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Review

NEW EMERGING FIELDS OF APPLICATION OF PROPOLIS

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Propolis (bee glue) is a sticky resinous material applied by honey bees *Apis mellifera* L. as a building material in their hives and as a defensive substance against infections. Propolis has been used as a remedy in traditional medicine systems all over the world, mainly to treat wounds and burns, sore throat, stomach ulcer, etc. Modern science has confirmed the antimicrobial and antiviral action of propolis, and has discovered numerous other beneficial pharmacological properties of bee glue: immunomodulating, anti-inflammatory, antiobesity, antitumor, and many others. For this reason, a significant number of products containing propolis have been developed and commercialized: medical devices, over-the-counter preparations, health foods and beverages, cosmetics. This review does not deal with propolis applications in the improvement and protection of human health. Instead, it is focused on some new and promising areas of propolis use and innovative propolis-containing products that have emerged in the last few years: improving the growth performance of livestock, food preservation, food packaging, textile materials for biomedical application, etc.

Keywords: propolis; livestock growth performance; food preservatives; food packaging

НОВИ ПОЛИЊА ВО ЗАРОДИШ ЗА ПРИМЕНА НА ПРОПОЛИС

Прополисот е леплив смолест материјал кој медоносните пчели, *Apis mellifera* L., го користат како градежен материјал за нивните улишта и како одбранбена супстанција од инфекции. Прополисот се користи и како лек во традиционалната медицина ширум светот, главно за лекување на рани и изгореници, болки во грлото, чир на желудникот итн. Модерната наука го потврди антимикробното и антивирусно дејство на прополисот и откри бројни други негови корисни фармаколошки својства како што се: имуномодулаторно, антиинфламаторно, против прекумерна телесна тежина, антитуморно и уште многу други. Поради сето ова се развиени и комерцијализирани голем број производи кои содржат прополис: медицински средства, препарати кои се продаваат без лекарски рецепт, здрава храна и напивки, козметички производи. Овој преглед не се занимава со употребата на прополисот за подобрување и заштита на човековото здравје. Наместо тоа, фокусот е на некои нови и ветувачки области за негова примена и на иновативни производи кои содржат прополис и кои се појавија во последните години, имено: подобрувања во одгледувањето на добиток, конзервирање на храна, пакување на храна, текстилни материјали за биомедицинска примена итн.

Клучни зборови: прополис; одгледување на добиток; конзерванси за храна; пакување на храна

1. INTRODUCTION

Propolis (bee glue) is a sticky resinous material applied by honey bees *Apis mellifera* L. as a building material in their hives. Bees use it to block holes and cracks and to cover the internal walls of the hive. Propolis is also an important element of the so-called social immunity of honey

bees: it can be considered a part of the bees' social immune system, providing the colony as a whole with some general defence against infections and parasites [1] because of its antimicrobial properties.

Bees produce propolis from lipophylic resinous materials which they collect from different plant parts (buds, young leaves, resins, etc.) by mixing them with wax and saliva [2]. They take the material for propolis production from plant excretions, which protect vulnerable parts of living plants from microbial infections. Thus, honeybees make use of the biosynthetic capacity of plants and utilize the secondary plant metabolites, forming the resins, for the same purpose as the plants: for protection. As a result, the activity against diverse microorganisms is an inherent property of propolis, a fact recognized by human beings millennia ago. Propolis has been used as a remedy in traditional medicine systems all over the world, mainly to treat wounds and burns, sore throat, stomach ulcer, etc. [3]. Modern science has confirmed the antimicrobial and antiviral action of propolis, and has discovered numerous other beneficial pharmacological properties of bee glue: immunomodulating, anti-inflammatory, antiobesity, antitumor, and many others [4]. For this reason, a significant number of products containing propolis have been developed and commercialized: medical devices, over-the-counter preparations, health foods and beverages, cosmetics. The interest of consumers and the demand for such products is steadily growing [5].

