KOREAN J. FOOD SCI. TECHNOL. Vol. 52, No. 6, pp. 627~631 (2020)
https://doi.org/10.9721/KJFST.2020.52.6.627

KOREAN JOURNAL OF
한국식품과학회지
FOOD SCIENCE AND TECHNOLOGY

Nutritional value and antioxidant potential of lemon seed and sprout

Yong-Sung Park[1], Sanjeev Kumar Dhungana[2], Il-Doo Kim[3], and Dong-Hyun Shin[1,]*
[1]*School of Applied Biosciences, Kyungpook National University*
[2]*Department of Southern Area Crop Science, National Institute of Crop Science, Rural Development Administration*
[3]*International Institute of Agricultural Research and Development, Kyungpook National University*

Abstract High amounts of lemon seeds are discarded as by-products of processing industries. It is important to find some measures, whereby they could be used in value-added ways. Although few studies have been conducted on lemon seed oils, no study has been conducted on the nutrient content of lemon seed sprouts. The objective of this study was to investigate the nutritional value and antioxidant potential of lemon seeds and sprouts. The 1,1-diphenly-2-picrylhydrazyl radical-scavenging potential, total polyphenol, and total free amino acid content were higher in the sprouts than in the seeds. Similarly, the content of such mineral elements as Fe, Na, and Zn, increased with germination. However, salicylic acid and total mineral content were lower in the sprouts than in the seeds. The results indicate that lemon seeds and sprouts could be regarded as high-value materials in food and cosmetic industries.

Keywords: antioxidant potential, cosmetic industry, lemon seed, nutritional value, sprout

Introduction

Lemon (*Citrus limon*) is a major cultivated citrus species, with a global annual production of 7.3 million tons (M'hiri et al., 2018). In addition to its fresh consumption, a large volume of lemon is processed to juice, lemonade, and dried lemon slices (Besil et al., 2019), which subsequently produces a significant amount of by-products (peels, seeds, and pulps) that is approximately 50% of the total lemon weight (Russo et al., 2014). Disposal of this large volume of by-products could pose environmental problems (Sharma et al., 2017). Lemon peels are utilized for obtaining fibers, pectin, essential oils, and polyphenol (Fidalgo et al., 2016; Gómez-Mejía et al., 2019; Willemsen et al., 2018). Lemon seeds are mainly used for oil extraction; however, recently, a study revealed its potential use in the extraction of cellulose nanocrystals (Zhang et al., 2020). It is important to explore other efficient techniques in order to widen the utilization of waste seeds for producing valuable products.

Lemon seeds could be utilized in producing cosmetic products, since they are rich in phenolic compounds and have considerable antioxidant activity (Falcinelli et al., 2020). In addition, lemon has also been recommended in the European Commission's Cosmetic Ingredients Database (CosIng Database) as a valuable plant for cosmetics production. Limonoids and flavonoids present in the methanolic extract of lemon seeds show a chemopreventive property against breast cancer (Kim et al., 2012).

Germination is one of the inexpensive methods to improve the nutrient content and antioxidant potential of seeds (Boulter and Barber, 1963; Cevallos-Casals and Cisneros-Zevallos, 2010; Desmaison and Tixier, 1986; Fernandez-Orozco et al., 2008). In addition to modification of existing nutrients, germination also releases new components (Spanier et al., 2001). There are very few studies conducted on lemon seed sprouts. A recent study by Falcinelli et al. (2020) analyzed the phenolic compounds and antioxidant activity of lemon seed sprouts. In this study, in addition to the assessing the phenolic content and antioxidant potential, we aimed to analyze the nutritional value of lemon seed and sprouts that could provide useful information on the application of lemon seeds.

Materials and Methods

Seed materials and sprouting

Lemon (Florida, Meyer, *Citrus limon* Burm. f.) fruits were purchased from a local store in Daegu, Korea. Seeds were separated from fruits and intact seeds were thoroughly washed with tap water and kept for sprouting. Lemon sprouts were produced using sprout cultivators (Chungsiroo SC-9000A, Shinchang Inc., Osan, Korea). The seeds and sprouts were automatically watered for 15 min every 2 h. The sprouting was carried out at room temperature (19±4°C) for 20 d. One hundred seeds or sprouts were sampled at 0, 10, and 20 d for analysis. The samples were named as LS-0 (day 0), LS-10 (lemon spouts harvested at 10 d) and LS-20 (lemon spouts harvested at 20 d). The samples were freeze-dried and were ground into a powder using a commercial grinder (Speed Rotor Mill, Model KT-02A, Seishin, Fukuoka, Japan). The powdered samples were packed into airtight sample bottle and stored at −20°C until analysis.

