Taraz University named after M.Kh. Dulaty

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BAIDILDAYEVA ASSEL KUANYSHEVNA

Research of microencapsulation technology of leather for footwear of people with pathological deviations of the feet

8D07211 - Leather goods industry

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Scientific consultant:
PhD, associate professor
Indira Jiyembetova
Taraz University named after
M.Kh. Dulaty
Kazakhstan

Foreign scientific consultant:
PhD, Prof.Dr.
Hüseyin Ata Karavana
Ege University
Türkiye

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TABLE OF CONTENTS

NORMATIVE REFERENCES

In this dissertation work, references are made to the following standards:

GOST 26167-2005 - Everyday footwear. General specifications.

GOST 56974-2016 (ISO 20881:2007) - Footwear. Performance requirements for components for footwear. Insoles.

GOST 56967-2016 (ISO 20882:2007) - Footwear. Performance requirements for components for footwear. Lining and socks.

GOST 940-2024 - Lining leather for footwear. Specifications.

GOST 939-2021 - Upper leather. Specifications.

GOST 19196-93 - Fabrics for shoes. General specifications.

GOST 56964-2016 (ISO 16187:2013) - Footwear and footwear components. Test methods to assess antibacterial activity.

ISO 5402-1:2022 - Leather - Determination of flex resistance.

ISO 11640:2018 - Leather - Tests for colour fastness - Colour fastness to cycles of to-and-fro rubbing.

ISO 105-C06:2010 - Textiles - Tests for colour fastness. Part C06: Colour fastness to domestic and commercial laundering.

Standard of the European Committee on Antimicrobial Susceptibility Testing.

DEFINITIONS

In this dissertation work, the following terms are used with relevant definitions:

Footwear refers to garments worn on the feet, which typically serve the purpose of protection against adversities of the environment, such as wear from rough ground, stability on slippery ground, and temperature.

The **footbed** is at the bottom, innermost part of the footwear that runs from the heel to the toe.

Pathological deviations of the feet are deformities or misalignments of the foot bones, including congenital conditions like clubfoot or acquired issues such as bunions, flatfoot, and hammertoes, neuropathic changes like loss of sensation, dry skin, ulcers, and infections.

Microencapsulation is a technology of covering a functional substance in a shell, it protects it from the influence of environmental influences, such as pollution and evaporation.

Microparticles are small, spherical, solid drug delivery systems ranging from 1-1000 μm in diameter.

Chitosan is the common name of a linear, random copolymer of β-(1-4)-linked d-glucosamine and N-acetyl-D-glucosamine whose molecular structure comprises a backbone linked through glycosidic bonds.

Laurel oil is a wild-crafted ingredient, meaning it is harvested by hand from wild plants in their native habitat, free from genetic modification.

Leather is a strong, flexible and durable material obtained from the tanning, or chemical treatment, of animal skins and hides to prevent decay.

The **lining** is the material inside the footwear that comes in contact with the entire foot: the sides, top, and heels.

A **foot ulcer** is an open sore on the foot, often caused by diabetes due to nerve damage (neuropathy) and poor circulation.

LIST OF ABBREVIATIONS

MP	- Microparticles
LEO	- Laurel essential oil
SEM	- Scanning electron microscopy
FT-IR	- Fourier-transform infrared spectroscopy
UV-Vis spectrophotometers	- Ultraviolet visible spectrophotometers
DFS	- Syndrome of diabetic foot
LLC	- A limited liability company
PBS	- Phosphate buffer saline
RI	- Refractive index
EE	- Encapsulation efficiency
LC	- Loading capacity
MHA	- Mueller-Hinton agar
SDA	- Sabouraud Dextrose agar
PLGA	- Poly lactic-co-glycolic acid

INTRODUCTION

General characterization of the work. This dissertation work deals with the microencapsulation technology of leather footbeds. In this dissertation work, the antibacterial properties of footwear leather with microparticles from essential laurel oil were researched.

According to the statistics of the Ministry of Health of the Republic of Kazakhstan on the population health and the activities of healthcare organizations in 2024, published in 2025, 1,193,381 people were diagnosed with diseases of the musculoskeletal system and connective tissue, and 328,300 people with diabetes [1]. The high level of development of modern society focuses on the health of the population and the comfort of the environment. In this regard, footwear needs to be improved as a vital element that accompanies a person.

One of the most common products in everyday life is footwear. It is important that footwear have properties that improve the quality of life of people with pathological deviations of the foot. Research in the field of footwear in the Republic of Kazakhstan had shown that there are a number of issues and barriers to development.

Diabetes is a global problem. Currently, the number of patients is growing, and the amount of money spent on treatment is growing. 20% of patients with diabetes suffer from foot ulcer. People with diabetes need special care for their feet. In such patients, any scratch, even the smallest wart, can lead to very serious consequences, leading to amputation. Callus is the accumulation and proliferation of thickened skin tissue, which is visible because of overproduction of epidermal cells. These pathological changes occur due to damage to the skin and subcutaneous tissue. The main factor in the violation of the integrity of the skin is the compression caused by improper distribution of the load on the human leg. Heel hyperkeratosis is a condition that affects the foot. Its shape can reach several centimeters. Dry dermis easily causes scratching, which can lead to discomfort and bleeding. In addition, most importantly, the damage leads to infection.

Mild and moderate skin infections are the most common pathology. Every year, about 10 million people seek emergency care for traumatic soft tissue injuries of varying severity. These and other pathological defects of the foot require the creation of a comfortable environment in the footwear in accordance with the hygienic requirements. Introduction of microcapsulation technology for footwear leather enables the production of products with modern, innovative indicators.

Microencapsulation technology was first introduced in the pharmaceutical industry as an attractive production process due to the widespread use of spray drying. Today, this technology is used in the textile, leather, pharmaceutical, food and agricultural industries. Microencapsulation technology is the process of converting a liquid or solution from a liquid state into a powder by spraying it in a hot drying medium. Microcapsule methods allow the production of particles of different sizes, up to hundreds of microns.

The relevance of the work. The footwear is used in everyday life, and its quality is important for hygiene and health. It is especially important to create a

comfortable footwear environment for people with pathological neuropathic foot deviations such as loss of sensation, dry skin, ulcers, and infections. The use of essential oil (laurel) creates an antibacterial environment in footwear, as it is a natural plant-derived material and contains numerous antibacterial components. With the help of microencapsulation technology, antibacterial properties are introduced into footwear for people with pathological deviations of the foot, such as persistent hyperkeratosis, onychomycosis, and diabetes.

Degree of problem research. This technology is not sufficiently studied in the Commonwealth of Independent States countries, there are only studies in the field of textiles: Odintsova O.I, Levshitskaya O.P, Chernova E.N, and etc. A patent research shows that technology not used in the leather and footwear industry of the Republic of Kazakhstan. However, global research shows that scientists like Karavana H., Bielak E, Marcinkowska E, Lawinska K, Liu G, Vieira Kopp V, etc. have made significant contributions in this field. Academician of the National Academy of Sciences of the Republic of Kazakhstan O.K. Madiev and et al. proposed the use of various antiseptic substances during tanning. Among them are metallic iodine, zinc oxide and chitosan. However, it is not possible to use microencapsulation technology during tanning. This is due to the volumetric dimensions of microparticles. Therefore, in this study, work was carried out with a leather footbeds.

The purpose of the work. Use of specific equipment for microencapsulation technology, improving the antibacterial properties of leather footbeds and footwear linings with chitosan and laurel oil, which contain antibacterial components, and increases the hygienic properties of footwear. The following **tasks** were investigated to achieve this goal:

1. Development of a complex for preparing solutions based on natural components of chitosan and laurel essential oil and conducting microencapsulation technology.
2. Development of a method for finishing coatings using microparticles containing natural components.
3. Analysis of the composition of microparticles.
4. Determination of the physicochemical properties of coatings and substrates coated with microparticles obtained on the basis of natural components.
5. Study of the microbiological parameters and antibacterial properties of coatings and substrates coated with microparticles.

Research object and materials. Wet-blue crust footwear leather without dye, three different footwear lining materials, laurel oil and chitosan.

Research methods. The following methods were used in the work: spray drying method, dip-coating and spraying, and microbiological tests. The MPs and leathers were assessed for morphology and chemistry via SEM, particle size distribution, FT-IR, UV-Vis spectroscopy, and antibacterial assays.

Experimental research was conducted in the laboratories of Ege University and Dokuz Eylul University (Izmir, Türkiye) and Taraz University named after M.Kh. Dulaty.

Scientific novelty of the dissertation research:

- Seven different natural solutions based on chitosan and laurel essential oil components for the production of microparticles were prepared and the technology was developed.
- The increase in the physicochemical properties of the footbeds treated with microparticles based on natural components was proven.
- The results of in vitro release of laurel oil from the samples showed that it was gradually and slowly released.
- Microbiological analyses of leather footbeds and footwear linings samples coated with microparticles confirmed antimicrobial properties.
- The results revealed the possibility of using them not only for footwear for people with pathological foot deviations, which was the primary goal, but also in general.

The theoretical and practical significance of the work lies in the use of microparticles prepared from natural chitosan and laurel oil to produce leather footbeds and footwear linings with antibacterial properties.

This study suggests that advancements in production methodologies could substantially enhance foot health and hygiene. In addition, employing this optimised method has significant potential to manufacture footbeds with a rapid and enduring antimicrobial effect. Therefore, this work is promising and in demand for the footwear industry.

The main provisions proposed for protection:

- Technology for obtaining microparticles in a Unopex B 15 mini spray dryer.
- Results of the influence of process parameters (component ratio, surfactant concentration, temperature, feed rate) on the yield and characteristics of microparticles.
- Application methods (spray and dip-coating) affecting the distribution of microparticles and the functional properties of the coatings.
- Results of the stability of the antimicrobial effect to no rubbing and mechanical rubbing (flex resistance, dry rubbing and wet rubbing).

The degree of reliability and approbation of the results.

The reliability of scientific findings, conclusions and recommendations is confirmed by the similarity of the research results.

The results of the dissertation work were implemented at the enterprise «Tarazski Kozhevennyi Zavod» LLP (The act of the implementation of the results of scientific research work at enterprises, 11.10.2025) (Annex H) and «TarazKozhObuv» LLP (The act of the implementation of the results of scientific research work at enterprises, 13.04.2026) (Annex J).

The results of the dissertation work were implemented at the educational process. Discipline was «Sanitary and hygienic requirements for leather products», studied in the 5th semester of the 3rd year in 2025-2026 academic year. (The act of the implementation of the results of scientific research work at educational process, 06.03.2026) (Annex K).

As part of the research conducted in this dissertation work, an application for a patent has been submitted (Incoming № 2026-67676. Barcode 4109542) (Annex L).

Publication of research results. The main provisions of the dissertation work were reported and discussed at the journals and conferences.

The article was published in journal included in the Web of Science and Scopus databases:

1. Assel Baidildayeva, Gizem Ceylan Türkoğlu, Mustafa Ökeer, Bayri Eraç, Huseyin Ata Karavana. «Microencapsulation of Laurel Essential Oil with Chitosan for Enhanced Durability and Antimicrobial Properties of Leather Footbeds». // Iranian polymer journal, 2024.

The article was published at an international conference indexed in Scopus:

1. Assel Baidildayeva, Gizem Ceylan Türkoğlu, Mustafa Ökeer, Bayri Eraç, Huseyin Ata Karavana. «Textile-based footwear linings functionalized with laurel oil microparticles: antimicrobial protection». // 10th International Conference «Advanced materials and systems (ICAMS 2024)», Bucharest, Romania, 2024.

Two articles were published in the publication, which was included in the list of the Science and Higher Education Quality Assurance Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

1. Assel Baidildayeva, Gizem Ceylan Türkoğlu, Indira Jiyembetova, Gulzira Jumabekova, Bekzhan Abzakbekuly. «Study of the antimicrobial properties of footwear materials of people with pathological deviations of the feet». // Mechanics and technology, Taraz, 2025, №1.

2. Assel Baidildayeva, Huseyin Ata Karavana, Indira Jiyembetova, Gulzira Jumabekova, Bekzhan Abzakbekuly. «Loading efficiency and *in vitro* release studies of microparticles treated on leather and footwear linings». // Mechanics and technology, Taraz, 2025, №3.

Two articles were published at international conferences:

1. Assel Baidildayeva. «Analysis of orthopedic insoles available on the Kazakhstan market». // International Scientific and Practical Conference, “Soha korxonalari uchun yuqori malakali kadrlar tayyorlashda milliy va xorijiy tajribalar”, Tashkent, Uzbekistan, 2022.
2. Assel Baidildayeva, Indira Jiyembetova. «Pathological deviations of the feet and the importance of corrective footwear». // XIII International scientific and practical conference of young scientists «Innovative development and the requirement of science in modern Kazakhstan”, Taraz, 2019.

Structure and volume of the dissertation. The dissertation consists of 113 pages, including normative references, definitions, abbreviations, introduction, 3 sections, conclusion, list of references, and annexes. The structure of the dissertation consists of 29 tables, 31 figures and 5 equations.

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1 STATE OF THE ART

1.1 The materials of the footwear

Footwear is part of a person's clothing that protects the feet from harmful external influences, and its priority is anatomy, hygiene and comfort. The choice of material for footwear is an important indicator, and natural materials such as textiles and leather are considered the most favourable.

In the design of comfortable footwear, a special place is occupied by materials that are soft and elastic for the upper and lower parts, as well as methods of fastening [2]. For the production of footwear without linings, elastic leather materials can be used as top materials, including thick leather, textile and artificial materials, which are characterized by properties close to elastic natural leather. Comfort is influenced by the lining used in footwear [3].

These are usually chrome-plated, light-colored aniline-dyed natural leather, as well as textiles. Thermoplastic sealant should have softness and elasticity; the shape should be stable. One of the main conditions that reduce the stiffness of footwear is the design of children's footwear molds.

The best material for footwear is leather. It contains 2 to 24% fat and water does not pass through its pores. With the help of felt, fabric and wool soles can increase the heat protection properties of footwear. Leather has been used and is being used as footwear material worldwide.

Leather is a strong, durable and flexible material obtained by the manufacture of leather of cattle. Leather is used to make furniture, clothes and accessories, and it is especially widely used in the manufacture of footwear. The material has characteristics such as tensile strength, damage resistance, air permeability, water permeability, and high elasticity [4]. Different types of leather are used with precise properties for specific footwear. Therefore, numerous finishing additives are used during tanning to improve the following characteristics: water resistance, antimicrobial and antistatic properties, resistance to damage, and perspiration.

Leather footwear protect the human body from the adverse effects of environmental factors, as well as ensure the normal functioning of the body, creating a favorable microclimate in the interior. Compliance with the hygienic requirements for footwear is determined by its properties, the most important of which are: water resistance, vapor permeability, air permeability, hygroscopic, moisture and antibacterial properties [5].

Leather is the most popular and sought-after material due to its high aesthetic and functional qualities. The most common type was footwear made of pigskin and calfskin. Pigskin, although not very flexible and rough, has the best water resistance and low price. Calf is softer and more pleasant to the touch. Exotic types of leather, such as crocodile or snake, are used to make luxury and expensive footwear.

Currently, artificial materials are widely used in the manufacture of leather and footwear. Artificial leather should be porous, vapor, air and waterproof, absorb and release moisture, be comfortable at high and low temperatures, do not change size and do not bend when the humidity changes. Artificial leather must be resistant to

mildew and not emit chemicals that can pose a health risk. In terms of durability, this option is significantly inferior to the natural one, but on the other hand, it has a higher moisture resistance, it can be easily painted in different colors and it holds its shape tightly [6].

Velour is made from the skins of small cattle - sheep, pigs, goats, and calves. It can be soft or hard, depending on the production technology. The difference between velour and suede is that different leather fragments are used to produce velour material. In contrast, suede is made only from perfectly smooth, first-class treated leather. There is a distinction between artificial and natural suede. The material of natural origin is made from the inner layer of the skin of calves, deer, and sometimes sheep or goats [7].

Artificial velour is an excellent woven microfiber material for universal use: it can be used as a women's material and as an inner shell for women's, men's and children's footwear. The microliner has a beautiful appearance and is pleasant to the touch. In addition, it is a very durable and abrasion-resistant material. Due to the structure of the micro-iner and, as a result, the high moisture permeability, ensures an optimal microclimate inside the footwear.

Nubuck is a dense and coarse material. It is made from natural calfskin, moose or deerskin. The napiness of the material is obtained due to a certain method of grinding [8]. Nubuck is also treated with protective moisture-repellent agents from the outside. Without special protection, the material absorbs moisture and loses its original appearance and properties.

Split is a type of natural leather. The raw materials for its production are cow and pig skins. Artificial split is a non-woven fabric with latex impregnation. It has properties similar to natural split, which is usually installed on the back of footwear. It is a very durable material with identical wear resistance characteristics to leather [9]. It has significant advantages over natural split, such as: cost-effectiveness, the possibility of multi-layered cutting, versatility of application, uniform thickness over the entire surface and a rich colour palette.

Eco-leather is a material that consists of two layers. The first layer, which is the base, is made of woven fabric. On top of the replacement polyurethane film. It looks very similar to genuine leather, but unlike it, is more resistant to impact and tearing.

Textile footwear are very popular due to their breathability and lightness. Natural and artificial fur, as well as textile materials: linen, cotton, synthetics are used for linings. Textile materials are widely used in the production of footwear, taking second place after natural leather [10, 11]. The main materials are fabrics, knitted and non-woven fabrics, artificial fur and felting materials and auxiliary materials are threads and textile accessories.

Footwear textile materials have lightness, softness, varied front surface and color, excellent vapor and air permeability, hygroscopicity, as well as good technological properties: they are easy to cut, as they are produced in given large sizes in width and length, while their properties are uniform in size [12].

Kirza is a multilayer material based on cotton or synthetic fabric, treated with film-forming substances (rubber, polymer). It is used as a skin substitute. The surface

of the kirza is designed to imitate pig skin. It is mainly used in the production of workboot and army boots [13, 14].

The classic material of the sole is a comfortable and reliable natural leather. The quality, durability and breathability of orthopedic footbeds covered with artificial leather. Fabric linings are used in sports footwear.

There are winter versions of the sole covered with warm material. It is better to choose technologically advanced mixed materials, as products made of pure felt or wool are prickly and even irritate the skin through socks [15, 16].

There are also gels made of gel. They are non-orthopedic and provide little support, but are recommended for people with diabetes who have minor leg injuries due to the soft material.

1.2 The technology of microencapsulation of leather

Leather is a strong and flexible material obtained by tanning animal skins, mostly cattle skins. Leather is a natural material widely used to create a wide range of footwear. Its unique characteristics include high tensile strength, elasticity, tear resistance, high porosity and air permeability. Depending on the type of footwear and its purpose, leather types with certain characteristics are required. For this purpose, many finishing additives and treatments are used during post-screening operations to improve some leather properties, such as water resistance, oleophobic, perspiration, fire resistance, antimicrobial properties and wear resistance or antistatic properties [17].

There are different microorganisms in different parts of the human body. Sweat is normally excreted from the body under normal conditions. It contains 98% water and urea, uric acid, fatty acids, lactic acid and sulfates. There are more sweat glands on the soles than on other parts of the body. Sweat from the feet when wearing footwear is broken down by the microbiota of the feet, resulting in an unpleasant odor on the footwear.

One of the most promising methods of antibacterial treatment is the treatment of materials with microencapsulated drugs. It provides long-lasting action and is safe for humans due to the ability to use the lowest concentration of the active substance and its controlled release. Microencapsulation is used in various fields. Microencapsulated insecticides are widely used in agriculture and everyday life, microcapsules with vitamins and essential oils are included in various cosmetic products, microencapsulated probiotics are used in veterinary feed additives. Introduction of a new technology of microencapsulation of materials allows to get a completely unique product with innovative quality and functionality [18]. Microencapsulation is the process of encapsulating a functional substance in a membrane that protects it from evaporation, contamination and other environmental effects and allows the substance to be released over a long period of time.

Nowadays, the modern market produces a wide range of innovative materials that improve and facilitate life. The use of new technologies allows to obtain materials of different structures with improved and new properties: protective, antiseptic, cosmetic, thermoregulatory and others.

Modification of materials requires the development of new technologies for fixing functional substances, which led to the introduction of the method of microencapsulation. In the light industry of Europe, Japan and the United States, microencapsulation technology began to be used when materials could not be given properties using other technologies or were economically inefficient [19].

Microcapsulation is the process of placing small particles of a substance into a thin film of film-forming material. Because of microencapsulation, the product is obtained in the form of individual microcapsules ranging in size from one micron to hundreds of microns.

Microencapsulation is widely used to ensure the controlled release of the required active substance. This technology allows the microcapsule membrane material to protect the active substance of the nucleus from adverse reactions, loss of light, heat and air or prolonged contact, and at the same time, the wall material is sensitive to heat, temperature or pH [20].

The content of microcapsules: the capsule substance called active or basic substance forms the core of microcapsules, and the encapsulated material forms the material of the shells. Shells serve to separate the particles of one or more substances from each other and from the environment until the moment of use. The ability of microcapsules to hold, isolate, and store substances is very important, and then released when needed.

The initial task in the study of modified materials is to justify the areas of their application, as well as the study of new properties of innovative materials.

There are many uses for microencapsulated products. Currently, the range of practical applications of microencapsulated materials is very large, from healthcare to space research. Recent years have been marked by the expansion of the range of microencapsulated products produced by industry. Today, it is difficult to name an area of the economy that does not use microcapsules or the effectiveness of their use is not clear or fundamental: cellulose materials, textiles, fillers for polymer molds, adhesives, components of polymer compositions, dyes, magnetic substances, feed products, insecticides, fertilizers, cosmetics household chemicals, enzymes and photographic materials [21].

Modern human spends most of his life in clothes and footwear. The constant contact of these materials with the body stimulates the development of the market of hypoallergenic materials. Such material contains a substance or drug that is constantly released into various parts of the human body and has special properties such as cleansing, fragrance, appearance, protection, preservation or correction of body odor [22].

The technology of production of such material was made possible by the invention of special microscopic capsules that fit into the fabric. The use of microencapsulation in clothing began in the 1990s.

Microencapsulation is actually a method of microencapsulation that acts as a barrier against microcapsule formation and solids and liquids. Microcapsules are synthesized by placing a thin layer of polymer on small solid particles or liquid droplets or dispersions of solids in liquids. The main content is released in controlled cases based on the destination [23].

This technology can be used to develop long-lasting fragrances, as well as to give the material repellent and antibacterial properties, the ability to vitaminize and moisturize human skin. The most common is to encapsulate the functional agent in the polymer to achieve the maximum effect, and then apply the composition to the material or fiber.

Spray drying is the most common method of microencapsulation used in the food industry due to its low cost of production, simplicity, ease of scaling and the ability to produce microparticles with good properties for repeated use. In recent years, spray drying has become the most important commercial process in the production of dry aromatizes [24]. Vitamins, minerals, dyes, flavorings of oils and fats, aromatic compounds, oleoresins and enzymes are encapsulated using this method. This is an economical and effective way to protect materials [25].

In the article of Sánchez-Navarro M.M. et al., functional materials with antimicrobial properties are studied by adding natural antimicrobial agents to ordinary materials (leather, fabrics, etc.) to give new properties and added value to footwear. Microencapsulation is an effective way to protect natural biocides from reactions with moisture, light and oxygen. High functionality is expected if the footwear material is treated with microencapsulated biocidal agents. The article discusses the evaluation of Melaleuca alternifolia (tea tree) oil, which is a natural essential oil, as an antimicrobial agent for use in footwear. In addition, these microcapsules with essential oil are synthesized by in situ polymerization using melamine formaldehyde resin as a coating material to increase the strength of natural biocides in footwear materials. Microcapsule characteristics such as particle size, morphology, and chemical properties were performed for the ratio of fat to polymer. Finally, the penetration of microencapsulated biocides into various footwear materials was assessed [17, p. 1723].

The aim of Buket Yılmaz et al. study was to develop an antibacterial treatment of the leather sole of footwear. Chitosan microparticles saturated with orange oil were used for this purpose. Emulsion compositions of different ratios were prepared and microparticles were made from these compositions using the spray-drying method. The resulting microparticles were applied to the skin of the sole through the finishing process. Successful encapsulation was confirmed by ultraviolet spectrophotometry, FT-IR and SEM. The size of the microparticles was clearly visible spheroidal shape in the range of 3-5 microns. The efficiency of microparticle encapsulation ranged from 79.41% ± 3.36% to 86.60% ± 1.13%. After microbiological tests and *in vitro* release studies on the epidermis, it was found that the prepared microparticles are able to deliver the base material. In addition, the successful use of microparticles has led to the antibacterial properties of this skin. The products and process were biodegradable, non-toxic and biocompatible [26].

In Fatih Yalçın et al. study, chlorhexidine digluconate was encapsulated in ethyl cellulose film material and then spray-dried to obtain mixed microparticles. The validity and functional quality of the obtained results were analyzed in the leather and lining used for the production of footwear for diabetics. Morphology, encapsulation efficiency and *in vitro* release characteristics are optimized for impregnation of diabetic leather footwear. Scanning electron microscopy was used to describe the

treated skin. SEM images showed that the microparticles are spherical, smooth in shape and adhere well to the skin. Finally, microbiological studies were performed on micronutrient-treated skin. This study showed that footwear with microparticles improve the quality of daily life of diabetics [27].

Bekzhan Abzalbekuly et al. article suggests the use of composite materials modified by the results of strength and structural studies of deformation, which allows to create orthopedic products with defined properties. Nanocomposite materials with antibacterial properties were synthesized and studied, which allowed to improve the hygienic properties of the product. New anthropometric data were obtained for the full-scale characteristics of the soles of the feet of patients with diabetes. Based on photoplantographic images, a computer program was developed to highlight the main dimensional characteristics of the foot, as well as to determine the basic parameters of orthopedic products. For the first time in Kazakhstan, footwear and orthopedic products based on composite materials for patients with diabetes have been produced. The use of comfortable footwear and orthopedic products based on composite materials has been found to reduce foot pressure and provide the best comfort when standing and walking [28].

1.2.1 Antibacterial properties

Fungi and bacteria are the most common causes of foot infections. In most cases, the immune system fights off pathogens. However, in some cases, when the immune system is weak and the pathogen is particularly strong, damaged skin allows the microorganism to easily penetrate vulnerable tissue.

While bacterial foot infections can happen to anyone, certain people are at increased risk for complications, including:

- Elderly people.
- People with diabetes, who often have poor circulation in the legs and a reduced ability to fight infection.
- People with weakened immune systems.
- People undergoing chemotherapy or taking immunosuppressant medications [29].

Staphylococcus aureus, *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida albicans* are common opportunistic and pathogenic microorganisms that cause infections of the skin, mucous membranes, and internal organs, especially when the immune system is weakened.

Staphylococcus aureus is a bacterium that is a common cause of purulent infections of the skin, soft tissues, and infections associated with medical devices.

Escherichia coli is a bacterium that is part of normal flora, but when introduced into other environments, it causes severe infections, as cystitis, pyelonephritis, and sepsis.

Pseudomonas aeruginosa is a bacterium that causes severe wound and hospital-acquired infections.

Candida albicans is a yeast-like fungus that causes candidiasis and mucosal lesions [30].

In the footwear industry, the main thing is the production of hygienic and high-quality footwear, as well as the elimination of the growth of microorganisms in footwear. Footwear contain moisture, warmth, nutrients from foot sweat and fat, so footwear provide a suitable environment for microbes to grow. In particular, foot odor is mainly due to isovaleric acid produced by *Staphylococcus epidermidis*, which breaks down the leucine present in sweat [31].

Substances with antibacterial properties possess the capacity to either eliminate bacteria or prevent their multiplication and growth. These substances target specific components of bacterial cells, like cell walls or nuclei, while leaving viruses unharmed. This targeted action makes them effective in combating bacterial infections.

Feet are one of the most active parts of our body. They endure daily stress from running, walking, work, and sports. Closed-toe shoes create the perfect environment for bacteria and fungi to thrive- warm, humid, and poorly ventilated. During the day, feet are kept in shoes, creating the perfect environment for sweating and bacteria to thrive. On average, one foot produces up to 250 mL of sweat per day [32].

The main problems people face are:

- Unpleasant odor (due to bacterial activity).
- A constant feeling of dampness and discomfort.
- Fungal infections of the skin and nails.
- Irritation or redness due to increased humidity.

When bacteria break down sweat, they release compounds that cause a pungent odor. This can lead to skin conditions. If fungus develops, which easily thrives in warm, damp shoes, people may experience problems such as itchy, flaky skin, cracks between the toes, and thickened and discolored nails [33].

Antibacterial properties in footwear are achieved through the use of special materials, bactericidal insoles, impregnations, and sprays that inhibit the growth of microbes and fungi, preventing unpleasant odor.

An important function of footwear is to provide a comfortable microclimate around the sole. The physical and hygienic properties of the material from which the footwear are made should contribute to maintaining the required temperature and humidity of the footwear in any microclimate conditions of the external environment. This is how the design of footwear, their dimensions and hygienic requirements for individual elements are determined [34].

If necessary, footwear must meet certain sanitary and hygienic requirements. It should have a therapeutic and other preventive effect on the body - it helps to cure bacterial infections, chafing diseases of the feet, inhibit the growth of bacteria, chemically destruction of sweat and damage to the material of footwear, and prevent the unpleasant smell of sweat.

Footwear made of leather protect the human body from the adverse effects of environmental factors and ensure the normal functioning of the body, creating a favourable microclimate in the internal space. Compliance with hygienic requirements for footwear is determined by their properties, the most important of which are: water resistance, vapour permeability, air permeability, hygroscopicity, humidity and antibacterial properties.

