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Chitosan And Dextran Based Powders – The Preparation, Performance Comparison and Potential Application in Forensic Examination of Latent Fingermarks

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Abstract: The papillary lines are unique for each person, and that feature is frequently used in modern forensic science to identify and distinguish individuals. Fingerprints are often present at the crime scene, but they are usually in the form of latent (invisible) marks which need to be visualized prior to the further processing. Many routinely employed commercial methods show harmful effect on human health, so the research groups are constantly trying to improve or develop some new approaches, and some of them are resorting to the utilization of bio(polymeric) materials. This paper deals with chitosan- and dextran-based biopowders prepared and characterized to evaluate their potential application in visualizing latent fingermarks. Chitosan and dextran are widely used in medicinal and pharmaceutical applications, but there are only a few studies regarding the utilization of these biopolymers as a component for the fingerprint powder. These biopolymeric materials offer many benefits, such as non-toxic properties, specific binding mechanisms, and they also satisfy the cost-benefit demands. Two chitosan-based formulations and one dextran-based formulation were obtained in simple synthesis processes. FT-IR analyses confirmed interactions between components of prepared systems. Optical microscopy showed that prepared powder formulations possess small and uniformly distributed particles, which contributed to their easy binding to the sweat and lipid residues present in the fingerprint trace. Prepared formulations were tested on a rubber (semi-porous) and glass (non-porous) surface. The results indicated that the obtained bio-based powders have the potential to complement commercially exploited physical systems/fingerprint powders in detecting and enhancing latent fingermarks.

Keywords: (Bio)polymers, Chitosan, Dextran, *Hydrangea macrophylla*, Latent Fingermarks, Forensics

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Introduction

Human skin is the largest organ in human body and consists of three basic layers: *epidermis*, a protective layer consisting mainly of dead cells; *dermis*, an inner layer composed of living cells: sweat (eccrine and apocrine) and sebaceous glands, collagen and elastic fibers, hair root, but also blood vessels and nerves (Choi, McDonagh, Maynard, & Roux, 2008); and *hypodermis*, a subcutaneous layer consisting mainly of fatty tissue (Sato, Kang, Saga, & Sato, 1989; Champod, Lennard, Margot, & Stoilovic, 2004). Dermal layer contains the papillary lines, which increase the exchange of oxygen, nutrients and waste materials between the dermis and the epidermis (Choi, McDonagh, Maynard, & Roux, 2008). They are genetically hereditary and also depend on external factors of the environment, so their creation is actually a stochastic process. Therefore, the papillary lines are unique for each person and represent the distinguishing characteristic between individuals (Champod, Lennard, Margot, & Stoilovic, 2004; Weyermann, Roux, & Champod, 2011). Fingerprints or fingermarks are the most present papillary line trace found at the crime scene (Champod, Lennard, Margot, & Stoilovic, 2004; Durose, Burch, Walsh, & Tiry, 2016). Due to their mentioned uniqueness, as well as the immutability, ease of classification and transferability, fingermarks are one of the main tools used for identification of individuals in forensic investigations (Mozayani & Noziglia, 2006).

In modern forensics, many methods and techniques are constantly being improved and developed with the aim to help law enforcement agencies to fight crime. Perpetrator and/or victim could leave different traces at the crime scene, so collection of evidence is probably the most important step toward solving a criminal act (Champod, Lennard, Margot, & Stoilovic, 2004; Mozayani & Noziglia, 2006). There are different types of material traces that could be found at the crime scene, such as hair, fibers, fabric, soil, building materials and biological materials (Champod, Lennard, Margot, & Stoilovic, 2004; Sonne, 2006). The strict procedure describes how to handle each of these traces, starting from their observation and collection to further (laboratory) analysis (Mozayani & Noziglia, 2006; Sonne, 2006). It is already well known that DNA analysis represents a "gold standard" for identification of individuals in nowadays forensic investigation, but one of the first approaches used for that purpose is dactiloscopy (Mozayani & Noziglia, 2006). It represents the identification or verification of individuals based on papillary line traces transferred from the surface of the skin to the substrate. For example, this method is broadly used in many government and private security systems and applications (with limited access) (Maltoni, Maio, Jain, & Prabhakar, 2009). On the other hand, fingerprint identification is a commonly used tool in forensic science. Based on their appearance, fingermarks are divided into two groups: visible and latent (invisible to the naked eye) (Champod, Lennard, Margot, & Stoilovic, 2004; Maltoni, Maio, Jain, & Prabhakar, 2009). These marks

represent about 10% of all material traces that could be recovered from a crime scene (Durose, Burch, Walsh, & Tiry, 2016). Latent fingermarks are often more challenging, since they need to be developed prior to collection and further processing, so for that purpose different optical, chemical and/or physical methods are exploited (Datta, Lee, Ramotowski, & Gaensslen, 2001; Bumbrah, Sharma, & Jasuja, 2016; Milašinović & Koturević, 2016).