---

*Corresponding author: Dong-Hyun Shin, School of Applied Biosciences, Kyungpook National University, Daegu 41566, Korea
Tel: +82-53-950-5707
Fax: +82-53-950-6880
Email: dhshin@knu.ac.kr

Received October 15, 2020; revised December 1, 2020;
accepted December 1, 2020

Sample powder preparation and extraction

The intact seeds (LS-0) and freshly harvested whole sprouts (LS-10 and LS-20) containing cotyledons, hypocotyl, and roots were kept at –70°C for 24 h before freeze-drying. The lyophilized samples were ground into powder using an electrical grinder (HIL-G-501, Hanil Co., Seoul, Korea) and filtered through a 100-mesh sieve.

The sample powder (1 g) was extracted for 2 h with absolute methanol (10 mL) using a shaking incubator (250 rpm, 25°C). The mixture was centrifuged (1660×*g*, 10 min) using a centrifuge (Gyro-406G, Gyrozen Co., Daejeon, Korea) and the obtained supernatant was filtered through a syringe filter (0.2 μm). The filtrate extract was used for 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging activity and total polyphenol assays.

Analysis of DPPH radical-scavenging activities

The DPPH free radical-scavenging potential of the samples was analyzed as described in earlier reports (Blois, 1958; Dhungana et al., 2015). In brief, an equal volume (100 μL) of the sample extracts and freshly prepared methanolic solution (0.05%, w/v) of DPPH was mixed into a 96-well microplate and incubated at room temperature for 30 min under dark condition. After 30 min of incubation, absorbance of the reaction mixtures was measured at 517 nm using a microplate reader (Multiskan GO, Thermo Fisher Scientific Inc., Vantaa, Finland).

Total polyphenol content analysis

Total polyphenol content (TPC) of samples was determined according to the Folin-Ciocalteau method (Singleton et al., 1999) as explained in a previous report (Dhungana et al., 2016). In brief, 50 μL of sample extracts were mixed with 1 mL 2% (w/v) aqueous sodium carbonate and was allowed to react at room temperature for 3 min, followed by addition of 50 μL 1 N Folin-Ciocalteau reagent. A microplate spectrophotometer (Multiskan GO; Thermo Fisher Scientific) was used to measure the absorbance of the reaction mixtures at 750 nm. TPC content in the samples was determined as gallic acid equivalent (GAE).

Salicylic acid analysis

Salicylic acid (SA) was determined according to a previous report (Seskar et al., 1998). The powdered sample (0.2 g) was extracted with absolute methanol and then centrifuged at 10,000×*g* for 20 min. The extracts were dried using a vacuum centrifuge and the dry pellets were dissolved in 2.5 mL trichloroacetic acid (5%). The mixture was vortexed with a solution of ethyl acetate: cyclopentane:isopropanol (49.5:49.5:1, v/v) and the top organic layer was transferred into a vial and then dried using nitrogen gas. SA was determined using high-performance liquid chromatography (HPLC) (Shimadzu, Japan) connected with a fluorescence detector (Shimadzu RF-10AxL) and a C18 reverse-phase HPLC column (HP Hypersil ODS, particle size 5=μm, pore size=120-A°; Waters). The conditions for HPLC were as follows: excitation and emission wavelengths were 305 and 365 nm, respectively; the flow rate was 1 mL/min; Solvent A: 100% MeOH; Solvent B: 100% water in 0.5% acetic acid; gradient (A%/B%): (30/70) 5 min→(40/60) 2.5 min→(60/40) 4.5 min→(30/70) 5 min→(30/70) 3 min.

Determination of mineral content

The mineral content of seed and sprout samples was quantified using an inductively coupled plasma atomic emission spectrometer (ICP AES: Varian Vista, Victoria, Australia) accordint to a previously described method (Skujins, 1998). In brief, 0.5 g sample powder was digested in a mixture of 65% nitric acid (15.0 mL) and 35% hydrogen peroxide (2 mL), followed by addition of an equal volume of distilled water. The mineral content of the samples was determined after calibrating the instrument with known standards.