Nowadays, footwear made of polymer or synthetic materials are often used. Such footwear has a significant disadvantage in terms of hygienic properties. The materials from which the footwear are made do not allow the skin to «breathe», and the skin of the feet becomes waterlogged [35]. As a result, unfavourable conditions are created, such as high humidity, a temperature of 33-37 °C and the presence of a large amount of nutrients in the form of exfoliated epidermis. In addition, they, in turn, are the optimal condition for the development of pathogens of dermatophytosis - pathogenic fungi of the genus *Trichophyton* (*Trichophyton mentagrophytes*, *Trichophyton rubrum*), as well as mould fungi (in particular, *Aspergillus niger*). This can lead to fungal lesions of the skin of the feet (mycoses) and appendages of the skin (nails) [27, p.148].

On average, hundreds of thousands of bacteria live on three-square centimeters of the sole and surface of the footwear. Footwear can contain up to 10,000 types of bacteria, the most popular of which are *Brevibacterium linens* and *Staphylococcus epidermidis*.

Now, the trend of consumer interest in hygiene sets new goals for the footwear industry. Due to high humidity, different temperature fluctuations, sweating of the feet and close contact of footwear with the foot, an environment for the growth of bacteria and fungi can be formed. In addition, the microbiological environment of footwear can lead to various infections [36]. The temperature rises as water condense on the skin and lining materials, and characteristic conditions can influence the microbiome of the foot. Thus, one of the important points in the improvement of footwear is the antimicrobial properties of materials.

The release of perspiration is a natural process; it is necessary to maintain normal heat transfer. Sweat contains products of mineral metabolism, protein metabolism, sulfate compounds, calcium salts, etc. Feet sweat because there are many sweat glands on the foot. During increased sweating of the feet and close contact between the leather and the foot, bacteria can form that lead to foot odour and foot infections. Therefore, it is advisable to create an antibacterial coating for footwear leather to solve these problems [37].

The peculiarity of the new hygienic bactericidal fabrics is that the antibacterial properties are created due to the structure of the materials, and not the treatment with special compounds, as it was before. The secret is in the composition of the fibers: ceramic elements embedded in the structure of the thread emit silver ions (as scientists have long proven, reacting with moisture, silver ions can prevent the growth of bacteria, fungi, etc.) [38]. According to the Italians, unlike the materials used so far, the properties of hygienic do not stop their action during operation, but, on the contrary, increase. In addition, they prevent the formation of unpleasant odors and prolong the freshness of footwear.

1.2.2 Chitosan

Chitosan is an N-deacetylated derivative of chitin, it is obtained from the shells of red-legged crabs or lower fungi by removing acyl. Chitosan is used as an encapsulating agent because it is a natural, biodegradable, low toxic and

biocompatible substance with antibacterial properties. It is also rather affordable, easy to find, sustainable and innocuous for humanity and the environment [39].

Chitosan is obtained from chitin, which is found in various marine crustaceans such as crabs or shrimp. Chitosan is a linear polysaccharide consisting of β-(1-4)-2-amino-2-deoxy-D-glucose (Figure 1.1) Chitosan can also be found in sea fungus and seaweed. Due to its properties, chitosan is a promising material for the development of functional coatings [40, 41].

Chitin was first mentioned in 1821, when a French scientist isolated this substance from insect tissues. In 1991, they developed a method for isolating chitosan from crab shells, and in 1997, this substance began to be used in the manufacture of various dietary supplements and medicines [2, p.82; 42, 43].

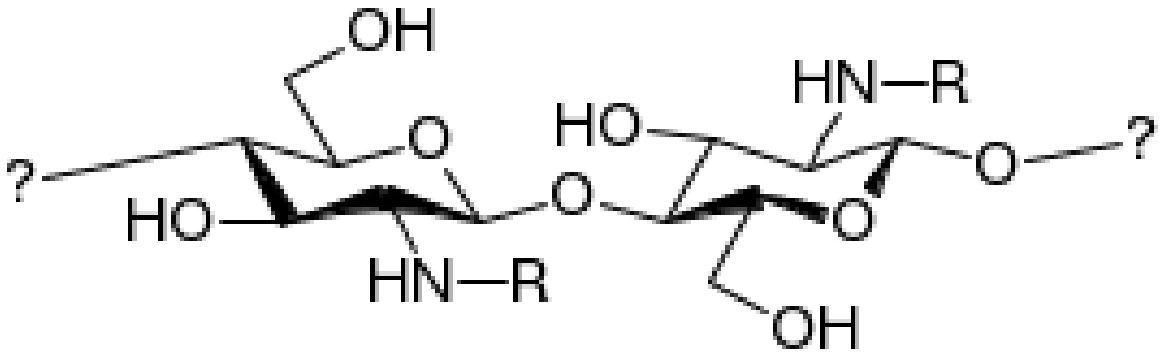


Figure 1.1 - Chitosan molecular structure

Due to several of factors, it is natural that science and industry are showing great interest in the discovery and use of naturally occurring polymers such as chitin and chitosan. These polymers possess several fascinating properties, including high biological activity and compatibility with human, animal, and plant tissues. They also do not pollute the environment, as they are completely degraded by microbial enzymes, and can be widely used in environmental conservation efforts [44].

Chitosan is a complex carbohydrate obtained from the exoskeleton of crustaceans (chitin) and the cell walls of fungi through an enzymatic reaction. This polysaccharide exhibits antimicrobial, antioxidant, and anti-inflammatory properties and has beneficial effects in the body. Therefore, chitosan is found not only in dietary supplements but is also widely used in the pharmaceutical, cosmetic, food, and other industries [45].

Chitosan is also used in veterinary medicine as a wound healing agent, enterosorbent, anti-inflammatory and antibacterial agent. The sorbent properties of chitosan have found their application in animal husbandry. In particularly polluted areas, chitosan is added to the diet of cattle to purify milk and avoid the development of infections [46]. Various studies are presented that describe the use of chitosan in the textile and footwear industry to create an antibacterial environment with promising results.

Chitosan has antibacterial, antiviral and antitoxic activity. Among the important and beneficial properties of chitosan is that it has an antimicrobial effect by suppressing pathogenic microflora. Its properties are explained by the fact that the

substance contains many cations. This allows it to «bind» to negatively charged structures on the surface of the bacteria. As a result, the metabolism of the cell with the environment is disturbed, and this leads to its death [47].

Chitosan plays an important role in providing antibacterial properties due to its unique chemical structure and biological activity. The antibacterial effect of chitosan is primarily attributed to the presence of positively charged amino groups in its molecular structure. In acidic environments, these amino groups become protonated, enabling chitosan to interact electrostatically with negatively charged components of bacterial cell membranes.

This interaction disrupts the integrity of the bacterial cell wall and membrane, leading to increased permeability and leakage of intracellular components. As a result, essential cellular processes are inhibited, ultimately causing bacterial cell death. Additionally, chitosan can form a polymeric film on the surface of microorganisms, which restricts the transport of nutrients and oxygen necessary for microbial growth [48].

Furthermore, chitosan can chelate essential metal ions and nutrients required for microbial metabolism, limiting bacterial proliferation. Due to these combined mechanisms, chitosan is widely considered an effective natural antimicrobial agent and is extensively used in biomedical materials, food preservation, and functional coatings for materials such as textiles, polymers, and leather products.

The antibacterial efficiency of chitosan is influenced by several factors, including its molecular weight, degree of deacetylation, concentration, pH of the medium, and the type of microorganisms involved. Consequently, optimizing these parameters is essential to achieve enhanced antimicrobial performance in various material applications [46, p. 1325].

One of the unique biological activities of chitosan is its ability to induce resistance to viral diseases in plants, inhibit viral infections in animals, and prevent the development of phage infections in infected microbial cultures.

A wide range of biological activity, biocompatibility, and biodegradability make chitosan polymer an attractive object for use in a variety of purposes. One of the first properties discovered in chitosan was its antibacterial and antifungal activities, which are currently being intensively developed by medicine, agriculture, food and textile industries. It is believed that the antibacterial properties of the polymer are primarily related to its effect on the cell walls of microorganisms [49].

Russian researchers conducted a series of experiments and found that chitosan has a pronounced inhibitory effect on bacteria. If the plastic is pre-treated with chitosan, it becomes more difficult for microorganisms to «adhere» to the surface.

In the article of Ivanushko L.A. et al., the antibacterial and antitoxic properties of chitosan and its derivatives (low molecular weight chitosan, acylated chitosan, chitooliprosaccharides, carboxypropyl chitosan) obtained by chemical or enzymatic degradation of the initial product were studied. As a result, the authors proved that chitosan and its derivatives have pronounced antimicrobial and anti-toxic properties [50].

In the research of Kulikov S.N. et al., the antibacterial activity of chitosan samples differing in molecular weight against *Escherichia coli* at different pH values

was studied. It is assumed that the antibacterial activity of chitosan is determined by the degree of protonation of its amino groups, which is variable and depends both on the degree of polymerisation of the substance and on the pH value of the medium. It has been shown that the antibacterial effect of chitosan is accompanied by damage to the bacterial cell wall, resulting in impaired permeability of membrane structures [51].

In the article by Kalugina D.S. et al., the advantages of the biodegradable polysaccharide chitosan, which possesses intrinsic antibacterial activity, as an alternative compound used in the final finishing of various textile materials. Chitosan has proven itself as a finishing agent, providing bacteriostatic activity to various textile materials. Chitosan also possesses a number of other unique properties: biocompatibility, non-toxicity, non-allergenicity, non-carcinogenicity, and breathability. Due to their chemical structure and composition, chitosan and its derivatives offer promising potential for use as antimicrobial, anticoagulant, hemostatic, antistatic, and color-enhancing coatings on textile materials based on various fiber types [52].

1.2.3 Essential oils and laurel oil

Essential oils are popular for their naturalness, fragrance, antimicrobial, antioxidant, antiviral, and antifungal properties. More than 2,500 plant species of the *Lauraceae* family grow in the subtropics and tropics of South and North America and East Asia. It grows in the mountains of Türkiye, Syria, Spain, Portugal, Morocco and the Canary Islands [53, 54, 55]. It has been known since the times of Ancient Greece, where it was considered a sacred plant. *Laurus nobilis L* is the most popular and used plant among the family. The leaves and fruits of this plant are used in folk medicine in the treatment of bacterial and fungal diseases and infections. Extracts of laurel leaves exhibit antimicrobial, soothing, antiepileptic and anti-inflammatory properties [56].

Laurel oil is a powerful natural antiseptic and antifungal. It destroys bacteria and fungi that cause athlete's foot, acne, and skin infections. It soothes itching and irritation, making it ideal for sensitive and reactive skin. It alleviates dermatological conditions such as eczema, psoriasis, and atopic dermatitis. It reduces redness and inflammation [57].

Laurel oil exhibits significant antibacterial activity due to the presence of biologically active compounds such as 1,8-cineole, eugenol, linalool, α-pinene, and β-pinene. These phytochemical constituents contribute to the antimicrobial efficacy of laurel oil through multiple mechanisms that affect the structure and function of bacterial cells.

One of the primary mechanisms of antibacterial action involves the interaction of hydrophobic components of laurel oil with the lipid bilayer of bacterial cell membranes. These compounds penetrate the phospholipid structure of the membrane, disrupting its integrity and increasing membrane permeability. As a result, leakage of intracellular components such as ions, nucleotides, and proteins occurs, leading to cellular dysfunction and eventual bacterial cell death [54, p. 1284].

In addition, the phenolic and terpene compounds present in laurel oil can interfere with essential enzymatic systems involved in bacterial metabolism. By inhibiting enzyme activity, laurel oil disrupts energy production and metabolic pathways necessary for bacterial survival and growth.

Laurel oil also exhibits antioxidant properties that can contribute indirectly to its antimicrobial activity. The bioactive compounds may induce oxidative stress in microbial cells by disturbing the balance of reactive oxygen species, which can damage cellular proteins, lipids, and nucleic acids [57, p. 520].

Furthermore, laurel oil has been reported to inhibit the formation of bacterial biofilms. Biofilms provide protective environments for microorganisms, enhancing their resistance to antimicrobial agents. By preventing biofilm formation or disrupting existing biofilms, laurel oil enhances the susceptibility of bacteria to antimicrobial action.

The antibacterial effectiveness of laurel oil depends on several factors, including its chemical composition, concentration, type of microorganism, and environmental conditions. Due to these properties, laurel oil is increasingly used as a natural antimicrobial agent in pharmaceuticals, food preservation, cosmetic formulations, and functional materials such as antimicrobial coatings for textiles and leather products [58].

Commercial essential laurel oil has a fresh camphor-aromatic odour with a spicy note and is a pale yellow to pale olive green in colour. Used since ancient times as a medicinal and cosmetic product, this oil is particularly valued for relieving skin ailments, cleansing the skin and strengthening hair. The laurel oil has antibacterial, anti-infectious, analgesic, antiviral, and antiseptic qualities [59]. Antioxidant and antibacterial properties of laurel oil: it protects the skin from free radicals and creates a natural barrier against bacteria. Some studies have researched the use of laurel oil to obtain anti-infective or odour effects, as well as to study bacterial properties.

There is some research about laurel oil microencapsulation:

In the research of Seyda Eyupoglu et al. laurel oil, lavender oil, and fennel oil (Aydın Corp., Türkiye) were microencapsulated with gum arabic wall material to produce single-use bee-repellent 100% cotton fabrics. Eleven different microcapsules were produced. The microcapsules were analyzed by optical microscope, FT-IR, and SEM. In the conclusion, was shown that the microcapsules received with lavender and fennel oils might be used to manufacture bee suits with bee repellent properties [60].

In the research of Motahareh Amiri et al. bay laurel (*Laurus nobilis*) essential oil (Chabaksar, Gilan) was nanocapsulated with chitosan-chia seed gum to increase the shelf life of quail fillets. The results of the chemical and microbial analysis showed that nanoencapsulation of laurel essential oil has increased antimicrobial and antioxidant properties, and suggested to use as a natural preservative in the meat industry [61].

In the research of Luis Medina-Torres et al. laurel infusions (*Litsea glaucescens*) (Durango, Mexico) was microencapsulated with maltodextrin. The research showed the possibility of encapsulation and interactions. The result was revealed the best

conditions of encapsulated laurel infusions: feed rate of 8 mL/min and 160 °C temperature [62].

In the research of Ahmet Yesilsu et al. fish oil was microencapsulated with rosemary, thyme and laurel extracts. In the conclusion, was shown that laurel and rosemary extracts might successfully be put in anchovy oil for raising the oxidative stability in microencapsulation [63].

In the research of Páulia Maria et al. laurel leaves essential oil (*Laurus nobilis L.*) was microencapsulatedby by supercritical fluid extraction of emulsion. As a result, encapsulation raised the thermal stability of the particles and kept the bacteriostatic and fungistatic activities of the laurel essential oil [64].

1.3 Analysis of data on pathological deviations of the feet

Not only medicine but also the environment and lifestyle play an important role in maintaining and strengthening health. It is important to understand that lifestyle is not just about having or not having bad habits. Lifestyle is a social category and it consists of living standards, culture, education, medicine, as well as the quality of products consumed [65]. Thus, footwear is one of the products that can affect human health.

The frequency of leg pain, as well as the occurrence of various foot deformities and foot problems increase with age. Pain is the first sign of a foot problem.

Research in the field of footwear in the Republic of Kazakhstan has shown that there are a number of issues and barriers to development. One of them is the lack of footwear developed for pathological deviations of the foot in people of any age. Foot deformities can be congenital in children and in adults as a result of exposure to living and working conditions, injuries, neurological diseases. In addition, during aging, pathological changes occur in the body, especially changes in the feet. Flat feet, heel spurs, deformities of the big toe affect the quality of life.

Pathological deviations of the foot are divided into different types, for example: deformity of the foot, hyperkeratosis of the foot, diabetic foot syndrome, warts on the front of the foot, curvature of the toes, ankle sprains, heel spurs, heel spurs and more [66].

According to international studies, 75% of the population suffers from foot pathology. The number of patients is growing, and the problem turned out to be very urgent, so a whole podiatry and podiatry specialty was divided.

In Minakov O.E. et al. article was said that diabetes mellitus - takes the third place in the structure of causes of death, affects 4-5% of the world's population. Syndrome of diabetic foot (DFS) is formed in 20-50% of patients and in 30% of cases leads to infectious-necrotic complications. When diagnosing DFS pay attention to the condition of the skin andfingers of the feet, bloodflow, the presence ofpain, to study sensitivity, to conduct capillaroscopy, polarography, ultrasonic dopplerography, radiography of foot bones, densitometry and angiography [67].

DFS is a formidable complication associated with impaired blood glucose metabolism in patients with diabetes mellitus, leading to dysfunction of the nerves, blood vessels, bones and soft tissues of the foot, which leads to the formation of

wounds, cracks, ulcers, infections of bones and soft tissues and as a result of gangrene of the foot and legs [68].

There are a number of reasons that, against the background of diabetes, lead to the development of DFS:

Peripheral neuropathy - pathological changes in the nerves of the legs that occur under the toxic effect of glucose in the patient's body. Violated sensitivity in the legs - pain, temperature, tactile. This leads to a change in gait, the appearance of injuries, calluses, cracks, and further to the formation of ulcers.

Diabetic angiopathy (impaired circulation) - a high level of glucose in the blood leads to changes in the wall of large and small vessels, the metabolism between the blood and tissues of the foot is disturbed. Dry skin, cracks, long-term non-healing wounds appear.

Infection - any wound, abrasion, bruising can provoke an infectious complication on the foot against the background of diabetes mellitus, which can lead to the formation of purulent ulcers, abscesses, foot phlegmon and gangrene.

There are 4 forms of DFS:

Neuropathic - when predominantly the nerves of the legs are affected.

Ischemic - when there is a primary lesion of small (microangiopathy) and large (macroangiopathy) vessels of the legs.

Mixed (neuroischemic) - both nerves and vessels of the legs are affected.

Musculoskeletal (osteoarthropathy) or Charcot foot - when the musculoskeletal structures of the foot are affected [69].

Diabetic osteoarthropathy is a rare but severe and sometimes unpredictable diabetic foot syndrome characterized by a combination of factors such as hyperglycemia, neuropathy, trauma and bone metabolism disorders, aseptic destruction of bone with acute aseptic destruction, and acute local inflammatory response. In the absence of specific treatment for this pathology, the patient experiences long-term incapacity for work or permanent disability.

In Maren Volmer-Thole et al. article showed that diabetic foot ulceration is a serious complication of diabetes mellitus worldwide and themost common cause of hospitalization in diabetic patients. The etiology of diabetic foot ulcerationsis complex due to their multifactorial nature; in the pathophysiology of diabetic foot ulcerationpolyneuropathy is important. Proper adherence to standard treatment strategies and interdisciplinarycooperation can reduce the still high rates of major amputations [70].

Callus is a local thickening and roughening of the skin, which has a white, yellowish or grayish tint. This is not only an aesthetic defect, but also a source of constant pain and other unpleasant sensations. In fact, corn is a protective reaction of the skin to mechanical stress. It occurs in the area that suffers the most from this effect.

Corns are divided into several types:

First is wet. It looks like a bubble filled with liquid (lymph). Its color is usually transparent, but if small blood vessels are affected, then it becomes reddish. The remains of a burst bubble give rise to the growth of dry corn.

Seconfd is dry. This is a slightly raised area of keratinized cells of a grayish-yellow color. Consists of several layers of hardened tissue.

Next one is rod. In the center of such calluses, there is a hole where the rod grows deep into the dermis. Deep-growing calluses bring pain;

Then are warts. Similar to dry corns, but still have differences. Calluses appear both on the hands and on the legs and have visible borders, and corns are characteristic only of the lower surface of the feet and are larger, and they do not have a clear limitation and a core.

Warts usually appear because of wearing footwear with too high heels, too tight or too light. They often appear on the most exposed parts of the foot. Warts are not just a cosmetic defect. They are a type of disease that often interferes with walking, causing pain and fatigue in the legs [71].

Normal healthy toes should grow straight, but sometimes one or both ends of the toes bend to the side and begin to sink into the soft tissues of the toes folds, which leads to their inflammation. The main symptoms of swollen toes are pain, redness and swelling of the skin around the toes, the appearance of discharge, an unpleasant odor, the growth of skin around the toes. Most often, this problem occurs on the thumbs, but it can also occur on others. Among the causes of improper toes growth and impaired penetration are improper toes cutting, constant compression of the toes with tight or narrow footwear, multiple toe injuries, heredity.

Foot cellulitis is a diffuse bacterial inflammation of the subcutaneous tissue of the distal lower limb. The disease is most often caused by staphylococci and streptococci. Risk factors for its development include foot trauma, diabetes, and chronic circulatory disorders [72].

Gangrene is a pathology in which organs and some parts of the body «die».

One of the most common types of skin diseases is hyperkeratosis. This is an excessive thickening of the stratum corneum of the epidermis. With the development of such a pathology, the horny cells begin to intensively divide and there is a violation of desquamation, which results in thickening of the skin. Moreover, the thickening can reach several centimeters. According to statistics, hyperkeratosis is observed in approximately 20% of men and 40% of women. As a rule, the problem occurs in separate areas and leads to a significant deterioration in the appearance of the skin [73].

Hyperkeratosis of the feet can occur on the entire sole or only on the heels. As a rule, this form is characterized by severe dryness and roughness of the skin, as well as a noticeable thickening in the affected areas. Allocate dry callus (local lesion with clear boundaries of thickening of the stratum corneum), callus (a sharply limited area of thickening of a round shape of small size) and soft callus (appears between the fingers as a result of high humidity) [74, 75].

The foot is the «foundation» of health, because it performs very important functions that provide various movements in life. Disorders of the structure and function of the foot lead to the development of various diseases.

1.4 Analysis of footbeds for pathological deviations

Production of orthopedic footwear is a complex and multifaceted process. Orthopedic footwear is footwear designed specifically to support people suffering from various ailments in the lower part of the foot. Special medical footwear appeared a long time ago and has always been aimed at supporting the movement of the foot.

Orthopedic footbeds are functional devices that optimize and correct the natural functions of the foot. From a technological point of view, there are two types of orthopedic footbeds: ready-made orthopedic footbeds, modified on the sole of the foot, and individual fully contact footbeds, made to order with a three-dimensional copy of the foot. All types of orthopedic footbeds can provide comfort and cushioning, which makes it convenient to walk and play sports. The use of ready-made soles in everyday footwear can be useful for a limited number of users who have a classic shape of the foot, without significant asymmetry, deformation or biomechanical problems [76].

Footwear with preventive properties make up a certain part of the consumer market. It is characterized by design solutions that provide maximum comfort in use, the presence of special parts such as anatomical footbeds, semi-insoles, rational scientifically based internal shape of footwear and the use of high-tech materials in footwear, physical, mechanical and hygienic performance. New design solutions and materials are adopted to make the correct footwear comfortable to wear and create the necessary conditions for the prevention of foot diseases and foot deformities.

There is a need to wear corrective footwear to prevent the spread of any foot pain, as well as for the simple comfort factor.

When designing footwear, the requirements of comfort and convenience become the main ones. The quality of footwear is determined not only by its durability and appropriate aesthetic design, but also by sufficient comfort, which is understood as the ability to create conditions for the normal functioning of the foot. The comfort of footwear is a complex indicator, the properties of which are usually divided into three groups. The first group consists of physiological properties that ensure the normal biomechanical functioning of the foot; the second includes hygienic properties that affect the safety and harmlessness of its wear conditions; the third describes the footwear with rationality and comfort, offers anthropometric properties [77].

When choosing footwear, research has shown that footwear has the following properties:

First is lightweight. Footwear should not be heavy or obstruct the child's movement.

Second is flexible. Footwear should not restrict foot movement or interfere with the child's natural movement. The foot should bend along the line of the toes in a natural position, where the foot bends when walking and running.

Third is air permeability. Footwear made of breathable natural materials such as leather, wool and fur create a beneficial microclimate for the feet by promoting natural heat regulation. The use of any synthetic materials in the structure of the

upper and lining of footwear that are in direct contact with the child's feet is considered undesirable.

Moreover, the main is antibacterial. If necessary, the footwear must meet certain sanitary and hygienic requirements. It should have a therapeutic and other preventive effect on the body - it helps to treat foot and mouth disease, inhibit the growth of bacteria, chemical damage to the skin and damage to the footwear material, to prevent unpleasant skin odors [78, 79].

There were researched some footbeds presented on the market of Kazakhstan.

Sample 1. Skeletal orthopedic footbed «Comforma» for the prevention and treatment of flat feet (Figure 1.2). Manufacturer LLC «Orto.Nik», Russia. Materilas: top layer material - natural leather; shaft material - Carbosane material; inner subframe material - Orthorel material; inner skeleton material - Orthorel material; middle layer material - Orthorel material; the bottom layer material - Paraskin non-woven material.

The sole is a frame made of Orthorel plastic, which is resistant to deformation, gives the sole shape and keeps the sole in the correct position inside the footwear, as well as does not interfere with the physiological movements of the foot while walking. The variable geometry and stiffness of the skeleton correspond to the anatomy of the foot. An enlarged horizontal arc pen made of non-corrosive Carbosane material reduces the stress on the front of the foot. The flexible heel area is designed to support physiologically correct gait and provide comfort. The bottom layer is made of wear-resistant Paraskin material.

Sample 2. Therapeutic and prophylactic orthopedic footbed «Comforma» (Figure 1.2). Manufacturer LLC «Orto.Nik», Russia. Materials: top layer material - microline; the bottom layer material is evaplast.

Functional values: moderate support of longitudinal and transverse arches, reduction of load on the anterior part of the foot, special relief in the lower part of the sole reduces the load on the most problematic areas of the anterior part of the foot - 2-4 feet bone tips, first foot-phalangeal joint and distal phalanx of the first toe.

Sample 3. Sursil-Ortho orthopedic footbed (Figure 1.2). Manufacturer LLC «Sursil-Orto», Russia.

Advantages and features of Sursil-Ortho orthopedic footbeds:

- Supports longitudinal and transverse arch of the foot.
- Reduces the impact load on the joints of the musculoskeletal system.
- Relieves foot fatigue.
- Reduces the load on problem areas of the foot.
- Corrects minor foot deformities.
- The upper layer of the sole is made of leather tanned with natural vegetables or modern artificial high-tech materials.

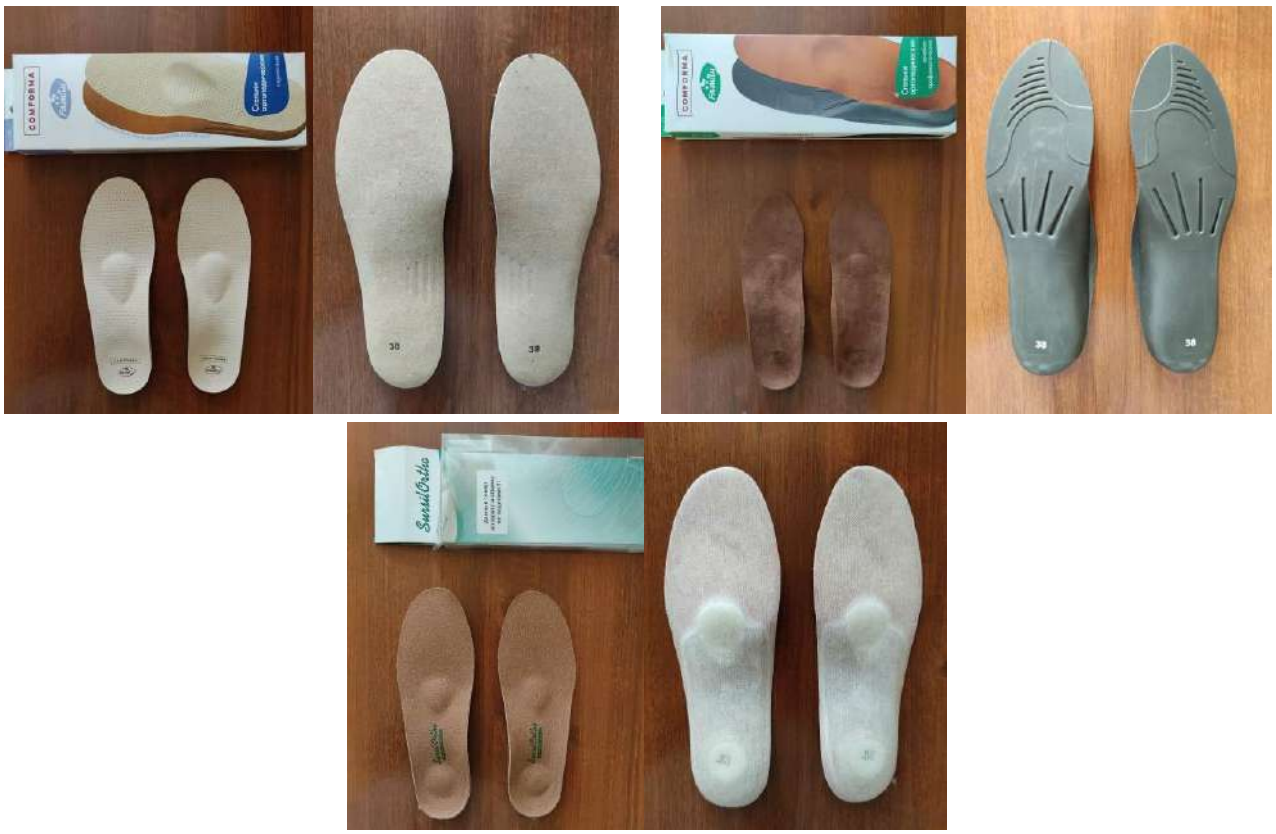


Figure 1.2 - Orthopedic footbeds (from left to right: sample 1, sample 2, sample 3)

Sample 4. Kolemen's orthopedic footbed (Figure 1.3). Manufacturer Türkiye.

Orthopedic footbeds help relieve many common symptoms, including: heel pain, knee pain, leg and back pain.

Figure 1.3 - «Kolemen's» footbeds (from left to right: footbed (a), leather footbed (b), for diabetes (c))

The orthopedic footbeds have a semi-rigid polypropylene sheath that provides support and shock absorption, while the upper cap is designed to reduce friction during sports exercises and provide comfort in daily use.

