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Usefulness of aloe vera (*Aloe vera*) as a potential ingredient of cosmetic preparations*

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ABSTRACT

Introduction: Skin ageing is a natural process caused by both intrinsic and extrinsic factors, such as exposure to solar radiation, smoking, environmental pollution, improper skin care, improper lifestyle, stress and lack of sleep. These factors accelerate the ageing process of the skin by impairing and limiting many of its functions. In order to protect the skin against the harmful effects of ultraviolet radiation, photoprotective preparations and antioxidants are used, which neutralize the action of free radicals affecting the abnormal homeostasis of the body. Antioxidants are the main group of ingredients used in anti-ageing prophylaxis. Many raw materials of natural origin are rich in these ingredients. The aim of the study was to assess the antioxidant activity of the aloe vera extracts and to evaluate extraction conditions including the effect of solvent used as an extractant on the observed antioxidant potential and the ability to absorb solar radiation by aloe vera (*Aloe vera*).

Materials and methods: The material for the study consisted of alcoholic extracts prepared from the peel and flesh of aloe vera. Extracts in 40%, 70% or concentrated ethanol, methanol, n-propanol and isopropanol were used. Extracts were obtained after 15, 30 or 60 min of ultrasound-assisted extraction. Antioxidant activity was determined spectrophotometrically using the DPPH and ABTS methods, while the Folin–Ciocalteu method was used to determine total polyphenol content. Absorption spectra of the prepared extracts were taken to evaluate the absorption capacity.

Results: The highest average antioxidant activity was shown by aloe leaf peel extract in 40% methanol, subjected to a 60 min extraction and determined by the DPPH method. For aloe vera leaf peel extracts tested by the DPPH and ABTS methods, the best solvent seems to be 40% methanol, while in the Folin–Ciocalteu method it was 96% ethanol. For aloe vera flesh extracts evaluated by the DPPH method, the best solvents were undiluted alcohols, while for those evaluated by the ABTS method, it was 40% methanol, and for the determination of total polyphenol content, it was 96% ethanol. If compared to the evaluated parts of the plant studied, aloe leaf peel showed the most favourable antioxidant properties of the raw materials used. The UV-VIS spectra of the majority of extracts show an absorption maximum at a wavelength of about 300 nm, which corresponds to the UVB range.

Conclusion: Aloe vera is a valuable source of antioxidant components. Ultrasound-assisted extraction is a useful method to isolate antioxidant substances from plant material. The antioxidant potential is influenced by the extraction time of the raw material and the solvent used. Aloe vera leaf peel extracts showed higher antioxidant activity than extracts prepared from its flesh. It can be successfully used as a raw material in anti-ageing prevention and as a potential photoprotective ingredient.

Keywords: *Aloe vera*; antioxidants; DPPH; ABTS; Folin–Ciocalteu method; photoprotection.

INTRODUCTION

The skin is one of the largest and most important human organs. It plays a key role as an organ that covers and shields all internal organs [1, 2]. In the cross-section of the skin, there are 3 basic layers: the epidermis, dermis and subcutaneous tissue, moreover, there are also skin appendages such as sweat glands, sebaceous glands, nails and hair, as well as blood and lymphatic vessels and numerous nerve endings [1, 3]. The skin has many important functions. First of all, it is a protective barrier, that separates the body from the external environment. It protects internal organs from mechanical trauma, harmful chemicals and other toxic external factors as well as against harmful microorganisms. Moreover, this tissue takes part in immune, excretory and respiratory processes. It prevents water loss and regulates water-electrolyte equilibrium to maintain proper homeostasis in the body. The skin plays a key role in thermoregulation, resorption (absorption through the skin of exogenous substances, such as drugs), and in receiving sensory stimuli from the external environment. Under the contribution of ultraviolet rays (UV), the skin synthesizes endogenous vitamin D3, which supports the immune system [2, 4, 5]. Systematic care of the skin with the use of appropriate preparations helps to maintain its proper appearance, delay the ageing process, and prevent the development of many diseases associated with it [2].

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Skin ageing is an individual, natural and, unfortunately, irreversible process. It is assumed that physiological skin ageing begins after the age of 25. There are 3 main groups of factors that affect the appearance of visible changes in the skin, namely, intrinsic factors, extrinsic factors and facial factors (so-called myostasis) related to our facial expressions [6, 7, 8, 9]. Intrinsic (endogenous) ageing is caused by innate mechanisms. Changes are due to the lapse of time or chronological ageing, hormonal dysregulation (menopause), cellular metabolism and individual genetic conditions. They are influenced by the deposition of harmful toxins and the formation of free radicals [7, 8, 10, 11].

Free radicals are atoms or molecules that have 1 or more unpaired electrons on their valence orbital, which constantly seek to pair up by taking or giving them away to other molecules. Reactive oxygen species (ROS) are atoms or molecules that are formed during the incomplete reduction of oxygen as a result of reactions occurring in the cell [12, 13, 14, 15]. Their low concentrations have physiological functions, such as activity as mediators and regulators of many cellular processes, while the higher concentrations of these molecules could cause cellular damage [14, 16]. As a result of the non-physiological action of free radicals, homeostasis, i.e. the normal functioning of the cell, is disrupted. When the amount of free radicals increases and cellular metabolism is disrupted, such a phenomenon is defined as oxidative stress [15, 17, 18].

Extrinsic (exogenous) ageing is primarily associated with overexposure to ultraviolet radiation, smoking, environmental pollutants and improper skin care. Improper diet, including the insufficient amount of water in the diet, vitamin deficiencies, stress, lack of physical activity and sleep deficiency can also lead to exogenous ageing. These factors accelerate skin ageing by impairing as well as limiting many of its functions [8, 9, 11, 19]. The most characteristic feature associated with skin ageing are wrinkles, which are located mainly around the eyes (so-called crow's feet), on the forehead (as horizontal or vertical furrows), on the cheeks, lower face, neck and around the mouth. As time went on dryness of the skin, which is associated with a deficiency of glycosaminoglycans (especially hyaluronic acid) and a decrease in the synthesis of the stratum corneum lipids is observed. The skin becomes thin, flabby and more sensitive. There is a loss of elasticity and resilience, deterioration of outlining and progressive sagging of the facial oval. These features are associated with gravitational forces, a decrease in fibroblast activity and disorders related to elastic, collagen and reticulin fibers of the subcutaneous tissue and dermis. Fat atrophy causes the cheeks to collapse, resulting in changes in facial proportions. The skin becomes grey due to the thickening of the stratum corneum or pale due to anemia. Telangiectasias, hyperpigmentation and discoloration can be found, and in a more advanced stage of skin ageing there may be disorders of keratinization, the appearance of seborrheic warts and even precancerous conditions. Ageing skin may be accompanied by pruritus, referred to as senile pruritus [6, 8, 11].