Identification of free amino acid profile

Free amino acid composition was analyzed according to the method described by Je et al. (2005). In brief, 1.5 g sample powder was homogenized at 12,000 rpm for 2 min with 10 mL ice-cold perchloric acid (6%, v/v) using a homogenizer (Ace, Nissei AM-7, Nihonseikei Kaisha Ltd., Tokyo, Japan) and then incubated in ice for 30 min. The incubated mixture was centrifuged at 2,000×*g* for 15 min and the obtained supernatant was filtered through a filter paper (Whatman No. 41). The pH of the filtrate was adjusted (7.0) with potassium hydroxide solution (33%, w/v) and centrifuged at 2,000×*g* for 10 min in order to remove the precipitates. The pH of the supernatant was adjusted (2.2) with 10 M HCl and then distilled water was added to make up the final volume to 50 mL. The profile of free amino acids was determined using an automatic amino acid analyzer (Biochrom-20, Pharmacia Biotech Co., Uppsala, Sweden).

Statistical analysis

The data were analyzed by analysis of variance using SAS 9.4 (SAS Institute, Cary, NC, USA). Significant differences among treatments were identified using Tukey's test ($p \le 0.05$). An average value of two replicates was reported.

Results and Discussion

Antioxidant potential

The DPPH radical-scavenging and Total polyphenol content (TPC) of LS-20 were significantly higher than those of LS-0 and LS-10 (Table 1). The TPC of LS-20 (3.75 mg GAE/g dry weight, DW) was 55.6% higher than that of LS-0 (2.41 mg GAE/g DW).

The higher DPPH radical-scavenging potential of LS-20 was expected, since the germination of seed is supposed to increase the antioxidant potentials (Cevallos-Casals and Cisneros-Zevallos, 2010; Falcinelli et al., 2020; Fernandez-Orozco et al., 2008). The higher antioxidant potential of sprouts may be attributed to their higher TPC. The sprouts grown for 20 d (LS-20) had less TPC than that found in a previous study (Falcinelli et al., 2020), in which sprout was grown for 8 weeks. This difference in TPC of the sprout indicated that phenolic content may increase with sprouting period of lemon seed. In addition, the variation may be attributed to genotypes and seed ripening stage (Falcinelli et al., 2018, 2017; Moulehi et al., 2012).

Lemon seeds and sprouts could be used to manufacture

Table 1. Changes in DPPH radical-scavenging activities, total polyphenol, and salicylic acid content of lemon seeds during germination

Sample1)	DPPH (% Inhibition)	Total polyphenol (mg GAE 2))/g of dry weight	Salicylic acid (ng/g dry weight)
LS-0	92.57±0.603)b	2.41±0.01b	13.60±0.122)a (100%)4)
LS-10	92.42±0.61b	2.52±0.05b	7.21±0.15b (47%)
LS-20	94.22±0.41a	3.75±0.05a	6.67±0.12c (51%)

1)LS-0, lemon seeds; LS-10, lemon seeds germinated for 10 days; LS-20, lemon seeds germinated for 20 days.
2)GAE, gallic acid equivalent.
3)Values are expressed as mean±standard deviation of two replicates. Values with different letters within a column indicate significant difference ($p \le 0.05$).
4)Percentage change on the basis of LS-0.

Table 2. Changes in mineral content (mg/kg of dry weight) of lemon seeds during germination

Element	Sample 1)		
	LS-0	LS-10	LS-20
Ca	2,422.54±13.752)a	2,314.70±34.95a	2,352.41±26.53a
Cu	16.23±0.04a	112.66±0.06c	13.50±0.08b
Fe	67.02±0.07c	75.08±0.57b	92.53±0.06a
K	9,147.49±30.93a	8,817.15±98.81b	8,718.21±61.80b
Mg	1,780.92±40.50a	1,750.84±45.09a	1,787.03±31.05a
Mn	10.34±0.03a	10.59±0.09a	10.42±0.06a
Na	260.60±0.45c	350.20±3.55b	448.97±5.34a
Zn	64.21±0.43c	74.29±0.78b	80.22±0.38a
Total	13,769.35	13,431.22	13,503.29

1)Samples are defined in Table 1.
2)Values are expressed as mean±standard deviation of duplicate experiments. Values with different letters within a column indicate significant difference ($p \le 0.05$).

cosmetic products and/or as food additives. Most skin care formulations are supplied with antioxidants that may help scavenge reactive oxygen species (ROS) and prevent or improve oxidative damage-related signs of aging (Athawale et al., 2011; Dreher and Maibach, 2000). Moreover, most anti-aging skin care formulations claim that antiaging effects are credited to the antioxidants present in the formulations, but cannot be synthesized in the human body (Montenegro, 2014). Antioxidant-rich foods may impede skin aging in adults aged more than 45 years (Hughes et al., 2020).