Sample 5. Aetrex sports orthopedic footbed (Figure 1.4). Manufacturer Aetrex. Worldwide, Inc., USA.

Aetrex Compette orthopedic elements are designed to prevent injuries, maintain body shape and maintain good health. These lightweight and flexible orthopedic products provide softness, cushioning and comfort during intense exertion.

Aetrex's strategically positioned, patented Lynco support provides foot balance and biomechanically balances the body, helping to address common ailments such as heel fascia, arch pain and metatarsalgia. Aetrex Compete Orthotics orthopedic products provide stability while running and feature an improved CopperGuard top coat that helps protect feet from bacteria, fungi and odors.

Figure 1.4 - «Aetrex» sports orthopedic footbed

Sample 6. Orthopedic footbed «Formthotics» (Figure 1.5). Manufacturer Foot Science International Ltd. Company, New Zealand.

Formtotics takes into account the individual biomechanical and neurological features of the movements in the verses. Formstotics orthoses are designed to: lighten

the soles of the feet, reduce the load, activate the muscle stabilizers, proprioception, increase stability and balance, improve gait.

Formthotics Junior is designed to ensure the natural placement of small feet in footwear and support the child's musculoskeletal system. Formthotics Junior medical foot orthoses are used for non-aggressive treatment of flat feet in hypermobile children and to provide optimal support for the musculoskeletal system and foot function.

Figure 1.5 - «Formthotics» and «Formthotics Junior»

In sample 1, the internal longitudinal arch of the foot is not clear, there is no external arch, and the supinator is located in the part of the foot bone. In sample 2, the inner longitudinal arch of the foot and the outer arch of the foot are clearly located in the supinator of the foot bone. In sample 3, the internal longitudinal arch of the foot is not clear, the outer arch of the foot is not supported, and the supinator is located between the foot bone and the footrest. In sample 4a, the inner longitudinal arch of the foot and the outer arch of the foot are clearly located between the supinator foot bone and the foot lift. In sample 4b, there is no internal longitudinal arch of the foot and no outer arch, the supinator is located between the foot bone and the foot lift. In sample 4c, the inner longitudinal arch of the foot is not clear, the outer arch is clear, there is no supinator. In sample 5, the internal longitudinal arch of the foot is not clear, there is no outer arch, and the supinator is located between the foot bone and the footrest. Samples 1-5 have built-in supinators. Scientifically, the supinator should be separate and the supinator should be attached to the middle part by drawing a line between the big toe and the proximal phalanx of the foot.

Conclusion on the first part

1. Based on the studied literature sources and patent data, the main requirements for the main materials for footwear: leather and lining materials were determined. Among them, special attention should be paid to antibacterial properties.

2. It is very important to create an antibacterial environment for people with pathological deviations. Especially for people, whose footwear should have antibacterial properties to prevent the spread of infections and ulcers when wearing footwear.

3. One of the most promising methods of antibacterial treatment is the treatment of materials with microencapsulated drugs. Spray drying is the most common method of microencapsulation.

4. Various studies are presented that describe the use of chitosan in the textile and footwear industry to create an antibacterial environment with promising results. Chitosan is used as an encapsulating agent because it is a natural, biodegradable, low toxic and biocompatible substance with antibacterial properties. The laurel oil has antibacterial, anti-infectious, analgesic, antiviral, and antiseptic qualities.

5. It was found that the footbeds on the Kazakhstan market help regulate the external shape of the foot. In addition, the need to create for the footbeds an additional antibacterial environment made from natural solutions was identified.

2 RESEARCH OBJECTIVE AND METHODS

The research was conducted with the aim of improving the antibacterial properties of footwear materials intended for people with pathological foot deviations in the Republic of Kazakhstan. For this category of patients, the materials of the inner part of the footwear, which have pronounced antimicrobial properties, are of special importance, capable of reducing the bacterial load, preventing the development of inflammatory processes and increasing comfort during long-term use of the footwear.

In Kazakhstan, the problem of stopping complications in patients remains socially significant. According to national survey, the number of patients with diabetes mellitus in the country increases annually, and at the same time, the risk of developing diabetic foot syndrome, ulcers and infectious complications increases. In 2023, the number of patients with diabetes was estimated at more than 309 thousand, in 2024 - about 328 thousand. Therefore, the development of preventive antibacterial materials for footwear is an important direction in reducing the risk of foot complications.

Laurel oil and chitosan were selected as active components of the study. The joint use of laurel oil and chitosan allows to obtain a composition of prolonged action with increased stability and efficiency, which is especially important for footwear materials for medical and preventive purposes.

Leather footbeds and footwear lining materials, which are widely used in the production of everyday and orthopedic footwear, were used as research objects. 3 mm thick footbeds used for everyday footwear were the object of study in this work. The choice of these materials is due to their direct contact with the surface of the foot, the ability to accumulate moisture and create conditions for the reproduction of microorganisms. Functional processing of leather footbeds and linings with an antibacterial composition was considered as an effective way to improve the hygienic and operational properties of footwear for people with pathological foot deviations.

2.1 Reagents and chemicals

In the encapsulation procedure, chitosan was used as an encapsulating polymer with a concentration of 1% (w/v) and molecular weight of 600,000-800,000. To prepare microparticles were used Laurel essential oil, acetic acid (glacial), surface-active agents: Tween 40 and Span 20, binder Tanapur One, wetting agent Periwet ELR (Table 2.1). Sodium carboxymethyl cellulose used as thickening agent and dispergator in finishing liquor.

In standard line for quantification n-hexane, ethanol absolute and methanol were used. These solvents were selected based on their chemical compatibility with the analytes and their ability to efficiently dissolve the sample components, ensuring accurate and reproducible measurements. The use of high-purity solvents also minimised potential interference during the analytical determination, thereby improving the reliability of the quantification results.

Table 2.1 - Reagents and chemicals

Reagents and chemicals	Company
Chitosan	Acros Organics, China
Laurel essential oil	Ephesus Spice& Essential Oil, Türkiye
Acetic acid (glacial)	Merck, Germany
Tween 40	Fisher Scientific, UK
Span 20	Merck Millipore Corporation, Spain
Tanapur One	Tanatex Chemicals, Netherlands
Periwet ELR	Dr Petry, Germany
Sodium carboxymethyl cellulose	Sigma-Aldrich, USA
N-hexane	EMD Millipore Corporation, Germany
Ethanol absolute	ISOLAB Chemicals, Türkiye
Methanol	Sigma-Aldrich, Merck, Germany
Wax	Fenice Kimya, Turkiye
The phosphate-buffered saline (PBS, pH 7.4)	BioShop, Canada
Mueller-Hinton agar	Oxoid, United Kingdom
Sabouraud Dextrose agar	Oxoid, United Kingdom

2.2 Equipment and techniques to conduct experiments

Microparticles were prepared in a spray dryer (Figure 2.1). The installation to carry out the process of microencapsulation consists of the following main parts:

- Spraying nozzle.
- Peristaltic pump.
- Feed selection valve.
- Control panel.
- Outlet filter.
- Outlet temperature sensor.
- Cyclonic separator.

The spraying nozzle ensured the atomization of the feed solution into fine droplets. The peristaltic pump was responsible for supplying the solution to the spraying system at a controlled flow rate. The feed selection valve allowed the regulation and selection of the feed stream. The control panel is used for monitoring and adjusting the operating parameters of the system. The outlet filter prevents the loss of fine particles and protects the exhaust system. The outlet temperature sensor provided continuous monitoring of the drying air temperature. The cyclonic separator enabled the efficient separation and collection of the formed microparticles from the drying air stream.

Figure 2.1 - Unopex B 15 Mini Spray Dryer

For experimental studies, the equipment indicated in the Table 2.2 was used.

Table 2.2 - Equipments and techiques

Equipments and techiques	Company
Spray dryer	Unopex B 15 Mini Spray Dryer, Türkiye
Magnetic stirrer	IKA C MAG HS 7, Germany
Homogenizer	IKA T25 digital Ultra Turrax, Germany
Scanning electron microscope	Thermo Scientific Apreo S., USA
Mastersizer 3000	Malvern Instruments Worcestershire, UK
FT-IR Spectrometer	Spectrum 100, PerkinElmer, USA
UV-Spectrophotometer-1800	Shimadzu Corporation, Japan
Water bath	Nüve BS 402, Turkiye
Magnetic stirrer	2mag MIXdrive 15 HT, Germany
KD 400 laboratory oven	Nuve, Türkiye
Laboratory stenter	Rapid Labortex Co Ltd, Taiwan
CM 3600d spectrophotometer	Konica Minolta, Japan

2.3 Footwear materials

The footwear leather used in this study was wet-blue crust leather, which had not been subjected to any dyeing or finishing treatments (Figure 2.2). This untreated state made the leather suitable for experimental application, allowing for controlled investigation of the effects of subsequent treatments or modifications.

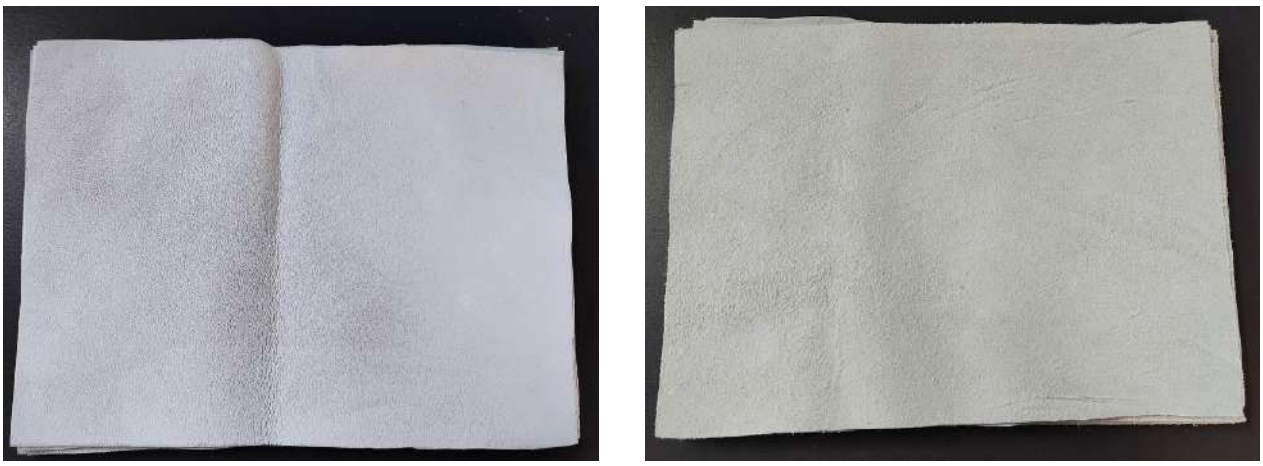


Figure 2.2 - The footwear leather

The footwear lining materials used in this study possessed the specific characteristics summarised in Table 2.3.

Table 2.3 - Characteristics of footwear lining materials

Name	Lining material	Weight (g/m^2)	No of Layers	Lining material properties		
				Outer Layer	Middle Layer	Bottom Layer
1	2	3	4	5	6	7
Lining 1		350	1	100% raw cotton woven fabric		
Lining 2		400	2	100% PET woven	-	100% cotton nonwoven

Continuation of Table 2.3

1	2	3	4	5	6	7
Lining 3		400 (L_1: 200 L_2: 160 L_3: 40)	3	70% PA + 30% PET Weft Knitting	100% PET Weft Knitting	100% PET Weft Knitting

These properties include lining material parameters, such as characteristics of outer layer, middle layer and bottom layer, which are critical for evaluating their performance in subsequent experimental treatments. Utilising materials with well-defined and documented characteristics allowed for a controlled assessment of the effects of the applied finishing and functionalization processes.

2.4 Obtaining microparticles and application

2.4.1 Preparation chitosan solution

To prepare the acetic acid solution, ultrapure water and acetic acid were mixed in a volume ratio of 1:2 (mL) in order to obtain a homogeneous solvent medium suitable for dissolving chitosan. The solution was stirred until complete mixing was achieved.

Subsequently, chitosan with a molecular weight of 600,000-800,000 was gradually added to the prepared acetic acid solution to obtain a 2% (w/v) chitosan solution. In this procedure, chitosan was dissolved in a 2% (v/v) acetic acid aqueous solution, which provides the acidic environment necessary for the protonation of amino groups in the chitosan structure and facilitates its dissolution.

The mixture was continuously stirred using an IKA C-MAG HS 7 Magnetic Stirrer (Figure 2.3) for approximately 30-40 minutes until a clear and homogeneous chitosan solution was obtained. This step ensured complete dissolution of the polymer and prevented the formation of aggregates, thereby providing a stable solution suitable for subsequent experimental procedures.

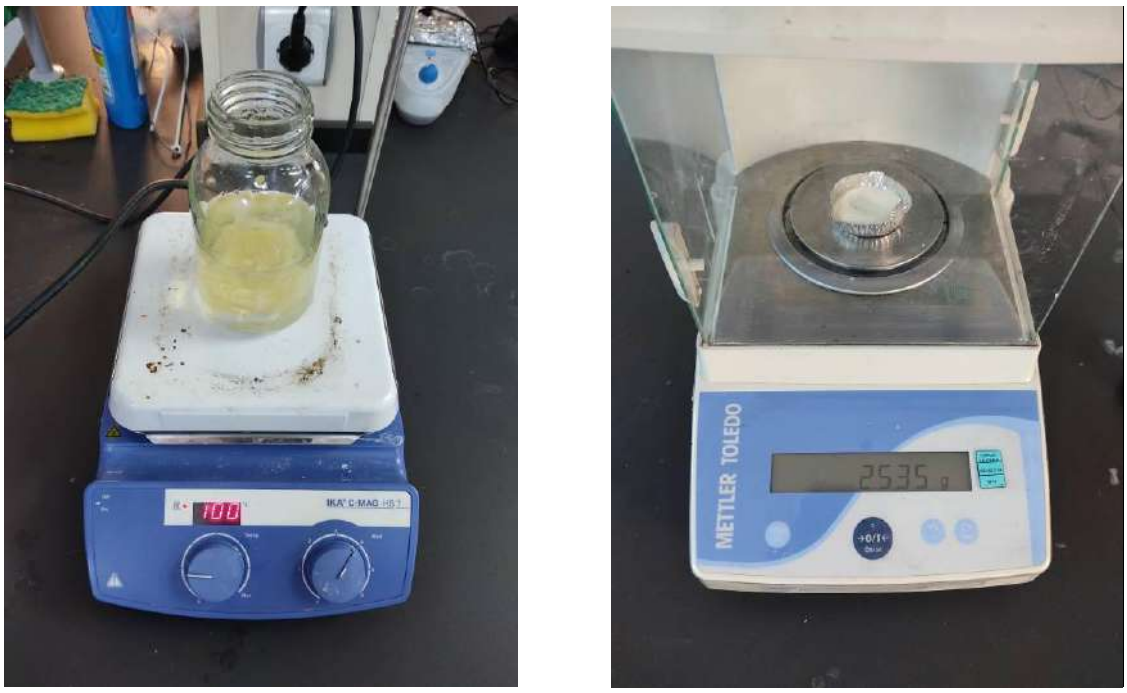


Figure 2.3 - IKA C MAG HS 7 magnetic stirrer and electronic scales

2.4.2 Preparation of Laurel oil solution

In the next step, laurel oil and the surfactants Tween 40 and Span 20 were incorporated into the chitosan solution using a homogenizer (Figure 2.4) for 10 minutes to ensure the formation of a uniform emulsion. The weights of the active components were carefully measured, with 80 g of Tween 40 and 20 g of Span 20 added to the mixture.

Figure 2.4 - IKA T25 digital Ultra Turrax

Table 2.4 - The composition of the formulations

Sample Code	Chitosan (w)	Oil (w)	Surface active agent (% of oil)
L_0	1	-	-
L_1	1	1	10
L_2	2	1	10
L_3	1	2	10
L_4	1	1	10
L_5	1	1	20
L_6	1	1	40

This homogenization process facilitated the thorough dispersion of the oil phase within the polymer matrix, promoting the stability and consistency of the resulting formulation for further microencapsulation or coating applications (Table 2.4).

2.4.3 Obtaining microparticles in spray dryer

The prepared laurel oil-based formulation was subsequently introduced into a spray-drying system for the production of microparticles. Prior to the encapsulation process, the formulation was subjected to a homogenization step to ensure a uniform distribution of the dispersed phase and to enhance the physicochemical stability of the feed solution. This pre-treatment is critical for achieving consistent droplet formation during atomization and for preventing phase separation or aggregation of active components.

Furthermore, homogenization contributes to the reduction of particle size of the dispersed oil phase, thereby improving encapsulation efficiency and promoting the formation of microparticles with controlled morphology and narrow size distribution. As a result, a stable and homogeneous feed mixture suitable for spray-drying microencapsulation was obtained, which is essential for ensuring reproducibility of the process and optimal functional properties of the final microparticulate system.

The microencapsulation process was carried out under controlled operating conditions. The inlet temperature of the drying system was maintained within the range of 160-170 °C, while the feed solution was delivered to the atomization system using a pump operating at a flow rate of 4-10 mL/min. In addition, the blower capacity was adjusted to 85-95% to ensure efficient drying airflow, and the compressor supplied air at a constant rate of 10 L/min, enabling proper atomization and formation of fine droplets during the spray-drying process (Figures 2.5, 2.6 and Table 2.5).

Under these experimental conditions, seven different formulations were produced, including a blank sample and samples labelled L_1, L_2, L_3, L_4, L_5, and L_6, each prepared according to specific compositional ratios (Table 2.4). The resulting microparticles were subsequently collected for further physicochemical, morphological, and microbiological analyses.

Figure 2.5 – Obtaining of microparticles

Table 2.5 - Spray drying parameters

Compositions	Inlet Temperature (°C)	Outlet Temperature (°C)	Pump Speed (mL/min)	Blower (%)	Compressor (L/min)
L_0, L_1, L_2, and L_3	160	90	5-10	85	10
L_4, L_5, and L_6	170	108	4	95	10

The duration of the microencapsulation process was determined by the feed solution volume and the pump flow rate used during the spray-drying procedure. In the present study, a constant solution volume of 250 mL was processed, while different pump speeds were applied in order to evaluate their influence on the total microencapsulation time. The processing time was calculated by dividing the total solution volume by the corresponding pump flow rate.

The microcapsulation time depended on the pump speed and volume of solution:

- 250 (mL) / 3 (mL / min) = 83 min.
- 250 (mL) / 4 (mL / min) = 62 min.
- 250 (mL) / 5 (mL / min) = 50 min.

These results indicate that the microencapsulation time is inversely proportional to the pump flow rate: as the pump speed increases, the total processing time decreases.

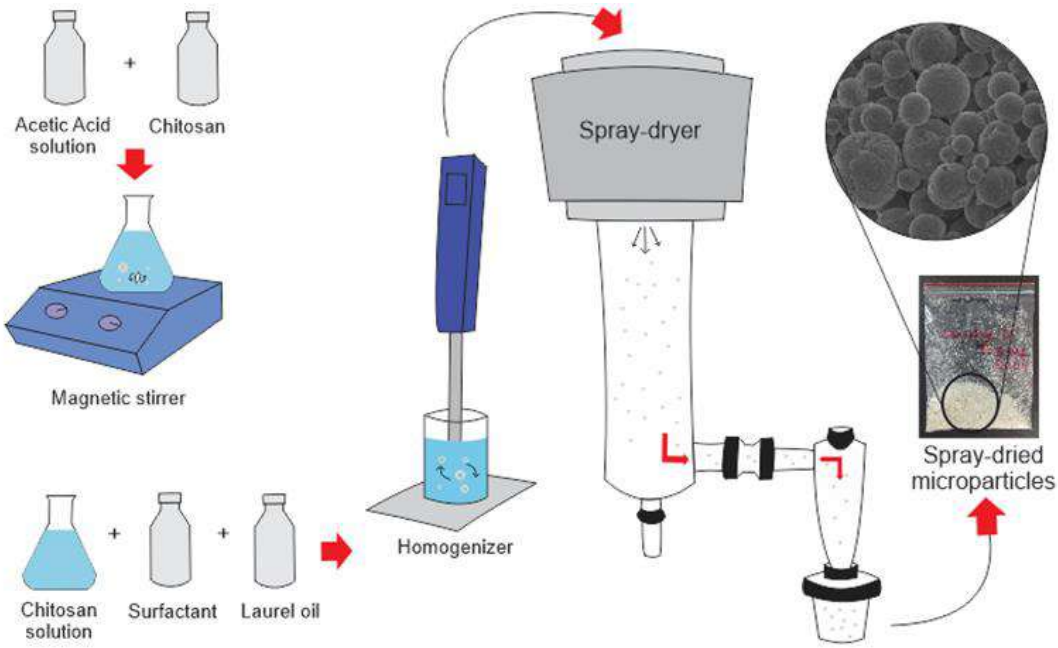


Figure 2.6 - The process of obtaning microparticles

2.4.4 Production yield

After completion of the spray-drying process, the obtained microparticles were carefully collected from both the product collection vessel and the cyclonic separator. The powder was gently removed from the inner surfaces using a soft brush in order to prevent particle loss and mechanical damage. The collected microparticles were then transferred into clean plastic zip-lock bags, which were tightly sealed to protect the samples from moisture absorption and environmental contamination (Figure 2.7). The samples were subsequently stored under appropriate laboratory conditions until further analysis and characterization (Table 2.6).

Table 2.6 - Production yield

Sample Code	Production (g)	Production (%)
L_0	1,033	41.32
L_1	1,042	22.84
L_2	0,683	18.21
L_3	0,893	11.9
L_4	1,596	31.92
L_5	1,669	33.38
L_6	1,239	24.78

The formula of production yield was calculated according to Equation 2.1.

$$\% \text{ Production yield} = \frac{\text{Practical amount}}{\text{Theoretical amount}} \times 100 \quad (2.1)$$

Figure 2.7 - Obtaned microparticles

2.5 Morphological characterizations of microparticles

The morphology of the microparticle surface was assessed using SEM at various magnifications. The samples were fixed on a holder and sputter-coated with a thickness of approximately 10 nm layer of Au:Pd (80:20) using a Leica EM ACE600 device in an argon atmosphere to increase resolution. The SEM analysis was performed at an accelerating voltage of 15 kV. The scale ruler is shown below the images. In addition, the particle size and distribution were determined using laser diffraction performed on a Mastersizer 3000 device by dry dispersion. A refractive index (RI) of 1.700 and an absorption index of 0.010 were used, the solvent was water (RI:1.33). To ensure the reliability and accuracy of the obtained results, all measurements were performed in triplicate under identical experimental conditions. The average values of the three independent measurements were subsequently calculated and used for further analysis, thereby minimising possible experimental errors and improving the reproducibility of the results.

2.6 Chemical characterization of microparticles

To determine the chemical structure and identify the characteristic functional groups of the spray-dried microparticles, Fourier-transform infrared spectroscopy with attenuated total reflectance was used. This analytical technique allows the investigation of molecular interactions and structural features of the obtained materials by recording their infrared absorption spectra over the selected wavelength range. The method provides valuable information on the presence of specific

chemical bonds and possible interactions between the components of the microparticles formed during the spray-drying process. The measurements included four scans with a resolution of 4 cm^{-1}, covering the range of wave numbers from 4000 to 500 cm^{-1}.

2.7 Ultraviolet visible spectrophotometric determination of Laurel essential oil

The problem of limited solubility, especially in water, makes it difficult to quantify materials, including essential oils. LEO, known for its diverse mixture of compounds [80], has been tested for solubility in various solvents, both polar and non-polar, such as methanol and n-hexane, to find out its solubility characteristics. In the end, n-hexane showed better solubility and concentration results and was chosen as the solvent for LEO. Subsequently, triple measurements were performed using a UV-visible spectrophotometer at 268 nm to draw a standard line for LEO, while solutions were prepared with concentrations of 0,1, 0,3, 0,5, 0,7, 1,0, 1,2 and 1.5 mg/mL using n-hexane (Figure 2.8). The equation of the standard line for n-hexane is presented in the Equation 2.2, with an R^2 value of 0.99, which means that 99% of the variability of the dependent variable is explained by the model, which indicates excellent compliance. The equation of the standard line for methanol is presented in the Equation 2.3.

$$y= (5.62 * 10^{-2})x + (8.96 * 10^{-3}) \quad (2.2)$$

$$y= (3.92 * 10^{-2})x + (1.14 * 10^{-3}) \quad (2.3)$$

Figure 2.8 - UV-Spectrophotometer-1800

2.8 Assessment of encapsulation efficiency and loading capacity

The effectiveness of encapsulation was determined by solvent extraction. To determine the encapsulation efficiency, 0.1 g of MPs was weighed and placed in 100 mL beakers. Then, 10 mL of 1% acetic acid solution was added to the beaker to dissolve chitosan, and the mixture was stirred for 60 minutes using a magnetic stirrer. After that, 50 mL of n-hexane was added to the beaker to dissolve LEO, and the solution was stirred for another 60 minutes. To estimate the amount of LEO present on the MPs surface, 0.1 g MPs samples were mixed with 50 mL of n-hexane for 60 minutes to dissolve only the surface oil. These samples were then filtered through a membrane filter with a pore size of 0.45 µm and measured using a UV spectrophotometer at a wavelength of 268 nm. The total and surface amounts of LEO were calculated using Equation 2.2.

$$\% \text{ EE} = \frac{\text{Total amount of LEO content} - \text{Surface amount of LEO content}}{\text{Total amount of LEO content}} \times 100 \quad (2.4)$$

$$\% \text{ LC} = \frac{\text{Total amount of LEO content} - \text{Surface amount of LEO content}}{\text{Total amount of Formulation Components}} \times 100 \quad (2.5)$$

Encapsulation efficiency (EE) and loading capacity (LC) were calculated using Equation 2.4 and Equation 2.5, respectively [81-83]. Three sets of samples were analysed, and the results are presented as averages with corresponding standard deviations.

2.9 *In vitro* release studies of Laurel essential oil microparticles

To evaluate studies on the release of LEO MPs *in vitro*, the process began with weighing 10 mg of MPs in 100 mL reagent bottles. In addition, 10 mg of MPs without LEO was weighed in another reagent bottle designated as L_0. Then, 40 mL of a buffer medium consisting of 32 mL of PBS and 8 mL of n-hexane was prepared and added to the bottles. These bottles were securely closed with lids and placed on a magnetic stirrer at 37°C, stirring at a speed of 300 rpm. At regular intervals, 4 mL of the sample was filtered through a filter with a pore size of 0.45 µm after shaking the bottles using a vortex. After that, 3.2 mL of PBS and 0.8 mL of n-hexane were injected into the medium. These analyses were performed in three repetitions to ensure the accuracy and reliability of the results. The standard error calculated with a 95% confidence interval is shown on the graphs.

2.10 Application of the microparticles to the materials

The antimicrobial properties of the leather footbeds were achieved by applying MPs during a standard finishing process used in the textile and leather industries.

Two methods were used: spraying and dip-coating. Due to the peculiarities of these processes, various finishing solutions were prepared.

The spraying method. Transfer of microparticles prepared for the production of footwear innersoles with aromatic and antibacterial properties to footwear innersole leather was carried out with the finishing process, which is widely applied in the leather industry. Microparticles of 20 g/m^2 were added to A4 sized leathers [84]. The finishing process was carried out with a hand gun. The spraying was conducted on the grain side of the leather only. The applied finish formulation is shown in Table 2.7.

In the dip-coating method, a finishing solution containing 1% (w/v) carboxymethyl cellulose, 1% (w/v) wetting agent, and 5 g/L polyurethane binder was prepared and utilized as the coating formulation. The components were thoroughly mixed to obtain a homogeneous solution with suitable viscosity and surface activity for effective coating. The prepared solution was used to treat the material by immersion, allowing the coating composition to uniformly penetrate and cover the surface of the substrate. This formulation was selected to improve the adhesion of the finishing layer, enhance the uniform distribution of active substances, and ensure the formation of a stable and durable coating on the material surface.

Table 2.7 - Recipe of the applied finishing process

Material Name	Quantity (part)	Application
Microparticle	12 (1,25 gr)	3 times Spray
Water	100	
Anionic wax	50	
Nonionic aliphatic polyurethane binder	25	

Table 2.8 - Finishing liquors regarding MPs and LEO concentration

Sample Code	Finishing Treatment	Application Amounts	
		MPs	LEO
S-O	Spraying of Oil		1.25 g
S-C	Spraying of Chitosan MPs	1.25g L_0	
S-M	Spraying of LEO MPs	1.25 g L_5	
S-2M	Double Spraying of LEO MPs	2.5 g L_5	
DC-O	Dip-coating of Oil		10 %w/v
DC-2O	Double dip-coating of Oil		20 %w/v
DC-C	Dip-coating Chitosan MPs	10 %w/v L_0	
DC-M	Dip-coating LEO MPs	10 %w/v L_5	

Details of finishing liquors regarding MPs and LEO concentration is given in Table 2.8. All leather samples were dried at 80 °C, fixed at 120 °C for 5 min, and

examined using a TM1000 tabletop SEM (Hitachi, Japan) after coating with gold-palladium.

By dip-coating method, 3 different lining materials were applied to five different solutions (Figure 2.9). Tanapur One was selected as the binding agent and Periwet ELR as the wetting agent.


Figure 2.9 - Dip-coating method

Freshly prepared finishing liquor, containing either pure laurel oil or laurel oil microparticles, was applied to the lining materials in order to impart functional properties to the substrate. The finishing formulation was uniformly distributed over the surface of the lining materials to ensure even penetration and coating of the material.