One of the most significant factors associated with premature skin ageing is overexposure to UV radiation. There are 3 ultraviolet wavelength ranges: UVA (320–400 nm) accounting for 95% of solar radiation reaching the earth, UVB (280–320 nm) comprising 5% of all radiation, and UVC (200–280 nm), which is totally absorbed by the ozone layer. UVA and UVB rays are responsible for the degradation processes and changes in the skin [12, 19, 20]. Symptoms include acute, immediate reactions that occur up to 24 h after exposure and chronic, delayed reactions that occur as a result of long-term UV exposure and cumulative doses of radiation [12, 21]. To protect against the harmful effects of UV radiation, cosmetic preparations with sunscreens and antioxidants are used to neutralize the action of free radicals, which are responsible for skin damage [22, 23]. The body's ability to protect itself against the action of ROS decreases with age, so it is important to use preventive measures to delay the ageing process [24].

Due to the great interest in natural cosmetics, the beneficial effects of plant-based raw materials are increasingly being used. Ingredients of natural origin contain many active compounds that, in addition to neutralizing free radicals, protect the skin from UV radiation. They also have a beneficial effect on the condition of the skin, and offset the effects of overexposure to UV radiation, such as sunburn, skin ageing and carcinogenesis. Photoprotective action is demonstrated by among others chamomile, green tea, propolis, walnut, rosemary, argan, sesame and macadamia oils, shea butter (obtained from the seeds of the butter tree), cocoa butter and aloe vera (*Aloe vera*) [22, 23].

Due to its beneficial cosmetic and medicinal properties, aloe vera is referred to as a miracle plant or natural healer. The plant was already known in ancient times, when civilization treated it on a par with a deity and attributed to it almost magical powers. Initially, aloe was classified in the lily family (*Liliaceae*) because it is related to the tuber, but English researcher Tom Reynolds added it to a new botanical group, the aloes (*Aloaceae*) [25]. Aloe vera is native to the desert areas of East Africa, South Africa, Madagascar and islands in the Indian Ocean. It can be also found in Mediterranean countries, China, the Arabian Peninsula and the Caribbean Sea region. Aloe has become so popular that it can be found in almost every region. In Europe, it is grown in greenhouses and in homes as a potted plant [26, 27].

The most valuable parts of aloe vera are the leaves, which should be harvested from at least 3-year-old plants. The products of aloe vera are aloe vera milk (known as alona) and aloe vera gel, which is richer in composition and more widely used than alona. Aloe gel consists of 99% water, while the rest is more than 100 other beneficial ingredients [28]. The multidirectional effect of aloe vera pulp is connected with the variety and quantity of active substances contained. The most significant effects are exerted by polysaccharides (the main component of aloe vera pulp), vitamins (all of the B group, C, E, beta-carotene, folic acid), amino acids (including alanine, cystine, glutamic acid, proline, hydroxyproline, serine, tyrosine, i.e. the basic dietary amino acids), polypeptides, minerals (e.g. sodium, potassium, magnesium, calcium, iron, zinc, manganese, copper, selenium, chromium), fatty acids (linoleic, linolenic, arachidonic, palmitic, stearic, myristic, caprylic), enzymes (e.g. peroxidase, catalase, superoxide dismutase, carboxypeptidase), anthraglycosides (e.g. aloin, isobarbaloin, anthracene, cinnamic acid ester, aloeic

acid, essential oils), organic acids (e.g. succinic, salicylic, citric and cinnamic acids), saponins (glycoside group compounds), tannins, flavonoids and steroids [26, 27, 29].

Due to such a rich composition, aloe vera is readily used to make ointments, creams and gels for many skin disorders, and is also taken orally in the form of juice to strengthen the body and prevent many diseases. It is primarily known as an elixir in skin regeneration and accelerating wound healing. The polysaccharides present exert a restorative effect, and trigger immune responses that affect epidermal regeneration. Aloe vera exhibits antibacterial, antiviral, antifungal and antiseptic effects [28]. Aloe vera gel has been proven to support the immune system and also to prevent cancer. It is used to treat gastrointestinal disorders such as indigestion and stomach ulcers, as well as to reduce liver damage. It also acts as a mild laxative to eliminate unhealthy constipation. Thanks to its saponin content, it exerts an astringent and soothing effect on mucosal irritation [26, 29].

Proteolytic enzymes found in aloe vera pulp, as well as the presence of acids (e.g. salicylic acid), make them keratolytic (exfoliating) agent, which removes dead skin cells. Aloe vera moisturizes, firms, nourishes and improves blood circulation in the skin [27, 30]. It also accelerates the processes of collagen and hyaluronic acid synthesis, thus influencing the delay of skin ageing. Aloe leaf extract exhibits photoprotective effects [22]. In a study conducted in Sri Lanka, aloe vera was found to be photostable during 21 days of UV exposure, showing an sun protection factor (SPF) of 28.86 ±0.11 [31]. It is also used after overexposure to sunlight as a substance that relieves burns and skin irritation.

The presence of enzymes such as glutathione peroxidase and superoxide dismutase in aloe vera contributes to its antioxidant properties. Also, the content of vitamins C and E, flavonoids, carotenoids and tannins has a beneficial effect on reducing cellular exposure to oxidative stress and free radical uptake [22, 29]. Aloe extract, due to the aloein present, inhibits tyrosinase and melanin aggregation. These processes are necessary to alleviate the effects of excessive tanning, i.e. hyperpigmentation [32]. The complex composition of aloe vera pulp and its multidirectional actions make the plant a subject of undergoing research. Due to its beneficial properties and lack of adverse reactions, aloe vera is one of the frequently chosen raw materials to treat skin lesions, as well as for the treatment of many diseases [27].

The aim of the study was to establish the antioxidant activity of aloe vera leaf peel and flesh extracts in 4 short-chain alcohols, to evaluate extraction conditions including the effect of solvent used as extractant on observed antioxidant potential and to determine the absorption spectra of the obtained extracts from the pulp and peel of the aloe leaf.

MATERIALS AND METHODS

Reagents: 2.2-diphenyl-1-picrylhydrazyl (DPPH), diammonium 2,2'-azinobis[3-ethyl-2,3-dihydrobenzothiazole-6-sulphonate] (ABTS) were purchased from Sigma-Aldrich (USA), methanol, n-propanol and isopropanol, sodium persulphate, sodium carbonate anhydrous and ascorbic acid, all of analytic grade, were obtained from Chempur, Piekary Śląskie, whereas ethanol was from Linegal Chemicals, Warsaw. Folin–Ciocalteau reagent was from Merck, Darmstadt, Germany.