Salicylic acid content

The SA content of the samples significantly reduced with the germination duration, with the highest value recorded for LS-0 (Table 1). The SA content of lemon seeds was reduced by 47 and 51% in LS-10 and LS-20, respectively.

The gradual reduction in SA content in LS-10 and LS-20 might be due to the physiological changes that take place during germination (Lee et al., 2010; Rajjou et al., 2006; Yanik et al., 2018). The SA content in skin care formulations was beneficial in whitening of skin (Ahn and Kim, 2006), reducing DNA damage, cell formation of sunburn (Kornhauser et al., 2009), suppressing of pain (Steen et al., 1995), and enhancing the anti-melasma effect of parent drugs (Hsieh et al., 2014). In another study by Lo'ay and Taher, (2018), SA-added edible coating of chitosan/poly-vinyl-pyrrolidine showed reduced browning in guava fruit skin, thus indicating the role of SA in food preservation.

Mineral content

The total mineral content of sprouts (13,431.22-13,503.29 mg/kg) was lower than that of seeds (13,769.35 mg/kg) (Table 2). However, some mineral elements, such as Fe, Na, and Zn, were higher in sprouts than in the seeds. K was the most abundant mineral in the samples, followed by Ca, Mg, and Na.

The variation in mineral elements might be affected by germination time, species, and kinds of water among others. The amount of Fe was higher in rapeseeds, small radish seeds, and white mustard seeds than in their sprouts whereas the amount of Ca and Zn was higher in the sprouts than in the seeds (Zieliñski et al., 2005).

Human diets, in general, lack a few elements such as Fe, Zn, Cu, Ca, and Mg (White and Broadley, 2009). Minerals such as Mg, K, and Ca are useful against hypertension (Houston and Harper, 2008). Fe plays a major role in oxygen transport, energy metabolism, mitochondrial respiration, DNA synthesis, and cellular growth and differentiation (Ganz, 2013). Zn contributes to growth, development, differentiation, DNA synthesis, RNA transcription, and cellular apoptosis (MacDiarmid, 2000). Mineral-rich food products, such as lemon seeds and sprouts, may be used for food fortification as do bamboo shoots (Chongtham et al., 2020).

Free amino acid composition

Germination substantially increased the total free amino acid content of lemon seeds (Table 3). However, the amount of certain

Table 3. Change in free amino acid composition (mg/g of dry weight) of lemon seeds during germination

Amino acid	Sample 1)		
	LS-0	LS-10	LS-20
Essential amino acid			
Histidine	0.357 2)	1.014	6.034
Isoleucine	1.072	1.164	6.127
Leucine	1.766	1.400	7.058
Lysine	1.469	1.434	5.045
Methionine	0.743	0.472	0.566
Phenylalanine	1.333	1.769	8.688
Threonine	1.061	1.584	8.403
Valine	1.16	1.553	12.259
Sub-total	8.961	10.390	54.180
Non-essential amino acid			
Alanine	2.523	7.753	10.791
Arginine	3.571	7.714	22.434
Aspartic acid	1.633	6.719	12.310
Glutamic acid	2.021	10.033	8.150
Glycine	1.363	1.073	3.588
Proline	6.763	14.718	16.846
Serine	2.149	6.393	18.995
Tyrosine	0.947	1.845	5.030
Sub-total	20.970	56.248	98.144
Other amino acid			
1-Methylhistidine	ND 3)	ND	ND
3-Methylhistidine	0.043	ND	ND
Anserine	ND	ND	ND
Carnosine	0.068	ND	ND
Citrulline	ND	ND	ND
Cystathionine	ND	ND	0.104
Cystine	ND	ND	1.745
Ethanol amine	1.775	1.093	1.502
Hydroxy proline	0.052	ND	0.185
Hydroxylysine	ND	ND	ND
Ornithine	ND	ND	ND
Phospho ethanol amine	ND	ND	ND
Phosphoserine	ND	ND	ND
Sarcosine	0.07	ND	ND
Taurine	ND	ND	ND
Urea	ND	ND	ND
α-Amino adipic acid	ND	ND	0.384
α-Amino-n-butyric acid	0.032	0.110	0.321
β-Alanine	0.782	0.374	0.582
β-Amino isobutyric acid	0.561	0.142	0.265
γ-Amino-n-butyric acid	12.96	6.175	7.412
Sub-total	16.343	7.894	12.500
Grand total	46.274	74.532	164.824