However, many routinely employed chemical and physical methods show harmful and hazardous influence on human health, so their continuous application is not recommended (Champod, Lennard, Margot, & Stoilovic, 2004). Hence, researchers are constantly developing some novel approaches that will overcome the mentioned problem and additionally be economically viable. Scientists are resorting to the employment of various bio(polymeric) materials, as well as the nanomaterials, whose utilization is still insufficiently known to the scientific public, especially in forensic applications (Milašinović N, 2016; Sen, Mohite, & Kayande, 2019). Recently, the system described by Costa et al. (2020), based on the electrodeposition of bilayer systems based on conjugated and fluorescent polymers was used for the development of latent fingerprints on stainless steel. The first layer of Polypyrrole or PEDOY was electrodeposited onto the surface containing a latent fingerprint and the second layer of a fluorescent Poly(2,2′:5′,2″-terthiophene) was electrodeposited onto the first layer. Prepared bilayer systems evinced fluorescent properties which can be used for development of latent fingerprints on stainless steel, due to the high definition of images in both visible and UV light. Lately, scientists are trying to develop a new approach based on (fluorescent) nanomaterials (quantum dots), due to their specific properties. A novel approach based on bifunctional composite powder with moderate magnetic properties and intense fluorescence via a layer-by-layer assembly route was prepared by Ding et al. (2021). The researchers proposed a fast synthesis of Fe3O4@SiO2-CD(n) powder possessing moderate magnetic and photoluminescence characteristics. The results demonstrated that this novel nanocomposite powder has two advantages over traditional fingerprint powder: the morphology and size, and organic functional groups, which could provide better adhesion and bonding in the interaction between fingerprint (sweat and lipid) residues and powders. Nevertheless, these systems need to be further examined.

This paper deals with chitosan- and dextran-based biopolymer powders, obtained in simple synthesis processes. Chitosan (Ch) is a cationic heteropolysaccharide, produced by partial deacetylation of chitin obtained from crab or shrimp shells using alkaline substances. Due to its specific polycationic properties, chitosan (usually with the addition of some components) can potentially bind to the residues present in the (latent) print, such as salts, lipids, organic acids, etc (Rinaudo, 2006). On the other hand, dextran is a complex, branched and hydrophilic polysaccharide composed of anhydroglucose rings, obtained from bacteria (particularly from Lactobacillus, Leuconostoc and Streptococcus species), widely

used in medicine and pharmacy (Wang, Dijkstra, & Karperien, 2016; Wasiak, et al., 2016). Up to our knowledge, there are currently a few studies regarding these biopolymers utilization in forensics, i.e. development of latent fingermarks (Vučković, Dimitrijević, & Milašinović, 2020; Vučković, Glođović, Radovanović, Janaćković, & Milašinović, 2020). Chitosan and dextran were used due to their relatively low price, non-toxic properties, specific binding mechanism, as well for their water solubility and easy filtration process (Rinaudo, 2006; Wang, Dijkstra, & Karperien, 2016). In this paper, two chitosan-based formulations and one dextran-based formulation were prepared and characterized with the aim to test and compare their performances in enhancement of latent fingermarks. The results showed that these systems could complement some of the routinely employed fingerprint powders/dusting formulations in forensics.

Materials and methods

Materials

Medium molecular weight chitosan (Mw ~243.000 g/mol) was obtained from Sigma-Aldrich (Germany) and TPP from Acros Organics (USA). Viscosity measurements were monitored using a Brookfield DV-E viscometer with a S00 spindle at a speed of 60 rpm. Distilled water was used for the preparation of all buffer solutions. Acetate buffers of a specific pH values were prepared by dissolving sodium acetate and acetic acid in distilled water. Buffer solutions were then used to dissolve chitosan flakes and TPP powder. All components were used without any purification or treatment.