The raw material applied in the study came from a home-grown plant. The flesh and leaf peel of aloe vera were used to prepare the extracts in 4 short-chain alcohols, i.e. methanol, ethanol, n-propanol and isopropanol. Ultrasound-assisted extraction was applied. All the solvents were used in 3 concentrations: 40%, 70% and undiluted. Extracts were prepared as follows: to 0.5 g of raw material in a glass test tube 10 cm^3 of alcohol was added. The tubes were closed with a plastic stopper and put into the ultrasonic bath (Sonic 0.5, Polsonic) for 15, 30 or 60 min. This method is generally referred to as green extraction techniques due to low solvent consumption and shortened extraction time [33, 34]. After ultrasound-assisted extraction, the extracts were filtrated and thereafter were transferred into the plastic tube and tightly closed. These extracts were stored in a dark place at room temperature until analysis. A total of 72 extracts were prepared.

To determine the antioxidant activity of the obtained extracts, 2 methods, i.e. ABTS and DPPH based on spectrophotometric measurements were applied. The procedure was analogous to that described in previous works [35, 36]. Antioxidant activity evaluated using DPPH and ABTS methods is expressed as the percent radical scavenging activity [%RSA]. Calibration curves of antioxidant activity vs. ascorbic acid concentration were $y = 96.76x + 0.60$, $R = 0.994$ and $y = 30.63x + 1.93$, $R = 0.998$ for DPPH and ABTS methods, respectively. To evaluate the total polyphenols content Folin–Ciocalteu method was used according to previously published papers [37, 38]. The obtained results calculated from calibration curve ($y = 0.123x – 0.0047$; $R = 0.999$) are presented as ascorbic acid equivalents – AAE (mmol/dm^3). All the extracts were evaluated in triplicate.

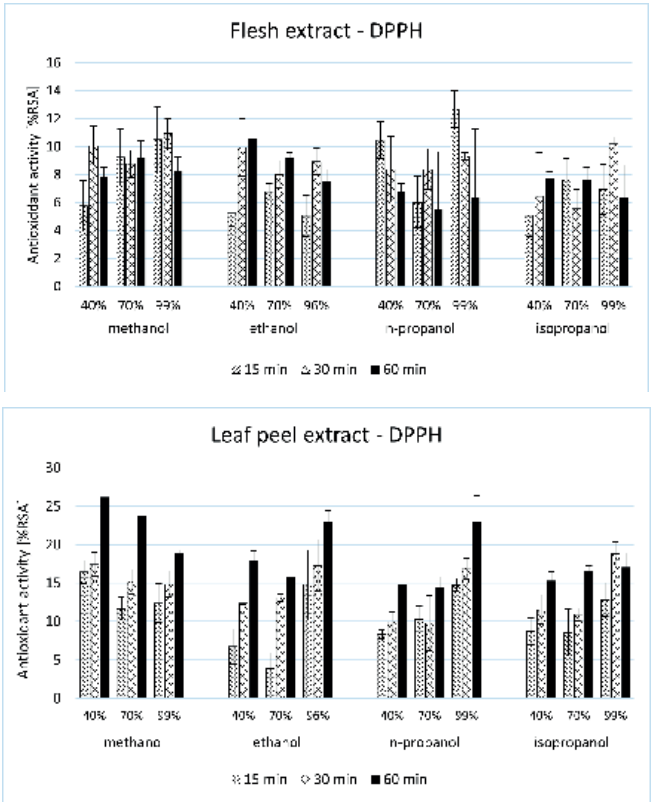
In order to assess the possibility of using aloe vera extracts to protect against UV radiation the absorption spectra in the range of 200–400 nm of the obtained extracts were also measured in order to evaluate their UV absorption capacity. For measurements, Spectroquant Pharo 300 spectrophotometer (Merck, Germany) was used. All the extracts, as mentioned previously, had a concentration of 5% (w/v). The results indicated the possibility of using the tested extracts to protect against UVA-UVB radiation.

Statistical analysis was done using the Excel program for Windows (Microsoft Office). The results are presented as arithmetic means ±standard deviation. To prepare calibration curves parameters of linear regression between antioxidant activity vs. ascorbic acid used as a standard and correlation coefficients were calculated.

RESULTS

Figure 1 presents the mean antioxidant activity evaluated with the DPPH method of flesh and leaf peel extracts obtained in 4 short-chain alcohols at 3 concentrations after ultrasound-assisted extraction of 15, 30 or 60 min. Among the tested raw materials, the peel of the aloe leaf showed the most favorable

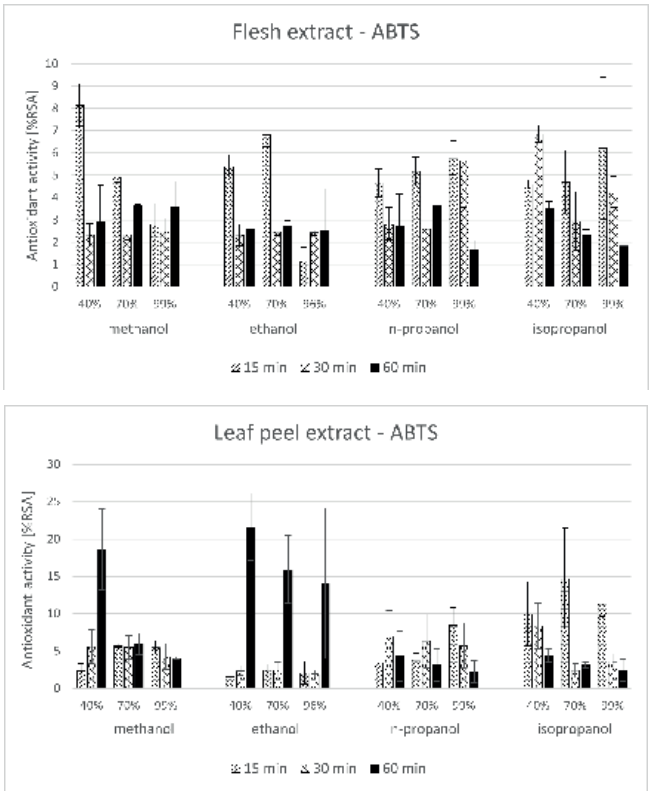
antioxidant properties. The highest antioxidant properties determined by the DPPH method were found in aloe vera leaf peel extracts obtained after 60-min ultrasonic extraction; however, slightly different results were observed in flesh extract – activities were generally lower. The lowest potential of the obtained extracts was found for aloe flesh extracts subjected to a 15-min ultrasonic-assisted extraction.