Table 2.9 - Application parameters

	CMC of solution (%)	Wetting Agent of solution (%)	Binder (g/L)	Capsule	Laurel Oil	Drying (°C)	Fixation
DC-O	1	1	-	-	10	80	-
DC-2O	1	1	-	-	20	80	-
DC-M	1	1	5	10	-	80	120 ºC 5 min
DC-2M	1	1	10	20	-	80	120 ºC 5 min
DC-C	1	1	10	10	-	80	120 ºC 5 min

The treated samples were then allowed to dry under controlled conditions, enabling the fixation of the active components and the formation of a stable finishing

layer on the surface of the lining material. The details about formulations are presented in Table 2.9.

2.11 Drying and washing materials

After the finishing treatment, the treated materials were subjected to a drying process in a laboratory oven at a temperature of 80 °C for 30 minutes. For this purpose, a KD 400 Laboratory Oven was used to ensure uniform heating and controlled drying conditions (Figure 2.10). This step was necessary to remove residual moisture and facilitate the proper fixation of the finishing composition on the material surface. After drying, the samples were cooled to room temperature and stored under standard laboratory conditions prior to further testing and characterisation.

Additionally, linings with DC-M, DC-2M, and DC-C were fixated on pin frames for 5 min at 120 °C in a laboratory stenter.

Figure 2.10 - Nuve KD 400 and laboratory stenter

The treated materials were subjected to washing tests in accordance with the requirements of the ISO 105-C06:2010 standard in order to evaluate the durability of the applied finishing treatment. The samples were washed three consecutive times at a temperature of 30 °C for 30 minutes using a Linitest Washing Machine (Figure 2.11). During the washing process, the IEC Non-Phosphate Reference Detergent (A) was used as the standard detergent. These conditions were selected to simulate typical domestic laundering processes and to assess the stability and resistance of the finishing layer and active components after repeated washing cycles (Figure 2.12).

Figure 2.11 - Linitest Washing Machine

Figure 2.12 - Obtained lining materials and leather

2.12 Dissolution studies on leather footbeds

The formulations designated as DC-M, DC-O, S-M and S-2M were treated in a water bath at a temperature of 32 °C using a water bath equipped with a magnetic stirrer operating at a speed of 300 rpm. A 20 mL of PBS: n-hexane mixture was used as the working medium.

Samples with a volume of 2.5 mL were taken at certain intervals, and UV spectrophotometer was measured at a wavelength of 268 nm. The measurements were performed three times, and the standard error calculated with a 95% confidence interval is shown on the graphs to confirm the statistical analysis.

2.13 Flexing and rubbing applications

The flex resistance test was performed in accordance with the requirements of the ISO 5402-1 (2022) standard (Figure 2.13). The objective of this test was to assess the durability and mechanical performance of leather footbeds incorporating MPs

under conditions simulating the repeated deflection caused by walking. For this purpose, the leather footbeds were carefully mounted in a flexometer and subjected to 100,000 controlled flexing cycles. This procedure allowed the evaluation of how the repeated bending and mechanical stress affect both the structural integrity of the leather and the retention of the functional properties imparted by the incorporated microparticles.

Figure 2.13 - Flexometer

In the rubbing fastness test, microencapsulated leather samples were subjected to three different rubbing tests by using wool felts impregnated with dry, wet and artificial sweat solutions. This test was carried out according to the ISO 11640 (2018) standard. In wet rubbing, the felts were soaked by boiling, and in sweat solution rubbing, they were made ready for the test by waiting for the felts to get wet and settle to the bottom of the beaker. For the rubbing fastness test, the footwear insock leather samples cut in 150x80 mm size were stretched 10% after they were attached to the device. Then, felts impregnated with dry, wet and sweat solution were attached to the device and rubbing was done 50 times for dry, 25 times for wet and sweat solution (Figure 2.14). Since the leathers used in the study were undyed, color measurements were made with a spherical spectrophotometer in order to determine the effect of rubbing on the finishing film.

Footwear footbeds are subjected to continuous mechanical rubbing due to the friction generated by foot movements during walking. In the present study, this mechanical interaction was simulated to evaluate the effects of rubbing forces on the treated leather samples. The test involved assessing both the physical response of the leather to repeated friction and the retention of its functional properties, particularly the antibacterial activity, after being subjected to rubbing. The evaluation allowed determination of the durability and effectiveness of the applied finishing or microencapsulation treatments under conditions that mimic real-life wear.

Figure 2.14 - To and fro rubbing fastness test device

2.14 Color measurement

A Konica Minolta brand CM 3600d model spectrophotometer was used to obtain numerical data on color changes after wet rubbing, dry rubbing and sweat solution rubbing tests on the innersole leathers of microencapsulated footwear with aromatic and antibacterial properties. D65 illuminator and 10° standard observers (CIE, 1986) were used for the measurements. Before starting the measurements, the device was calibrated with standard white and standard black. For leather samples with the specified tests, 5 readings were taken from the leather of each sample. The colorimetric color coordinates L* (brightness/lightness), a* (red-green color coordinate) and b* (yellow-blue color coordinate) shown in Figure 2.15 were read directly with the spectrophotometer used connected to the computer.

In the system, the L* parameter represents the lightness coordinate, ranging from 0 (black) to 100 (white). Therefore, an increase in L* value corresponds to an enhancement in brightness or lightness of the sample, indicating a shift toward a lighter appearance. Conversely, a decrease in L* value reflects a reduction in brightness, resulting in a darker visual perception.

The chromaticity coordinates a* and b* describe the color directions within the color space. Specifically, the a* axis represents the red-green component: positive a* values (+a*) indicate a shift toward the red region, while negative a* values (-a*) indicate a shift toward the green region. Similarly, the b* axis corresponds to the yellow-blue component, where positive b* values (+b*) denote an increase in yellowness, and negative b* values (-b*) indicate an increase in blueness.

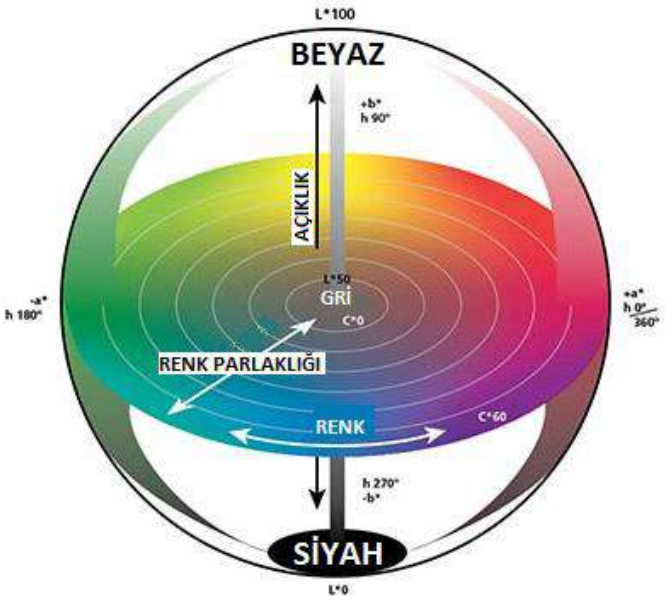


Figure 2.15 - L*, a* and b* colorimetric color coordinates (Mouw and Pantone, 2019)

2.15 Antimicrobial assays

The antibacterial and antifungal properties of leather footbeds and footwear linings were studied by diffusion in agar discs against standard bacterial strains, such as *Staphylococcus aureus* ATCC 29213, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853 and yeast strain *Candida albicans* ATCC 90028 in accordance with the standards of the European Committee on Antimicrobial Susceptibility Testing (EUCAST) (www.eucast.org).

Standard strains of bacteria and yeast were transplanted onto Petri dishes with Muller-Hinton agar (MHA) and Sabouraud Dextrose agar (SDA), respectively, and incubated at 37 °C for 24-48 hours. Standard suspensions of microorganisms were prepared from the obtained colonies in sterile saline solution (8.5 g/L) on the McFarland turbidity scale of 0.5. 100 µl of suspension were taken and applied to the surface of Petri dishes with MHA (SDA for *C. albicans*) with sterile swabs, and then left to dry for 5 minutes at room temperature. Then, samples of leather footbeds with a diameter of 12 mm were placed on Petri dishes. Next, Petri dishes were incubated at 37 °C for 24-48 hours, and the diameters of the zones formed around the leather samples were measured to determine antimicrobial activity [85-87]. To control possible contamination, leather samples were placed and incubated on MHA (or SDA) plates not inoculated with microorganisms [98, p. 1019].

Conclusion on the second part

1. Leather and three different lining materials (cotton woven fabric, PET woven and PET weft knitting) were used as the main material. To prepare microparticles were used chitosan, Laurel essential oil, acetic acid (glacial), surface-active agents Tween 40 and Span 20, binder Tanapur One, wetting agent Periwet ELR and

thickening agent Sodium carboxymethyl cellulose used. Microparticles were obtained on Unopex B 15 Mini Spray Dryer. Microparticles were collected using a soft brush and transferred into zip-lock bags. Microparticles were applied to leather and linings by two methods: spraying and dip-coating.

2. Morphological and chemical characterisations of microparticles, antimicrobial assays of microparticle-coated materials were determined in accordance with relevant standards.

3. SEM images were used to determine the morphological structure. FT-IR was used to determine the chemical structure. The determination of encapsulation efficiency was conducted through a solvent extraction method. After finishing treatment, the materials were dried and washed.

4. Physical tests such as flex resistance test, to and fro rubbing fastness test and colour measurement were used. The flex resistance test was conducted to determine the ability of the material to withstand repeated bending and deformation without the formation of cracks, delamination, or structural damage. The to-and-fro rubbing fastness test was employed to evaluate the resistance of the material surface to abrasion and color transfer under repeated friction. Instrumental color measurements were performed using a colorimetric system based on the CIE L*a*b* color space, allowing precise quantification of color parameters, including lightness (L*) and chromatic coordinates (a*, b*).

5. Antibacterial and antifungal properties of the leather footbeds and footwear lining materials were systematically evaluated against representative Gram-positive and Gram-negative bacterial strains, namely *Staphylococcus aureus, Escherichia coli*, and *Pseudomonas aeruginosa*, as well as the fungal strain *Candida albicans*. These test microorganisms were selected due to their relevance as common pathogens associated with skin infections and their frequent involvement in microbial contamination of footwear materials.

3 RESULTS AND DISCUSSION

3.1 Evaluation of Laurel essential oil microparticles

MPs were synthesized using the spray-drying method in this research. Spray drying is a well-established technique for producing MPs, involving the conversion of liquid substances into dry particles. It is worth noting that MPs generated through the spray-drying method may not exhibit perfectly smooth spherical shapes. The abrupt exposure to high temperatures in the hot chamber often results in the formation of indented spheres [88, 89]. This method is known for its simplicity and generally offers higher yields in terms of speed compared to alternative encapsulation methods [98, p. 1020].

However, the yield in the spray dryer can be affected by various factors, such as the risk of the solution adhering to the chamber walls due to temperatures below the glass transition temperature, solution evaporation at temperatures exceeding the stickiness temperature, and particle suction from the exhaust due to strong aspiration. These outcomes are highly contingent on the viscosity of the prepared solution and the glass transition temperature of the components. Proper control of the inlet and outlet temperatures is important to ensure that the drying process occurs within the optimal temperature range to prevent stickiness and wall deposition while ensuring efficient drying. One of the previous studies evaluating the microencapsulation yield of Laurel essential oil with used Arabic gum wall material reported that the production yield was ranged in 43.6-59.4% [90].

The production yield in this study ranged from 11.90% to 41.32% (as shown in Table 2.1), with the blank chitosan MPs yielding the highest percentage. Notably, the addition of LEO to the solution led to reduced production yields due to changes in viscosity. Consequently, it was determined that working with a 1:1 Chitosan: LEO ratio (L_2) was more practical for optimizing polymer-essential oil interactions (L_1, L_2, and L_3). In subsequent experiments (L_4, L_5, and L_6), the outlet temperature and blower speed were increased to 108 °C and 95%, respectively, while decreasing the pump speed to 4 mL/min (as detailed in Table 2.2).

Furthermore, the surfactant ratio was optimized to enhance production efficiency (Table 2.1). The L_5 formulation, which included 20% surfactant relative to the oil, resulted in the highest production yield at 33.38%, followed closely by L_4 at 31.92%. In contrast, increasing the surfactant content (L_6) led to a thicker solution, making it challenging to feed into the device and hindering effective drying. Consequently, the yield for L_6 was lower at 24.78% compared to L_4 and L_5 [98, p. 1020].

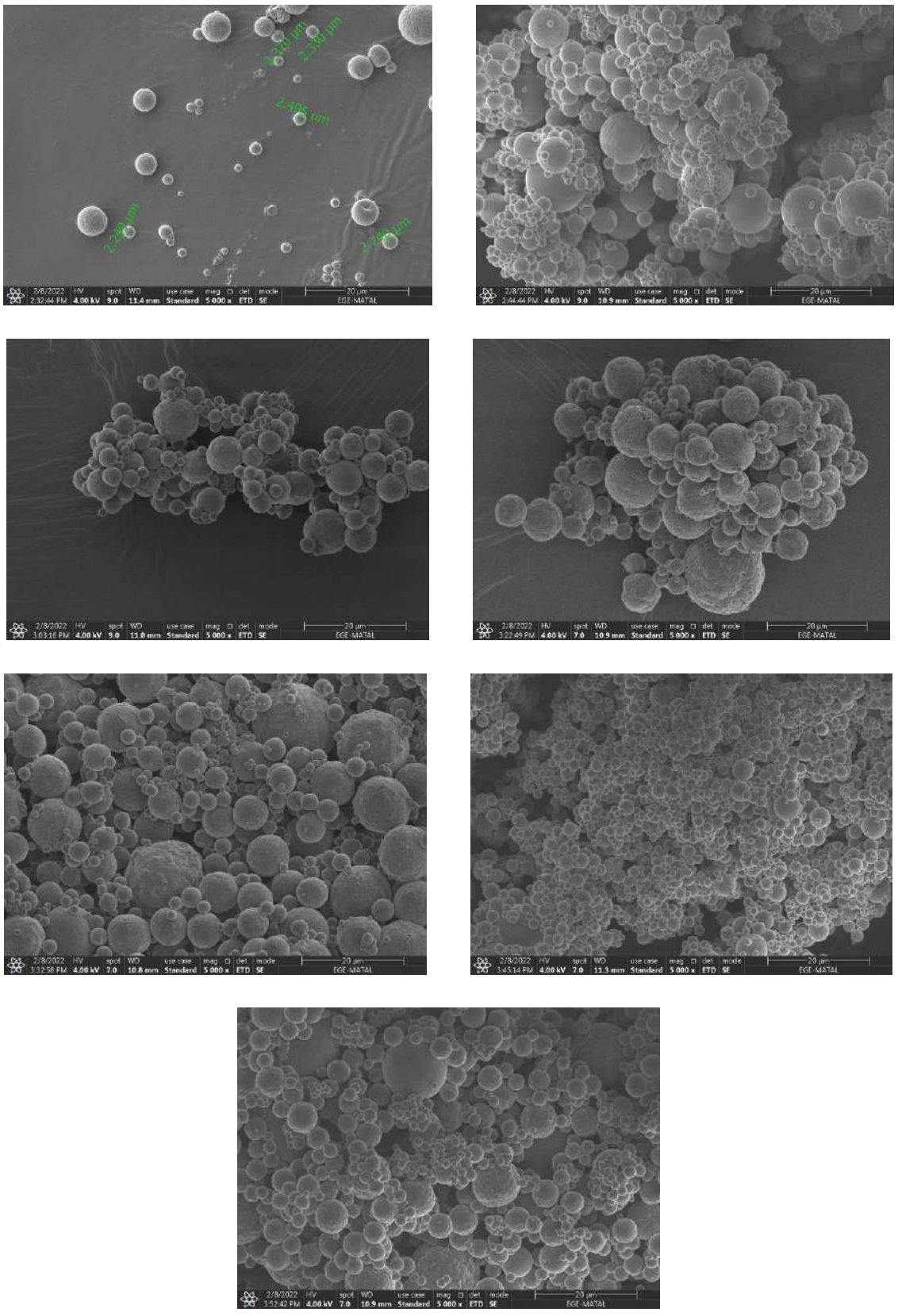
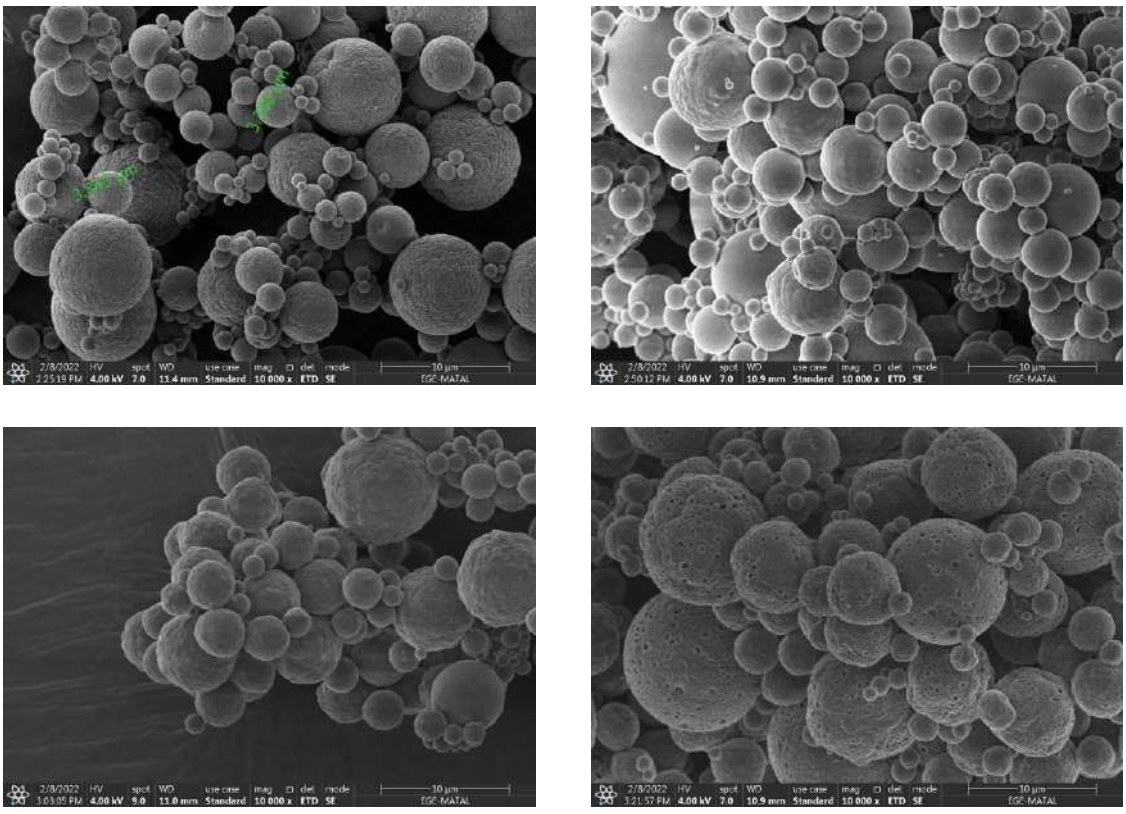


Figure 3.1 - Photomicrographs of laurel capsules under scanning electron microscopy x 5,000 (from left to right: L_0, L_1, L_2, L_3, L_4, L_5, L_6)

The morphology of MPs was examined through SEM, 5,000x, 10,000x and 20,000x magnified photomicrographs presented in Figures 3.1, 3.2 and 3.3

respectively. A comparison of L_1, L_2, and L_3 revealed that L_1 displayed a more uniform particle distribution and a smoother surface. However, L_1 encountered agglomeration issues due to inadequate drying. Proper drying in spray drying depends on factors such as inlet and outlet temperatures, airflow rate, and feed rate. Insufficient inlet temperature or excessive feed rate can lead to partially dried, sticky particles prone to agglomeration. Optimizing these parameters is essential to prevent agglomeration and ensure free-flowing microparticles [98, p. 1020].

The elevated temperature not only increased yield but also resulted in smaller particle sizes due to enhanced solvent evaporation and rapid particle solidification, reducing the time available for particle growth and preventing agglomeration. When comparing L_5 to L_6 at the same magnification, it was evident that L_5 demonstrated a higher production yield and a more uniform particle distribution, characterized by a narrower size range around the target mean diameter. The size and shape of the microparticles play important roles in microparticular systems. The release of the active ingredients can be efficiently sustained by microparticles with improved monodispersity and encapsulation efficiency [91, 98, p. 1020].



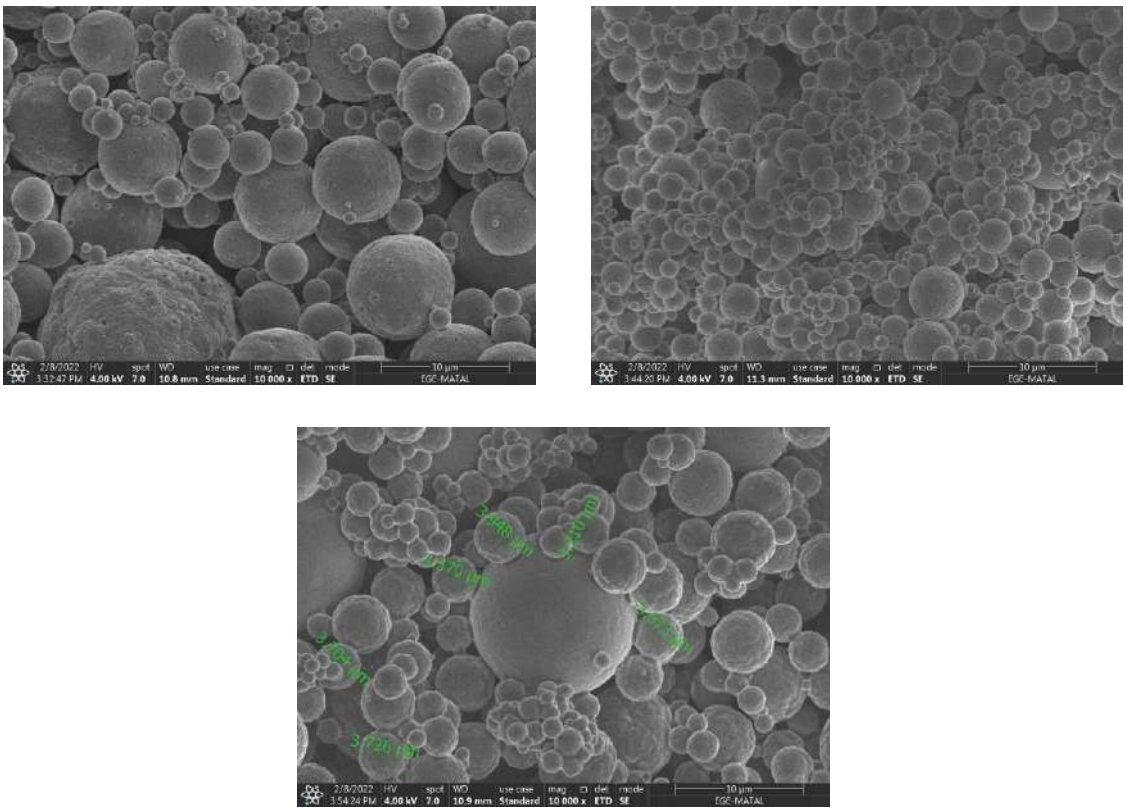
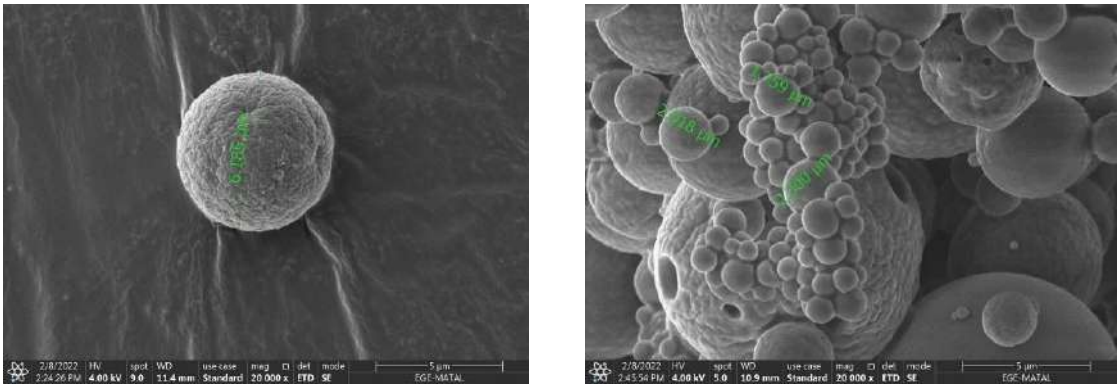


Figure 3.2 - Photomicrographs of laurel capsules under scanning electron microscopy x 10,000 (from left to right: L_0, L_1, L_2, L_3, L_4, L_5, L_6)

As a result, the L_5 formulation was selected as the optimal formulation for further research. In the existing literature, MPs produced using this method typically exhibit an indented structure [88, p. 723; 89, p. 16]. However, the near-perfect spherical shape achieved in this study was attributed to the stable emulsion obtained prior to feeding it into the spray drying unit [98, p. 1021].



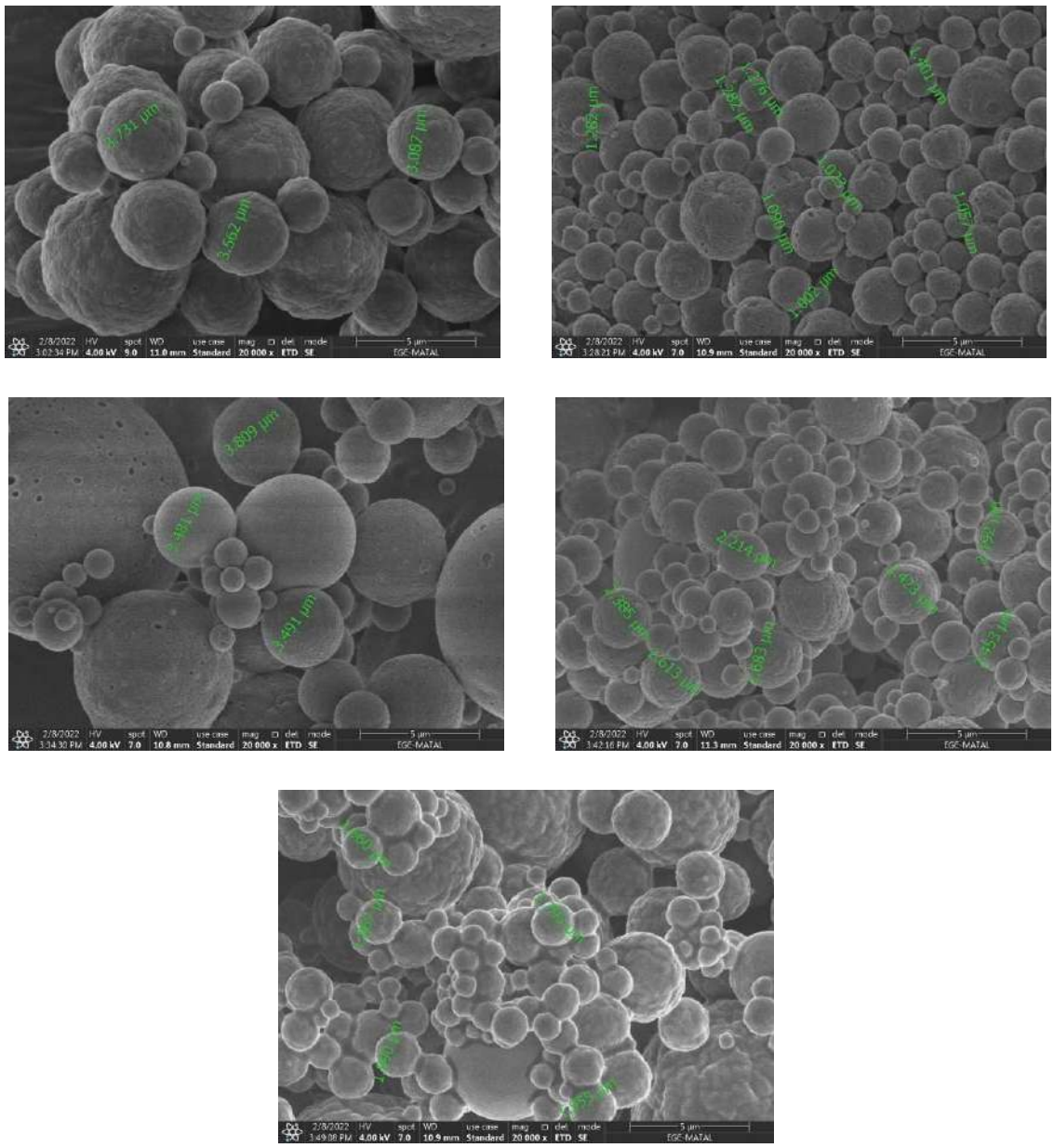


Figure 3.3 - Photomicrographs of laurel capsules under scanning electron microscopy x 20,000 (from left to right: L_0, L_1, L_2, L_3, L_4, L_5, L_6)

The particle size measurement ($D_{50\%}$ (median), $D_{90\%}$, and $D_{10\%}$ values) and distribution results of blank chitosan MPs and L_5 are presented in Table 3.1 and Figure 3.4, respectively. The median indicates the middle number in a data set and demonstrates that half of the MPs are below this value. Similarly, 90% and 10% of the MPs reside the $D_{90\%}$ and $D_{10\%}$, respectively [90, p. 145]. 90% of the blank MPs (L_0) were under 32.9 µm whereas D_{90} of L_5 was found as 63.6 µm. It was concluded that the optimum MP formulation with LEO had wider size distribution than the blank chitosan. However, there were smaller MPs in the L_5 formulation compared to blank MPs with a lower median value (12.2 µm). Formerly reported that MPs between 20-40 mm were applicable in textile finishing [92].

