MAKÜ FEBED

ISSN Online: 1309-2243
http://dergipark.org.tr/makufebed
https://doi.org/10.29048/makufebed.1151182

Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi 13(Ek Sayı 1): 417-422 (2022)
The Journal of Graduate School of Natural and Applied Sciences of Mehmet Akif Ersoy University 13(Supplementary Issue 1): 417-422 (2022)

Derleme Makale / ***Review Paper***

Applications of Double Layered Hydroxides in Cosmetics

Emine KUTLU[1*], Fatih Mehmet EMEN[1], Ruken Esra DEMIRDOGEN[2]

[1]Department of Chemistry, Faculty of Arts and Science, Burdur Mehmet Akif Ersoy University, Burdur, Turkey
[2]Department of Chemistry, Faculty of Science, Çankırı Karatekin University, Çankırı, Turkey

Geliş Tarihi (Received): 30.07.2022, Kabul Tarihi (Accepted): 12.11.2022
Sorumlu Yazar (Corresponding author): emine1044@gmail.com*
+90 248 2133076 *+90 248 2133099*

ABSTRACT

Since ancient Egypt cosmetics have been a part of our life. Cosmetic products appeal to a large variety of areas ranging from perfume, hair dyes and care products, toothpastes, dermal care products, face-eye make-up materials. Cosmetic products contain biological active components. These active compounds generally are sensitive to parameters such as light, pH, temperature and air oxidation and they are not stable. This also causes unwanted possibilities such as degradation of cosmetic products. Layered double hydroxides (LDHs), which are two-dimensional (2D) nanostructures, due to their extraordinary physicochemical properties may be a good alternative for to overcome these drawbacks. LDHs have found wide application areas such as removal of heavy metals, radio nucleotides, organic pollutants, oil pollution, hydrogen production and they are used in super capacitors, cells, solar cells, catalysis and in biomaterials for environmental, energy and catalysis. Moreover, nanostructured LDHs have been used as successful carriers for cosmetic products due to their wide surface areas, expandable interlayers that can host active molecules, biocompatibility, high water retention capacity, high swelling ability and cost-effectiveness. This study provides good practices of LDHs in cosmetics for UV protection, skin care and antimicrobial properties.

Keywords: Cosmetics, cosmeceuticals, double layered hydroxides, LDH

Çift Katmanlı Hidroksitlerin Kozmetikte Uygulamaları

ÖZ

Yeryüzünde kozmetik kullanımı Mısırlılar zamanından günümüze kadar uzanmaktadır. Kozmetik ürünleri parfüm, saç boya ve bakım ürünleri, diş macunları, cilt bakım ürünleri, yüz-göz makyaj malzemeleri vs. şeklinde geniş bir alana hitap eder. Kozmetik ürünleri bünyesinde biyolojik aktif bileşenler bulundurur. Bu aktif bileşenler genellikle ışık, pH, sıcaklık ve havanın oksidasyonu gibi parametrelere karşı duyarlı olup stabil değildir. Bu durum kozmetik ürünlerinin bozulması gibi istenmeyen olasılıkları beraberinde getirir. Olağanüstü fizyokimyasal özellikleri sayesinde nanoyapılı iki boyutlu (2D) katmanlı çift hidroksitler (LDH'ler) bu olumsuzluklara bir çözüm alternatifidir. LDH'lerin özellikle ağır metal çıkarma, radyonüklid yakalama, organik kirletici arıtma, petrol kirliliğinin giderilmesi, hidrojen üretimi, süper kapasitörler, piller, güneş pilleri, kataliz ve biyomateryal dahil çevre, enerji, kataliz ve biyomateryaller ile ilgili çok çeşitli alanlarda uygulamaları mevcuttur. Ayrıca nanoyapılı LDH'ler; sahip oldukları geniş yüzey alanı, aktif molekülleri barındıracak genişleyebilir ara katmanı, biyouyumluluk özelliği, yüksek su tutma kapasitesi, şişme özellikleri ve düşük maliyetleri nedeniyle kozmetik taşıyıcılar olarak kullanılır. Bu çalışmada LDH'lerin kozmetik amaçlı (UV koruması, cilt bakımı ve antimikrobiyal özellikler gibi) uygulamalarından örneklemeler yapılacaktır.