Dextran powder was purchased from Sigma-Aldrich (USA) and methanol from Centrohem (Serbia). Distilled water was used for the preparation of the extraction medium. The medium was prepared by dissolving the sufficient amount of citric acid in distilled water, in order to obtain the solution with concentration of 0.0033M. The extraction medium was used for total anthocyanins extraction from *Hydrangea macrophylla* flowers and afterwards, the obtained total anthocyanins extract was used to dissolve dextran powder. Besides *Hydrangea macrophylla*, all materials were used without further treatment or purification.

Preparation of chitosan-based biopowders

In order to optimize the various parameters for conjugate synthesis, the following parameters were varied: the mass and concentration of the components, and the pH of the initial solutions. Briefly, chitosan solutions were prepared by dissolving 0.2000 g of chitosan flakes in 100 ml of acetate buffer (pH adjusted around 4.32 allowing the protonation of chitosan amino groups which approximately corresponds to the pH of the sweat (~ 4.5)) (Hejjaji, Smith, & Morris, 2017 (b)), to

obtain 0.2% (w/v) chitosan solution. TPP solutions were obtained by dissolving 0.0840 g of TPP powder in 100 ml of acetate buffer, to obtain 0.084% (w/v) TPP solution. In order to obtain the appropriate volume of the final solution, the experimental procedures described by Hejjaji et al. (2017 (b)) were modified, and the chitosan solution was added to the TPP solution in different ratios: 6/1, 4/1, 1/1, 1/4 and 1/6 (Ch/TPP). During the synthesis of the conjugates, the samples were mixed at low speed and at room temperature using a magnetic stirrer, and the particles were spontaneously formed due to ionic crosslinking of chitosan chains by TPP. Prepared particle suspensions were left at 37 °C until complete evaporation of the solvent, and afterwards the synthetized conjugates were ground with pestle and mortar to fine powders and kept in a desiccator until further use.

Preparation of dextran-based biopowder

The extraction medium (pH ~ 3.84) was prepared by applying the experimental procedures described by Adjé et al. (2010). This medium was used for total anthocyanins extraction from flowers of *Hydrangea macrophylla*. Briefly, 3.5000 g of chopped *Hydrangea macrophylla* flowers were added to 350 ml of extraction medium in a round-bottom flask, then transferred to an ultrasonic bath (*VabSonic*, Serbia; 20 kHz operating frequency and with max input power of 150 W) for one hour, and at room temperature. Afterwards, the suspension was filtered using a metal sieve and filter paper, respectively, and the filtrate (i.e. liquid total anthocyanins extract) was kept at 4 °C until further use. The obtained extract was used to achieve the different color of desired biopowder, as well for better enhancement through complexing with fingerprint sweat and lipid residues, since it was demonstrated that anthocyanins have indicator chemical properties (i.e. color change in accordance with change in pH value) (Chandrasekhar, Madhusudhan, & Raghavarao, 2012; Vučković, Dimitrijević, & Milašinović, 2020).

Furthermore, the dextran-based biopowder was prepared by a simple precipitating method. Briefly, 1.0000 g of dextran powder was dissolved in 100 ml of prepared total anthocyanins extract, to obtain 1% (w/v) dextran solution. The mixture was stirred at low speed (~300 rpm) and at room temperature using a magnetic stirrer. After homogenization, methanol in 1:3 v/v ratio (mixture:methanol) was added, in order to precipitate polymer from the mixture, and the suspension was filtered using a filter paper. After air-drying at room temperature for ~24h, dry precipitate was kept at 37 °C for ~10 hours. Finally, the obtained dry formulation was ground to fine powder and kept likewise the chitosan-based formulations.

Characterization of the prepared powder formulations

FT-IR and ATR FT-IR analyses

Prepared chitosan-based powder formulations were recorded in dry state, using the *Bomem MB* 100 FT-IR spectrophotometer. Samples in the amount of 1.5 mg were mixed and ground with 75 mg of potassium bromide and then compressed into pellets at a pressure of 11 t for about a minute, using the *Graseby Specac* model: 15.011. The spectra were obtained in the wavenumber range between 4000 to 400 cm^{-1}, at 25 °C with 4 cm^{-1} resolution.