Table 3.1 - Mean particle size of MPs with LEO produced by spray drying

Sample	Particle Size D_{10} (µm)	Particle Size D_{50} (µm)	Particle Size D_{90} (µm)	SPAN [a]
L_0	8.5	16.4	32.9	1.47
L_5	4.5	12.2	63.6	4.85

*The D_{50} has been defined as the diameter where half of the particles' size below this value. 90% of the particles' size below the D_{90}, and 10% of the particles' size below the D_{10}.

[a] SPAN=$\frac{D_{90\%} - D_{10\%}}{D_{50\%}}$ is polydispersity index. Higher span value indicates a wide size distribution and higher polydispersity.

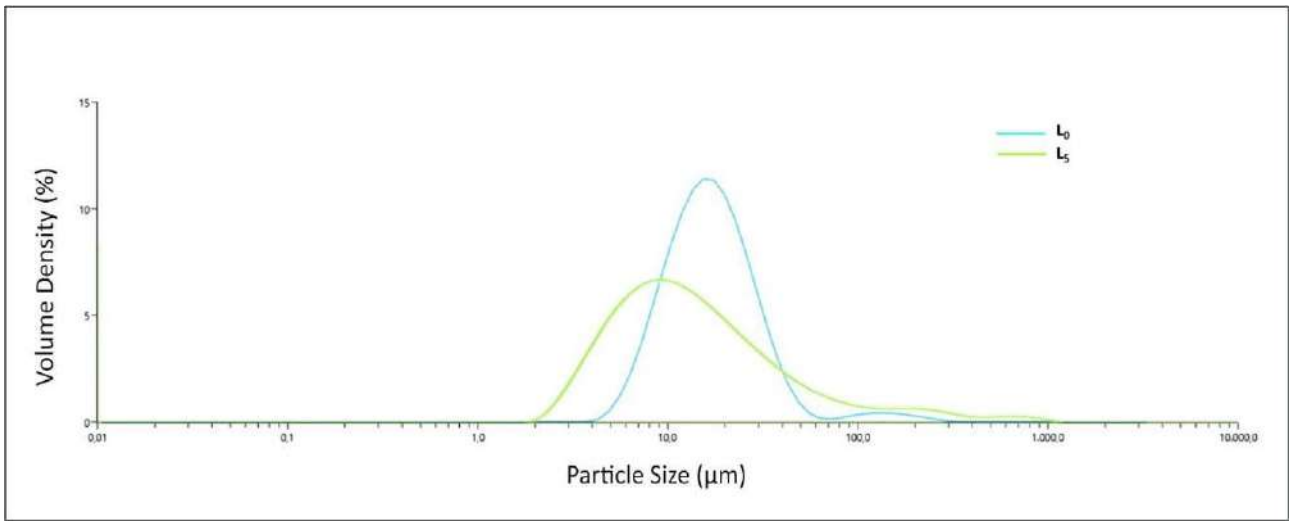


Figure 3.4 - The particle size distribution of L_0 and L_5 MPs

Also, the unimodal distribution observed in the L_0 and L_5 formulations which enhances the reproducibility and stability of microparticulate systems, making them well-suited for surface applications [93]. Consequently, both L_5 and the blank chitosan MPs are appropriate for the intended uses [98, p. 1021].

3.2 The Fourier-transform infrared spectroscopy spectra results

The FT-IR spectra of chitosan, LEO, and L_5 are given in Figure 3.5. The FT-IR spectrum of chitosan revealed its characteristic peaks at 3450 cm^{-1} corresponded to stretching vibrations N-H and O-H, at 2912 and 2862 cm^{-1} corresponded to asymmetric and symmetric stretching vibrations of C-H bonds, respectively. The band at 1662 cm^{-1} indicated the presence of a C=O bond in the acetamide group (amide I). The band at 1583 cm^{-1} fitted the bending vibrations of the N-H group (amide II). The band at 1416 showed deformation vibrations C-H bonds, and 1377-1331 cm^{-1} C-N bonds. The bands at 1149, 1068, and 1032 cm^{-1} corresponded to vibrations of C-O stretching [94, 98, p. 1021].

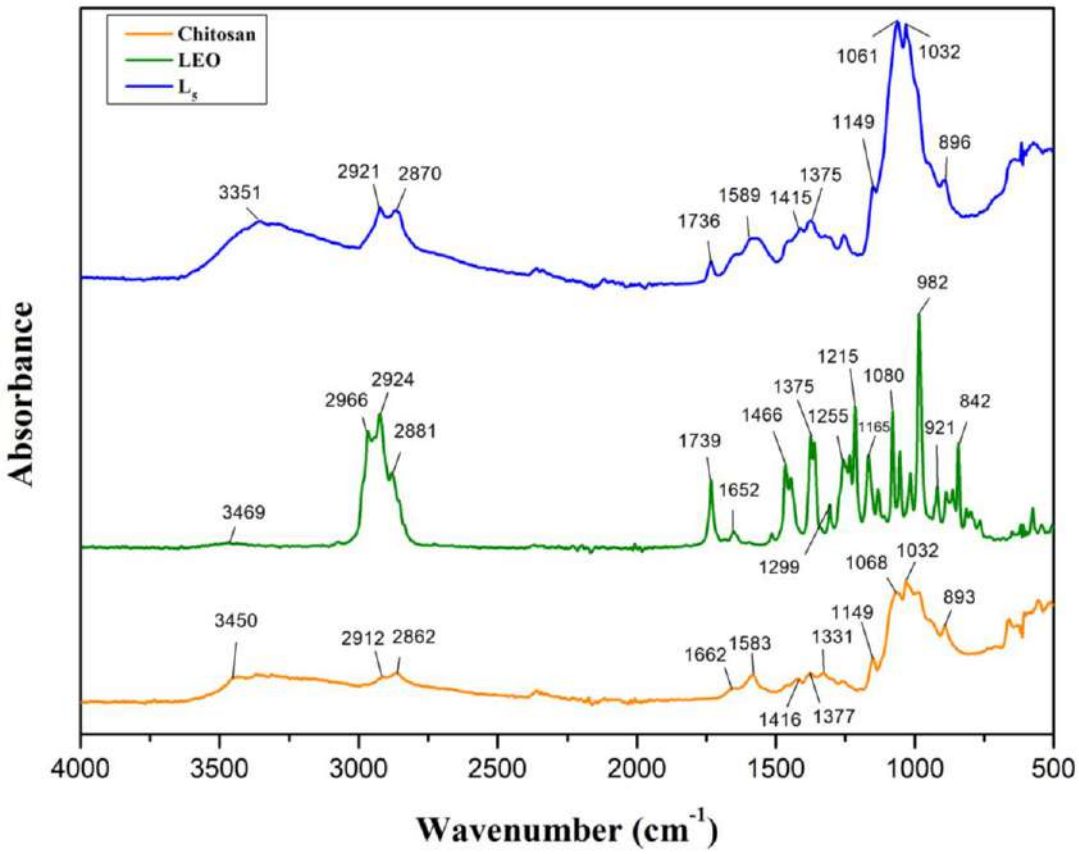


Figure 3.5 - FT-IR spectra of chitosan, LEO and L_5

The spectrum of LEO represented its characteristics bands in the 3600-3200 cm^{-1} range due to O-H stretching vibrations (alcohol group), and the band 2881 and 2966 cm^{-1} indicated the presence of a C-H stretching (aliphatic hydrocarbons group). The peak at 1739 cm^{-1} was attributed to the C=O stretching of the esters group. The band at 1652 cm^{-1} pointed out the presence of a C=C bond in the olefinic group. The bands at 1375 and 1466 cm^{-1} fitted to deformation vibrations of C-H bending (terpenoid group). Similar results have been reported in the research of Eyupoglu et al. [60, p. 1419], which showed LEO characteristics bands in 2922 cm^{-1} (C-H stretching), 1732 cm^{-1} (C=O stretching), 1361 and 1465 cm^{-1} (C-H stretching). There were characteristic out-of-plane C-H bending vibrations at 982 cm^{-1}. In the study by Medina-Torres et al. [62, p. 2] spray dried laurel infusions were analyzed with FT-IR-spectra and showed the signal wavelengths 1020 cm^{-1} (C-O; C-O-C), 1440 cm^{-1} (-CH2; -CH; =C-H), 1519 cm^{-1} (R-CO-NH −R), 1600 cm^{-1} (C-C, C=C, H-O-H) and 2387 cm^{-1} (CH2, nCH3). FT-IR spectrum of L_5 MPs did not undergo significant changes and resembled both shell polymer and the essential oil. The broad band of O-H peaked at around 3350cm^{-1} appeared in L_5. The band at 2870 and 2921 cm^{-1} of C-H stretching and at 1736 cm^{-1} of C=O stretching revealed the presence of the LEO in the MPs. The peak 1589 cm^{-1} was assigned to aromatic C-C stretching. The bands at 1375 and 1415 cm^{-1} indicated the presence of C-H bending. The consistent nature of the peaks in the encapsulated powder indicates no significant chemical interaction between LEO and the wall material. The study confirms that LEO is incorporated

into the polymeric matrix without notable chemical interactions with chitosan [98, p. 1021].

3.3 Encapsulation efficiency results

3.3.1 Encapsulation efficiency results of methanol

The results of the encapsulation efficiency analysis revealed notable differences across the solvents used in the evaluation. In particular, the L_5 microparticle formulation exhibited lower encapsulation efficiency when methanol was used as the extraction solvent compared to n-hexane. This difference may be attributed to the variation in solvent polarity and its interaction with the encapsulated laurel oil and the polymeric shell material.

Quantitative analysis indicated that the encapsulation efficiency of the L_5 microparticles, as determined using methanol, was relatively low, at approximately 10% (Table 3.2 and 3.3). The reduced value suggests a limited retention of the active compound within the microparticle matrix under these analytical conditions. In contrast, the use of n-hexane demonstrated a comparatively higher ability to extract the encapsulated oil, indicating that solvent selection plays an important role in accurately determining the encapsulation performance of the prepared microparticles.

Table 3.2 - 3 times repeated results of L_5 encapsulation efficiency with methanol

Name	Total concentration	Under curve area (273 nm)	Surface concentration	Under curve area (273 nm)
L_5-1-1	0.315	0.262	0.272	0.245
L_5-1-2	0.338	0.271	0.27	0.244
L_5-1-3	0.353	0.277	0.267	0.243
L_5-2-1	0.22	0.224	0.197	0.215
L_5-2-2	0.217	0.223	0.195	0.214
L_5-2-3	0.215	0.222	0.205	0.218
L_5-3-1	0.162	0.201	0.107	0.179
L_5-3-2	0.154	0.198	0.104	0.178
L_5-3-3	0.159	0.2	0.107	0.179

	L_5-1	L_5-2	L_5-3
1	2	3	4
Total Concentration	0.335	0.217	0.158
Under curve area (268 nm)	0.27	0.223	0.2
Surface Concentration	0.269	0.199	0.106

Continuation of Table 3.2

1	2	3	4
Under curve area (268 nm)	0.244	0.216	0.179
Equation 3			
Total Concentration	0.545	0.425	0.366
Surface Concentration	0.479	0.407	0.312
Encapsulation Efficiency	12.160	4.396	14.635

Table 3.3 - Encapsulation efficiency of L_5 with methanol

L_5	Total Concentration	Surface Concentration	Encapsulation Efficiency
	(mg/mL)	(mg/mL)	(%)
	0.445 ± 0.091	0.399 ± 0.084	10.397 ± 5.342

These findings highlight the significance of solvent-matrix interactions in encapsulation studies and emphasise the importance of selecting appropriate analytical conditions when evaluating the efficiency of microencapsulation systems.

3.3.2 Encapsulation efficiency results of n-hexane

As shown in Tables 3.4 and 3.5, MPs L_5 demonstrated a high encapsulation efficiency of 90.02% and a surface oil content of 9.98%. The encapsulation efficiency of spray-dried particles usually ranges from 48.9% to 99.5% [85, p. 80; 95]. The calculated loading capacity of MPs LEO was 24.98%.

Table 3.4 - 3 times repeated results of L_5 encapsulation efficiency with n-hexane

Name	Total concentration	Under curve area (268 nm)
L_5-1-1	4.714	0.274
L_5-1-2	4.821	0.28
L_5-1-3	4.998	0.29
L_5-2-1	3.985	0.233
L_5-2-2	4.002	0.234
L_5-2-3	3.985	0.233
L_5-3-1	3.54	0.208
L_5-3-2	3.558	0.209
L_5-3-3	3.576	0.21

	L_5-1	L_5-2	L_5-3
Total Concentration	4.844	3.991	3.558
Under curve area (268 nm)	0.281	0.233	0.209
Surface Concentration	0.588	0.481	0.499
Under curve area (268 nm)	0.042	0.036	0.037
Equation 2			
Total Concentration	0.546	0.447	0.397
Surface Concentration	0.054	0.041	0.043
Encapsulation Efficiency	90.19	90.78	89.10

Encapsulation efficiency in this research was higher and the loading capacity was similar in comparison with the study by Ercin et al., which reported an encapsulation efficiency of 59.25% and a loading capacity of 25.65% for PLGA nanoparticles loaded with laurel oil [82, p. 1899].

Table 3.5 - Encapsulation efficiency of L_5 with n-hexane

L_5	Total Concentration	Surface Concentration	Encapsulation Efficiency	Surface Oil Content	Loading Capacity
	(mg/mL)	(mg/mL)	(%)	(%)	(%)
	0.46 ± 0.08	0.05 ± 0.01	90.02 ± 0.85	9.98 ± 0.85	24.98 ± 4.19

Given the high encapsulation efficiency, the two-step method combining high-speed emulsification followed by spray drying is an industrially viable encapsulation method for essential oils.

3.4 The *in vitro* release results of microparticles

3.4.1 The *in vitro* release results of microparticles with methanol

The *in vitro* release behaviour of the prepared MPs in methanol is presented in Tables 3.6 and 3.7. The obtained results demonstrate a controlled and sustained release profile of the encapsulated active substance over a period of 6 hours. Such a release pattern indicates that the microparticle matrix effectively regulates the diffusion of the active compound from the polymeric structure into the surrounding medium.

Quantitative analysis showed that the release rate was approximately 0.01 mg/mL after 60 minutes. Furthermore, the concentration of the released compound remained relatively stable throughout the experimental period, and even after 360

minutes, the measured value was still close to 0.01 mg/mL. This behaviour suggests that the microparticle system provides a slow and controlled release mechanism, which may be advantageous for prolonged functional activity in practical applications.

Table 3.6 - Study of *in vitro* release profiles of microparticles with methanol (Annex B)

Time	Absorbance(268 nm)	Concentration (mg/mL)
1h-1	0.063	0.016
1h-2	0.058	0.005
1h-3	0.072	0.040
2h-1	0.087	0.078
2h-2	0.090	0.087
2h-3	0.072	0.040
3h-1	0.074	0.045
3h-2	0.082	0.065
3h-3	0.079	0.059
4h-1	0.066	0.026
4h-2	0.076	0.050
4h-3	0.076	0.050
5h-1	0.076	0.049
5h-2	0.082	0.065
5h-3	0.079	0.058
6h-1	0.062	0.015
6h-2	0.065	0.022
6h-3	0.059	0.007

Table 3.7 - *In vitro* release of MPs with methanol

Time (h)	1	2	3	4	5	6
Time (min)	60	120	180	240	300	360
Concentration (mg/mL)	0.021	0.068	0.056	0.042	0.058	0.015
Standard deviation	0.014	0.020	0.008	0.011	0.006	0.006

However, comparative analysis revealed that n-hexane provided better solubility of the active compound and resulted in higher detectable concentrations during the analytical measurements. Therefore, n-hexane was selected as the preferred solvent for further determination and quantification of LEO in the subsequent experiments.

3.4.2 The *in vitro* release results of microparticles with n-hexane

Figure 3.6 displays the *in vitro* release results of MPs with PBS:n-hexane. The shown line graph illustrates a controlled release behavior over 6 hours. The data showed that the release rate was 0.985 mg/mL after 60 min, and it was 6.86 mg/mL after 360 min (Tables 3.8 and 3.9). MPs release patterns fluctuated over time when exposed to the release medium, showing an increase. In the literature, the release of orange oil from spray-dried chitosan particles demonstrated an initial explosive release, followed by a slow release rate, mainly due to the rapid release of compounds adsorbed on the surface of the particles. While, no explosive release was observed in this study, probably because the emulsion preparation stage effectively reduced the surface oil content to 9.98% compared to their higher recorded range of 13.6% to 20.6%, thereby contributing to a more controlled and gradual release [26, p. 444; 96].

Table 3.8 - Study of *in vitro* release profiles of microparticles with n-hexane (Annex B)

Time	Absorbance(268 nm)	Concentration (mg/mL)
1h-1	0.063	1.0
1h-2	0.058	0.9
1h-3	0.072	1.1
2h-1	0.087	1.4
2h-2	0.090	1.4
2h-3	0.072	1.1
3h-1	0.074	1.2
3h-2	0.082	1.3
3h-3	0.079	1.3
4h-1	0.066	1.0
4h-2	0.076	1.2
4h-3	0.076	1.2
5h-1	0.076	1.2
5h-2	0.082	1.3
5h-3	0.079	1.2
6h-1	0.062	0.9
6h-2	0.065	1.0
6h-3	0.059	0.9

Table 3.9 - *In vitro* release of MPs with n-hexane

Time (min)	60	120	180	240	300	360
Concentration (mg/mL)	0,99	2,30	3,54	4,67	5,91	6,86
Standard deviation	0,101	0,141	0,057	0,081	0,044	0,044

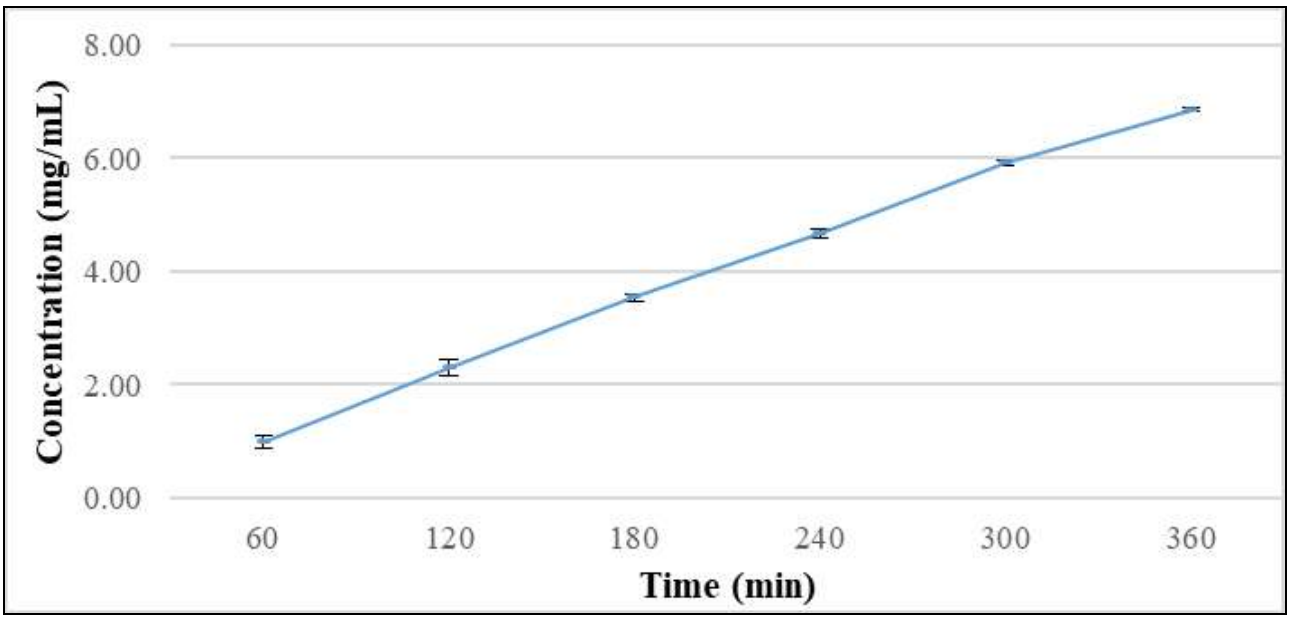
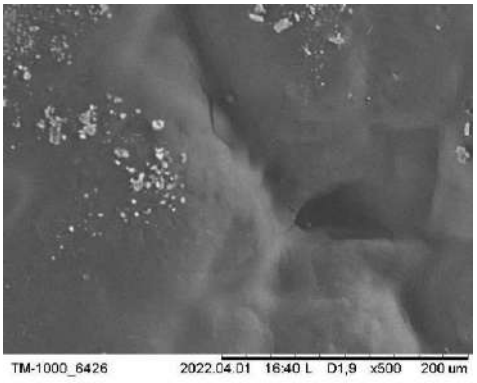


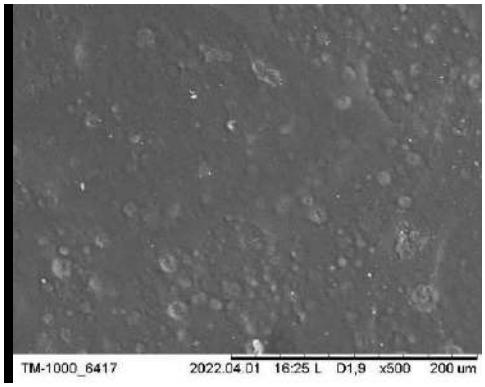
Figure 3.6 - *In vitro* release of MPs with n-hexane

The results of this study show a gradual and sustained release pattern, eliminating the possibility of a sudden explosive release. The concentration started with 0,99 mg/mL in 1 h and increased to 6,86 mg/mL in 6 h. This modified release profile of spray-dried chitosan MPs suggests that LEO is released gradually over time, prolonging the bioactive effects of the encapsulated oil.

3.5 Scanning electron microscopy of the leathers with the microparticles

Micrographs of the treated leathers taken in a scanning electron microscope showed successful transfer of MPs to the leather while maintaining structural integrity after application (Figures 3.7, 3.8 and 3.9). The dip-coating resulted in clusterisation of the MPs, which was unevenly distributed over the leather sample. On the contrary, spray application resulted in a uniform distribution of the MPs layer under a thin, continuous coating. As could be expected, the oil-treated leathers S-O and DC-O showed no discernible particles. In the research of Eyupoglu et al. [60, p. 1418], cotton fabrics treated with microcapsules of lavender/gum arabic, fennel/gum arabic, laurel/gum arabic and diethyltoluamide/gum arabic also showed a generally spherical and smooth surface.





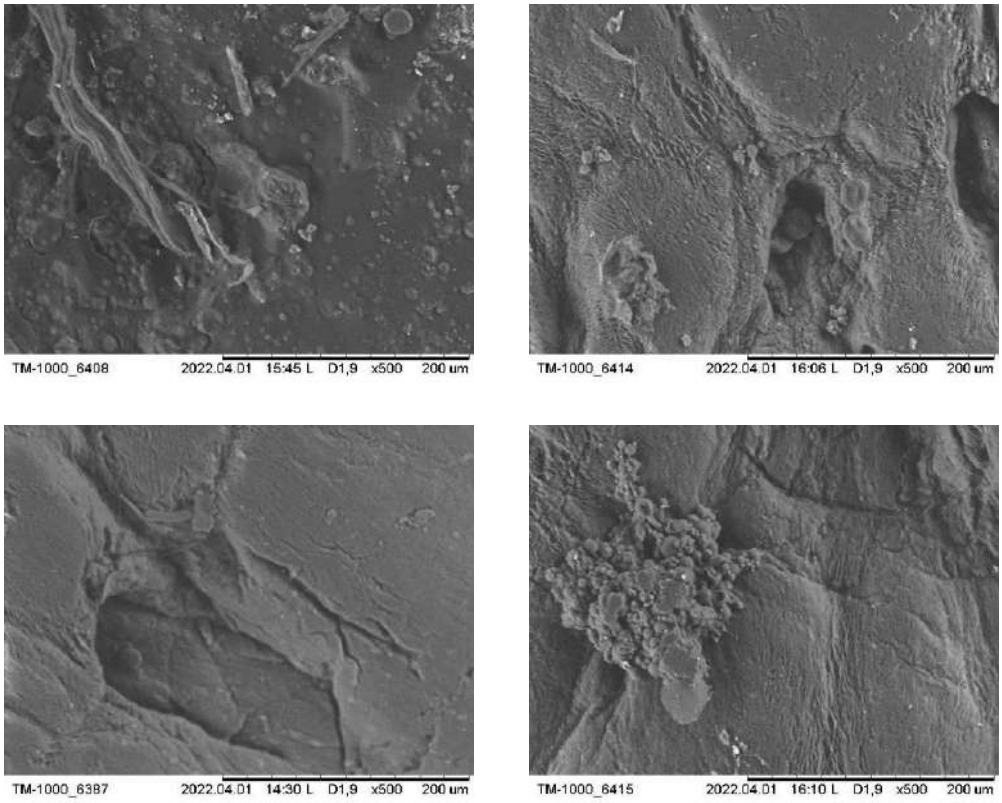
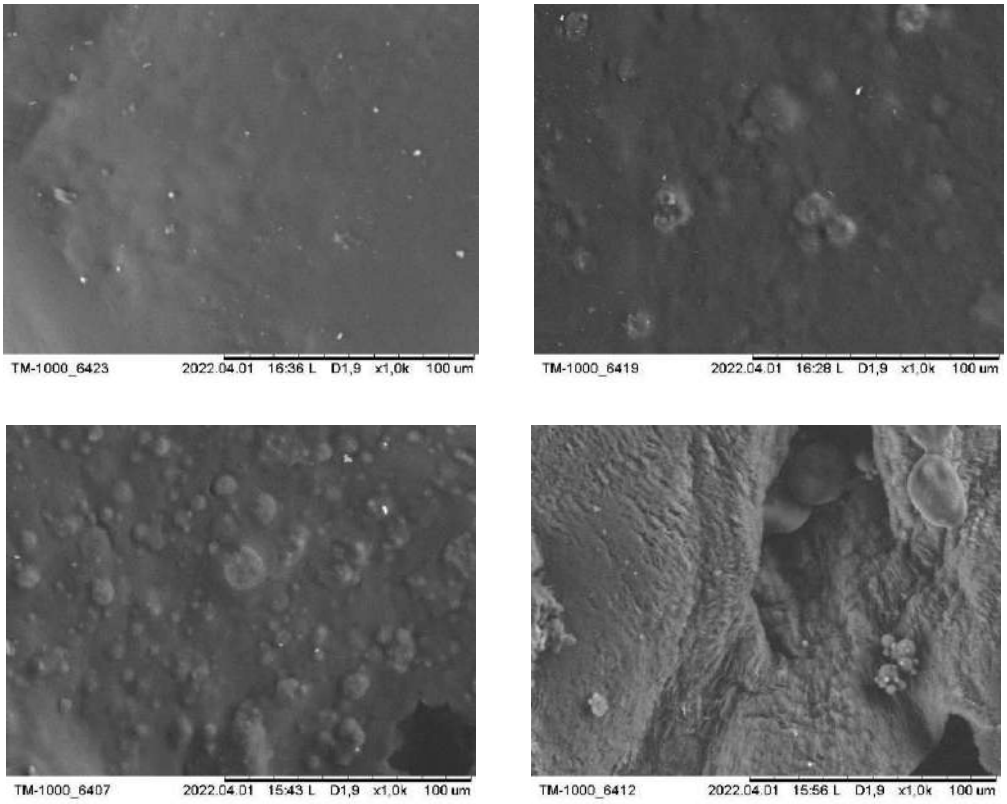


Figure 3.7 - SEM photomicrographs of MPs treated leathers at 500X magnification (from left to right: S-O; S-C; S-M; S-2M; DC-C; DC-M)