Anahtar Kelimeler: Kozmetik, kozmesötikler, çift katmanlı hidroksitler, LDH

Emine KUTLU, https://orcid.org/0000-0003-0211-1006
Fatih Mehmet EMEN, https://orcid.org/0000-0002-4974-2940
Ruken Esra DEMIRDOGEN, https://orcid.org/0000-0003-1274-7905

INTRODUCTION

The word "cosmetics" is derived from the Greek words KOSM TIKOS means skilled in ordering, arranging and decorating. The Turkish wording "kozmetik" came from the French word for KOSMTIKOS "cosmetique" (Özçelik and Bebekli, 2015).Turkey Pharmaceuticals and Medical Devices Agency has defined the cosmetic product in accordance with the 4th article of the Cosmetics Regulation in its guide published on cosmetic products. According to this definition, "any substance prepared to be applied on the external parts of the human body; epiderma, nails, hair, lips and external genitalia or teeth and oral mucosa, whose sole or main purpose is to clean these parts, to endow nice odor, to change their outer appearance, to protect them, to keep them in a good condition or to correct body odor, or mixtures" is defined as a cosmetic product (URL-1, 2021). Cosmetic care products are products that are used directly or indirectly on human skin, mucosa, hair and nails for a long time. Therefore, it is very important that they are safe for human health. In addition to light metals such as aluminum, heavy metals such as lead, mercury, cadmium, arsenic and nickel are found in various cosmetic products (color cosmetics, face and body care products, hair cosmetics, herbal cosmetics, etc.). Moreover, these products contain chemicals such as copper, iron, chromium and cobalt the amount of which should not exceed a certain limit. These chemicals found in cosmetics can cause direct skin irritation or they may be absorbed by the skin and thus go into blood circulation and finally accumulate in various parts of the body to cause toxic effect. Many studies reported that metal exposure causes various topical -mainly allergic contact dermatitis- and systemic effects (Borowska and Brzóska, 2015). In addition to these, generally there are also biologically active substances in cosmetic products. These bioactive substances are sensitive to certain parameters such as temperature, light, pH, oxidation. In cosmetics, maintaining the stability of these bioactive substances, increasing their effectiveness and slow release are important parameters to be controlled (Ammala, 2013). Today the physical, chemical and biological problems in cosmetics are tried to be resolved via the developments achieved in nano-technology. Systems such as solid lipid nanoparticles, microneedles, patches, titanium dioxide and zinc oxide nanoparticles are used in cosmetics to target and control the release of active substances on the skin (Silva et al., 2019). Inorganic nanoparticles in recent years; namely, layered double hydroxides (LDH), also called anionic clays, have attracted the attention of researchers as carriers in cosmetic applications. LDHs are generally given with the structural formula $[M^{II}_{(1-x)}M^{III}_{x}(OH)_2]^{x+}[A^{n}_{x/n}]\cdot mH_2O$. Here, M^{II} (Mg^{II}, Zn^{II}, Ni^{II}, Co^{II}, Fe^{II}, Cu^{II}) is a divalent and M^{III} (Al^{III}, Cr^{III}, Fe^{III}, Mn^{III}, Ga^{III}, In^{III}) are trivalent metal cations. The M^{II}/M^{III} molar ratio is generally in the range between 0.20 and 0.33. In Figure 1 is given the schematic presentation of LDHs (Mishra et al., 2018).