The ATR-FTIR analyses of dextran-based biopowders were performed using Nicolet iS10 FTIR spectrometer (Thermo Scientific, USA), with a diamond attenuated total reflectance (ATR) smart accessory in the range of 4000-400 cm^{-1} at a resolution of 2 cm^{-1} and at 25 °C.

Optical microscopy

The obtained biopowder formulations based on chitosan and dextran were recorded with optical microscope Leica FS C Comparison Macroscope, equipped with The Leica IM Matrox Meteor II Driver Software Module. Powders were recorded in dry state, with and without backlight. Prior to imaging under the microscope, latent fingermarks deposited onto glass microscopic slides were developed using prepared biopowders.

Enhancement of latent fingermarks

With the aim to evaluate and compare the performances of prepared powders, one male donor, using only a thumb of the right hand, deposited its sebaceous/oily and dry fingerprints onto a rubber (semi-porous) and glass (non-porous) surface. Fingermarks were then left under laboratory (humid) conditions for ~ 30 min, which allowed the traces to dry and reduce the residues, by the time the latent marks were developed with synthetized powder formulations, using BVDA Squirrel hair brush (BVDA, The Netherlands) (International Fingerprint Research Group, 2014). Visualization of all dry fingermarks was poor and, therefore, these marks are not shown in this paper (scientific public is familiar with the fact that dry marks represent a great challenge in the forensic examination of fingermarks (Lennard, 2007).

Optical microscopy was used to approximate the size and uniformity of prepared biopowders, as well to determine their potential in visualizing latent fingermarks on the glass surface (showing the best results of visualization). Therefore, sebaceous fingerprints randomly deposited onto the glass microscopic slides (properly labeled) using a technical scale in order to simulate the real conditions and determine the pressure on the surfaces (force accommodated to 100–150 g/

fingerprint), were left for a few minutes and then prepared biopowder formulations based on chitosan and dextran were used for their visualization. After the short period, the first group of fingerprints was halved with the thick slide barrier, and the chitosan-based powders were applied on the same fingerprint, using BVDA Squirrel hair brush. The second group of fingermarks were developed with dextran-based biopowder. Such type of visualization enabled a direct comparison between applied powder formulations, to evaluate their size and uniformity, as well as the efficiency in enhancing latent fingermarks (International Fingerprint Research Group, 2014).

Results and discussion

The biopowders formation mechanisms were tested using (ATR) FT-IR analyses, while the morphology and uniformity of the particles was characterized by optical microscopy. Chitosan-based powder formulations were labeled as S(Ch/TPP), where "S" refers to the sample, "Ch" to chitosan, and "TPP" to the cross-linking agent content used to prepare the desired formulations, while synthetized dextran-based biopowder was marked as "Dex". Obtained powders were tested on a rubber and glass surface. Prepared powders were applied multiple times on different fingerprints on both substrates, to determine the reproducibility of their application. Total number of developed fingerprints was 18 (9 per substrate, i.e. 3 per used powder). The best results were obtained with the sebaceous fingermarks deposited onto the glass surface and developed with formulation S(6/1). On the other hand, the development of fingerprints on rubber surface was poor, since that surface contains many bulges and indentations, thus disabling the binding of the prepared powders to the fingerprint residues. Therefore, additional studies of these systems should be conducted to improve and expand their application on different substrates.

Figure 1 shows the sebaceous fingermarks of one donor, deposited onto the rubber and glass surface and developed with prepared powder formulations based on chitosan and dextran. The prints were photographed under visible light with a 12 MP camera (aperture $f/2.2$, pixel size 1.22 μm) using a black background surface to obtain adequate contrast. Development of sebaceous fingermarks on glass surface was satisfying, since all powder formulations have visualized fingerprints with complete image and patterns, the papillary lines (without disruption in their flow) and some minutiae points, as well.