DPPH – 2.2-diphenyl-1-picrylhydrazyl; %RSA – percent radical scavenging activity

FIGURE 1. Antioxidant activity of flesh and leaf peel extracts in different alcohols obtained by ultrasound-assisted extraction (15, 30 or 60 min) evaluated by the DPPH method and expressed as %RSA. Vertical lines represent standard deviations

Figure 2 presents the mean antioxidant activity evaluated with the ABTS method of flesh and leaf peel extracts prepared in 4 short-chain alcohols at 3 concentrations after ultrasound-assisted extraction of 15, 30 or 60 min. Similarly to the DPPH method, the highest antioxidant properties determined by the ABTS method were found in aloe vera leaf peel extracts in ethanol obtained after 60-min ultrasonic extraction. In contrast to the DPPH method, the highest antioxidant activities for flesh extracts were generally observed after 15 min extraction.



ABTS – diammonium 2,2'-azinobis[3-ethyl-2,3-dihydrobenzothiazole-6-sulphonate]; %RSA – percent radical scavenging activity

FIGURE 2. Antioxidant activity of flesh and leaf peel extracts in different alcohols obtained by ultrasound-assisted extraction (15, 30 or 60 min) evaluated by ABTS method and expressed as %RSA. Vertical lines represent standard deviations

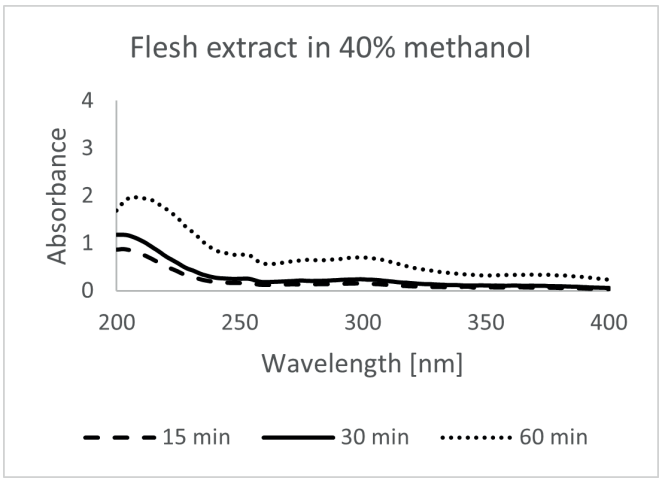
Table 1 contains mean (±standard deviation) total polyphenol contents evaluated using the Folin–Ciocalteu method in the extracts of leaf flesh and leaf peel prepared in 4 different short-chain alcohols at 3 different alcohol concentrations. The results are expressed as AAE (mmol/dm^3). In the majority of cases, a higher content of total polyphenols was observed in leaf peel extracts than in flesh extracts.

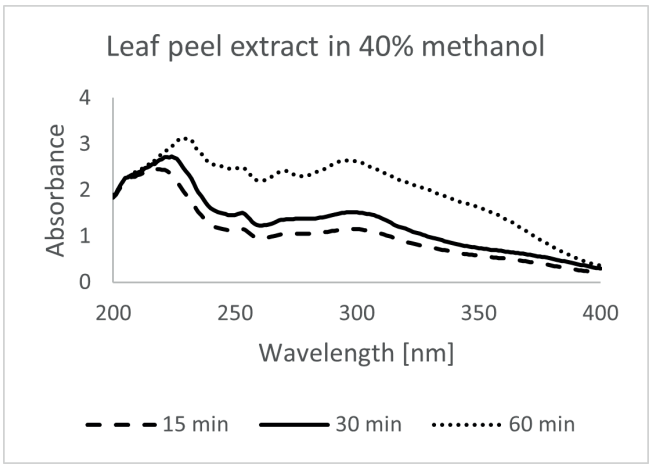
To evaluate the possibility of using aloe vera extracts to protect against UV radiation, the absorption spectra in the range of 200–400 nm of the obtained extracts in all the tested solvents were also measured. Figure 3 presents UV-VIS spectra of flesh and leaf peel extract in methanol of different concentrations obtained after 15 min (dashed line), 30 min (solid line) and 60 min (dropped line) ultrasound-assisted extraction, Figure 4 – similar spectra of ethanol extracts, while Figures 5 and 6 – spectra of extracts in n-propanol and isopropanol, respectively. All the spectra, particularly those of leaf peel extracts, show distinct clear absorbance in the long-wave UV, so certain extracts could be considered as a component of photoprotective preparations.

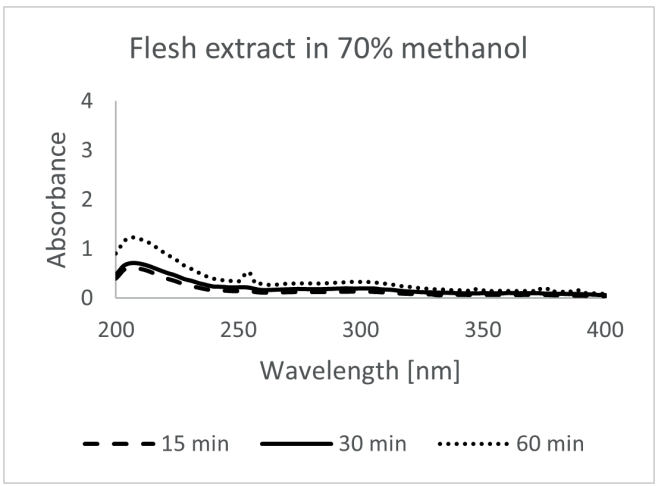
TABLE 1. Mean (± standard deviation) total polyphenol contents in extracts of different parts of *Aloe vera* evaluated using the Folin–Ciocalteu method and expressed as ascorbic acid equivalents