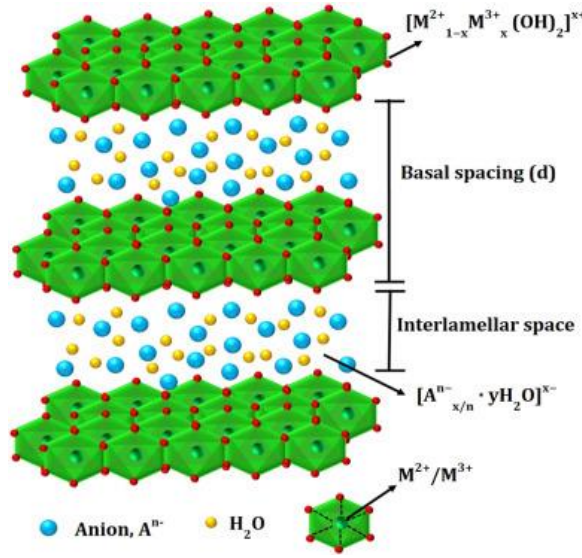

Figure 1. Schematic presentation of the chemical structure of LDHs

LDHs have unique properties such as facile synthesis methods, high water retention capacity, biocompatibility, low toxicity, favorable ion-exchange capacity, increasing stability of the functional groups, capability of vectorising the active species and controlled release (Silva et al., 2019; Kesavan Pillai et al., 2020). Moreover, the low cost and ability to allow a wide variety of chemical modifications to be made create a lot of application areas for LDHs (Silva et al., 2019). LDHs are preferred in various fields (i.e., pharmaceuticals, nutraceuticals and cosmetics) for to increase the water solubility and bioavailability of bioactive substances as well as for to prevent their degradation and improve their pharmacokinetic properties and formulation stability (Conterosito et al., 2015). The favorable properties of LDH (i.e., high adsorption capacity, good anion exchange property and stabilization potential) are very valuable in cosmetics. Due to their high adsorption capacity, LDHs can be used to eliminate skin leaks, encapsulate skin-sensitive coloring and UV-screening agents. Thanks to their anion exchange properties, LDHs can be used in anti-wrinkle and skin regeneration formulations for to distribute active ingredients in a stable manner. LDHs can be used to render stability to unstable molecules (i.e., retinoic acid, ascorbic acid and tocopherol, etc.) used in cosmetics. Moreover, the rheological properties of various formulations and emulsions can be further improved by this method (Patel et al., 2010). The ultraviolet (UV) rays of the sun are known to have negative effects on human skin. They are various skin problems ranging from mild burns in their simplest form to skin cancer and other sun-related diseases. Sun creams (UV filters) have been used for years to protect the skin against this UV exposure. These UV filters, which are applied topically on the skin, protect the skin from the harmful consequences of UV radiation by absorption or reflection. Some of the organic molecules used in sun cream formulations are sensitive to light. Therefore, direct contact with the skin causes irritation and allergic reactions (Perioli et al., 2006). Adding the organic molecules in the suncreams to the 2D inorganic materials –the LDHs- both these organic molecules would be protected and their direct contact with the skin would be avoided. The anions in the interlayers in LDHs that are held together by electrostatic interaction provide chemical protection and stability to organic molecules. Some research examples related to UV protection of LDH (Table 1) (Silva et al., 2019), skin care, antimicrobial activity and other cosmetic applications are given in Table 2, respectively (Kesavan Pillai et al., 2020).