It is very important to note that the chemical composition of propolis is far from constant. It varies significantly depending on the specific plant resin used by the honeybees in propolis production. At different locations with their particular climatic and phyto-geographic conditions, the plant sources are different and as a result the chemistry of propolis alters dramatically [6]. This could be a grave problem in propolis standardization and quality control [6], although serious efforts have been made to overcome this problem and some results have already been achieved [7]. Notably, although of different chemical composition, propolis from different locations always demonstrates considerable biological activity [8, 9].

Obviously, propolis has a number of applications in the improvement and protection of human health. However, in this review we will not deal with these applications. Instead, we will focus on some new and promising areas of propolis use and innovative propolis-containing products that have emerged in the last few years.

2. PROPOLIS CHEMISTRY AND CHEMICAL DIVERSITY

Whatever the suggested applications of propolis, its use is based on its chemical and biological properties, and these properties are determined by the chemical constituents of the propolis. As already mentioned, propolis chemistry is highly variable; it depends on the source plant and respectively on the specificity of the local flora at the site of collection, as well as on the preference of honeybees towards specific available botanical sources. A brief overview of published chemical data reveals that in a particular phyto-geographic region, bees demonstrate a constant and unambiguous preference for particular propolis source plants, and for this reason, different propolis types exist (for recent review articles on propolis chemistry, see [10–13]).

It is important to note that different propolis types contain constituents of diverse structural types, mainly phenolics of different classes. Basic information on the most widespread propolis chemical types and their major constituents is presented in Table 1.

The useful properties of propolis are due to its plant-derived constituents but, surprisingly, the different chemical composition does not always lead to significant differences in pharmacological and physicochemical properties. Nevertheless, some specificity has been observed; for example, the diterpene-rich Mediterranean propolis has weak antioxidant activity, in contrast to the polyphenol-rich types (especially Brazilian green and poplar type), while its antibacterial properties are comparable to those of poplar type. For this reason, studies of any type of propolis application must always be accompanied by chemical characterization of the particular propolis used in the experiments, or at least by determining the chemical type of this propolis. During the last decade, the awareness that propolis is a product of variable chemical composition and that there are many propolis types became common knowledge. Nevertheless, a significant number of studies on propolis pharmacology and applications are yet published without any chemical analysis of the bee glue, and this makes them practically useless. This is most unfortunate because, among them, there are investigations of high quality, regarding the biological and technological content, and also ones that report valuable applications.

T a b l e 1

Characteristic constituents of most widespread chemical types of propolis

Geographical origin	**Propolis type**	**Basic source plant source**	**Characteristic constituents**	**References**
Europe, Western Asia, China, South Africa, North America, New Zealand	Poplar type	Bud exudates of polar trees, mainly *Populus nigra*	Pinocembrin, galangin, chrysin, pinobanksin 3-O-acetate, pentenyl caffeates, phenethyl caffeate (CAPE), caffeic acid, ferulic and isoferulic acid	[14–20]
Brazil (Sao Paulo, Rio de Janeiro, Minas Gerais)	Brazilian green	Leaf exudates of *Baccharis dracunculifolia*	Artepillin C, baccharin, druparin, aromadendrine, caffeoylquinic acids	[21, 22]
Brazil (North-East part), Cuba, Mexico	South American red	Exudates of *Dalbergia ecastophyllum*, other *Dalbergia* species	Medicarpin, vestitol, 3-O-methyl vestitol	[23–25]
Southern Greece and Greek islands, Crete, Sicily, Malta, Adriatic Coast of Croatia	Mediterranean	*Cupressus sempervirens* resin	Diterpenic acids (cupressic, isocupressic, imbricataloic), totarol, ferruginol	[26–29]
Indoinesia, Oman, Brazil, Myanmar, Thailand	*Mangifera* type	*Mangifera indica* fruit exudate	Cardols, cardanols, anacardic acids, cycloartane triterpenes	[30–34]

3. NEW FIELDS OF PROPOLIS APPLICATION

The information concerning uses of propolis in areas other than human medicine and quality of life is represented in Table 2, grouped in accordance with the specific applications.