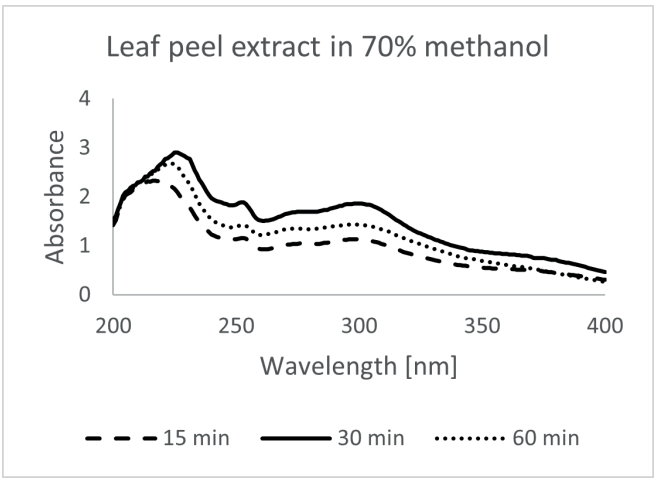
plant part analyzed	Total polyphenol content (AAE, mmol/dm³) determined using the F–C method				
	extractant		time of ultrasound-assisted extraction		
	solvent	concentration	15 min	30 min	60 min
Leaf peel	methanol	40%	0.294 ±0.025	0.324 ±0.110	0.102 ±0.014
		70%	0.229 ±0.162	0.264 ±0.053	0.115 ±0.020
		99%	0.132 ±0.053	0.262 ±0.092	0.167 ±0.047
	ethanol	40%	0.075 ±0.011	0.362 ±0.105	0.330 ±0.044
		70%	0.099 ±0.046	0.189 ±0.152	0.143 ±0.026
		96%	0.302 ±0.264	0.189 ±0.084	0.370 ±0.051
	propan-1-ol	40%	0.232 ±0.041	0.205 ±0.123	0.373 ±0.033
		70%	0.156 ±0.032	0.167 ±0.061	0.273 ±0.100
		99%	0.126 ±0.051	0.094 ±0.072	0.330 ±0.014
	propan-2-ol	40%	0.118 ±0.079	0.213 ±0.173	0.259 ±0.112
		70%	0.121 ±0.042	0.162 ±0.102	0.373 ±0.135
		99%	0.210 ±0.125	0.153 ±0.013	0.254 ±0.103
Leaf flesh	methanol	40%	0.240 ±0.080	0.178 ±0.140	0.248 ±0.097
		70%	0.115 ±0.081	0.175 ±0.118	0.251 ±0.010
		99%	0.283 ±0.115	0.186 ±0.043	0.107 ±0.061
	ethanol	40%	0.264 ±0.046	0.305 ±0.096	0.335 ±0.039
		70%	0.243 ±0.033	0.124 ±0.049	0.118 ±0.030
		96%	0.362 ±0.275	0.376 ±0.111	0.281 ±0.151
	propan-1-ol	40%	0.208 ±0.058	0.210 ±0.120	0.148 ±0.023
		70%	0.221 ±0.051	0.167 ±0.153	0.083 ±0.044
		99%	0.115 ±0.102	0.289 ±0.086	0.162 ±0.127
	propan-2-ol	40%	0.167 ±0.105	0.137 ±0.036	0.102 ±0.051
		70%	0.170 ±0.091	0.286 ±0.075	0.134 ±0.056
		99%	0.072 ±0.020	0.251 ±0.045	0.251 ±0.114

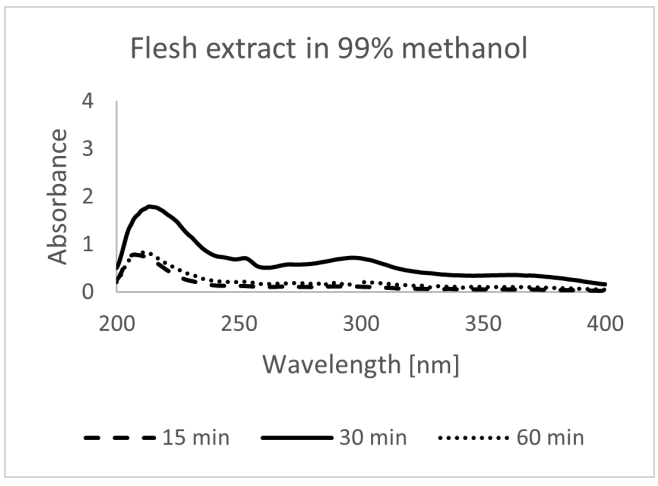
AAE – ascorbic acid equivalents; F–C – Folin–Ciocalteu











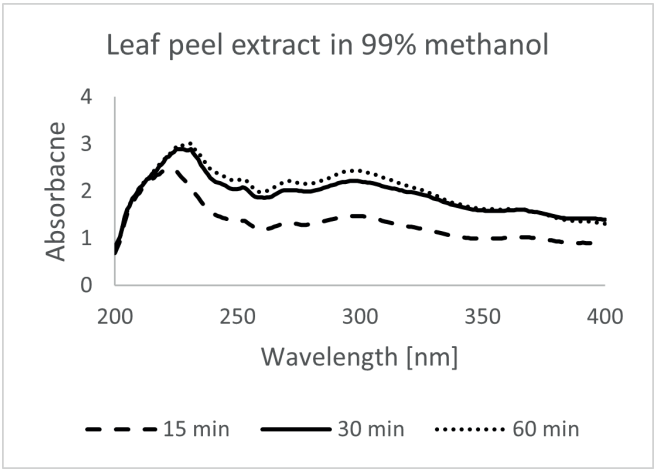


FIGURE 3. UV-VIS spectra of flesh and leaf peel extract in methanol of different concentrations obtained after 15 min (dashed line), 30 min (solid line) and 60 min (dropped line) ultrasound-assisted extraction