Table1. Some research examples on UV protection applications of LDH

LDH	Active Agent	Method	Ref.
ZnAl	3,4-dihydroxycinnamic acid (Cinnamic acid) 4- hydroxy-3,5-dimethoxycinnamic acid (Sinapic acid,SA) 3-amino-5-trifluoromethylbenzoic acid (FBA)	Coprecipitation	(Khan et al., 2011)
ZnAl	2,4-dihidroxybenzophenone-5-sulfonate	Coprecipitation	(Li et al., 2014)
ZnTi	3,4-dihydroxycinnamic acid (Cinnamic acid)	Ion Exchange	(Li et al., 2017)
MgAl ZnAlZnTi	Zinc Titanium salts	Coprecipitation	(Wang et al., 2017)
ZnAl	4-hydroxy-3-methoxybenzoic acid (Methyl paraben) 2-hydroxy-4-methoxybenzophenone-5-sulfonic acid (Sulisobenzone) 4-hydroxy-3-metoxycinnamic acid (Ferulic acid) 4,4'-diaminostilben-2,2'-disulphonic acid (Flavonic acid) p-aminobenzoic acid (Vitamin B_{10}) (2E)-3-(1H-imidazol-4-yl)prop-2-enoic acid (Urocanic acid)	Anion Exchange and/or Coprecipitation	(He et al., 2004)
ZnAl	3,4-dihydroxycinnamic acid (Cinnamic acid) 3,4-dimethoxycinnamic acid (Dimethylcaffeic acid) p-hidroksisinnamik acid (p-coumaric acid)	Coprecipitation	(Sun et al., 2008)
ZnTi	p-aminobenzoic acid (Vitamin B_{10})	Ion Exchange	(Li et al., 2016)
ZnAl	3,4-dihydroxycinnamic acid (Cinnamic acid) p-methoxycinnamic acid	Coprecipitation	(Sun et al., 2007)
MgAl ZnAl	p-aminobenzoic acid (Vitamin B_{10})	Ion Exchange	(Perioli et al., 2006)
MgAl ZnAl	2-phenyl-1 H-benzimidazol-5-sulphonic acid (Eusolex 232)	Anion exchange and/or Coprecipitation	(Perioli et al., 2006)
ZnAl	5-benzoyl-4-hydroxy-2-methoxy-benzenesulfonic acid (Sulisobenzone)	Ion Exchange	(Perioli et al., 2008)
ZnAl	Dodecylsulphate (Lauryl sulfate) Dodecylbenzenesulphonate	Coprecipitation	(Cursino et al., 2013)
ZnAl	Disodium 2,2'-dihydroxy-4,4'-dimethoxy-5,5'-disulfobenzophenone (Benzophenone 9)	Ion Exchange and Coprecipitation	(Mohsin et al., 2014)
MgAl ZnAl	(2S)-2-[(4-{[(2-amino-4-hydroxypteridin-6-yl)methyl]amino}phenyl)formamido]pentanedioic acid (Folic acid)	Coprecipitation	(Pagano et al., 2019)

LDH: layered double hydroxides; UV: Ultraviolet; ZnAl: zinc-aluminum; ZnTi: zinc-titanium; MgAl: Magnesium-aluminum

Table 2. Some research on skin care, antimicrobial activity and other cosmetic applications of LDH