1)Samples are defined in Table 1.
2)Values are expressed as mean of duplicate experiments.
3)ND, non-detectable.

essential and non-essential amino acids, such as leucine, lysine, methionine, and glycine, were higher in seeds than in sprouts. A total of 21 free amino acids were detected whereas the amounts of nine amino acids were non-detectable in all samples.

Typically, germination increases amino acid content of the germinating seeds because the reserved proteins of the seeds are hydrolyzed to synthesize free amino acids, which are then interconverted and used for the biosynthesis of new compounds (Boulter and Barber, 1963). Similar results of increased amino acids in germinated seeds were found in peanut (Wang et al., 2005) and red bean (Mun et al., 2020).

Amino acids are the building blocks of proteins and they function as the nitrogenous backbones for vital compounds including neurotransmitters and hormones. The essential amino acids must be exogenously supplied through diets since they cannot be synthesized *de novo* by an organism as per requirements. Inadequate supply of essential amino acids may cause severe clinical disorders such as kwashiorkor and marasmus (Coward and Lunn, 1981).

Amino acids are also among the key ingredients of skin care formulations, since they play important roles in promoting a beautiful skin. For instance, arginine helps to restore visible skin damage; histidine soothes the skin and has antioxidant properties; methionine protects the skin from harmful substances; lysine strengthens the skin's surface; and proline, leucine, and glycine make fine lines and wrinkles less deep.

Conclusion

The DPPH radical-scavenging potential and Total polyphenol content (TPC) were higher in the seeds than in the sprouts. However, Salicylic acid (SA) was lower in the sprouts than in the seeds. The amount of certain mineral elements, such as Fe, Na, and Zn, increased with germination; however, the total mineral content was higher in the seeds. The free amino acid content of sprouts was substantially higher than that of the seeds. Both the seeds and sprouts of lemon exhibited their potential applications as a high-value material in food and cosmetic industries.

Acknowledgments

This study was supported by the Research Fund, 2020 of Kyungpook National University, Daegu, Korea.

Conflict of interest

The authors declare no conflict of interest.

References

Ahn HH, Kim I-H. Whitening effect of salicylic acid peels in asian patients. Dermatol. Surg. 32: 372-375 (2006)

Athawale R, Salavkar S, Tamanekar R. Antioxidants in skin ageing-Future of dermatology. Int. J. Green. Pharm. 5: 161 (2011)

Besil N, Rezende S, Alonzo N, Cesio MV, Rivas F, Heinzen H. Analytical methods for the routinely evaluation of pesticide residues in lemon fruits and by products. SN Appl. Sci. 1: 618 (2019)

Blois MS. Antioxidant determinations by the use of a stable free radical. Nature 181: 1199-1200 (1958)

Boulter D, Barber JT. Aminoacid metabolism in germinating seeds of *Vicia faba* L. in relation to their biology. New Phytol. 62: 301-316 (1963)

Cevallos-Casals BA, Cisneros-Zevallos L. Impact of germination on phenolic content and antioxidant activity of 13 edible seed species. Food Chem. 119: 1485-1490 (2010)

Chongtham N, Bisht MS, Bajwa HK, Santosh O, Indira A. Mineral elements in bamboo shoots and potential role in food fortification. J. Food Compos. Anal. 103662 (2020)

Coward WA, Lunn PG. The biochemistry and physiology of kwashiorkor and marasmus. Br. Med. Bull. 37: 19-24 (1981)

Desmaison AM, Tixier M. Amino acids content in germinating seeds and seedlings from *Castanea sativa* L. Plant Physiol. 81: 692-695 (1986)

Dhungana SK, Kim B-R, Son J-H, Kim H-R, Shin D-H. Comparative study of *CaMsrB2* gene containing drought-tolerant transgenic rice (*Oryza sativa* L.) and non-transgenic counterpart. J. Agron. Crop. Sci. 201: 10-16 (2015)

Dhungana SK, Kim I-D, Kwak H-S, Shin D-H. Unraveling the effect of structurally different classes of insecticide on germination and early plant growth of soybean [*Glycine max* (L.) Merr.]. Pestic. Biochem. Physiol. 130: 39-43 (2016)

Dreher F, Maibach H. Protective effects of topical antioxidants in humans. pp. 157-164. In: Current Problems in Dermatology. Thiele J, Elsner P (eds). Basel, Karger (2000).