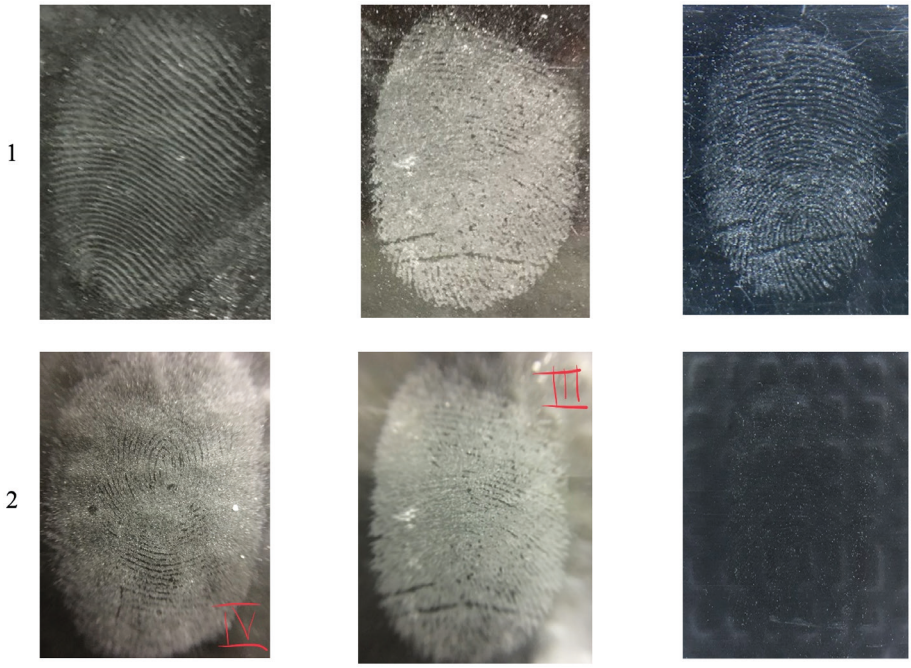

Figure 1. Sebaceous fingerprints developed on: 1) glass and 2) rubber surface, using the following powder formulations: a) S(6/1); b) S(1/1); c) Dex; and recorded under visible light using black background surface for better contrast.

When observing fingerprints developed on (non-porous) glass surface (Figure 1, 1), it is evident that the best results are obtained with formulation S(6/1) (Figure 1, 1, a)), while formulations S(1/1) and Dex showed relatively satisfying results, which may be associated with a diameter size and uniformity of particles. As confirmed by optical microscopy, smaller particles better adhere and bind to sweat and lipid fingerprint residues, which was noticeable with formulation S(6/1). Powder particles of formulation S(6/1) developed the papillary lines without disruption in their flow, visualized the minutiae points and did not remain in the interpapillary space. On the other hand, formulations S(1/1) and Dex (Figure 1, 1, b) and c)) somewhat "overpowdered" a fingerprint due to larger and non-uniform distribution of particles (Gürbüz, Özmen Monkul, İpeksaç, Gürtekin Seden, & Erol, 2015).

Development of latent fingermarks on rubber (semi-porous) surface was poor (Figure 1, 2), since that substrate contains many bulges and indentations, thus disabling the binding of the prepared biopowders to the fingerprint residues. It was not possible to visualize clear fingerprint pattern and the papillary lines, since many particles of prepared powders retained in the interpapillary space.

(ATR) FT-IR analyses

The FT-IR analysis was performed to confirm the formation of the chitosan-based conjugates, in the ionotropic gelation process. Figure 2 shows the spectra of pure TPP and formulations S(1/1) and S(6/1). In the spectrum of a pure TPP (Figure 2, spectrum 1), characteristic peak at 1215 cm^{-1} indicates the stretching of P=O bonds (Dudhani & Kosaraju, 2010). The peak at 1145 cm^{-1} could be due to the symmetric and asymmetric stretching of the PO_2 groups, while the peak at 1093 cm^{-1} can be associated with symmetric and asymmetric stretching of PO_3 groups. Peak at 903 cm^{-1}, may be related with asymmetric stretching of P–O–P bonds (Hejjaji, Smith, & Morris, 2017 (a)).