LDH	Active Agent	Application Area	Method	Ref.
Zn-LDH	Vitamin A, Retinoic acid –RA (2E,4E,6E,8E)-3,7-Dimethyl-9-(2,6,6-trimethylcyclohex-1-en-1-yl)nona-2,4,6,8-tetraen-1-yl hexadecanoate), Ascorbic acid, Vitamin C ((5R)-[(1S)-1,2-Dihydroxyethyl]-3,4-dihydroxyfuran-2(5H)-one), Vitamin E ((2R)-2,5,7,8-Tetramethyl-2-[(4R,8R)-4,8,12-trimethyltridecyl]-3,4-dihydrochromen-6-ol) Zinc salt	Skin care	Coprecipitation	(Choy et al., 2007)
CaAl	Ascorbic acid, Vitamin C ((5R)-[(1S)-1,2-Dihydroxyethyl]-3,4-dihydroxyfuran-2(5H)-one)	Skin care	Coprecipitation	(Gao et al., 2014)
MgFe ZnFe	Ascorbic acid, Vitamin C (5R)-[(1S)-1,2-Dihydroxyethyl]-3,4-dihydroxyfuran-2(5H)-one)	Skin care	İyon değişimi	(Gasser, 2009)
ZnAl	4-hexyl resorcinol	Skin care	Coprecipitation	(Mosangi et al., 2016)
ZnAl	Cafeic acid (3,4-dihxdrocinnamic acid)	Antiwrinkle	Coprecipitation	(Bastianini et al., 2018)
NiAl	Murexide (Ammonium 2,6-dioxo-5 -[(2,4,6-trioxo-5-hekzahydropyrimidinylidene) amino] -3H-pyrimidine-4-olate)	Nailpolish pigment	Coprecipitation	(Kovalenko et al., 2017)
ZnTi	Kogic acid (5-Hydroxy-2-(hydroxymethyl)-4-pyrone, 2-hydroxymethyl-5-hydroxy-γ-pyrone)	Melamine synthesis inhibitor Bacteriostatic agents	Ion exchange	(Wang et al., 2019)
MgAl ZnAl	Alpha lipoic acid (ALA, (R)-5-(1,2-Dithiolan-3-yl)pentanoic acid)	Antiaging Free radical cleansing agent	Ion exchange	(Pagano et al., 2019)
MgAl ZnAl	Vitamin A, Retinoic acid –RA (2E,4E,6E,8E)-3,7-Dimethyl-9-(2,6,6-trimethylcyclohex-1-en-1-yl)nona-2,4,6,8-tetraen-1-yl hexadecanoate)	Acne treatment	Ion exchange	(Perioli et al., 2015)
MgAl	Biogenic silver structures [fungus filtrate of Fusariumoxysporum strain (551)	Anti-microbial activity	Coprecipitation	(Marcato et al., 2013)
MgAl	Encapsulated citrate ions	Anti-Fungal activity	Ion Exchange	(Perera et al., 2015)
ZnAl	Silver nanoparticles	Anti-microbial activity-In Deodorants	Coprecipitation	(Ballarin et al., 2015)
ZnAl	DL-mandelic acid (Hydroxy(phenyl)acetic acid)	Anti-microbial activity	Ion Exchange	(Tang et al., 2018)

LDH: layered double hydroxides; UV: ultraviolet; ZnAl: zinc-aluminum; ZnTi: zinc-titanium; MgAl: magnesium-aluminum; NiAl: Nickel-aluminum; ZnFe: zinc-iron; MgFe: Magnesium-iron

CONCLUSION

This study reviews the research on the use of LDH in cosmetics in recent years. Recently, researchers focused on LDHs as carrier systems for cosmetic ingredients. Due to their many fascinating properties, LDHs can be used for safe storage, stability and controlled topical distribution of cosmetic products. It is possible to change the rheological properties of these products just by adjusting the weight percentage of LDH in the cosmetic formulation. Moreover, variety can be increased by suitably modifying cationic or anionic surfactants in the interlayers in LDHs. Cosmetic care products can be endowed with antibacterial, antifungal and antimicrobial properties via modifying LDHs. New LDHs can be synthesized to create variety to meet the sectoral needs and for to be exploited in desired applications. However, difficulties remain regarding the *in vivo* evaluation of these materials.

REFERENCES

Ammala, A. (2013). Biodegradable polymers as encapsulation materials for cosmetics and personal care markets. *International Journal of Cosmetic Science*, *35*(2): 113-124.

Ballarin, B., Mignani, A., Mogavero, F., Gabbanini, S., Morigi, M. (2015). Hybrid material based on ZnAl hydrotalcite and silver nanoparticles for deodorant formulation. *Applied Clay Science*, *114*: 303-308.

Bastianini, M., Faffa, C., Sisani, M., Petracci, A. (2018). Caffeic acid-layered double hydroxide hybrid: a new raw material for cosmetic applications. *Cosmetics*, *5*(3): 51; DOI:10.3390/COSMETICS5030051.

Borowska, S., Brzóska, M. M. (2015). Metals in cosmetics: implications for human health. *Journal of Applied Toxicology*, *35*(6): 551-572.

Choy, J. H., Choi, S. J., Oh, J. M., Park, T. (2007). Clay minerals and layered double hydroxides for novel biological applications. *Applied Clay Science*, *36*(1-3): 122-132.