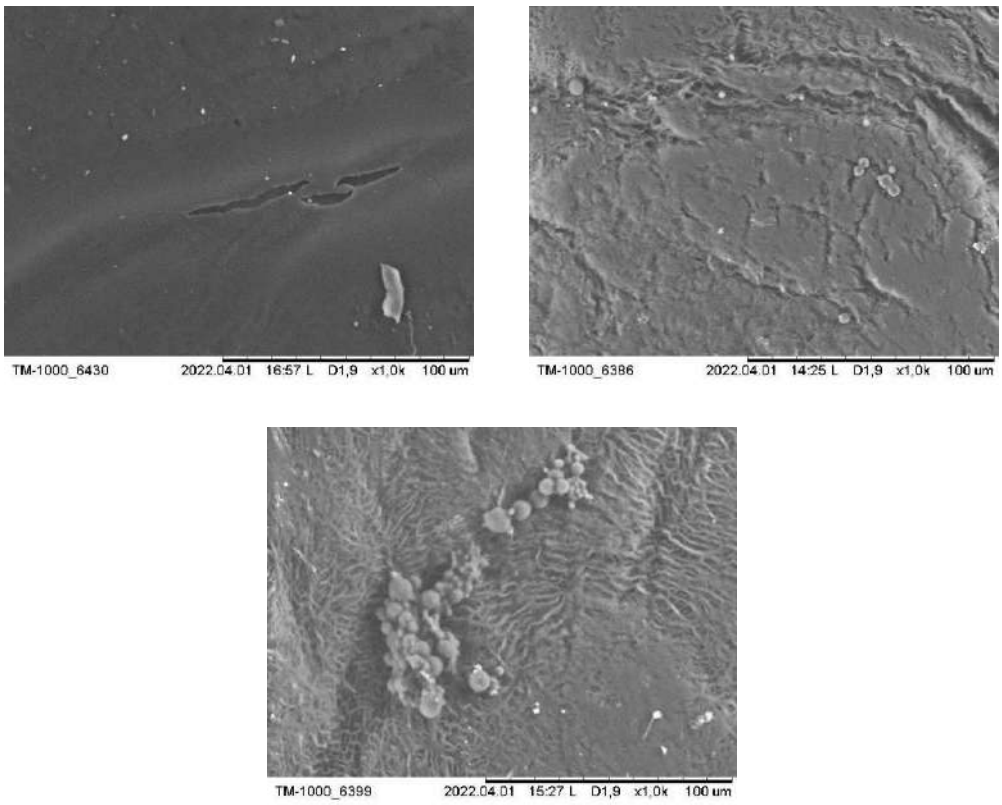
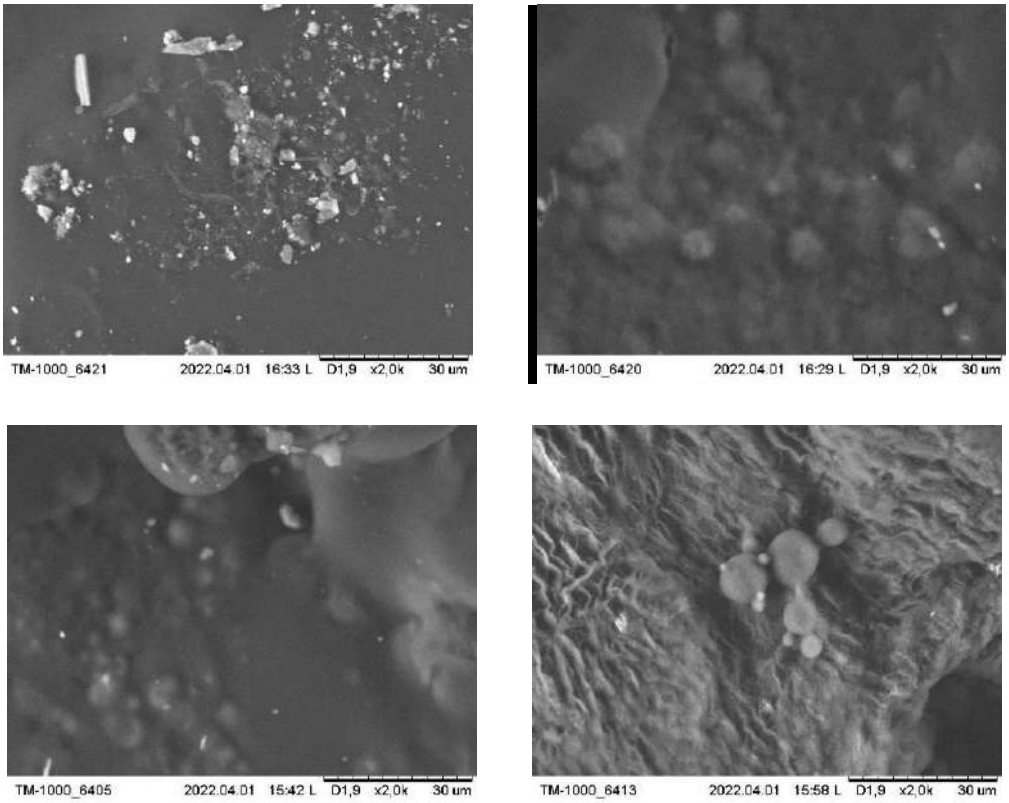


Figure 3.8 - SEM photomicrographs of MPs treated leathers at 1,000X magnification (from left to right: S-O; S-C; S-M; S-2M; DC-O; DC-C; DC-M)



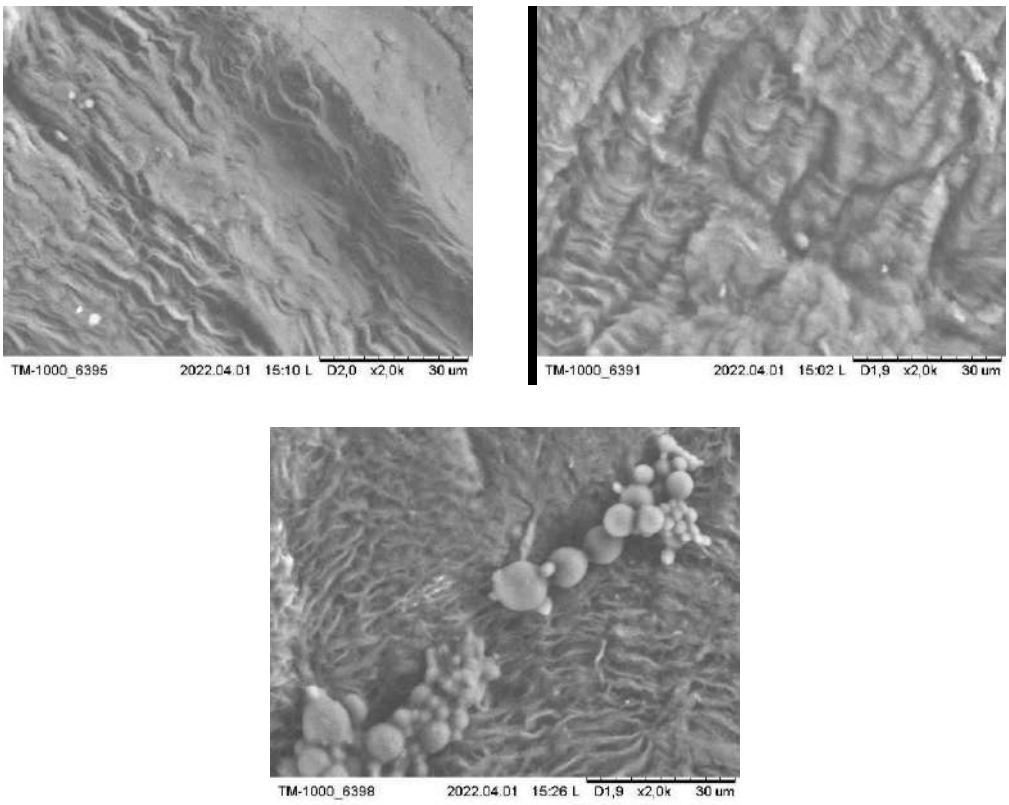


Figure 3.9 - SEM photomicrographs of MPs treated leathers at 2,000X magnification (from left to right: S-O; S-C; S-M; S-2M; DC-O; DC-C; DC-M)

It is important to note that in this research, the spray application method resulted in a higher concentration of MPs on the leather surface, which emphasizes its effectiveness. On the contrary, it was found that dip-coating application is less optimal for reliable fixation of MPs on the leather. It is noteworthy that the spraying method allowed to immobilize a larger amount of MPs even at a low concentration of the application solution, which was a deliberate decision to prevent clogging of the nozzles.

3.6 The loading efficiency in different types of fabrics

The results of the loading efficiency analysis indicated that the lining materials treated with the DC-M formulation containing laurel oil exhibited higher uptake of the active compound compared to the linings treated with the other experimental solutions. This observation suggests that the DC-M treatment method facilitated a more effective incorporation of the essential oil into the structure of the lining materials, possibly due to improved interaction between the finishing formulation and the substrate surface (Tables 3.10, 3.11, and 3.12) [101, p. 213].

After repeated washing cycles, a decrease for essential oil retained in the materials was observed. After three washing cycles, the concentration of the essential oil was reduced; however, a detectable quantity of the active substance remained within the structure of the lining fabrics. This indicates that the applied finishing

treatment provided a certain level of resistance to washing and contributed to the partial retention of the functional component within the material matrix.

Table 3.10 - Loading efficiency of unwashed fabrics (Annex C)

Name	Under curve area (268 nm)	Concentration (mg/mL)
DC-O -Lining1-1	0.264	4.536
DC-O -Lining1-2	0.256	4.394
DC-O -Lining2-1	0.389	6.759
DC-O -Lining2-2	0.336	5.816
DC-O -Lining3-1	0.224	3.825
DC-O -Lining3-2	0.247	4.234
DC-2O -Lining1-1	0.255	4.376
DC-2O -Lining1-2	0.175	2.953
DC-2O -Lining2-1	0.19	3.22
DC-2O -Lining2-2	0.221	3.771
DC-2O -Lining3-1	0.324	5.603
DC-2O -Lining3-2	0.365	6.332
DC-M -Lining1-1	0.288	4.963
DC-M -Lining1-2	0.271	4.66
DC-M -Lining2-1	0.266	4.572
DC-M -Lining2-2	0.312	5.39
DC-M -Lining3-1	0.325	5.621
DC-M -Lining3-2	0.405	7.044
DC-2M -Lining1-1	0.177	2.989
DC-2M -Lining1-2	0.191	3.238
DC-2M -Lining2-1	0.23	3.931
DC-2M -Lining2-2	0.232	3.967
DC-2M -Lining3-1	0.361	6.261
DC-2M -Lining3-2	0.233	3.985

Table 3.11 - Loading efficiency after 3 washes (Annex D)

Name	Under curve area (268 nm)	Concentration (mg/mL)
1	2	3
DC-O -Lining1-1	0.064	0.979
DC-O -Lining1-2	0.062	0.937
DC-O -Lining2-1	0.133	2.212
DC-O -Lining2-2	0.156	2.621
DC-O -Lining3-1	0.091	1.453

Continuation of Table 3.11

1	2	3
DC-O -Lining3-2	0.056	0.831
DC-2O -Lining1-1	0.057	0.860
DC-2O -Lining1-2	0.049	0.712
DC-2O -Lining2-1	0.118	1.945
DC-2O -Lining2-2	0.136	2.259
DC-2O -Lining3-1	0.069	1.068
DC-2O -Lining3-2	0.058	0.872
DC-M -Lining1-1	0.034	0.451
DC-M -Lining1-2	0.041	0.576
DC-M -Lining2-1	0.073	1.133
DC-M -Lining2-2	0.084	1.341
DC-M -Lining3-1	0.060	0.914
DC-M -Lining3-2	0.059	0.890
DC-2M -Lining1-1	0.069	1.062
DC-2M -Lining1-2	0.032	0.416
DC-2M -Lining2-1	0.084	1.329
DC-2M -Lining2-2	0.116	1.898
DC-2M -Lining3-1	0.155	2.597
DC-2M -Lining3-2	0.151	2.532

Table 3.12 - The loading efficiency of laurel oil in different types of fabrics

	DC-O	DC-2O	DC-M	DC-2M	DC-C
Lining 1	4.47 ± 0.10	3.66 ± 1.01	4.81 ± 0.21	3.11 ± 0.18	4.0 ± 0.24
Lining 1 - 3 Washes	0.958 ± 0.014	0.786 ± 0.005	0.514 ± 0.010	0.739 ± 0.010	0.0 ± 0.0
Lining 2	6.29 ± 0.67	3.50 ± 0.39	4.98 ± 0.58	3.95 ± 0.03	4.3 ± 0.18
Lining 2 - 3 Washes	2.417 ± 0.010	2.102 ± 0.005	1.237 ± 0.015	1.614 ± 0.010	0.7 ± 0.0
Lining 3	4.03 ± 0.29	5.97 ± 0.52	6.33 ± 1.01	5.12 ± 1.61	4.9 ± 0.28
Lining 3 - 3 Washes	1.142 ± 0.010	0.970 ± 0.000	0.902 ± 0.014	2.565 ± 0.005	0.7 ± 0.0

All tested lining materials demonstrated the ability to retain the essential oil within their structure to some extent, confirming the compatibility of the finishing formulations with the textile substrate. Comparative analysis also revealed that there was no statistically significant difference between the materials treated with pure essential oil and those treated with microcapsule-based formulations. This finding suggests that both treatment approaches were capable of providing comparable levels of essential oil incorporation and retention within the lining materials under the tested conditions.

3.7 *In vitro* release studies of microparticles treated leathers

The *in vitro* release results of leathers impregnated with LEO-loaded MPs are displayed in Figure 3.10. The graph illustrates the controlled release of oil from leather samples over a 24-hour period. DC-O served as a reference for the release behavior of unencapsulated LEO on leather. The MPs exhibited distinctive characteristics, beginning with a minor initial burst release, followed by a sustained release rate thereafter. It was discernible that the release of DC-O (Laurel Oil) from the MPs gradually escalated over time as they came into contact with PBS. This phenomenon showed that the LEO undergoes rapid disintegration within the PBS medium, presumably attributable to the slightly alkaline nature of PBS. Similar to the controlled release behavior observed in our study, previous research had demonstrated that orange oil trapped inside microparticles in exhibited sustained release up to 24 hours, with variations in release rates influenced by polymer concentration (Tables 3.13 and 3.14) [26, p. 445; 98, p. 1023].

Table 3.13 - *In vitro* release of MPs treated leathers (Annex E)

Time (h)	Time (min)	S-M	S-2M	DC-M	DC-O
0	0	0	0	0	0
0.50	30.00	9.62	4.76	2.136	5.7362
1.00	60.00	21.77	11.48	3.405	11.831
1.50	90.00	32.62	16.25	6.962	24.480
3.00	180.00	41.54	21.02	11.203	28.007
4.00	240.00	51.87	31.39	16.222	46.726
5.00	300.00	59.32	42.72	22.047	66.944
6.00	360.00	67.80	58.01	27.321	86.055
24.00	1440.00	83.81	74.43	32.111	116.091

Table 3.14 - Standard deviation

Time (h)	Time (min)	S-M	S-2M	DC-M	DC-O
0	0	0	0	0	0
0.50	30.00	0.709	2.076	0.035	0.358
1.00	60.00	0.157	1.947	0.678	2.882
1.50	90.00	2.279	3.006	1.223	11.965
3.00	180.00	4.445	5.302	3.014	12.650
4.00	240.00	0.692	7.252	5.806	1.663
5.00	300.00	2.998	4.495	9.841	12.712
6.00	360.00	3.458	7.759	13.317	14.931
24.00	1440.00	3.338	10.144	15.751	28.182

Nevertheless, it was noteworthy that the variations in chitosan concentration within the formulations did not appear to have an appreciable impact on the release

rate. A comparative analysis of the different formulations revealed that the drug release ratio from leather specimens impregnated with DC-O surpasses that of leather treated with DC-M, as well as S-M and S-2M. The observed release rate of DC-M was the slowest. It is primarily due to the ineffective application of dip-coating, as evident in SEM images. The limited presence of MPs on the leather suggests that, despite using a concentrated MP solution, the relatively heavy MPs likely slid away during the dip-coating process. S-2M exhibited a slower release compared to S-M.

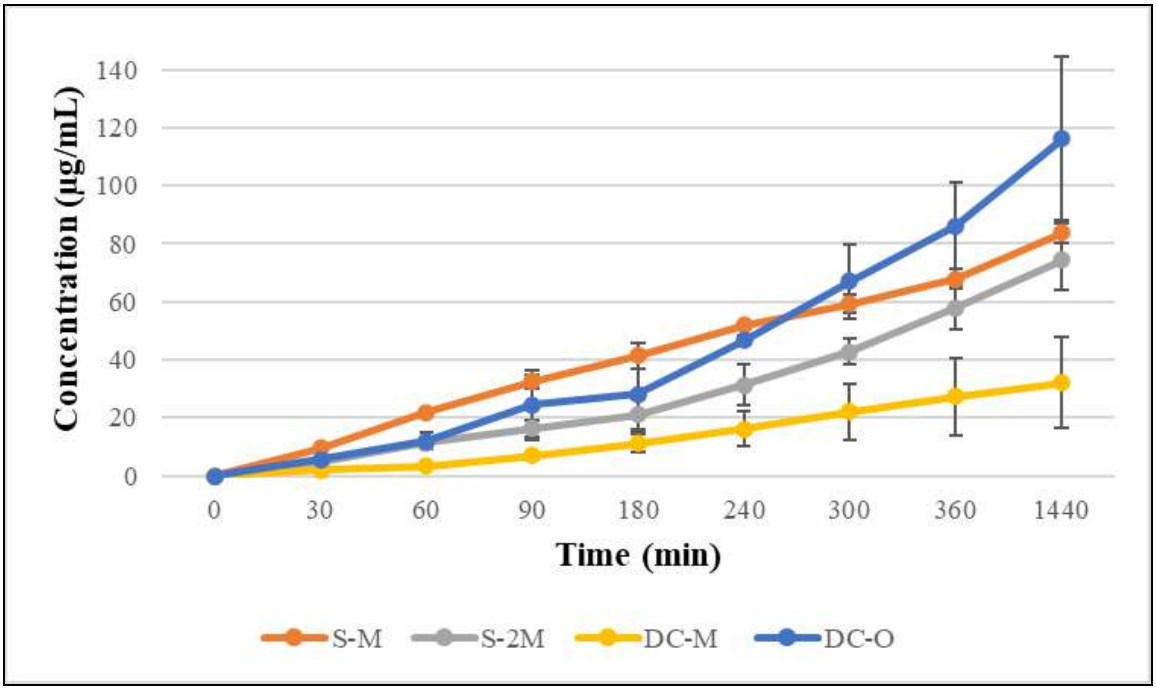


Figure 3.10 - *In vitro* release of MPs treated leathers

This phenomenon is believed to be attributable to the microparticles being deeply embedded beneath the coating material, masking their release. The *in vitro* release results of all MPs treated leathers increased based on time as the *in vitro* release results of MPs with PBS:n-hexane. Comparing the formulations among each other, the drug release of S-M leather had a similar concentration with n-hexane MPs [98, p. 1022; 101, p. 215].

3.8 Color measurement on research leather and lining materials

The results of colour changes with L*. a* and b* data showed in Tables 3.15, 3.16 and 3.17 respectively (Annex A).

Lining 1 with DC-O, DC-2O and DC-C was darker than the original one to 4.5%, 3.1% and 2.6%, respectively, was brighter, red and yellow. Lining 1 with DC-2M was darker than the original one to 0.5%, more matte, less red and yellow. Lining 2 with DC-O, DC-M, DC-2M and DC-C was darker than the original one to 7.9%, 4.6%, 7.5% and 11.9%, more matte, less red and yellow. Lining 2 with DC-2O was darker than the original one to 8.1%, more matte and yellow, but less red. Material 3 with DC-O, DC-2O, DC-M, and DC-2M was darker than the original one to 2.6%,

4.1%, 1.2% and 0.7%, brighter, more yellow, less green. Lining 3 with DC-C was darker than the original one to 4.0%, more matte and yellow, less green [99, p. 28].

Table 3.15 - L* (lightness) values of research leather and lining materials

	Lining 1 (Original: 82.061)	Lining 2 (Original: 29.708)	Lining 3 (Original: 52.432)	Leather (Original: 82.517)
DC-O	78.354 Differences= -3.707	27.370 Differences= -2.338	51.048 Differences= -1.384	77.737 Differences = -4.780
DC-2O	79.558 Differences= -2.503	27.293 Differences= -2.415	50.268 Differences= -2.164	-
DC-M	82.076 Differences= 0.015	28.331 Differences= -1.377	51.786 Differences= -0.646	75.380 Differences = -7.137
DC-2M	81.688 Differences= -0.373	27.491 Differences= -2.217	52.052 Differences= -0.380	-
DC-C	79.941 Differences= -2.120	26.177 Differences= -3.531	50.345 Differences= -2.087	76.023 Differences = -6.494

Table 3.16 - a* (red/green value) values of research leather and lining materials

	Lining 1 (Original: 2.126)	Lining 2 (Original: 2.849)	Lining 3 (Original: -2.385)	Leather (Original: -3.135)
DC-O	2.836 Differences= 0.710	2.635 Differences= -0.214	-2.246 Differences= 0.139	-3.914 Differences = -0.779
DC-2O	2.620 Differences= 0.494	2.529 Differences= -0.320	-2.162 Differences= 0.223	-
DC-M	2.081 Differences= -0.045	2.192 Differences= -0.657	-1.885 Differences= 0.500	-4.486 Differences = -1.351
DC-2M	1.756 Differences= -0.370	2.489 Differences= -0.360	-1.981 Differences= 0.404	-
DC-C	2.273 Differences= 0.147	2.314 Differences= -0.535	-1.966 Differences= 0.419	-5.028 Differences = -1.893

Table 3.17 - b* (blue/yellow value) values of research leather and lining materials

	Lining 1 (Original: 13.134)	Lining 2 (Original: 8.012)	Lining 3 (Original: 1.913)	Leather (Original: 5.936)
DC-O	15.404 Differences= 2.270	7.882 Differences= -0.130	2.148 Differences= 0.235	8.076 Differences = 2.140
DC-2O	14.125 Differences= 0.991	8.056 Differences= 0.044	2.576 Differences= 0.663	-
DC-M	11.276 Differences= -1.858	6.932 Differences= -1.080	1.913 Differences= 1.156	8.593 Differences = 2.657
DC-2M	13.072 Differences= -0.062	7.889 Differences= -0.614	3.964 Differences= 2.051	-
DC-C	14.177 Differences= 0.147	7.428 Differences= -0.584	2.044 Differences= 0.131	7.735 Differences = 1.799

Leather with DC-O, DC-M and DC-C was darker than the original one to 5.8%, 8.6% and 7.9%, respectively, was brighter, more green and yellow.

3.9 Antimicrobial properties

3.9.1 Antimicrobial properties of leathers with microparticles

Figure 3.11 displays the results of microbiological tests conducted on treated leathers. Following incubation, the diameters of the growth inhibition zones, where no microbial growth occurs, formed around the leather samples (each with a diameter of 12 mm) were measured in millimeters and recorded. In the studies conducted, it was observed that all leather samples prevented the growth of microorganisms in the 12 mm areas where they were placed. There was no discernible microbial proliferation on the contact surface of the leathers [98, p. 1024].

All seven applications of leather samples exhibited antimicrobial activity against the tested micro-organisms. The antimicrobial effectiveness against the yeast strain *Candida albicans* was more pronounced compared to bacterial strains. Leather samples showed the most potent antibacterial activity against *Staphylococcus aureus* among the examined bacterial strains. Among all the micro-organisms, DC-O displayed the most potent activity against *Candida albicans*. On the flex resistance tests, it exhibited zones of 12+13 mm, while on no rubbing and wet rubbing, it demonstrated zones of 12+10 mm (Table 3.18) [98, p. 1026; 100, p. 404].

It is suggested that the compounds contained in the essential oils have antimicrobial effects by causing damage to the cell membranes of microorganisms. Compounds of laurel essential oil such as 1,8 cineole, α-terpinyl acetate, α-terpineol

and terpinen-4-ol are thought to be responsible for the antimicrobial activity [97]. It was observed that the most sensitive bacteria examined in our study was the gram-positive *Staphylococcus aureus*. This is because gram-positive bacteria do not have an outer membrane, unlike gram-negative bacteria. Unlike Gram-negative bacteria, which possess an additional outer lipid membrane acting as a permeability barrier, Gram-positive bacteria are characterized by a relatively thick peptidoglycan layer that is more accessible to antimicrobial agents. In a study evaluating the antimicrobial effect of laurel essential oil, it was found more effective against gram-positive bacteria such as *Enterococcus faecalis* and *Staphylococcus aureus* than the gram negatives. [98, p. 1024; 100, p. 405].

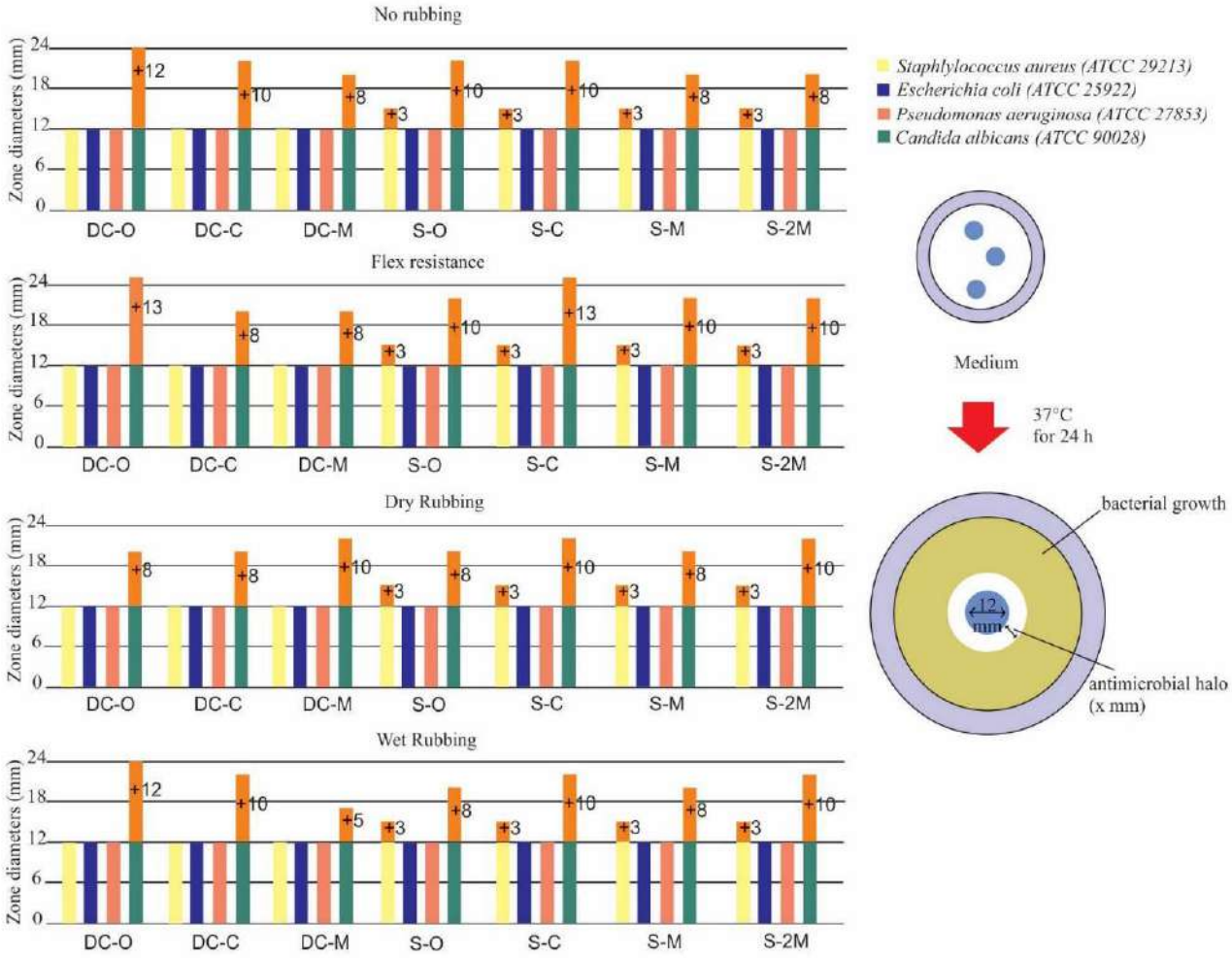


Figure 3.11 - Inhibition zone diameters of leather samples against standard microorganism strains (mm)

Table 3.18 - The results of microbiological tests

Microorganism	DC-O	DC-C	DC-M	S-O	S-C	S-M	S-2M
1	2	3	4	5	6	7	8
S. aureus							
No Rubbing	12+0	12+0	12+0	12+3	12+3	12+3	12+3

Continuation of Table 3.18

1	2	3	4	5	6	7	8
Flex resistance	12+0	12+0	12+0	12+3	12+3	12+3	12+3
Dry Rubbing	12+0	12+0	12+0	12+3	12+3	12+3	12+3
Wet Rubbing	12+0	12+0	12+0	12+3	12+3	12+3	12+3
E. coli							
No Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Flex resistance	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Dry Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Wet Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
P. aeruginosa							
No Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Flex resistance	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Dry Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
Wet Rubbing	12+0	12+0	12+0	12+0	12+0	12+0	12+0
C. albicans							
No Rubbing	12+12	12+10	12+8	12+10	12+10	12+8	12+8
Flex resistance	12+13	12+8	12+8	12+10	12+13	12+10	12+10
Dry Rubbing	12+8	12+8	12+10	12+8	12+10	12+8	12+10
Wet Rubbing	12+12	12+10	12+5	12+8	12+10	12+8	12+10

The findings from the study conducted by Amiri et al. [61, p. 6525] indicated that Bay LEO possessed antimicrobial activity against both *Staphylococcus aureus* and *Escherichia coli*. This antimicrobial property was attributed to the presence of phenolic compounds within the essential oil. Notably, Gram-positive bacteria such as *Staphylococcus aureus* exhibited relatively lower resistance to this antimicrobial effect. Our study also confirms this data. Moreover, in a separate investigation conducted by Yılmaz and Karavana [26], the antimicrobial test outcomes of chitosan orange oil microcapsules indicated that the orange oil within leather samples exhibited greater efficacy in comparison to the inherent antimicrobial properties of chitosan. In our study, both DC-O and S-O, formulated without chitosan, demonstrated significant effectiveness. This implies that LEO possesses inherent antibacterial properties, and when encapsulated with chitosan, it retains not only its robust antimicrobial capacity but also the advantage of controlled release. Moreover, despite repeated flexing and no rubbing, there was no significant reduction in antimicrobial activity, and the effect remained intact. This suggests that the antibacterial efficacy will persist for an extended period during the regular use of footbeds [98, p. 1025].

3.9.2 Antimicrobial properties of linings with microparticles

The results of the antimicrobial test gained by the disc diffusion method indicated that the addition of laurel oil to the medium-exhibited antibacterial activity against all test organisms, with the largest growth inhibition zones observed in *C.*

albicans, confirming the strong antifungal properties of the oil. These results highlight the potential of laurel oil as an effective antimicrobial agent in various applications. Nevertheless, chitosan capsules with laurel oil and chitosan capsules without laurel oil did not show any inhibitory effect on the growth of microorganisms in relation to standard strains of bacteria and yeast [99, p. 29].

3.10 Economic and environmental efficiency

According to the results of the study, the economic efficiency of the given microparticles was calculated.

According to the technological process, 5 ml of acetic acid, 2.5 g of chitosan, 2.5 g of laurel oil, as well as 0.4 g of Tween 40 and 0.2 g of Span 20 additional components were used to prepare 250 ml of working solution. As a result of encapsulation based on this composition, 1.669 g of microparticles were obtained from 250 ml of solution. During the experiment, 1 g of microparticles was used for functional finishing of one pair of footbeds.

During the experiment, 1 g of microparticles was used for functional finishing of one pair of footbeds. Accordingly, the cost of 1 g of microparticles is 1268 tenge, which proves the economic efficiency of the proposed technology and does not significantly increase production costs (Tables 3.19 and 3.20).