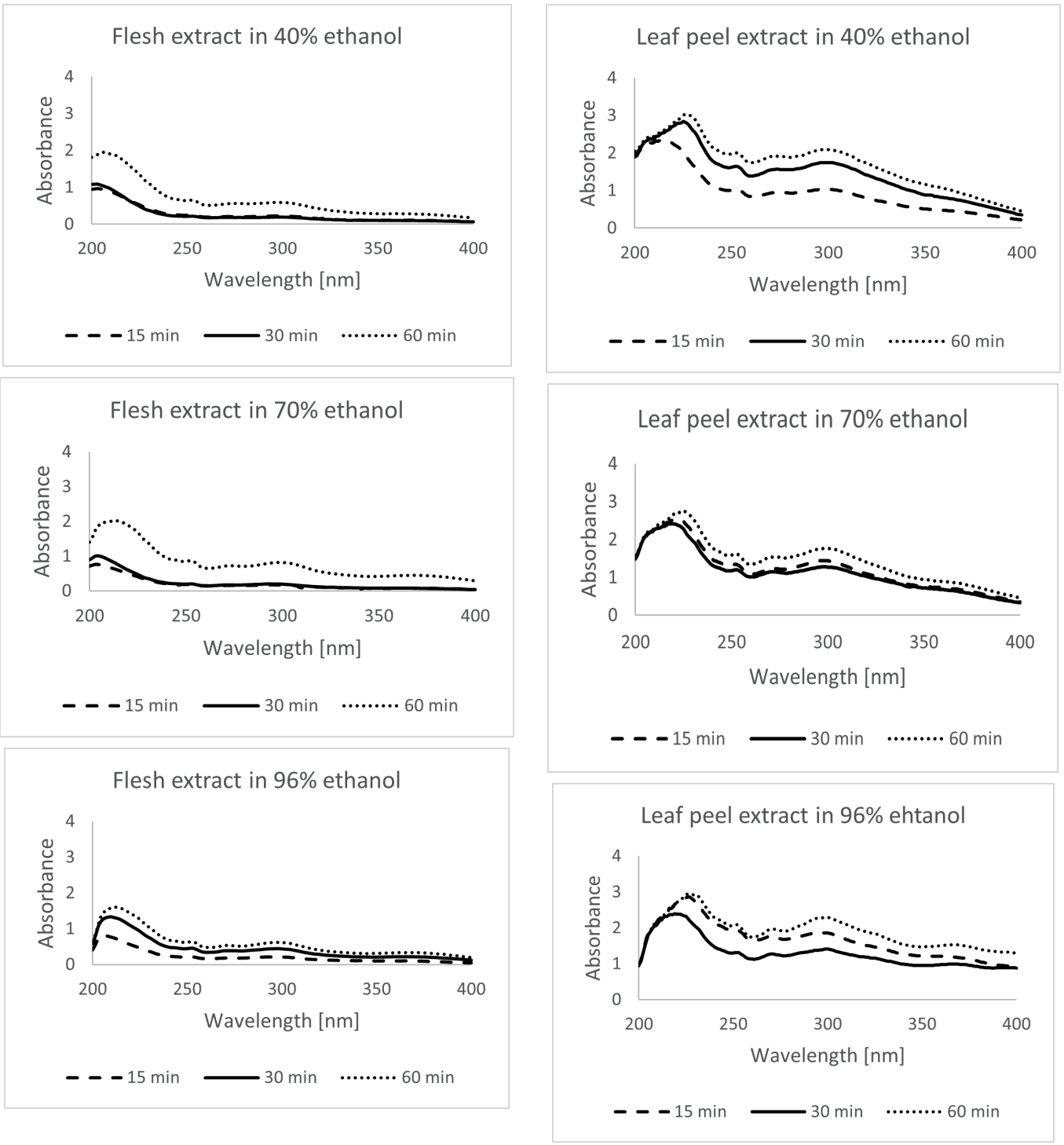


FIGURE 4. UV-VIS spectra of flesh and leaf peel extract in ethanol of different concentrations obtained after 15 min (dashed line), 30 min (solid line) and 60 min (dropped line) ultrasound-assisted extraction

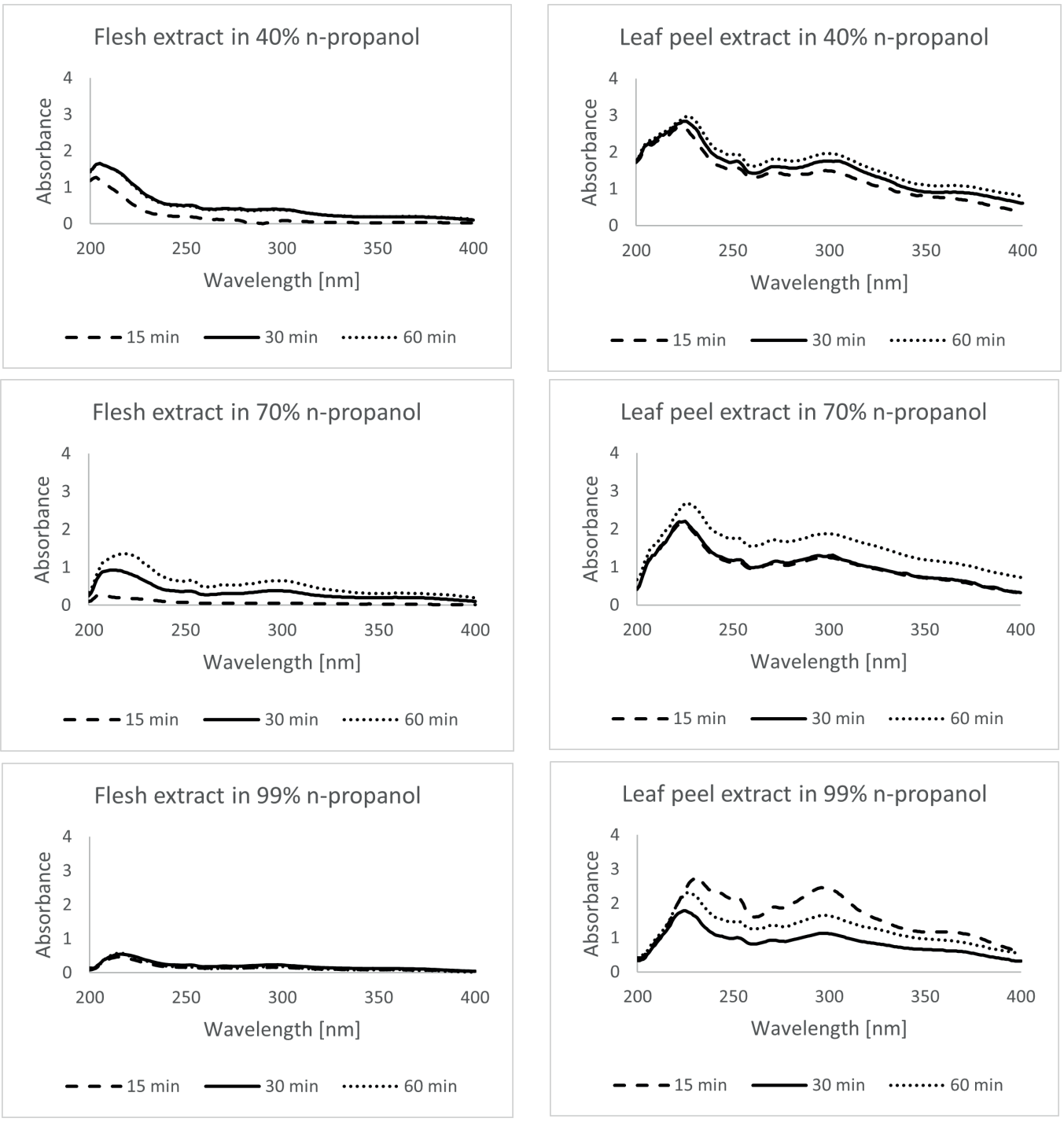


FIGURE 5. UV-VIS spectra of flesh and leaf peel extract in n-propanol of different concentrations obtained after 15 min (dashed line), 30 min (solid line) and 60 min (dropped line) ultrasound-assisted extraction