One of these areas is the use of propolis in improving the growth performance and productivity of livestock. The test subjects have been different animal species, including poultry (chickens, laying hens, quails) [35–48], lambs [49, 50], cattle [51], sheep [52], pigs [53], and fish: sea bass [54], rainbow trout [55–57], Nile tilapia [58–60], and carp [61] (Table 2). In general, propolis has a positive effect on the biochemical parameters, growth and productivity of the test animals, and is regarded as a possible alternative to antibiotics in animal feed. In addition, it has the advantage of not inducing resistance in microorganisms [120, 121].

It is important to note that in the literature there are many articles dealing with the effect of propolis on the growth and productivity of domestic animals, many more than the references cited in Table 2. The reason for not mentioning them in this review is the fact that their authors have not presented any information on the propolis used: neither the geographic origin, nor chemical data. In many cases, there are no data even about the method of extraction or treatment of the propolis in order to administer it to the test animals. Such results are irreproducible and have no real scientific value, thus they have not been summarized here.

Another area of intensive research in the last few years is the application of propolis in the preservation of foods. Food preservatives include mainly antimicrobials and antioxidative agents. Antimicrobials added to foods serve two purposes: to control natural spoilage of food and to avoid/control contamination by microorganisms, including pathogenic ones (of food safety concern) [122]. On the other hand, food antioxidants are used for extending shelf life and impeding decay [123], mainly by preventing lipid peroxidation and rancidification, which are the most common types of oxidation occurring in foodstuffs during storage [124]. Propolis favorably brings together antioxidant and antimicrobial properties, and low toxicity. This remarkable combination makes it an excellent candidate for preserving different foods. Successful experiments have been performed for utilization of propolis extracts in the preservation of numerous products: fruit juices [62–65], fruits [68–77], vegetables [78–85], eggs [86–91], meat and fish products [92–100] (Table 2). This field of application of propolis is rapidly growing, as indicated by the growing number of publications. In addition, these studies as a rule include a reasonable chemical characterization of the propolis used. However, the large-scale commercial use of propolis as a food preservative is not yet a reality, because it would require proper standardization.