Table 3.19 - Calculation of the cost of solvent raw materials

Reagents	Measurement	Cost, tenge
Chitosan	100 g	15 173
Laurel oil	100 g	31 428
Acetic acid	100 mL	1 320
Tween 40	100 g	3 164
Span 20	100 mL	11 960
Total		63 045

Table 3.20 - Cost per 1 gram of microparticle

Reagents	Amount for 1 gram of microparticles, g	Cost per 1 g of microparticle, tenge
Chitosan	2,5	379
Laurel oil	2,5	786
Acetic acid	5	66
Tween 40	0,4	13
Span 20	0,2	24
Total		**1 268**

In addition, it was found that the time for obtaining microparticles directly depends on the solution feed rate: at a speed of 3 mL/min, the process duration is 83

minutes, while at speeds of 4 mL/min and 5 mL/min it is reduced to 62 and 50 minutes, respectively. In this regard, working at a low speed (3 ml/min) can lead to an increase in production time and reduce the efficiency of the overall process. Therefore, the use of high speeds by optimizing technological modes is more economically rational.

Traditional antimicrobial finishes often use heavy metal ions (silver, copper) and synthetic biocides. The microencapsulated system based on a biodegradable, low-toxic natural biopolymer (chitosan) and a plant-based bioactive substance (laurel essential oil) used in the study is environmentally safe.

The proposed Spray-drying technology is a relatively clean technological process, allows replacing synthetic and toxic antimicrobial agents, ensuring a controlled gradual release of active substances. This, in turn, reduces the harmful load on the environment and complies with the principles of environmentally sustainable production.

Conclusion on the third part

1. Microparticles obtained from chitosan and laurel oil solutions were used for the study. The morphological characteristics of the microparticles in each solution were examined using a scanning electron microscopy. As a result, the most effective L_5 formulation was identified for further study.

2. It was concluded that the optimum microparticle formulation with LEO had wider size distribution than the blank chitosan.

3. The results of colour changes data with L*, a* and b* of footwear Lining 1, 2, 3 and leather footbeds applied with 5 solutions showed that most materials became darker than the original one.

4. The FT-IR spectra of chitosan, LEO, and L_5 were studied. The consistent nature of the peaks in the encapsulated powder indicated that there was no significant chemical interaction between LEO and the wall material. The study confirmed that LEO was incorporated into the polymeric matrix without notable chemical interactions with chitosan.

5. The encapsulation efficiency and *in vitro* release results of n-hexane and methanol showed that n-hexane offered better solubility and concentration results, and was therefore chosen as the solvent for LEO.

6. SEM images of the treated leathers revealed the successful transfer of microparticles onto the leather, with preserved structural integrity post-application. Between the two used methods, it was demonstrated that the spraying method was a more appropriate technique for applying microparticles to the leather footbeds than the dip-coating method.

7. Between all five solutions, the loading efficiency of laurel oil in linings with DC-M was higher than in linings treated with other solutions. After three washes, the essential oil ratio has decreased, but all the linings could retain the essential oil in their structure.

8. The *in vitro* release results of all microparticles treated leathers increased based on time, as the *in vitro* release results of microparticles with PBS: n-hexane.

The drug release of S-M leather had a similar concentration to n-hexane microparticles.

9. All types of leather footbeds and footwear lining samples demonstrated pronounced antimicrobial activity against the tested microorganisms, confirming the effectiveness of the applied functional treatment. The results indicated that the materials exhibited inhibitory effects against both bacterial strains (*Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa*) and the fungal strain *Candida albicans*, suggesting a broad-spectrum antimicrobial performance. Notably, the largest inhibition zones were recorded against *Candida albicans*, indicating a higher susceptibility of the fungal strain compared to the bacterial cultures. Overall, the obtained results demonstrate that the developed leather footbeds and footwear lining materials possess effective and stable antimicrobial properties, with particularly strong activity against fungal microorganisms, thereby enhancing their functional and protective performance in practical applications.

10. The results of the study demonstrated that only 1 g of microparticles is sufficient for the functional finishing of one pair of footbeds, with a cost of 1268 tenge. This finding confirms the economic feasibility of the proposed technology and indicates that it does not lead to a significant increase in production costs.

CONCLUSION

In carrying out this dissertation work, a method for using LEO and chitosan to achieve prolonged antimicrobial protection on leather footbeds and linings was developed. The combination of the results obtained in the dissertation work allows drawing the following conclusions:

1. Based on the research literature sources and patent data, it is determined that creating an antibacterial environment for people with pathological deviations is very important. It is recommended for people with syndrome of diabetic foot syndrome, infections, foot cellulitis, gangrene and hyperkeratosis to wear footwear with some antibacterial properties to prevent the spread of infections.

2. Chitosan, Laurel essential oil, acetic acid (glacial), surface-active agents Tween 40 and Span 20, binder Tanapur One, wetting agent Periwet ELR and thickening agent Sodium carboxymethyl cellulose were used to prepare microparticles.

3. Different experimental solutions, including the blank sample and formulations labeled L_1, L_2, L_3, L_4, L_5, and L_6, were collected under controlled conditions using specifically designed preparation protocols. The collection process was carried out at a temperature range of 160-170 °C, with a pump flow rate maintained between 4 and 10 mL/min. These carefully controlled parameters ensured reproducible formation of the solutions and maintained the stability and uniformity of the collected samples for subsequent analyses.

4. The microparticles were examined for morphology and chemical composition using scanning electron microscopy, particle size distribution analysis, FT-IR spectroscopy, and UV-visible spectroscopy. SEM imaging revealed that, among the various microparticles, L_5 exhibited excellent product yield, a uniform particle size distribution, and a near-spherical morphology. L_5 microparticles demonstrated high encapsulation efficiency of 90.02% and a surface oil content of 9.98%. The L_5 microparticles with methanol showed lower encapsulation efficiency, it was about 10%.

5. The spraying and dip-coating methods were used to apply microparticles to materials. A study demonstrated that the spray method is more suitable for applying microparticles to leather footbeds, as spraying resulted in a uniform distribution of the microparticle layer under a thin, continuous coating.

6. The FT-IR spectrum of chitosan revealed its characteristic peaks at 3450 cm^{-1} corresponded to stretching vibrations N-H and O-H, at 2912 and 2862 cm^{-1} corresponded to asymmetric and symmetric stretching vibrations of C-H bonds, respectively. The spectrum of LEO represented its characteristics bands in the 3600-3200 cm^{-1} range due to O-H stretching vibrations (alcohol group), and the band 2881 and 2966 cm^{-1} indicated the presence of a C-H stretching. FT-IR spectrum of L_5 MPs did not undergo significant changes and resembled both shell polymer and the essential oil.

7. The results of *in vitro* release of microparticles with n-hexane showed a gradual and slow release from 0.985 mg/mL in 1 hour to 6.86 mg/mL in 6 hours, which increased with time upon contact with phosphate buffer saline. This

observation indicated the rapid disintegration of laurel oil within the medium. The *in vitro* release results of MPs with methanol did not show release, it was 0.01 in 60 min mg/mL, and after 360 min still was around 0.01 mg/mL.

8. Scanning electron microscopy analysis of the leather samples treated with microparticles revealed the successful transfer and uniform distribution of the microparticles across the surface. High-resolution images confirmed that the microparticles adhered effectively to the footbeds without agglomeration or uneven deposition. Furthermore, the leather's structural integrity was maintained after application, as evidenced by the absence of cracks, fibre disruption, or surface deformation at the microscopic level. These results indicate that the applied microparticle treatment is compatible with the leather matrix, allowing for the incorporation of functional agents while preserving the intrinsic morphological characteristics of the material.

9. *In vitro* leather release studies showed that DC-O release from microparticles gradually increased over time when exposed to phosphate-buffered saline, indicating rapid degradation of LEO.

10. The results of the colourimetric analysis, expressed in terms of the L (lightness), a (red-green), and b* (yellow-blue) parameters, for Lining 1, 2, 3, and leather samples treated with the five different solutions indicated noticeable changes in colour characteristics. Overall, the majority of the treated materials exhibited a decrease in L* values compared to their original, untreated state, suggesting that the samples became darker after application. Additionally, variations in the a* and b* values were observed, reflecting subtle shifts in the hue and chromaticity of the materials. These findings demonstrate that the applied treatments had a measurable impact on the visual appearance of both the leather and lining materials, which is important for evaluating the aesthetic compatibility of the finishing processes.

11. Microbiological analyses conducted on leather footbeds and footwear lining samples coated with microparticles confirmed that footwear leather and lining possesses pronounced antimicrobial properties. All leather and lining sample variants demonstrated significant antimicrobial efficacy against the tested microorganisms, with DC-O effectiveness against *Candida albicans* being particularly noteworthy. In flex resistance tests, it demonstrated zones of 12+13 mm, while in both no rubbing and wet rubbing tests, it demonstrated zones of 12+10 mm. These analytical data confirm that the application of laurel oil and chitosan microparticles to leather footbeds and linings is an effective method of hygiene control using natural ingredients.

12. All test and analysis results demonstrate that antibacterial microparticles were produced via spray drying and successfully incorporated into footbeds. When studying the negative impact of unpleasant odours and bacterial growth in the footwear of people with pathological deviations on their quality of life, this study can address an important issue and offers advantages over other antibacterial chemicals due to the solution's non-toxic nature. In conclusion, this research could be useful not only for people with pathological foot deviations, but also for all consumers.

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ANNEX A

Color measurement

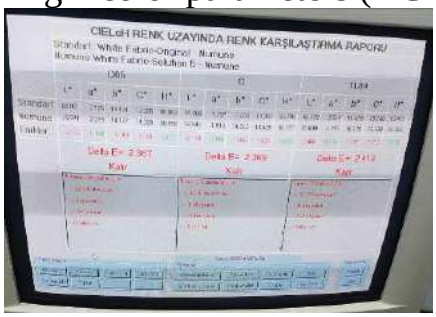
Lining 1 color parameters (DC-O)

Lining 1 color parameters (DC-2O)

Lining 1 color parameters (DC-M)

Lining 1 color parameters (DC-2M)

Lining 1 color parameters (DC-C)



Lining 2 color parameters (DC-O)

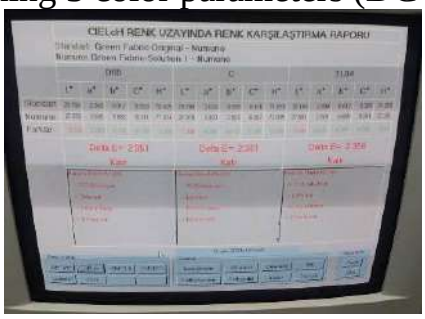
Lining 2 color parameters (DC-2O)

Lining 2 color parameters (DC-M)

Lining 2 color parameters (DC-2M)

Lining 2 color parameters (DC-C)

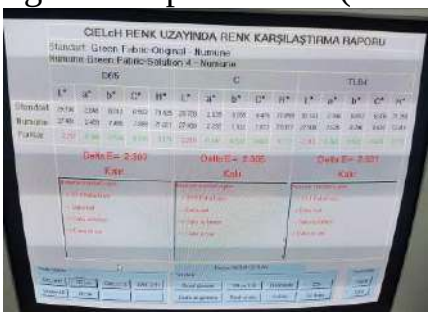
Lining 3 color parameters (DC-O)



Lining 3 color parameters (DC-2O)

Lining 3 color parameters (DC-M)

Lining 3 color parameters (DC-2M)

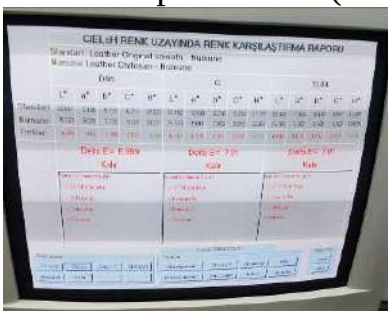


Lining 3 color parameters (DC-C)

Leather color parameters (DC-O)

Leather color parameters (DC-M)

Leather color parameters (DC-C)



ANNEX B

Complete data of *in vitro* release profiles of microparticles with methanol

Name	Concentration (ug/mL)	Under curve area (232 nm)	Dilution Factor
sample1-1_1h	0.466	0.062	1.0
sample1-2_1h	0.468	0.063	1.0
sample1-3_1h	0.468	0.063	1.0
sample2-1_1h	0.459	0.059	1.0
sample2-2_1h	0.457	0.058	1.0
sample2-3_1h	0.457	0.058	1.0
sample3-1_1h	0.488	0.072	1.0
sample3-2_1h	0.488	0.072	1.0
sample3-3_1h	0.488	0.072	1.0
sample1-1_2h	0.52	0.086	1.0
sample1-2_2h	0.522	0.087	1.0
sample1-3_2h	0.522	0.087	1.0
sample2-1_2h	0.529	0.09	1.0
sample2-2_2h	0.529	0.09	1.0
sample2-3_2h	0.531	0.091	1.0
sample3-1_2h	0.488	0.072	1.0
sample3-2_2h	0.488	0.072	1.0
sample3-3_2h	0.488	0.072	1.0
sample1-1_3h	0.493	0.074	1.0
sample1-2_3h	0.493	0.074	1.0
sample1-3_3h	0.493	0.074	1.0
sample2-1_3h	0.511	0.082	1.0
sample2-2_3h	0.511	0.082	1.0
sample2-3_3h	0.509	0.081	1.0
sample3-1_3h	0.506	0.08	1.0
sample3-2_3h	0.504	0.079	1.0
sample3-3_3h	0.504	0.079	1.0
sample1-1_4h	0.477	0.067	1.0
sample1-2_4h	0.475	0.066	1.0
sample1-3_4h	0.475	0.066	1.0
sample2-1_4h	0.497	0.076	1.0
sample2-2_4h	0.497	0.076	1.0
sample2-3_4h	0.497	0.076	1.0
sample3-1_4h	0.497	0.076	1.0
sample3-2_4h	0.497	0.076	1.0
sample3-3_4h	0.497	0.076	1.0
sample1-1_5h	0.502	0.078	1.0
sample1-2_5h	0.497	0.076	1.0

sample1-3_5h	0.491	0.073	1.0
sample2-1_5h	0.518	0.085	1.0
sample2-2_5h	0.509	0.081	1.0
sample2-3_5h	0.504	0.079	1.0
sample3-1_5h	0.504	0.079	1.0
sample3-2_5h	0.504	0.079	1.0
sample3-3_5h	0.504	0.079	1.0
sample1-1_6h	0.466	0.062	1.0
sample1-2_6h	0.466	0.062	1.0
sample1-3_6h	0.466	0.062	1.0
sample2-1_6h	0.473	0.065	1.0
sample2-2_6h	0.473	0.065	1.0
sample2-3_6h	0.473	0.065	1.0
sample3-1_6h	0.459	0.059	1.0
sample3-2_6h	0.459	0.059	1.0
sample3-3_6h	0.459	0.059	1.0

Complete data of *in vitro* release profiles of microparticles with n-hexane

Name	**Concentration**	**Under curve area (232 nm)**
sample1-1_1h	0.468	0.062
sample1-2_1h	0.468	0.063
sample1-3_1h	0.468	0.063
sample2-1_1h	0.459	0.059
sample2-2_1h	0.457	0.058
sample2-3_1h	0.457	0.058
sample3-1_1h	0.488	0.072
sample3-2_1h	0.488	0.072
sample3-3_1h	0.488	0.072
sample1-1_2h	0.52	0.086
sample1-2_2h	0.522	0.087
sample1-3_2h	0.522	0.087
sample2-1_2h	0.529	0.09
sample2-2_2h	0.529	0.09
sample2-3_2h	0.531	0.091
sample3-1_2h	0.488	0.072
sample3-2_2h	0.488	0.072
sample3-3_2h	0.488	0.072
sample1-1_3h	0.493	0.074
sample1-2_3h	0.493	0.074
sample1-3_3h	0.493	0.074
sample2-1_3h	0.511	0.082

sample2-2_3h	0.511	0.082
sample2-3_3h	0.509	0.081
sample3-1_3h	0.506	0.08
sample3-2_3h	0.504	0.079
sample3-3_3h	0.504	0.079
sample1-1_4h	0.477	0.067
sample1-2_4h	0.475	0.066
sample1-3_4h	0.475	0.066
sample2-1_4h	0.497	0.076
sample2-2_4h	0.497	0.076
sample2-3_4h	0.497	0.076
sample3-1_4h	0.497	0.076
sample3-2_4h	0.497	0.076
sample3-3_4h	0.497	0.076
sample1-1_5h	0.502	0.078
sample1-2_5h	0.497	0.076
sample1-3_5h	0.491	0.073
sample2-1_5h	0.518	0.085
sample2-2_5h	0.509	0.081
sample2-3_5h	0.504	0.079
sample3-1_5h	0.504	0.079
sample3-2_5h	0.504	0.079
sample3-3_5h	0.504	0.079
sample1-1_6h	0.466	0.062
sample1-2_6h	0.466	0.062
sample1-3_6h	0.466	0.062
sample2-1_6h	0.473	0.065
sample2-2_6h	0.473	0.065
sample2-3_6h	0.473	0.065
sample3-1_6h	0.459	0.059
sample3-2_6h	0.459	0.059
sample3-3_6h	0.459	0.059

ANNEX C
Loading efficiency of unwashed fabrics

Thermo SCIENTIFIC

User Information

Name: Administrator

Experiment Information

File Name: C:\VISIONcollect\Data\2022\F. Teknoloji\SYK\defneyağ-sample.qdt
Title: Untitled-2
Experimental Date: 04-29-2022 15:12:39
Instrument Serial No.: EA-1002017
Firmware Version: 100312
Software Version: Thermo Scientific VISIONcollect
Software Version 1.5 Build 3

Method

Experiment Type : Quantification Sample

Experiment Setup	Baseline Correction	Quantification Sample
Data Type: Absorbance Sampling: Single Cell Holder Mode: Fast Scan No.: 30 Integration No. : 1	Use: No	Analysis Name: linearity Concentration Unit: ug/mL Use Wavelength (nm): 268 Curve Zero Offset: Yes Curve Order: 1 Standard Concentration: 1, 1, 1, 3, 3, 3, 5, 5, 5, 7, 7, 7

Result Data

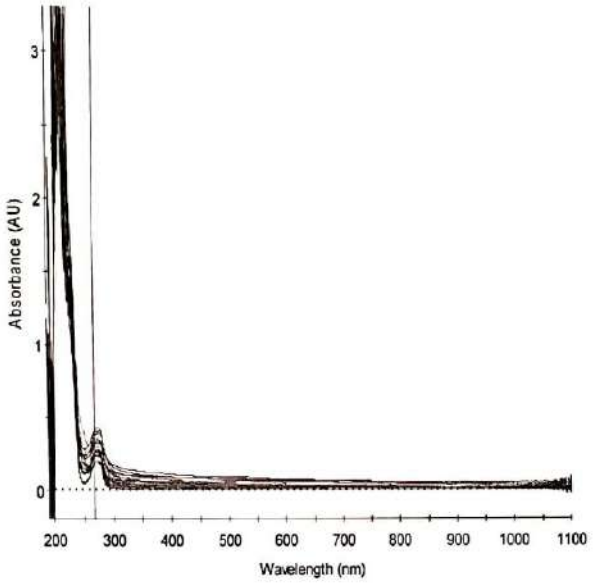
Function: Y = 5,62E-02X + 8,96E-03
R^2: 0,9869

Name	Concentration (ug/mL)	AU(268,000nm)	Dilution Factor	Original Conc.(ug/mL)
s1-zigzag-1	3,825	0,224	1,0	3,825
s1-zigzag-2	4,234	0,247	1,0	4,234
s1-ten-1	4,536	0,264	1,0	4,536
s1-ten-2	4,394	0,256	1,0	4,394
s1-siyah-1	6,759	0,389	1,0	6,759
s1-siyah-2	5,816	0,336	1,0	5,816
s2-zigzag-1	5,603	0,324	1,0	5,603
s2-zigzag-2	6,332	0,365	1,0	6,332
s2-ten-1	4,376	0,255	1,0	4,376
s2-ten-2	2,953	0,175	1,0	2,953
s2-siyah-1	3,220	0,19	1,0	3,220
s2-siyah-2	3,771	0,221	1,0	3,771
s3-zigzag-1	5,621	0,325	1,0	5,621
s3-zigzag-2	7,044	0,405	1,0	7,044
s3-ten-1	4,963	0,288	1,0	4,963
s3-ten-2	4,660	0,271	1,0	4,660
s3-siyah-1	4,572	0,266	1,0	4,572
s3-siyah-2	5,390	0,312	1,0	5,390
s4-zigzag-1	6,261	0,361	1,0	6,261
s4-zigzag-2	3,985	0,233	1,0	3,985
s4-ten-1	2,989	0,177	1,0	2,989
s4-ten-2	3,238	0,191	1,0	3,238
s4-siyah-1	3,931	0,23	1,0	3,931
s4-siyah-2	3,967	0,232	1,0	3,967
s5-zigzag-1	5,158	0,299	1,0	5,158
s5-zigzag-2	4,767	0,277	1,0	4,767
s5-ten-1	3,860	0,226	1,0	3,860
s5-ten-2	4,198	0,245	1,0	4,198
s5-siyah-1	4,429	0,258	1,0	4,429
s5-siyah-2	4,180	0,244	1,0	4,180

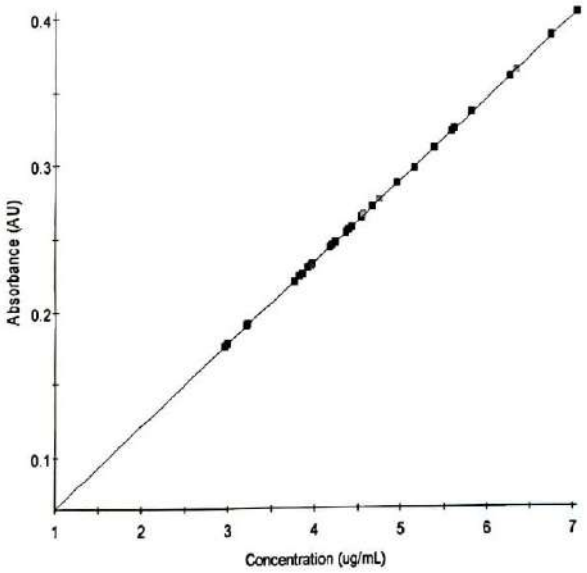
Spectrum List

Name	Date	Mode	Scan No.
s1-zigzag-1	29.04.2022 15:33:15	Fast	30
s1-zigzag-2	29.04.2022 15:35:30	Fast	30
s1-ten-1	29.04.2022 15:38:22	Fast	30
s1-ten-2	29.04.2022 15:40:02	Fast	30

Sample Spectrum



Calibration Curve



ANNEX D

Complete data of loading efficiency of unwashed fabrics (concentration values integrated to the standard curve drawn with methanol)

Name	Under curve area (268 nm)	Concentration	Mean	Standard deviation
DC-O -Lining1-1	0.264	0.32	0.310	0.014
DC-O -Lining1-2	0.256	0.3		
DC-O -Lining2-1	0.389	0.634	0.567	0.095
DC-O -Lining2-2	0.336	0.5		
DC-O -Lining3-1	0.224	0.22	0.249	0.040
DC-O -Lining3-2	0.247	0.277		
DC-2O -Lining1-1	0.255	0.297	0.197	0.142
DC-2O -Lining1-2	0.175	0.096		
DC-2O -Lining2-1	0.19	0.134	0.173	0.055
DC-2O -Lining2-2	0.221	0.212		
DC-2O -Lining3-1	0.324	0.471	0.523	0.073
DC-2O -Lining3-2	0.365	0.574		
DC-M -Lining1-1	0.288	0.38	0.359	0.030
DC-M -Lining1-2	0.271	0.338		
DC-M -Lining2-1	0.266	0.325	0.383	0.082
DC-M -Lining2-2	0.312	0.441		
DC-M -Lining3-1	0.325	0.473	0.574	0.143
DC-M -Lining3-2	0.405	0.675		
DC-2M -Lining1-1	0.177	0.101	0.119	0.025
DC-2M -Lining1-2	0.191	0.137		
DC-2M -Lining2-1	0.23	0.235	0.238	0.004
DC-2M -Lining2-2	0.232	0.24		
DC-2M -Lining3-1	0.361	0.564	0.403	0.228
DC-2M -Lining3-2	0.233	0.242		
DC-C -Lining1-1	0.226	0.225	0.249	0.033
DC-C -Lining1-2	0.245	0.272		
DC-C -Lining2-1	0.258	0.305	0.287	0.025
DC-C -Lining2-2	0.244	0.269		
DC-C -Lining3-1	0.299	0.408	0.381	0.039
DC-C -Lining3-2	0.277	0.353		

Complete data of Loading efficiency after 3 washes

Name	Under curve area (268 nm)	Concentration	Mean	Standard deviation
DC-O -Lining1-1-1	0.063	0.961	0.979	0.018
DC-O -Lining1-1-2	0.065	0.997		
DC-O -Lining1-1-3	0.064	0.979		
DC-O -Lining1-2-1	0.061	0.926	0.937	0.010
DC-O -Lining1-2-2	0.062	0.943		
DC-O -Lining1-2-3	0.062	0.943		
DC-O -Lining2-1-1	0.133	2.206	2.212	0.010
DC-O -Lining2-1-2	0.133	2.206		
DC-O -Lining2-1-3	0.134	2.224		
DC-O -Lining2-2-1	0.156	2.615	2.621	0.010
DC-O -Lining2-2-2	0.156	2.615		
DC-O -Lining2-2-3	0.157	2.633		
DC-O -Lining3-1-1	0.091	1.459	1.453	0.010
DC-O -Lining3-1-2	0.09	1.441		
DC-O -Lining3-1-3	0.091	1.459		
DC-O -Lining3-2-1	0.056	0.837	0.831	0.010
DC-O -Lining3-2-2	0.056	0.837		
DC-O -Lining3-2-3	0.055	0.819		
DC-2O -Lining1-1-1	0.058	0.872	0.860	0.010
DC-2O -Lining1-1-2	0.057	0.854		
DC-2O -Lining1-1-3	0.057	0.854		
DC-2O -Lining1-2-1	0.049	0.712	0.712	0
DC-2O -Lining1-2-2	0.049	0.712		
DC-2O -Lining1-2-3	0.049	0.712		
DC-2O -Lining2-1-1	0.119	1.957	1.945	0.010
DC-2O -Lining2-1-2	0.118	1.939		
DC-2O -Lining2-1-3	0.118	1.939		
DC-2O -Lining2-2-1	0.136	2.259	2.259	0
DC-2O -Lining2-2-2	0.136	2.259		
DC-2O -Lining2-2-3	0.136	2.259		
DC-2O -Lining3-1-1	0.069	1.068	1.068	0
DC-2O -Lining3-1-2	0.069	1.068		
DC-2O -Lining3-1-3	0.069	1.068		
DC-2O -Lining3-2-1	0.058	0.872	0.872	0
DC-2O -Lining3-2-2	0.058	0.872		
DC-2O -Lining3-2-3	0.058	0.872		
DC-M -Lining1-1-1	0.034	0.445	0.451	0.010
DC-M -Lining1-1-2	0.034	0.445		

DC-M -Lining1-1-3	0.035	0.463		
DC-M -Lining1-2-1	0.041	0.57	0.576	0.010
DC-M -Lining1-2-2	0.041	0.57		
DC-M -Lining1-2-3	0.042	0.588		
DC-M -Lining2-1-1	0.072	1.121	1.133	0.021
DC-M -Lining2-1-2	0.074	1.157		
DC-M -Lining2-1-3	0.072	1.121		
DC-M -Lining2-2-1	0.084	1.335	1.341	0.010
DC-M -Lining2-2-2	0.084	1.335		
DC-M -Lining2-2-3	0.085	1.352		
DC-M -Lining3-1-1	0.06	0.908	0.914	0.010
DC-M -Lining3-1-2	0.061	0.926		
DC-M -Lining3-1-3	0.06	0.908		
DC-M -Lining3-2-1	0.059	0.89	0.890	0.018
DC-M -Lining3-2-2	0.06	0.908		
DC-M -Lining3-2-3	0.058	0.872		
DC-2M -Lining1-1-1	0.068	1.05	1.062	0.010
DC-2M -Lining1-1-2	0.069	1.068		
DC-2M -Lining1-1-3	0.069	1.068		
DC-2M -Lining1-2-1	0.032	0.41	0.416	0.010
DC-2M -Lining1-2-2	0.032	0.41		
DC-2M -Lining1-2-3	0.033	0.428		
DC-2M -Lining2-1-1	0.084	1.335	1.329	0.010
DC-2M -Lining2-1-2	0.084	1.335		
DC-2M -Lining2-1-3	0.083	1.317		
DC-2M -Lining2-2-1	0.115	1.886	1.898	0.010
DC-2M -Lining2-2-2	0.116	1.904		
DC-2M -Lining2-2-3	0.116	1.904		
DC-2M -Lining3-1-1	0.155	2.597	2.597	0
DC-2M -Lining3-1-2	0.155	2.597		
DC-2M -Lining3-1-3	0.155	2.597		
DC-2M -Lining3-2-1	0.061	0.926	0.920	0.010
DC-2M -Lining3-2-2	0.061	0.926		
DC-2M -Lining3-2-3	0.06	0.908		
DC-2M -Lining3-2-1 repeat	0.151	2.526	2.532	0.010
DC-2M -Lining3-2-2 repeat	0.152	2.544		
DC-2M -Lining3-2-3 repeat	0.151	2.526		
DC-C -Lining1-1-1	0.01	0.018	0.018	0
DC-C -Lining1-1-2	0.01	0.018		