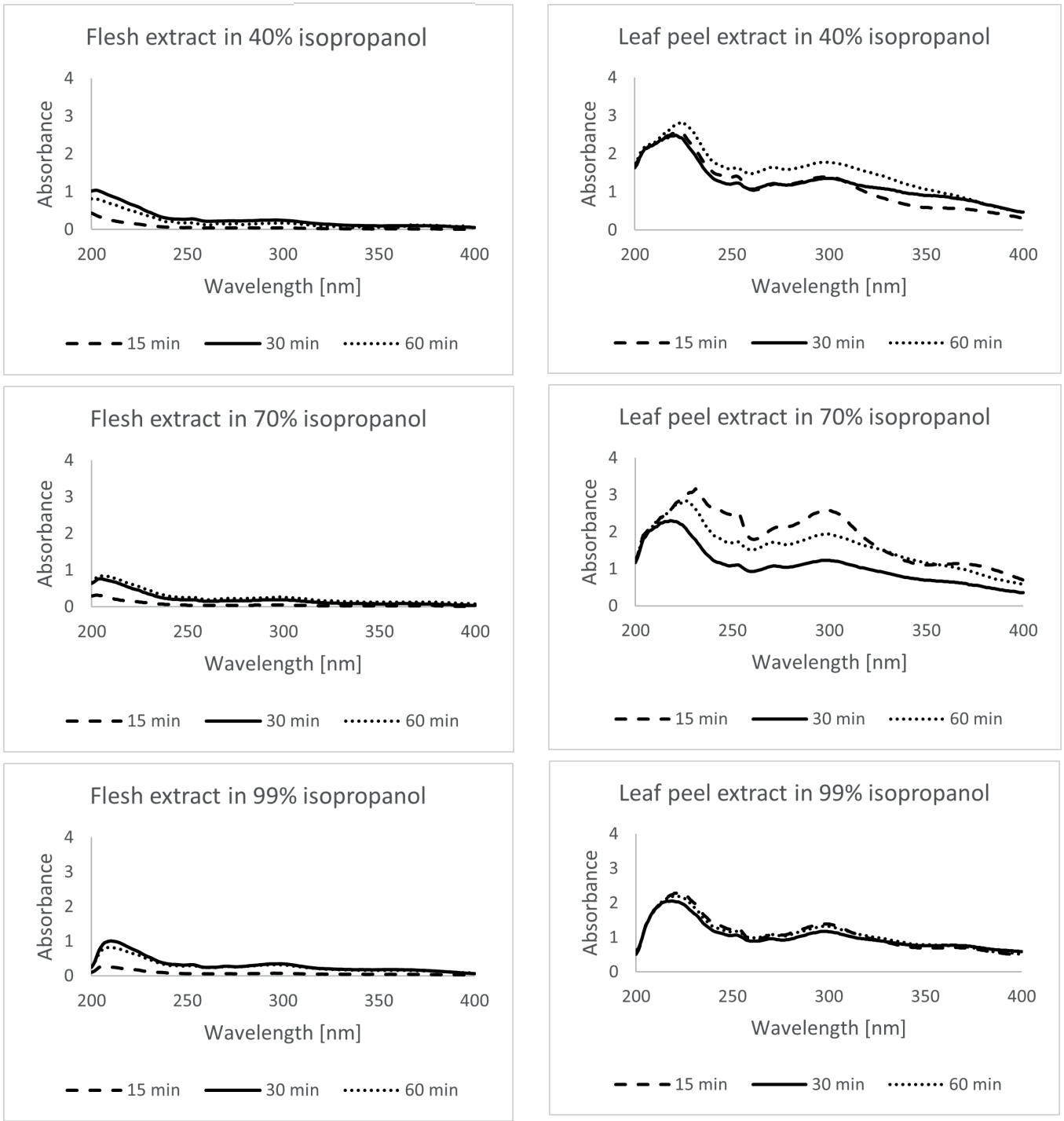


FIGURE 6. UV-VIS spectra of flesh and leaf peel extract in isopropanol of different concentrations obtained after 15 min (dashed line), 30 min (solid line) and 60 min (dropped line) ultrasound-assisted extraction

DISCUSSION

The ageing of the body is an inevitable and natural process. Internal and external factors influence changes in the structure of the skin [30]. Then, the epidermis becomes thinner, the skin becomes dry, the elasticity decreases, and deep and superficial wrinkles appear, which are the first and characteristic signs of ageing [8, 11]. Cosmetology is a constantly evolving field to meet the expectations of even the most demanding customers who want to slow down ageing and stay healthy for as long as possible. In anti-ageing prophylaxis, it is essential to know the factors that accelerate the process, as well as those that slow it down [7]. Factors that accelerate the ageing process include cigarette smoking, alcohol abuse, improper diet and skin care, environmental pollution, hormonal disorders and genetic predisposition.

Ultraviolet radiation is one of the most important factors affecting skin ageing [8, 9]. Overexposure to UV could lead to the formation of free radicals, as well as the occurrence of burns, which cause changes in the structure and functions of the skin. Excessive amounts of free radicals cause DNA damage, disrupt the body's homeostasis and have a destructive effect on the skin [12, 20]. To prevent the harmful effects of ROS, the body has developed the so-called antioxidant system to convert free radicals into inactive forms or to completely inhibit their formation [16, 39]. The line of protection is also made up of antioxidants, which are part of the antioxidant protective system. Their function is to capture and neutralize the action of free radicals. The most important antioxidants include vitamins A, C, and E, polyphenols and carotenoids.

Raw materials of plant origin, thanks to their beneficial ingredients, also protect the skin against the harmful effects of ROS. Cosmetic manufacturers constantly test plant parts in order to find the best formulation [40, 41]. In addition to formulations containing antioxidant ingredients, the daily use of UV filters is also important. They can be divided into physical and chemical filters, as well as those of natural origin. Their function is to absorb or reflect sunlight, prevent the formation of free radicals, and protect the skin against sunburn. The use of anti-ageing products and the use of professional treatments can significantly delay skin ageing [22, 23].

Interest in natural cosmetics continues to grow. Thanks to the wide access to products of natural origin, consumers have the opportunity to choose cosmetics that will meet their expectations. Aloe vera is a plant known for many years. It consists of 99% water, while the rest consists of more than 100 beneficial components, such as: polysaccharides, vitamins, amino acids, polypeptides, minerals, fatty and organic acids, saponins and enzymes [26, 27, 28]. Aloe vera is primarily known for its strong anti-inflammatory and regenerative effects. It also exhibits moisturizing, antibacterial, antiviral, antifungal and antiseptic properties. It is readily used in formulations by cosmetic manufacturers and successfully used by consumers. It is used in anti-ageing prevention for its antioxidant and photoprotective effects [22, 28]. Despite many studies, aloe vera still surprises and continues to arouse considerable interest. It is a very popular and widely available plant nowadays, thus it has aroused a desire to conduct research to evaluate selected properties that could be useful in cosmetic preparations.