Conterosito, E., Palin, L., Antonioli, D., Viterbo, D., Mugnaioli, E., Kolb, U., Gianotti, V. (2015). Structural Characterisation of Complex Layered Double Hydroxides and TGA-GC-MS Study on Thermal Response and Carbonate Contamination in Nitrate-and Organic-Exchanged Hydrotalcites. *Chemistry–A European Journal*, *21*(42): 14975-14986.

Cursino, A. C. T., da Silva Lisboa, F., dos Santos Pyrrho, A., de Sousa, V. P., Wypych, F. (2013). Layered double hydroxides intercalated with anionic surfactants/benzophenone as potential materials for sunscreens. *Journal of Colloid and Interface Science*, *397*: 88-95.

Gao, X., Chen, L., Xie, J., Yin, Y., Chang, T., Duan, Y., Jiang, N. (2014). In vitro controlled release of vitamin C from Ca/Al layered double hydroxide drug delivery system. *Materials Science and Engineering: C*, *3:* 56-60.

Gasser, M. S. (2009). Inorganic layered double hydroxides as ascorbic acid (vitamin C) delivery system-Intercalation and their controlled release properties. *Colloids and Surfaces B: Biointerfaces*, *73*(1): 103–109.

He, Q., Yin, S., Sato, T. (2004). Synthesis and photochemical properties of zinc–aluminum layered double hydroxide/organic UV ray absorbing molecule/silica nanocomposites. *Journal of Physics and Chemistry of Solids*, *65*(2-3): 395-402.

Kesavan Pillai, S., Kleyi, P., de Beer, M., Mudaly, P. (2020). Layered double hydroxides: An advanced encapsulation and delivery system for cosmetic ingredients-an overview. *Applied Clay Science*, *199*(5): 105868; DOI:10.1016/j.clay.2020.105868.

Khan, S. B., Liu, C., Jang, E. S., Akhtar, K., Han, H. (2011). Encapsulation of organic UV ray absorbents into layered double hydroxide for photochemical properties. *Materials Letters*, *65*(19-20): 2923-2926.

Kovalenko, V., Kotok, V., Yeroshkina, A., Zaychuk, A. (2017). Synthesis and characterisation of dye-intercalated nickel-aluminium layered-double hydroxide as a cosmetic pigment. *Восточно-Европейский журнал передовых технологий*, 5(12): 27-33.

Li, S., Shen, Y., Xiao, M., Liu, D., Fa, L., Wu, K. (2014). Intercalation of 2,4-dihydroxybenzophenone-5-sulfonate anion into Zn/Al layered double hydroxides for UV absorption properties. *Journal of Industrial and Engineering Chemistry*, 20(4): 1280-1284.

Li, Y., Tang, L. P., Zhou, W., Wang, X. R. (2016). Fabrication of intercalated p-aminobenzoic acid into Zn-Ti layered double hydroxide and its application as UV absorbent. *Chinese Chemical Letters*, *27*(9): 1495-1499.

Li, Y., Tang, L., Ma, X., Wang, X., Zhou, W., Bai, D. (2017). Synthesis and characterization of Zn-Ti layered double hydroxide intercalated with cinnamic acid for cosmetic application. *Journal of Physics and Chemistry of Solids*, *107*: 62-67.

Marcato, P. D., Parizotto, N. V., Martinez, D. S. T., Paula, A. J., Ferreira, I. R., Melo, P. S., Alves, O. L. (2013). New hybrid material based on layered double hydroxides and biogenic silver nanoparticles: antimicrobial activity and cytotoxic effect. *Journal of the Brazilian Chemical Society*, *24*: 266-272.

Mishra, G., Dash, B., Pandey, S. (2018). Layered double hydroxides: A brief review from fundamentals to application as evolving biomaterials. *Applied Clay Science*, *153*: 172-186.

Mohsin, S. M. N., Hussein, M. Z., Sarijo, S. H., Fakurazi, S., Arulselvan, P., Taufiq-Yap, Y. H. (2014). Optimization of UV absorptivity of layered double hydroxide by intercalating organic UV-absorbent molecules. *Journal of biomedical nanotechnology*, *10*(8): 1490-1500.