DC-C -Lining1-1-3	0.01	0.018		
DC-C -Lining1-2-1	0.014	0.09	0.090	0
DC-C -Lining1-2-2	0.014	0.09		
DC-C -Lining1-2-3	0.014	0.09		
DC-C -Lining2-1-1	0.047	0.677	0.671	0.010
DC-C -Lining2-1-2	0.046	0.659		
DC-C -Lining2-1-3	0.047	0.677		
DC-C -Lining2-2-1	0.056	0.837	0.837	0
DC-C -Lining2-2-2	0.056	0.837		
DC-C -Lining2-2-3	0.056	0.837		
DC-C -Lining3-1-1	0.064	0.979	0.979	0
DC-C -Lining3-1-2	0.064	0.979		
DC-C -Lining3-1-3	0.064	0.979		
DC-C -Lining3-2-1	0.043	0.605	0.605	0
DC-C -Lining3-2-2	0.043	0.605		
DC-C -Lining3-2-3	0.043	0.605		

ANNEX E

In vitro release of microparticles treated leathers

Name	Concentration (ug/mL)	AU (268nm)	Dilution Factor	Original Conc.(ug/mL)
S-M-1-1_30min	7.435	0.427	1	7.435
S-M-1-2_30min	7.417	0.426	1	7.417
S-M-1-3_30min	7.346	0.422	1	7.346
S-M-2-1_30min	6.439	0.371	1	6.439
S-M-2-2_30min	6.457	0.372	1	6.457
S-M-2-3_30min	6.457	0.372	1	6.457
S-2M-1-1_30min	3.362	0.198	1	3.362
S-2M-1-2_30min	3.327	0.196	1	3.327
S-2M-1-3_30min	3.327	0.196	1	3.327
S-2M-2-1_30min	4.785	0.278	1	4.785
S-2M-2-2_30min	4.785	0.278	1	4.785
S-2M-2-3_30min	4.749	0.276	1	4.749
DC-M-1-1_30min	2.099	0.127	1	2.099
DC-M-1-2_30min	2.135	0.129	1	2.135
DC-M-1-3_30min	2.17	0.131	1	2.17
DC-M-2-1_30min	0	-0.151	1	0
DC-M-2-2_30min	0	-0.148	1	0
DC-M-2-3_30min	0	-0.15	1	0
DC-O-1-1_30min	6.012	0.347	1	6.012
DC-O-1-2_30min	6.083	0.351	1	6.083
DC-O-1-3_30min	6.083	0.351	1	6.083
DC-O-2-1_30min	5.39	0.312	1	5.39
DC-O-2-2_30min	5.425	0.314	1	5.425
DC-O-2-3_30min	5.407	0.313	1	5.407
S-M-1-1_60min	12.664	0.721	1	12.664
S-M-1-2_60min	12.717	0.724	1	12.717
S-M-1-3_60min	12.735	0.725	1	12.735
S-M-2-1_60min	11.792	0.672	1	11.792
S-M-2-2_60min	11.561	0.659	1	11.561
S-M-2-3_60min	11.401	0.65	1	11.401
S-2M-1-1_60min	6.741	0.388	1	6.741
S-2M-1-2_60min	6.795	0.391	1	6.795
S-2M-1-3_60min	6.955	0.4	1	6.955
S-2M-2-1_60min	6.617	0.381	1	6.617
S-2M-2-2_60min	6.599	0.38	1	6.599
S-2M-2-3_60min	6.563	0.378	1	6.563
DC-M-1-1_60min	2.01	0.122	1	2.01

DC-M-1-2_60min	1.85	0.113	1	1.85
DC-M-1-3_60min	1.797	0.11	1	1.797
DC-M-2-1_60min	2.793	0.166	1	2.793
DC-M-2-2_60min	2.811	0.167	1	2.811
DC-M-2-3_60min	2.757	0.164	1	2.757
DC-O-1-1_60min	8.413	0.482	1	8.413
DC-O-1-2_60min	8.324	0.477	1	8.324
DC-O-1-3_60min	8.449	0.484	1	8.449
DC-O-2-1_60min	3.789	0.222	1	3.789
DC-O-2-2_60min	3.771	0.221	1	3.771
DC-O-2-3 _60min	3.807	0.223	1	3.807
S-M-1-1_90min	12.948	0.737	1	12.948
S-M-1-2_90min	13.037	0.742	1	13.037
S-M-1-3_90min	13.002	0.74	1	13.002
S-M-2-1_90min	8.769	0.502	1	8.769
S-M-2-2_90min	8.698	0.498	1	8.698
S-M-2-3_90min	8.573	0.491	1	8.573
S-2M-1-1_90min	3.771	0.221	1	3.771
S-2M-1-2_90min	3.807	0.223	1	3.807
S-2M-1-3_90min	3.842	0.225	1	3.842
S-2M-2-1_90min	5.763	0.333	1	5.763
S-2M-2-2_90min	5.728	0.331	1	5.728
S-2M-2-3_90min	5.728	0.331	1	5.728
DC-M-1-1_90min	1.922	0.117	1	1.922
DC-M-1-2_90min	1.779	0.109	1	1.779
DC-M-1-3_90min	1.779	0.109	1	1.779
DC-M_2-1_90min	5.265	0.305	1	5.265
DC-M-2-2_90min	5.336	0.309	1	5.336
DC-M-2-3_90min	5.247	0.304	1	5.247
DC-O-1-1_90min	21.485	1.217	1	21.485
DC-O-1-2_90min	20.881	1.183	1	20.881
DC-O-1-3_90min	20.418	1.157	1	20.418
DC-O-2-1_90min	4.358	0.254	1	4.358
DC-O-2-2_90min	4.394	0.256	1	4.394
DC-O-2-3_90min	4.323	0.252	1	4.323
S-M-1-1_3h	2.846	0.169	1	2.846
S-M-1-2_3h	2.882	0.171	1	2.882
S-M-1-3_3h	2.668	0.159	1	2.668
S-M-2-1_3h	15.083	0.857	1	15.083
S-M-2-2_3h	15.118	0.859	1	15.118
S-M-2-3_3h	14.923	0.848	1	14.923
S-2M-1-1_3h	2.74	0.163	1	2.74
S-2M-1-2_3h	2.686	0.16	1	2.686

S-2M-1-3_3h	2.597	0.155	1	2.597
S-2M-2-1_3h	6.919	0.398	1	6.919
S-2M-2-2_3h	6.848	0.394	1	6.848
S-2M-2-3_3h	6.83	0.393	1	6.83
DC-M-1-1_3h	2.544	0.152	1	2.544
DC-M-1-2_3h	2.597	0.155	1	2.597
DC-M-1-3_3h	2.668	0.159	1	2.668
DC-M-2-1_3h	5.959	0.344	1	5.959
DC-M-2-2_3h	5.941	0.343	1	5.941
DC-M-2-3_3h	5.728	0.331	1	5.728
DC-O-1-1_3h	4.145	0.242	1	4.145
DC-O-1-2_3h	4.127	0.241	1	4.127
DC-O-1-3_3h	4.18	0.244	1	4.18
DC-O-2-1_3h	2.953	0.175	1	2.953
DC-O-2-2_3h	2.864	0.17	1	2.864
DC-O-2-3_3h	2.882	0.171	1	2.882
S-M-1-1_4h	15.012	0.853	1	15.012
S-M-1-2_4h	14.976	0.851	1	14.976
S-M-1-3_4h	14.834	0.843	1	14.834
S-M-2-1_4h	5.763	0.333	1	5.763
S-M-2-2_4h	5.692	0.329	1	5.692
S-M-2-3_4h	5.674	0.328	1	5.674
S-2M-1-1_4h	8.627	0.494	1	8.627
S-2M-1-2_4h	8.573	0.491	1	8.573
S-2M-1-3_4h	8.538	0.489	1	8.538
S-2M-2-1_4h	12.166	0.693	1	12.166
S-2M-2-2_4h	12.166	0.693	1	12.166
S-2M-2-3_4h	12.077	0.688	1	12.077
DC-M-1-1_4h	2.526	0.151	1	2.526
DC-M-1-2_4h	2.455	0.147	1	2.455
DC-M-1-3_4h	2.419	0.145	1	2.419
DC-M-2-1_4h	7.542	0.433	1	7.542
DC-M-2-2_4h	7.488	0.43	1	7.488
DC-M-2-3_4h	7.666	0.44	1	7.666
DC-O-1-1_4h	8.538	0.489	1	8.538
DC-O-1-2_4h	8.306	0.476	1	8.306
DC-O-1-3_4h	8.04	0.461	1	8.04
DC-O-2-1_4h	29.933	1.692	1	29.933
DC-O-2-2_4h	30.147	1.704	1	30.147
DC-O-2-3_4h	27.301	1.544	1	27.301
S-M-1-1_5h	9.676	0.553	1	9.676
S-M-1-2_5h	9.623	0.55	1	9.623
S-M-1-3_5h	9.498	0.543	1	9.498

S-M-2-1_5h	5.354	0.31	1	5.354
S-M-2-2_5h	5.319	0.308	1	5.319
S-M-2-3_5h	5.23	0.303	1	5.23
S-2M-1-1_5h	13.855	0.788	1	13.855
S-2M-1-2_5h	13.873	0.789	1	13.873
S-2M-1-3_5h	13.802	0.785	1	13.802
S-2M-2-1_5h	8.858	0.507	1	8.858
S-2M-2-2_5h	8.804	0.504	1	8.804
S-2M-2-3_5h	8.769	0.502	1	8.769
DC-M-1-1_5h	2.117	0.128	1	2.117
DC-M-1-2_5h	2.135	0.129	1	2.135
DC-M-1-3_5h	2.17	0.131	1	2.17
DC-M-2-1_5h	9.587	0.548	1	9.587
DC-M-2-2_5h	9.551	0.546	1	9.551
DC-M-2-3_5h	9.374	0.536	1	9.374
DC-O-1-1_5h	7.595	0.436	1	7.595
DC-O-1-2_5h	7.595	0.436	1	7.595
DC-O-1-3_5h	7.417	0.426	1	7.417
DC-O-2-1_5h	33.988	1.92	1	33.988
DC-O-2-2_5h	30.912	1.747	1	30.912
DC-O-2-3_5h	33.739	1.906	1	33.739
S-M-1-1_6h	8.893	0.509	1	8.893
S-M-1-2_6h	8.893	0.509	1	8.893
S-M-1-3_6h	8.876	0.508	1	8.876
S-M-2-1_6h	8.111	0.465	1	8.111
S-M-2-2_6h	8.075	0.463	1	8.075
S-M-2-3_6h	7.969	0.457	1	7.969
S-2M-1-1_6h	12.273	0.699	1	12.273
S-2M-1-2_6h	12.29	0.7	1	12.29
S-2M-1-3_6h	12.361	0.704	1	12.361
S-2M-2-1_6h	18.32	1.039	1	18.32
S-2M-2-2_6h	18.213	1.033	1	18.213
S-2M-2-3_6h	18.266	1.036	1	18.266
DC-M_1-1_6h	2.153	0.13	1	2.153
DC-M_1-2_6h	2.117	0.128	1	2.117
DC-M_1-3_6h	2.028	0.123	1	2.028
DC-M_2-1_6h	8.449	0.484	1	8.449
DC-M_2-2_6h	8.413	0.482	1	8.413
DC-M_2-3_6h	8.467	0.485	1	8.467
DC-O-1-1_6h	17.466	0.991	1	17.466
DC-O-1-2_6h	17.252	0.979	1	17.252
DC-O-1-3_6h	16.559	0.94	1	16.559
DC-O-2-1_6h	21.361	1.21	1	21.361

DC-O-2-2_6h	21.308	1.207	1	21.308
DC-O-2-3_6h	20.667	1.171	1	20.667
S-M-1-1_24h	15.954	0.906	1	15.954
S-M-1-2_24h	15.901	0.903	1	15.901
S-M-1-3_24h	15.865	0.901	1	15.865
S-M-2-1_24h	15.919	0.904	1	15.919
S-M-2-2_24h	16.168	0.918	1	16.168
S-M-2-3_24h	16.256	0.923	1	16.256
S-2M-1-1_24h	14.3	0.813	1	14.3
S-2M-1-2_24h	14.193	0.807	1	14.193
S-2M-1-3_24h	14.211	0.808	1	14.211
S-2M-2-1_24h	18.604	1.055	1	18.604
S-2M-2-2_24h	18.604	1.055	1	18.604
S-2M-2-3_24h	18.551	1.052	1	18.551
DC-M-1-1_24h	2.562	0.153	1	2.562
DC-M-1-2_24h	2.757	0.164	1	2.757
DC-M-1-3_24h	2.384	0.143	1	2.384
DC-M-2-1_24h	7.097	0.408	1	7.097
DC-M-2-2_24h	7.026	0.404	1	7.026
DC-M-2-3_24h	6.901	0.397	1	6.901
DC-O-1-1_24h	0	-0.427	1	0
DC-O-1-2_24h	0	-0.427	1	0
DC-O-1-3_24h	0	-0.428	1	0
DC-O-2-1_24h	16.754	0.951	1	16.754
DC-O-2-2_24h	16.79	0.953	1	16.79
DC-O-2-3_24h	15.847	0.9	1	15.847

ANNEX F

Document confirming completion of the internship

PARTICIPATION CERTIFICATE

Assel Baidildayeva

has successfully completed her training programme on "Leather Goods Industry" in Ege University, Engineering Faculty, Department of Leather Engineering from 24th January 2022 to 25th February 2022.

Assoc. Prof. Dr. Ersin ONEM
International Relations and Erasmus Coordinator

ANNEX G

Certificate of participation in an international conference

ANNEX H
Act of implementation into production

Ғылыми-зерттеу жұмыстарының нәтижелерін кәсіпорындарға енгізу кесімі	Н 4-1.1.30 – 2024 20.12.2024	DULATY UNIVERSITY

КЕЛІСІЛДІ
«М.Х.Дулати атындағы ТарУ» Ке АҚ
Басқарма мүшесі ғылым және
цифрландыру жөніндегі проректор
С.Ә. Орынбаев
М.О.
«__» ____ 2025ж.

БЕКІТЕМІН
«Таразский кожевенный завод» ЖШС
директоры
А.Н. Даукенов
М.О.
«__» ____ 2025ж.

Ғылыми-зерттеу жұмыстарының нәтижелерін кәсіпорындарға ЕНГІЗУ КЕСІМІ

Бұл кесіммен 8D07211 «Былғары бұйымдарының индустриясы» білім беру бағдарламасының докторанты А. Байдильдаеваның, PhD, қауымдастырылған профессор Б. Абзалбекұлының «Текстиль, материалтану және стандартизация» кафедрасында орындалған «Табандарының патологиялық ауытқулары бар адамдардың аяқ киімдеріне арналған былғарыларды микрокапсулдау технологиясын зерттеу» тақырыбындағы зерттеу жұмысының нәтижелері «Таразский кожевенный завод» ЖШС өндірісіне енгізілгені расталады.

Енгізілген нәтиженің түрі: Патологиялық ауытқулары бар адамдардың аяқ киімдерінде бактерияға қарсы орта жасау мақсатында жаңа өңдеу құрамын қалыптастыру. Лавр майы мен хитозан негізінде былғарының бактерияға қарсы қасиетін арттыру.

Енгізу формасы: өсімдік тектес табиғи материал болып табылатын және құрамында бактерияға қарсы компоненттердің көп мөлшері бар лавр майы және беттік белсенді заттар Tween 40 пен Span 20 қосындылары және бактерияға қарсы қасиетке ие хитозан негізінде дайындалған ерітінділерді заманауи технологияларды пайдаланып әрлеу технологиясында қолдану.

ҒЗЖ нәтижесінің жаңашылдығы: Лавр майы мен хитозан негізінде жасалған ерітінділерден алынған микрокапсулдардар жағылған былғары ұлтарақтарының бактерияға қарсы қасиетін арттыру мақсатында әрлеу түрін жетілдіру.

Тәжірибелік-өнеркәсіптік тексеру: Микрокапсулдармен жағылған былғары ұлтарақтарының физико-механикалық көрсеткіштері стандарттардың тиісті талаптарына сәйкес келеді. Ұлтарақтар жақсартылған гигиеналық және бактерияға қарсы қасиеттерге ие.

Енгізілді: Микрокапсулдармен жағылған былғары ұлтарақтарын табандарының патологиялық ауытқулары бар адамдардың аяқ киімдеріне қолдану ұсынылды.

Әлеуметтік және ғылыми-техникалық тиімділік: Қолданылған компоненттер қоршаған ортаға зиянсыз, табиғи материалдардан алынған.

Университеттен

ҒЗҚБ бастығы Ж. Шонгараева

ПБ қызметінің басшысы Б. Есмаханов

ҒЗЖ жетекшісі Б. Абзалбекұлы

Докторант А.К. Байдильдаева

Кәсіпорыннан

Енгізуге жауапты

Бас инженер К.А. Әбдуалі

ANNEX J

Act of implementation into production

Ғылыми-зерттеу жұмыстарының нәтижелерін кәсіпорындарға енгізу кесімі	Ф 4-1.1 ҒЗБ – 30 – 2025	DULATY UNIVERSITY

КЕЛІСІЛДІ
«М.Х.Дулати атындағы ТарУ» Ке АҚ
Басқарма мүшесі ғылым және
цифрландыру жөніндегі проректор
Т.О.Орынбаев
М.О. 04 2026 ж.

БЕКІТЕМІН
«ТаразКожОбувь» ЖШС
директоры
Е.Д.Абдыбаев
М.О. 04 2026 ж.

Ғылыми-зерттеу жұмыстарының нәтижелерін кәсіпорындарға ЕНГІЗУ КЕСІМІ

Бұл кесіммен «Табандарының патологиялық ауытқулары бар адамдардың аяқ киімдеріне арналған былғарыларды микрокапсулдау технологиясын зерттеу» тақырыбындағы зерттеу жұмысы бойынша жасалған әрлеу технологиясының тәжірибелі киюден өткізілгені расталады.

Ұлтарақ сипаттамасы: Қазақстан нарығында кездесетін хром жартылай өңделген былғарыдан (вет-блю) жасалған ұлтарақтар.

Әрленген ұлтарақтарды тәжірибелі киюден өткізу уақыты: 10.03.2026-10.04.2026 ж. аралығында.

Тәжірибелі киюді өткізу жағдайлары: табанның патологиялық ауытқулары бар сатып алушылар, күнделікті киюге.

Берілген уақыт кезенінде әрленген ұлтарақтардың бактерияға қарсы жеткілікті пайдалану қасиеттері анықталды.

Жұмыстың нәтижесінде сатып алушылардың берілген кезеңнен кейінгі әсерлері электронды сауалнама түрінде алынды. Сауалнама нәтижесінде тұрақты гиперкератоз, онихомикоз және қант диабеті секілді патологиялық аурулармен ауыратын респонденттердің жауаптары әрленген ұлтарақтар жай ұлтарақтарға қарағанда кию барысында бактерияға қарсы қасиеттерімен, жағымсыз иістерді жасыратын әдемі лавр майы иісімен, терлеу барысында жағымды әсерлермен ерекшеленетінін атап өтті. Құрамында экологиялық таза өнімдер қолданылғандықтан ешқандай аллергия, қызару тудырмағанын көрсетті.

Университеттен:
ҒЗКБ бастығы Ж. Шонгараева
ҒЗЖ жетекшісі Б.Абзалбекұлы
Докторант А.Байдильдаева

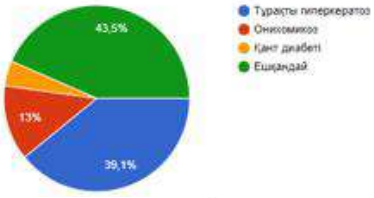
Кәсіпорыннан:
Енгізуге жауапты
Сату менеджері Ишанкулов В.Т.

Құрметті респондент!

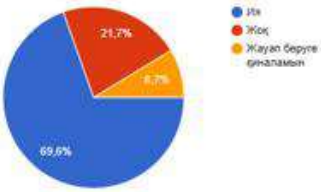
М.Х. Дулати атындағы Тараз университетінің докторанты диссертациялық жұмысын орындау барысында зерттеулер жүргізуде, бұл сауалнаманың мақсаты әрленген ұлтарақтардың сіздерге берген әсерін анықтау.

Барлық берілген сұрақтарға жауап берулеріңізді сұранамын.

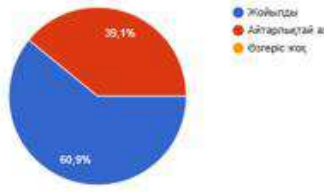
Сізде табанның қандай патологиялық ауытқулары бар?



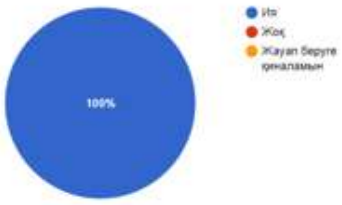
Әрленген ұлтарақтың сыртқы көрінісі бойынша басқа ұлтарақтардан ерекшелігі болды ма?



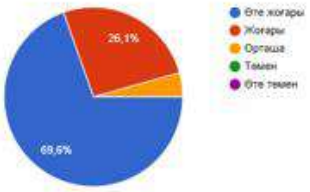
Аяқ терісінде бактериялық немесе саңырауқұлақ белгілердің таралмауына септігін тигізді ме?



Әрленген ұлтарақ аяқ киімнің гигиеналық сапасын арттыруға әсерін береді ме?

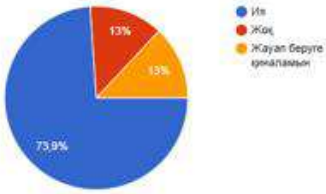


Әрленген ұлтарақты қолдану кезінде жалпы жайлылық деңгейін қалай бағалайсыз?

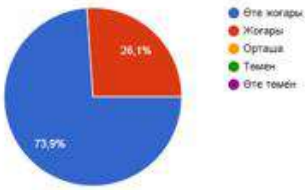


Ұлтарақты қолданғаннан кейін аяқтағы жағымсыз иісті жоюға әсері болды ма?

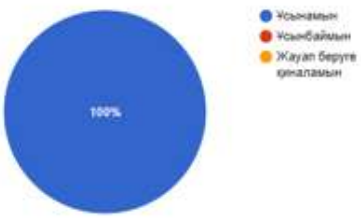
23 ответа



Ұлтарақтың антимикробтық әсерін жалпы қалай бағалайсыз?



Бұл әрленген ұлтарақ нарыққа шықса басқа адамдарға ұсынар ма едіңіз?



ANNEX K

Act of implementation into the educational process

ҒЗЖ (ТКЖ) нәтижелерін оқу үрдісіне енгізу кесімі	Ф 4-1.1 ҒЗБ – 04 – 2025	DULATY UNIVERSITY

БЕКІТЕМІН
Ғылым және цифрландыру жөніндегі проректор
_____ С.Э.Орынбаев
(қолы)
«___» _____ 2026 ж.

Ғылыми-зерттеу жұмыстарының нәтижелерін оқу үрдісіне
ЕНГІЗУ КЕСІМІ
2025- 2026 оқу жылы

Осы кесіммен «Табандарының патологиялық ауытқулары бар адамдардың аяқ киімдеріне арналған былғарыларды микрокапсулдау технологиясын зерттеу» тақырыбындағы зерттеу жұмысының «Текстиль, материалтану және стандартиазция» кафедрасында Байдильдаева Асель Куанышевнаның орындалған жұмыс нәтижелері 6В07222 – «Былғары бұйымдарының инновациялық технологиялары» БББ-ның «Былғарыдан жасалған бұйымдарға қойылатын санитарлық-гигиеналық талаптар» пәнінен «Аяқ киім материалдарының бактерияға қарсы қасиетін анықтау» тақырыбында практикалық сабағы енгізілгені расталады.

1. ҒЗЖ (ТКЖ) нәтижелерінің жаңашылдығы: Патологиялық ауытқулары бар адамдардың аяқ киімдерінде бактерияға қарсы орта жасау маңыздылығы анықталды. Микробөлшектер жағылған былғары ұлтарақтары мен текстильді астарлардың ерекшеліктері көрсетілді. Лавр майы мен хитозан негізінде былғарының бактерияға қарсы қасиеттері қарастырылды.

2. Оқу-тәжірибелік тексеру: 3 курс студенттерінің 5 семестрі, 3 жыл ұзақтыққа.

3. Енгізу тиімділігі: Студенттердің арасында былғары бұйымдарының гигиеналық қасиеттерінің көрсеткіштері ішінде бактерияға қарсы қасиеттер маңыздылығы туралы ақпарат алуға септігін тигізеді.

ГжКД директоры	(қолы)	А.А. Кабдушев
ОӨБ басшысы	(қолы)	М.К. Нурпеисов
Кафедра меңгерушісі	(қолы)	Р.Т. Кауымбаев
Автор	(қолы)	А.К. Байдильдаева

1 беттен 1 бет

ANNEX L
Application for a patent

Дата поступления 31.08.2026	(85) Дата перевода международной заявки на национальную фазу	(21) Регистрационный №	(22) Дата подачи

☐ (86) регистрационный номер международной заявки и дата международной подачи, установленные получающим ведомством

☐ (87) номер и дата международной публикации международной заявки

☐ (96) номер евразийской заявки и дата подачи заявки, установленные получающим ведомством

☐ (97) номер и дата публикации евразийской заявки

ЗАЯВЛЕНИЕ
о выдаче патента
Республики Казахстан на изобретение

Предоставляя указанные ниже документы, прошу (просим) выдать патент Республики Казахстан на изобретение на имя заявителя(ей)

Код страны по стандарту ВОИС ST.3 (если он установлен): KZ

(71) Заявитель(и):

1. БАЙДИЛЬДАЕВА АСЕЛЬ КУАНЫШЕВНА
ASSEL BAIDILDAYEVA
Койгелди 192-55, Тараз, 080000

(указывается полное имя или наименование и местожительство или местонахождение. Данные о местожительстве авторов-заявителей приводятся в графе, рядом с графой с кодом (72)

Заполняется только при испрашивании приоритета по дате, более ранней, чем дата подачи заявки в РГП «Национальный институт интеллектуальной собственности»

Прошу (просим) установить приоритет изобретения по дате:

☐ подачи первой(ых) заявки(ок) в государстве-участнике Парижской конвенции (пунктом 2 статьи 20 Закона)

☐ подачи более ранней заявки в РГП «Национальный институт интеллектуальной собственности» в соответствии с пунктом 4 статьи 20 Закона

☐ подачи первоначальной заявки в РГП «Национальный институт интеллектуальной собственности» в соответствии с пунктом 5 статьи 20 Закона

☐ приоритета первоначальной заявки (пунктом 5 статьи 20 Закона)

☐ поступления дополнительных материалов к более ранней заявке (пунктом 3 статьи 20 Закона)

(31) № первой, более ранней, первоначальной заявки	(32) Дата испрашиваемого приоритета	(33) Код страны подачи по ST.3 (при испрашивании конвенционного приоритета)

(54) Название изобретения
СПОСОБ ПОЛУЧЕНИЯ МИКРОКАПСУЛ НА ОСНОВЕ ХИТОЗАНА И ЭФИРНОГО ЛАВРОВОГО МАСЛА
ХИТОЗАН ЖӘНЕ ЛАВР ЭФІРІ МАЙЫ НЕГІЗІНДЕ МИКРОКАПСУЛАЛАР АЛУ ӘДІСІ

Адрес для переписки (полный почтовый адрес и имя адресата)
АБЗАЛБЕКҰЛЫ БЕКЖАН, Л. Украшка 19, Тараз, Республика Казахстан, 080000

Телефон:	Мобильный тел.	Факс:	Адрес электронной почты
87470825196			bekontiru@mail.ru

(74) Патентный поверенный (полное имя, регистрационный номер) или представитель заявителя(ей) (полное имя или наименование)

Перечень прилагаемых документов	Количество листов в 1 экземпляре	Количество экземпляров	
☐ приложение к заявлению			
☑ описание изобретения	3	1	
☑ формула изобретения	1	1	
☐ чертеж(и) и иные материалы			
☑ реферат	1	1	
☑ документ об оплате подачи заявки	1	1	
☐ документ, подтверждающий наличие оснований для уменьшения размера оплаты			(место для штампа РГП «Национальный институт интеллектуальной собственности»)
☐ копия(и) первой(ых) заявки(ок) (при испрашивании конвенционного приоритета)			
☐ документы заявки на иностранном языке			
☐ доверенность, удостоверяющая полномочия патентного поверенного или представителя			
☐ другой документ (указать)			

№ фигуры чертежей, предлагаемой для публикации с формулой(рефератом)

(72) Автор(ы) (указывается полное имя)	Полный почтовый адрес местожительства, включая наименование страны и ее код по стандарту ВОИС ST.3, если он установлен
1. АБЗАЛБЕКҰЛЫ БЕКЖАН ABZALBEKULY BEKZHAN	Л. Украинка 19, Тараз, KZ, 080000
2. БАЙДИЛЬДАЕВА АСЕЛЬ КУАНЫШЕВНА ASSEL BAIDILDAYEVA	Койгелди 192-55, Тараз, KZ, 080000
3. ГАФУРОВ ЖАХОНГИР КАБУЛОВИЧ JAKHONGIR K GAFUROV	ул. Бойтепова дом9, Ташкент, UZ, 444402
4. ТАШМУХАМЕДОВ ФАРХАД РАХМАДЖАНОВИЧ FARKHAD TASHMUKHAMEDOV	Ул. Толе би 60, Тараз, KZ, 080000
5. ХУСЕЙН АТА КАРАВАНА HUSEYIN ATA KARAVANA	Борнова, TR

Я (мы)
прошу (просим) не упоминать меня (нас) как автора(ов) при публикации сведений о выдаче патента на изобретение

Подпись(и) автора(ов):

Согласен на использование сведений, составляющих охраняемую законом тайну, содержащуюся в информационных системах

Подпись
31.08.2026

Подписано с помощью ЭЦП. БАЙДИЛЬДАЕВА АСЕЛЬ
Роль (Заявитель, Автор)

Подпись(и) заявителя(ей), (при подписании от имени юридического лица подпись руководителя скрепляется печатью)