Falcinelli B, Famiani F, Paoletti A, D'Egidio S, Stagnari F, Galieni A, Benincasa P. Phenolic compounds and antioxidant activity of sprouts from seeds of citrus species. Agriculture 10: 33 (2020)

Falcinelli B, Maranghi S, Paoletti A, Marconi O, Rosati A, Famiani F, Benincasa P. Sprouting olive (*Olea europaea* L.) seeds as a source of antioxidants from residual whole stones. Sci. Hortic. 240: 558-560 (2018)

Falcinelli B, Marconi O, Maranghi S, Lutts S, Rosati A, Famiani F, Benincasa P. Effect of genotype on the sprouting of pomegranate (*Punica granatum* L.) seeds as a source of phenolic compounds from juice industry by-products. Plant Foods Hum. Nutr. 72: 432-438 (2017)

Fernandez-Orozco R, Frias J, Zielinski H, Piskula MK, Kozlowska H, Vidal-Valverde C. Kinetic study of the antioxidant compounds and antioxidant capacity during germination of *Vigna radiata* cv. Emmerald, *Glycine max* cv. Jutro and *Glycine max* cv. Merit. Food Chem. 111: 622-630 (2008)

Fidalgo A, Ciriminna R, Carnaroglio D, Tamburino A, Cravotto G, Grillo G, Ilharco LM, Pagliaro M. Eco-friendly extraction of pectin and essential oils from orange and lemon peels. ACS Sustain. Chem. Eng. 4: 2243-2251 (2016)

Ganz T. Systemic iron homeostasis. Physiol. Rev. 93: 1721-1741 (2013)

Gómez-Mejía E, Rosales-Conrado N, León-González ME, Madrid Y. Citrus peels waste as a source of value-added compounds: Extraction and quantification of bioactive polyphenols. Food Chem. 295: 289-299 (2019)

Houston MC, Harper KJ. Potassium, magnesium, and calcium: Their role in both the cause and treatment of hypertension. J. Clin. Hypertens. 10: 3-11 (2008)

Hsieh P-W, Aljuffali IA, Fang C-L, Chang S-H, Fang J-Y. Hydroquinone-salicylic acid conjugates as novel anti-melasma actives show superior skin targeting compared to the parent drugs. J. Dermatol. Sci. 76: 120-131 (2014)

Hughes MCB, Williams GM, Pageon H, Fourtanier A, Green AC. Dietary Antioxidant Capacity and Skin Photoaging: A 15-Year Longitudinal Study. J. Invest. Dermatol (Accepted). https://doi.org/10.1016/j.jid.2020.06.026

Je J-Y, Park P-J, Jung W-K, Kim S-K. Amino acid changes in fermented oyster (*Crassostrea gigas*) sauce with different fermentation periods. Food Chem. 91: 15-18 (2005)

Kim J, Jayaprakasha GK, Uckoo RM, Patil BS. Evaluation of chemopreventive and cytotoxic effect of lemon seed extracts on human breast cancer (MCF-7) cells. Food Chem. Toxicol. 50: 423-430 (2012)

Kornhauser A, Wei R-R, Yamaguchi Y, Coelho SG, Kaidbey K, Barton C, Takahashi K, Beer JZ, Miller SA, Hearing VJ. The effects of topically applied glycolic acid and salicylic acid on ultraviolet radiation-induced erythema, DNA damage and sunburn cell formation in human skin. J. Dermatol. Sci. 55: 10-17 (2009)

Lee S, Kim S-G, Park C-M. Salicylic acid promotes seed germination under high salinity by modulating antioxidant activity in Arabidopsis. New Phytol. 188: 626-637 (2010)

Lo'ay AA, Taher MA. Influence of edible coatings chitosan/PVP blending with salicylic acid on biochemical fruit skin browning incidence and shelf life of guava fruits cv. 'Banati.' Sci. Hortic. 235: 424-436 (2018)