T a b l e 2

New emerging propolis applications

Propolis applications	Propolis extract	Propolis type / origin	Reference
1	2	3	4
Growth performance improvement of lifestock			
Poultry			
Ross Broiler Chickens	96% Ethanol extract	Iran	[35]
Ross 308 Broiler Chick (heat stressed)	70% Ethanol extract	Eastern Anatolia	[36, 37]
Broiler chicks (male Ross 708)	-	Brazilian green type	[38]
Broiler chickens	70% Ethanol extract	Poplar type, Iran	[39]
Broilers (Ross 308)	70% Ethanol extract	Poplar type, China	[40]
Broiler chickens	50% Ethanol extract	Adquirió en Maringá-PR, Brazil	[41]
Chickens Hubbard JV	80% Ethanol extract	Slovak Republic	[42]
Chicken hybrid combination Ross 308	80% Ethanol extract	Slovak Republic	[43]
Meat-type chicken Nanbu Kashiwa	Propolis residue after alcohol extraction	Iwate, Japan	[44]
Broiler chick	Alcoholic extract	Brazilian green type	[45]
Local quails	Raw propolis	Duhok, Iraq	[46]
Laying hens, heat stressed	70% Ethanol extract	Eastern Anatolia	[47]
Hens' egg incubation	-	Central zone of Republic of Moldova	[48]
Ungulate domestic animals			
Lambs	70% Ethanol extract	Brazilian green propolis	[49]
Lambs (Santa Inês x Dorper)	70% Ethanol extract	Brazilian red propolis	[50]
Crossbred (½ Angus *vs.* ½ Nellore) bulls	Ethanol extract	Maringá PR, Brazil	[51]
Castrated male sheep	70% Ethanol extract	Pernambuco State, Brazil.	[52]
Growing pigs	70% Ethanol extract	Poplar propolis	[53]
Fish			
Juvenile European sea bass (*Dicentrarchus labrax* L.) at low temperature stress	Water extract	Dalmatia region, middle Croatia	[54]
Rainbow trout (*Oncorhynchus mykiss*)	95% Ethanol extract	Kunming, China	[55]
Rainbow trout (*Oncorhynchus mykiss*)	96% Ethanol extract	Iran	[56]
Rainbow trout (*Oncorhynchus mykiss*)	80% Ethanol extract	Urmia, Iran	[57]
Nile tilapia (*Oreochromis niloticus*)	Water extract	Egypt	[58]
Nile tilapia (*Oreochromis niloticus*)	Cereal alcohol extract	Brazilian brown propolis	[59]
Nile tilapia (*Oreochromis niloticus*) fingerlings	Ethanol extract	Dakahlia province, Egypt	[60]
Carp (*Cyprinus carpio*)	70% Ethanol extract	Poplar type	[61]
Preservative effect in food industry			
Beverages			
Unpasteurized fruit juices (apple, orange, white grape and mandarin)	Ethanol extracts	Turkey	[62]
Unpasteurized juices	30% Alcohol extract	Kozie Kąty apriary (southern Poland).	[63]
Apple juice	80% Ethanol	Kayseri, Turkey.	[64]
Apple juice	Food supplement containing raw propolis	Poplar type propolis, Spain	[65]
Production of distilled beverages	Ethanol extracts	Bebedouro-SP, Brazil: green propolis; Formiga-MG, Brazil: brown propolis	[66]
Distilled beverage (sugarcane spirit)	80% Ethanol extract	Brazilian green and brown propolis type	[67]
Fruits			
Mandarins	Ethyl acetate extract	Hebei Province, China	[68]
Orange	96% Ethanol extract	Iraq (Baghdad)	[69]
Apple	96% Ethanol extract	Iraq (Baghdad)	[70]
Sweet cerry	Ethanol and water extracts	Hatay province, Turkey	[71]
Grapefruit cv. Star Ruby	70% Ethanol extract	Hatay province, Turkey	[72]
'Kent' mango fruits	70% Ethanol extract	Brazilian green type	[73]
Dragon fruit	80% Ethanol extract	Selangor state Malaysia; China	[74, 75]
Papaya	95% Ethanol extract	China	[76]