In this paper, the antioxidant potential of extracts from the peel of the aloe leaf and its pulp depending on the time of ultrasound-assisted extraction was evaluated. The study made it possible to compare the antioxidant activity of the prepared extracts. The 2 most characteristic methods, i.e. DPPH and ABTS were used to estimate antioxidant potential, while the total polyphenol content was determined using the Folin–Ciocalteu method.

The highest antioxidant activity of aloe leaf peel extracts evaluated by the DPPH method and the highest polyphenol content determined by the Folin–Ciocalteu method were shown by the majority of samples subjected to a 60-min extraction (Fig. 1, Tab. 1). The highest antioxidant activity of aloe vera flesh extracts evaluated by the ABTS method was shown mainly by samples subjected to 15-min extraction (Fig. 2), while in the DPPH and Folin–Ciocalteu methods was shown by most samples extracted for 30 min (Tab. 1, Fig. 1). For aloe vera leaf peel extracts tested by the DPPH and ABTS methods, the best solvent seemed to be 40% methanol, while in the Folin–Ciocalteu method it was 96% ethanol. For aloe vera flesh extracts evaluated by the DPPH method, the best solvents were undiluted alcohols (Fig. 1), whereas for extracts evaluated by the ABTS method it was 40% methanol (Fig. 2), and for the determination of total polyphenol content it was 96% ethanol. If compared to the evaluated parts of the plant studied, aloe leaf peel showed the most favorable antioxidant properties of the raw materials used.

Khaing presented the results of the study on the antioxidant activity of aloe vera evaluated using the DPPH method. Fresh aloe vera leaves were used to prepare extracts, which were initially washed with distilled water, dried, and then ground into powder. The powder was extracted with 95% ethanol at 90°C for 6 h and evaporated to a concentrated extract. The leaf extract thus concentrated was used for further tests. The prepared raw material was dissolved in methanol, ethanol and ethyl acetate. Antioxidant activity was determined according to the spectrophotometric DPPH method. One mL of various concentrations of aloe extracts (5, 10, 15, 20 and 25 µg/mL) were mixed with 2 mL of freshly prepared purple DPPH solution (0.01 mM). Each sample was mixed thoroughly and kept at room temperature for 30 min and then tested for DPPH radical neutralizing activity by reading the absorbance at 517 nm. Based on the results of the study, it was concluded that methanolic extracts of aloe vera evaluated by the DPPH method were the most effective in scavenging free radicals [42].

Hu et al. determined the concentration of polysaccharides and flavonoids of 2-, 3- and 4-year-old aloe vera. Ethanol extracts were prepared from aloe vera. Their antioxidant activity evaluated with the DPPH method was compared with butylated hydroxytoluene (BHT, antioxidant) and α-tocopherol. All aloe vera extracts showed significant antioxidant activity. The results showed that the 3-year-old aloe contained significantly higher levels of polysaccharides and flavonoids than the

2- and 4-year-old plants. The antioxidant activity was as follows: 3-year-old aloe > BHT > 4-year-old aloe > α-tocopherol > 2-year-old aloe. These studies suggested that the antioxidant activity and active ingredient levels of aloe vera were influenced by its growth phase [43].

The work of Moniruzzaman et al. also drew attention to the use of aloe vera as a potential antioxidant ingredient. Fresh and fleshy aloe leaves were extracted with 80% ethanol, and then their activity was tested. It has been observed that ethanol extracts from aloe leaf peel contain phenolic compounds and a high content of flavonoids. These extracts showed a high ability to scavenge DPPH radicals and to reduce iron(III) ions, as determined by the ferric ion reducing antioxidant parameter (FRAP) method. Aloe gel extracts also showed significant antioxidant properties, but they were lower than those of extracts of aloe leaf peel [44].

Mailadi and Damak highlighted the antioxidant activity of aloe vera depending on the solvent used and the method carried out. An ethanolic extract of aloe vera leaf peel was prepared and fractionated by liquid-liquid separation using hexane, ethyl acetate, chloroform–ethanol and butanol. The total polyphenols content of the 4 different fractions was determined using the Folin–Ciocalteu method, and their antioxidant potential was tested using some *in vitro* models, such as antioxidant capacity using the phosphomolybdenum method, β-carotene bleaching method and RSA using the DPPH method. The presented results proved that the chloroform–ethanol fraction showed the highest phenol content and the highest radical scavenging and reduction activity [45].

In addition to determining the antioxidant properties, the absorption spectra of the prepared extracts from the peel and pulp of the aloe leaf were also collected in the present work. The spectra made it possible to assess whether aloe vera is a raw material capable of absorbing UV radiation. The obtained results indicated that the absorption maximum was found around 300 nm, which corresponds to the range of UVB radiation (280–320 nm). In order to determine the SPF of studied aloe extracts, further research is required. Napagoda et al. used aloe vera leaf extract as a control while examining the photoprotective capacity of medicinal plants. The aloe vera extract was exposed to sunlight for 21 days. Sun protection factor values were determined after 7, 14 and 21 days. The obtained results showed that aloe vera extracts were photostable and showed an SPF of about 29 [31].

Based on the presented as well as other studies, it can be concluded that aloe vera exhibits antioxidant properties. Moreover, the wavelengths of absorbed radiation corresponding to the UVB range indicate that this raw material can also be used as a potential photoprotective agent, which is essential for proper skin care. The presented study was based on the use of extracts from the peel of the aloe leaf or its pulp. Methanolic extracts showed the highest antioxidant potential in the majority of cases. Despite many scientific reports on the health-promoting properties of aloe vera, the plant is still of great interest. Consumers appreciate aloe vera due to its strong moisturizing and regenerative properties; however, its antioxidant and photoprotective effects should also be taken into account. Cosmetic manufacturers should include such information on the label of a product to increase knowledge and awareness among users. Aloe vera can be used as a base in cosmetics, which will increase the beneficial effects of the entire formulation. Aloe vera is a safe raw material that retards the skin ageing process and could be applied in cosmetic preparations.

CONCLUSIONS

1. Aloe vera is a valuable source of antioxidant compounds.
2. Ultrasound-assisted extraction is a useful method to isolate antioxidant substances from plant material.
3. The antioxidant potential of the extracts is influenced by the extraction time of the raw material and the solvent used. The antiradical activity of the obtained extracts increased with the extraction time.
4. Aloe vera leaf peel extracts showed higher antioxidant activity than extracts prepared from its flesh.
5. The tested raw material can be successfully used as a component of anti-ageing preparations and as a potential photoprotective agent.

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