Mosangi, D., Moyo, L., Pillai, S. K., Ray, S. S. (2016). Acetyl salicylic acid–ZnAl layered double hydroxide functional nanohybrid for skin care application. *RSC advances*, *6*(107): 105862-105870.

Özçelik, H., Bebekli, Ö. (2015). Cosmetics Industry Overview. *Anamas Dergisi*, 3(4): 3-12.

Pagano, C., Calarco, P., Ceccarini, M. R., Beccari, T., Ricci, M., Perioli, L. (2019). Development and characterization of new topical hydrogels based on alpha lipoic acid-Hydrotalcite hybrids. *Cosmetics*, *6*(2): 35; DOI:10.3390/COSMETICS6020035.

Patel, H. A., Bajaj, H. C. (2010). Natural and synthetic layered materials as cosmetic ingredients. *Focus on Aminoacids, Peptıdes Hı-Tech Ingredients*, 4: 31-36.

Perera, J., Weerasekera, M., Kottegoda, N. (2015). Slow release anti-fungal skin formulations based on citric acid intercalated layered double hydroxides nanohybrids. *Chemistry Central Journal*, *9*(1): 1-7; DOI:10.1186/s13065-015-0106-3.

Perioli, L., Ambrogi, V., Rossi, C., Latterini, L., Nocchetti, M., Costantino, U. (2006). Use of anionic clays for photoprotection and sunscreen photostability: hydrotalcites and phenylbenzimidazole sulfonic acid. *Journal of Physics and Chemistry of Solids*, *67*(5-6): 1079-1083.

Perioli, L., Nocchetti, M., Ambrogi, V., Latterini, L., Rossi, C., Costantino, U. (2008). Sunscreen immobilization on ZnAl-hydrotalcite for new cosmetic formulations. *Microporous and mesoporous materials*, *107*(1-2):180-189.

Perioli, L., Pagano, C., Nocchetti, M., Latterini, L. (2015). Development of smart semisolid formulations to enhance retinoic acid topical application. *Journal of Pharmaceutical Sciences*, *104*(11): 3904-3912.

Silva, T. A. D., Silva, T. A. D., Nascimento, T. G. D., Yatsuzuka, R. E., Grillo, L. A. M., Dornelas, C.B. (2019). Recent advances in layered double hydroxides applied to photoprotection. *Einstein (São Paulo)*, *17*; DOI:10.31744/einstein_journal/2019RW4456.

Sun, W., He, Q., Luo, Y. (2007). Synthesis and properties of cinnamic acid series organic UV ray absorbents–interleaved layered double hydroxides. Materials Letters, 61(8-9): 1881-1884.

Sun, W., He, Q., Lu, L., Liu, H. (2008). Synthesis and properties of layered double hydroxides intercalated with cinnamic acid series organic UV ray absorbents. *Materials chemistry and physics*, *107*(2-3): 261-265.

Tang, L. P., Cheng, H. M., Cui, S. M., Wang, X. R., Song, L. Y., Zhou, W., Li, S. J. (2018). DL-mandelic acid intercalated Zn-Al layered double hydroxide: A novel antimicrobial layered material. *Colloids and Surfaces B: Biointerfaces*, *165*: 111-117.

URL-1 (2021). https://www.titck.gov.tr/faaliyetalanlari/kozmetik/kozmetik-mevzuati (Accessed Date: 08.06.2022)

Wang, X. R., Li, Y., Tang, L. P., Gan, W., Zhou, W., Zhao, Y. F., Bai, D. S. (2017). Fabrication of Zn-Ti layered double hydroxide by varying cationic ratio of Ti4+ and its application as UV absorbent. Chinese Chemical Letters, 28(2): 394-399.

Wang, X. R., Cheng, H. M., Gao, X. W., Zhou, W., Li, S. J., Cao, X. L., Yan, D. (2019). Intercalation assembly of kojic acid into Zn-Ti layered double hydroxide with antibacterial and whitening performances. *Chinese Chemical Letters*, *30*(4): 919-923.