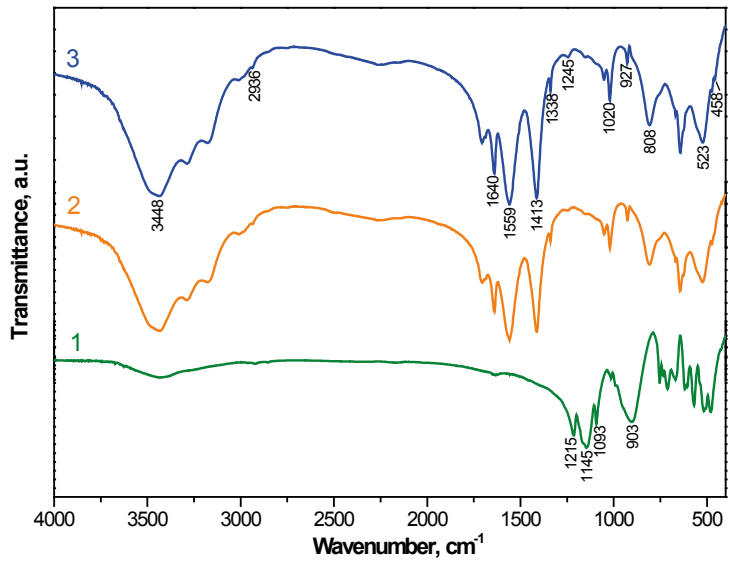

Figure 2. FT-IR spectra of: 1) pure TPP; 2) S(1/1) and 3) S(6/1).

On both spectra of prepared formulations (Figure 2, spectra 2 and 3), a characteristic strong and wide absorption band around 3448 cm^{-1} might indicate the overlapping stretching and bending of OH and NH_2 groups (Milašinović, et al., 2016). The presence of the peak at 1640 cm^{-1} could be the result of antisymmetric deformation vibrations of the NH_3^+ groups of chitosan (Žalnėravičius, Paškevičius, Mažeika, & Jagminas, 2018), while the peak around 1559 cm^{-1} indicates the deformation of the N–H bond (amide band II in chitosan) (Hejjaji, Smith, & Morris, 2017 (a)). Small shoulder peak around 1338 cm^{-1} could be associated with deformation of the O–H bond at –CH–OH (Wang & Liu, 2014), while the appearance of the absorption peak at 1020 cm^{-1} could be due to the swinging of NH_3^+ (Roddick-Lanzilotta, Connor, & McQuillan, 1998).

ATR FT-IR analyses were carried out to determine interactions between components of dextran-based biopolymer system. Figure 3 shows spectra of pure dextran, initial dextran solution, total anthocyanins extract and prepared biopowder formulation. All spectra in Figure 3 contain some characteristic bands: 3700-3000 cm-1 due to the O–H stretching and 2360 cm-1 due to the stretching of C–H (Mehta, Rucha, Bhatt, & Upadhyay, 2006; Carp, et al., 2010; Mitić, Cakić, & Nikolić, 2010). The band at 1154 cm-1 at spectra of pure dextran, initial dextran solution and dextran-based biopowder (Figure 3, a, c, d) can be assigned to the stretching vibrations of the C–O–C bond and glycosides bridge, while band at 1017 cm-1 can be associated with the stretching of C–O–H (Chiu, Hsiue, & Chen, 2004; Mehta, Rucha, Bhatt, & Upadhyay, 2006; Mitić, Cakić, & Nikolić, 2010). The weak band at 1110 cm−1 can be ascribed to the vibration of the C–O bond at the C4 position of the glucopyranose units (Mitić, Cakić, & Nikolić, 2010). Peaks at 905, 841, and 758 cm-1 can be assigned to the α-glucopyranose ring deformation modes (Cakić, Nikolić, Ilić, & Stanković, 2005; Carp, et al., 2010). Small shoulder peak at 1077 cm-1 may be due to the complex vibrations involving the stretching of the C6–O6 bond with the participation of deformational vibrations of the C4–C5 bond (Nikolić, Cakić, Mitić, & Ilić, 2008; Guerrero, Kerry, & de la Caba, 2014). On the other hand, an increase in intensity of peak at 1077 cm-1 at spectra of prepared biopowder (Figure 3, d), when compared to the spectra of pure dextran (Figure 3, a), can be related with complexing of dextran chains with the compounds (polyphenols, anthocyanins, etc.) present in the total anthocyanins extract.