1	2	3	4
Papaya (*Carica papaya* L. cv. Hawaiiana)	Ethanol extract	Llanta Azul apiary, Zaragoza (Antioquia – Colombia)	[77]
Vegetables			
Rice (*Oryza sativa*, var. *hinohikari*)	Absolute ethanol, methylene chloride and hexane extracts	Brazilian green propolis	[78]
Carrot (minimally processed)	25% Water and alcohol extracts	Brazilian green propolis	[79]
Lettuce	Ethanol extract	Bragança, Portugal	[80]
Cucumber	70% Ethanol extracts	Pato Branco (PR), Brazil	[81]
Beans, carrots against white rot disease	Alcohol extract	Iraq	[82]
Mixed vegetables for soup	Propolis extract	Argentina	[83]
Celery, leek and butternut squash (minimally processed)	Ethanolic extract; standardized to 10% propolis extract	Mendoza province, Argentina	[84]
Chilli (*Capsicum annuum* L.)	Ethanol extract	Brazilian green propolis	[85]
Eggs			
Eggs quality during storage	70% Ethanol extract	Hatay province, Turkey	[86, 87]
Japanese quail eggs	70% Ethanol extract	Hatay province, Turkey	[88–90]
Hens eggs	Ethanol extract	Parana state, Brazil,	[91]
Meat products			
Fresh oriental sausage	95% Ethanol extract	Cairo, Egypt	[92]
Sausages	96% Ethanol extract	Boyacá, Colombia	[93]
Fermented meat sausage "Alheira"	95 % ethanol	Vila Franca, Viana do Castelo, Portugal	[94]
Beef patties	Commercial ethanol extracts	Sonora, Mexico, poplar type	[95]
Poultry meat product-cured cooked ham	96% Ethanol extract	Slovakia	[96]
Fish products			
Nile tilapia (*Oreochromis niloticus*) fillets, frozen storage	Water extract	Egypt	[97]
Cachama fish (*Piaractus brachypomus*) fillets (refrigeration)	96% Ethanol extract	Boyacá, Colombia	[98]
Fresh fish burgers	70% Ethanol extract	La California, LI, Italy	[99]
Fresh shibuta (*Barbus grypus*) fillets	Water extract	Fanus Natural Company, Trabzon, Turkey	[100]
Others			
Milk protein concentrate (diary beverages)	94 % Ethanol extract Water extract	Canada	[101]
Food packaging			
Chitosan-propolis coated polypropylene films	80% Ethanol extract	Konya region, Turkey.	[102]
Antimicrobial edible coating of Bell Pepper	95% Ethanol extract	China	[103]
Active film with antimicrobial effect, reduces oxidation of butter during storage	70% Ethanol extract	Brazilian red propolis	[104]
Lactic acid polymer packaging films containing propolis	Standardized propolis extract EPID®	Italy	[105]
Cassava starch films containing propolis	Commercial ethanolic propo-lis extract Brazil, 12% (w/v) dry solid	Brazil	[106]
Textile materials for biomedical applications			
Antibacterial activity, water repellent and UV protection of cotton textiles	70% Ethanol extract	Monofia province, Egypt	[107]
Antibacterial finishing of cotton fabrics	30% Ethanol extract	North-East Romania	[108]
Electrospun propolis/polyurethane composite nanofibers	THF/DMF solution	Australia	[109]
Electrospun bicomponent mats of poly(vinyl alcohol) (PVA) and aqueous propolis solution	Water extracts	Vilnius, Lithuania	[110]
Orally fast dissolving fibers by electrospinning process with polyvinyl pyrrolidone (PVP) and polyvinyl alcohol (PVA)	70% Ethanol extract	Chiangmai Healthy Product Co., Ltd. (Thailand)	[111]
Other applications			
Inhibition of corrosion for carbon steel in aqueous media	Water propolis extract	Poplar type Daqahlia province (delta Nile), Egypt	[112]
Propolis as a novel membrane and its application in phenol biosensors	Acetone extract	Urmia, northwestern Iran	[113]

1	2	3	4
Propolis in organic/inorganic interfaces optoelectronic applications	96% Ethanol extract	Ukraine	[114, 115]
Nanodiamond Restorative Materials containing propolis (hydrogel)	Hydroalcoholic extracts	Australia Brazilian green propolis type Uruguyan Propolis	[116]
Application to air filters (in air purifiers or heating, ventilation, and air-conditioning (HVAC) systems)	Ethanol extract	Korea	[117, 118]
Effect on the ruminal degradation of nutrients and reduction of methanogenesis in ruminants	70 % ethanol extract	Brazilian red Egyptian brown	[119]

Closely related to food preservation is the application of propolis as a constituent of the so-called active packaging materials, based on the incorporation of active substances, mainly natural antimicrobial and antioxidant agents, in food bio-opackaging materials [105]. Its incorporation in polylactic acid films, and films obtained from starch and cellulose nanocrystals, has given excellent results in the preservation of cheese, butter [104] and bell peppers [103]. It has been confirmed that propolis can be used successfully in a coating of gelatin or cellulose nanocrystals onto plastic films, whereas coating of propolis directly on cellulosic materials is not suitable as a packaging material because of the lack of stability of the polyphenol fraction [125]. The diffusivity of propolis compounds in polylactic acid polymer for the development of anti-microbial packaging films has also been studied [105].

Incorporation of propolis in textiles for producing antimicrobial textile materials for different purposes, such as wound dressing, tissue engineering, medical and hygienic use, has also been studied. Propolis has been used either by the incorporation of a small amount of bee glue in electrospun polymer microfibers [109, 110], or as an eco-friendly finish for cotton fabric within the scope of a green strategy [107, 108].

A few other, unexpected applications of propolis are presented in Table 2 under **Others**: as a corrosion inhibitor, as a pesticide in horticulture, for optoelectronic applications, in air filters, etc. Propolis could even contribute to the actions against global warming, because it reduces the methanogenesis in ruminants [119]. Only time will tell whether these applications will be widely accepted.

