, O.A., Bakkari, M.A., Alqahtani, S.S., Alshahrani, S., Menachery, S.J., Alam, M.I., Elmobark, M.E., ur Rehman, Z. 2021. Bioactive principles in exudate gel from the leaf of *Aloe fleurentiniorum*, traditionally used as folkloric medicine by local people of Aridah and Fayfa mountains, Saudi Arabia. *Arabian Journal of Chemistry*, **14**: 103400.
- Mpiiana, P.T., Tshibangu, D.S., Kilembe, J.T., Gbolo, B.Z., Mwanangombo, D.T., Inkoto, C.L., Lengbiye, E.M., Mbadiko, C.M., Matondo, A., Bongo, G.N., Tshilanda, D.D. 2020. Identification of potential inhibitors of SARS-CoV-2 main protease from *Aloe vera* compounds: a molecular docking study. *Chemical Physics Letters*, **754**: 137751.
- Mukherjee, P.K., Nema, N.K., Maity, N., Mukherjee, K., Harwansh, R.K. 2014. Phytochemical and therapeutic profile of *Aloe vera*. *Journal of Natural Remedies*, **14**: 1-26.
- Muthii, R.Z., Mucunu, M.J., Peter, M.M., Gitahi, K.S. 2015. Phytochemistry and toxicity studies of aqueous and methanol extract of naturally growing and cultivated *Aloe turkanensis*. *Journal of Pharmacognosy and Phytochemistry*, **3**: 144-7.

- Nejatzadeh-Barandozi, F., Enferadi, S.T. 2012. FT-IR study of the polysaccharides isolated from the skin juice, gel juice and flower of *Aloe vera* tissues affected by fertilizer treatment. *Organic and Medicinal Chemistry Letters*, **2**: 1-9.
- Oda, B.K., Erena, B.A. 2017. *Aloes* of Ethiopia: A review on uses and importance of *Aloes* in Ethiopia. *International Journal of Plant Biology Research*, **5**: 1-6.
- Onyeike, E.N., Osuji, J.O. 2003. *Research Techniques in Biological and Chemical Sciences*, 403pp. Springer field Publishers Ltd., Owerri, Nigeria.
- Ranghoo-Sanmukhiya, M., Govinden-Soulange, J., Laverne, C., Khoiratty, S., Da Silva, D., Frederich, M., Kodja, H. 2010. Molecular biology, phytochemistry and bioactivity of three endemic *Aloe* species from Mauritius and Réunion islands. *Phytochemical Analysis*, **21**: 566-74.
- Ray, A., Gupta, S.D., Ghosh, S., Aswatha, S.M., Kabi, B. 2013. Chemometric studies on mineral distribution and microstructure analysis of freeze-dried *Aloe vera* L. gel at different harvesting regimens. *Industrial Crops and Products*, **51**: 194-201.
- Saad, F., Mohamed, A.L., Mosaad, M., Othman, H.A., Hassabo, A.G. 2021. Enhancing the rheological properties of *Aloe vera* polysaccharide gel for use as an eco-friendly thickening agent in textile printing paste. *Carbohydrate Polymer Technologies and Applications*, **2**: 100132.
- Salehi, B., Albayrak, S., Antolak, H., Krêgiel, D., Pawlikowska, E., Sharifi-Rad, M., Upreti, Y., Tsouh Fokou, P.V., Yousef, Z., Amiruddin Zakaria, Z., Varoni, E.M. 2018. *Aloe* genus plants: from farm to food applications and phytopharmacotherapy. *International Journal of Molecular Sciences*, **19**: 2843.
- Sarwar, M. 2013. The inhibitory properties of organic pest control agents against aphid (Aphididae: Homoptera) on Canola *Brassica napus* L. (Brassicaceae) under field environment. *International Journal of Scientific Research in Environmental Sciences*, **1**: 195.
- Sbhatu, D.B., Berhe, G.G., Hndeya, A.G., Abdu, A., Mulugeta, A., Abraha, H.B., Weldemichael, M.Y., Tekle, H.T., Gebru, H.A., Taye, M.G., Kidanemariam, H.G. 2020. Hair washing formulations from *Aloe elegans* todaro gel: the potential for making hair shampoo. *Advances in Pharmaceutical and Pharmaceutical Sciences*, **2020**: 8835-120.
- Sbhatu, D.B., Berhe, G.G., Hndeya, A.G., Abraha, H.B., Abdu, A., Gebru, H.A., Taye, M.G., Mulugeta, A., Weldemichael, M.Y., Tekle, H.T., Kidanemariam, H.G. 2020. Formulation and physicochemical evaluation of lab-based *Aloe adigratana* Reynolds shampoos. *International Journal of Analytical Chemistry*, **2020**: 7.
- Serrano, M., Valverde, J.M., Guillén, F., Castillo, S., Martínez-Romero, D., Valero, D. 2006. Use of *Aloe vera* gel coating preserves the functional properties of table grapes. *Journal of Agricultural and Food Chemistry*, **54**: 3882-6.
- Sierra-García, G.D., Castro-Ríos, R., González-Horta, A., Lara-Arias, J., Chávez-Montes, A. 2014. Acemannan, an extracted polysaccharide from *Aloe vera*: a literature review. *Natural Product Communications*, **9**: 1217-1221.
- Steenkamp, V., Stewart, M.J. 2007. Medicinal applications and toxicological activities of *Aloe*. Products. *Pharmaceutical biology*, **45**: 411-20.
- Surjushe, A., Vasani, R., Saple, D.G. 2008. *Aloe vera*: a short review. *Indian Journal of Dermatology*, **53**: 163.
- Sun, Y.N., Kim, J.H., Li, W., Jo, A.R., Yan, X.T., Yang, S.Y., Kim, Y.H. 2015. Soluble epoxide hydrolase inhibitory activity of anthraquinone components from *Aloe*. *Bioorganic and Medicinal Chemistry*, **23**: 6659-65.
- Wintola, O., Afolayan, A.J. 2011. Phytochemical constituents and antioxidant activities of the whole leaf extract of *Aloe ferox* Mill. *Pharmacognosy Magazine*, **7**: 325-333.
- Tom R. 2004. *Aloes: the genus Aloe*, 408pp. CRC Press, Boca Raton.
- World Health Organization. 1999. WHO monographs on selected medicinal plants. *World Health Organization*.
- Yadeta, A.T. 2022. Food applications of *Aloe* species: a review. *Journal of Plant Science and Phytopathology*, **6**: 024- 032.
- Zarkogianni, M., Karypidis, M., Savvidis, G., Nikolaidis, N. 2019. The Use of *Aloe vera* as a natural thickening agent for the printing of cotton fabric with natural dyes. *International Journal of Science and Research*, **8**: 147-51.