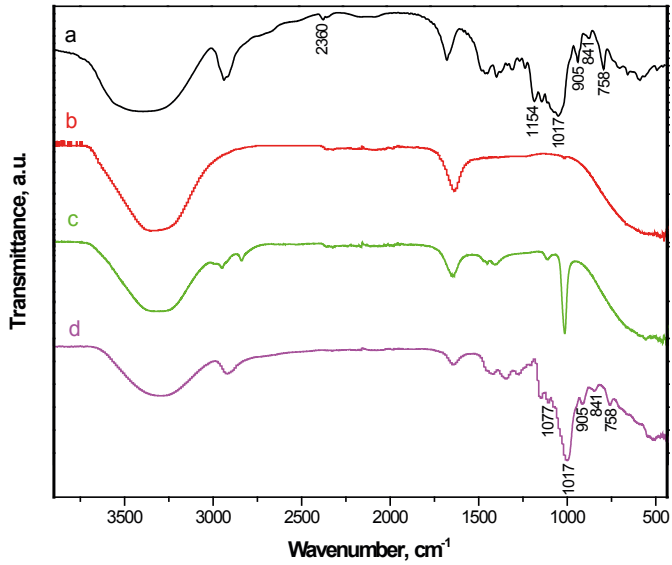

Figure 3. ATR FT-IR spectra of: a) pure dextran; b) total anthocyanins extract; c) initial dextran solution and d) dextran-based biopowder.

Optical microscopy

The structure of prepared formulations

Figure 4 shows images of obtained powder formulations taken by Leica FS C Comparison Macroscope, equipped with The Leica IM Matrox Meteor II Driver Software Module, using magnification ×75 and dark-field contrast technique. Since the best results were obtained with fingermarks deposited onto non-porous (glass) surface and developed with formulations S(6/1) and Dex, the same were used for further analyses. Powders were spread over the microscopic glass slides in the form of a fine (thinner) and amassed (thicker) layer, in order to approximate and compare the uniformity and size of the particles.

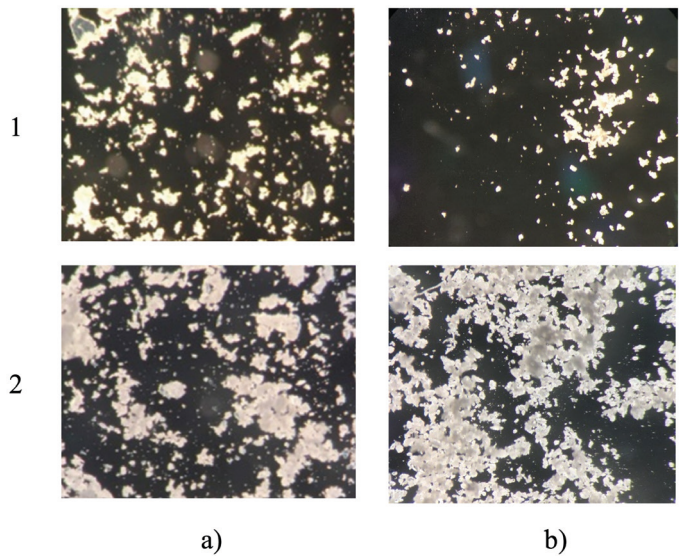

Figure 4. Microscopic images of prepared powders, spread over the microscopic slides and recorded with optical microscope (magnification ×75, using dark-field contrast technique): a) S(6/1) and b) Dex. Numbers 1 and 2 denote images with powders in a form of fine (thinner) and amassed (thicker) layer, respectively.

By observing the thin layers (Figure 4, 1, a) and b)), it is apparent that both prepared powder formulations possess comparably uniform and small diameter particles which were lightly applied and did not stick to the microscope slides (dry and clean), while at the same time were easily ground with pestle and mortar during the preparation process. Those features were even more obvious when comparing the thicker layers of prepared formulations (Figure 4, 2, a) and b)). The dark-field contrast technique was used to achieve the best possible contrast between powders and the background, which enabled the smallest particles to be spotted.

Testing of powder formulations

In order to determine the reproducibility and possibility of application of synthetized powders, following the procedures proposed by the International Fingerprint Research Group (2014), fingerprints were deposited onto microscopic glass slides using a technical scale (force applied to accommodate 100-150 g/fingerprint) and left for a few minutes. After this period, the first group of latent fingermarks was separated into halves using a thin glass barrier, and then two different powder formulations were used for their visualization – the sample S(6/1) was applied on the left and sample S(1/1) on the right barrier side (Figure 5, a)). On the other hand, the second group of latent fingermarks was developed with Dex (Figure 5, b)), with the aim to directly compare biopolymer powders based on Ch and Dex. Afterward, fingermarks were recorded with above mentioned Leica FS C Comparison Macroscope, using dark-field (Figure 5, 1) and bright-field contrast techniques (Figure 5, 2), with the ×15 magnification (for fingermarks developed with S(6/1) and S(1/1)) and ×7.5 magnification (for fingermark developed with Dex).