MacDiarmid CW. Zinc transporters that regulate vacuolar zinc storage in *Saccharomyces cerevisiae*. EMBO J. 19: 2845-2855 (2000)

M'hiri N, Ghali R, Ben Nasr I, Boudhrioua N. Effect of different drying processes on functional properties of industrial lemon byproduct. Process Saf. Environ. Prot. 116: 450-460 (2018)

Montenegro L. Nanocarriers for skin delivery of cosmetic antioxidants. J. Pharm. Pharmacogn. Res. 2: 73-92 (2014)

Moulehi I, Bourgou S, Ourghemmi I, Tounsi MS. Variety and ripening impact on phenolic composition and antioxidant activity of mandarin (*Citrus reticulate* Blanco) and bitter orange (*Citrus aurantium* L.) seeds extracts. Ind. Crops. Prod. 39: 74-80 (2012)

Mun J-H, Kim I-D, Dhungana SK, Park Y-S, Kim J-H, Shin D-H. Yield and quality characteristics of Korean red bean sprouts produced with different time of seed soaking. Food Sci. Biotechnol. 29: 197-206 (2020)

Rajjou L, Belghazi M, Huguet R, Robin C, Moreau A, Job C, Job D. Proteomic investigation of the effect of salicylic acid on arabidopsis seed germination and establishment of early defense mechanisms. Plant. Physiol. 141: 910-923 (2006)

Russo M, Bonaccorsi I, Torre G, Sarò M, Dugo P, Mondello L. Underestimated sources of flavonoids, limonoids and dietary fibre: Availability in lemon's by-products. J. Funct. Foods 9: 18-26 (2014)

Seskar M, Shulaev V, Raskin I. Endogenous methyl salicylate in pathogen-inoculated tobacco plants. Plant Physiol. 116: 387-392 (1998)

Sharma K, Mahato N, Cho MH, Lee YR. Converting citrus wastes into value-added products: Economic and environmently friendly approaches. Nutrition 34: 29-46 (2017)

Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. Method. Enzymol. 299: 152-178 (1999)

Skujins S. Handbook for ICP-AES (Varian-Vista). A Short Guide to Vista Series ICP-AES Operation. Varian International AG, Zug, Switzerland (1998)

Spanier AM, Shahidi F, Parliment TH, Mussinan C, Ho C-T, Tratras Contis E, Kayahara H, Tsukahara K, Tatai T. Flavor, health and nutritional quality of pre-germinated brown rice. pp. 546-551. In: Food Flavors and Chemistry: Advances of the New Millennium. Spanier AM, Shahidi F, Parliment TH, Mussinan C, Ho C-H, Contis CT (eds). Royal Society of Chemistry, London, United Kingdom (2001)

Steen KH, Reeh PW, Kreysel HW. Topical acetylsalicylic, salicylic acid and indomethacin suppress pain from experimental tissue acidosis in human skin: Pain 62: 339-347 (1995)

Wang K-H, Lai Y-H, Chang J-C, Ko T-F, Shyu S-L, Chiou RY-Y. Germination of peanut kernels to enhance resveratrol biosynthesis and prepare sprouts as a functional vegetable. J. Agric. Food. Chem. 53: 242-246 (2005)

White PJ, Broadley MR. Biofortification of crops with seven mineral elements often lacking in human diets-iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 182: 49-84 (2009)

Willemsen KLDD, Panozzo A, Moelants K, Cardinaels R, Wallecan J, Moldenaers P, Hendrickx M. Effect of pH and salts on microstructure and viscoelastic properties of lemon peel acid insoluble fiber suspensions upon high pressure homogenization. Food Hydrocoll. 82: 144-154 (2018)

Yanik F, Aytürk Ö, Çetinbaş-Genç A, Vardar F. Salicylic acid-induced germination, biochemical and developmental alterations in rye (*Secale cereale* L.). Acta Bot. Croat. 77: 45–50 (2018)

Zhang H, Chen Y, Wang S, Ma L, Yu Y, Dai H, Zhang Y. Extraction and comparison of cellulose nanocrystals from lemon (*Citrus limon*) seeds using sulfuric acid hydrolysis and oxidation methods. Carbohydr. Polym. 238: 116180 (2020)

Zieliñski H, Frias J, Piskuła MK, Kozłowska H, Vidal-Valverde C. Vitamin B1 and B2, dietary fiber and minerals content of Cruciferae sprouts. Eur. Food Res. Technol. 221: 78-83 (2005)