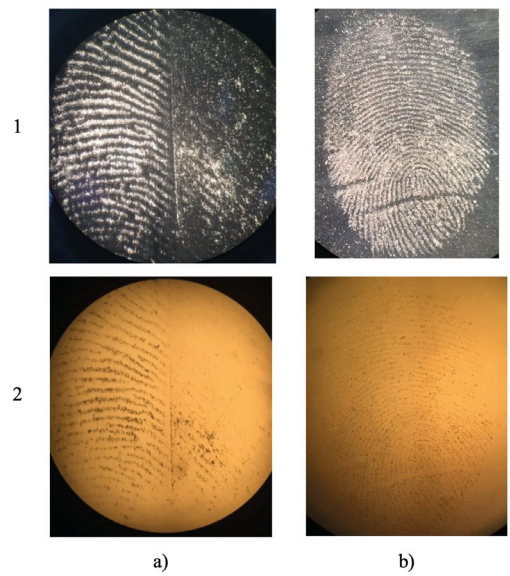

Figure 5. Sebaceous fingermarks deposited onto glass microscopic slides, left for a few minutes and developed using: a) S(6/1) (left-half side of the images) and S(1/1) (right-half side of the images); and b) Dex, recorded with optical microscope, magnification: a) ×15 and b) ×7.5, using: 1) dark-field and 2) bright-field contrast techniques.

When comparing powders S(6/1) and S(1/1), it is obvious that prepared powder sample S(6/1) showed better binding to the fingerprint (sweat and lipid) residues, developing the papillary lines with their continuous flow and making per-

ceptible some minutiae points, as well (Figure 5, a)). As we hypothesized, this may be related with a smaller diameter size of particles of sample S(6/1) when compared with sample S(1/1) (Gürbüz, Özmen Monkul, İpeksaç, Gürtekin Seden, & Erol, 2015). On the other hand, sample S(1/1) did not obtain good interaction with the fingerprint residues, maybe due to a larger and non-uniform distribution of particles. Additionally, development of latent fingermarks with sample Dex (Figure 5, b)) was comparably good as with sample S(6/1), with visualization of basic fingerprint pattern, the papillary lines and minutiae points. However, particles of powder Dex remained in some regions of the interpapillary space, which may be associated with their diameter size and the binding mechanism. Therefore, very satisfying visualization of sebaceous fingerprints on glass substrate was achieved, and with relatively cheap and less harmful powder systems.

Nevertheless, dry fingermarks could not be developed with prepared powders, due to the lack of sweat and lipid residues of fingermarks. Those marks have to be comprehensively tested to overcome one of the main problems in the forensic examination of fingerprints (Lennard, 2007).

Conclusions

In this paper, chitosan- and dextran-based powder formulations were obtained in different synthesis processes and characterized to evaluate the possibility of their application in the detection and enhancement of latent fingermarks. The main goal of this research was to compare the performances of prepared biopowders. Chitosan and dextran were used due to their availability and relatively low price, water solubility, non-toxic properties and specific binding mechanisms. Since many of the commercially exploited fingerprint powders showed detrimental effect to human health and the environment, prepared powder formulations offer healthier working conditions. Based on the obtained results, sample S(6/1) showed the best properties with sebaceous fingermarks developed on glass surface. Advantages of this formulation are small and uniform particle distribution, satisfying binding to the fingerprint sweat and lipid residues, clear visualization of fingerprint basic pattern and other specific characteristics, and the system is less harmful and satisfies the cost-benefit requirements. However, as already stated, dry fingermarks need to be thoroughly investigated. On the other hand, as many fingerprint powders, prepared formulations are easily handled and applicable, requiring no prior knowledge and the method itself is non-destructive, avoiding irreversible loss of traces. Finally, additional research could include other (bio)polymers, bio-based indicators or amino acids, to spread the utilization of these systems on other substrates and under different conditions, with the aim to complement or replace some of the routinely employed dusting formulations in developing latent fingermarks.

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