4. CONCLUSIONS

The review of recent propolis literature demonstrates the potential of propolis to be used for the development of diverse innovative products, not only medicines and cosmetics but also in the field of the food industries, packaging, animal husbandry, etc. For this to happen, the combined efforts of researchers and technologists from different areas will be needed in order to make better use of bee glue.

REFERENCES

[1] M. Simone, J. D. Evans, M. Spivak, Resin collection and social immunity in honey bees, *Evolution* **63**, 3016–3022 (2009). DOI: 0.1111/j.1558-5646.2009.00772.x.

[2] E. Crane, *Beekeeping: Science, Practice and World Recourses*, Heinemann, London, 1988.

[3] E. L. Ghisalberti, Propolis: A review, *Bee World* **60**, 59–84 (1979). DOI: 10.1080/0005772X.1979.11097738.

[4] J. M. Sforcin, V.Bankova, Propolis: is there a potential for the development of new drugs? *J. Ethnopharmacol.* **133**, 253–260 (2011). DOI: 10.1016/j.jep.2010.10.032.

[5] D. Suarez, D. Zayas, F. Guisado, Propolis: Patents and technology trends for health applications, J*ournal of Business Chemistry* **2**, 119–125 (2005).

[6] V. Bankova, Chemical diversity of propolis and the problem of standardization, *J. Ethnopharmacol*. **100**, 114–117 (2005). DOI: 10.1016/j.jep.2005.05.004.

[7] M. Popova, V. Bankova, S. Bogdanov, I. Tsvetkova, C. Naydenski, G.- L. Marcazzan, A.-G. Sabatini, Chemical characteristics of poplar type propolis of different geographic origin, *Apidologie* **38**, 306–311 (2007). DOI: 10.1051/apido:2007013.

[8] A. Kujumgiev, I. Tsvetkova, Y. Serkedjieva, V. Bankova, R. Christov, S. Popov, Antibacterial, antifungal and antiviral activity of propolis of different geographic origin, *J. Ethnopharmacol.* **64**, 235–240 (1999)q. DOI: 10.1016/S0378-8741(98)00131-7.

[9] V. Seidel, E. Peyfoon, D.G. Watson, J. Fearnley, Comparative study of the antibacterial activity of propolis from different geographical and climatic zones. *Phytother. Res.* **22**,1256–1263 (2008). DOI: 10.1002/ptr.2480.

[10] P. Ristivojević, J. Trifković, F. Andrić, D. Milojković-Opsenica, Poplar-type propolis: chemical composition, botanical origin and biological activity, *Nat. Prod. Commun.* **10**, 1869–1876 (2015).

[11] S. Huang, C. P. Zhang, K. Wang, G. Q. Li, F.L. Hu, Recent advances in the chemical composition of propolis, *Molecules* **19**, 19610–19632 (2014). DOI: 10.3390/molecules191219610**.**

[12] V. Bankova, B. Trusheva, Chemical profiles of different ptopolis types in relation to their biological activity. In: T. Farooqui, A. Farooqui (Eds), *Beneficial Effects of Propolis on Human Health and Chronic Diseases*. NOVA Science Publishers, New York, 2013, pp. 1–38.

[13] M. P. Popova, Structural basis of antimicrobial activity of Mediterranean propolis, In: T. Farooqui, A. Farooqui (Eds), *Beneficial Effects of Propolis on Human Health*, NOVA Science Publishers, New York, 2013, pp. 171–188.

[14] V. S. Bankova, S. S. Popov, N. L. Marekov, A study on flavonoids of propolis, *J. Nat. Prod.* **46**, 471–474 (1983). DOI: 10.1021/np50028a007.

[15] E. Nagy, V. Papay, G. Litkei, Z. Dinya, Investigation of the chemical constituents, particularly the flavonoid components of propolis and *Populi gemma* by the GC/MS method, L. Farkas, M. Gabor, F. Kallay (Eds), *Flavonoids and Bioflavonoids*. Amsterdam: Elsevier, 1985, pp. 233–240.

[16] W. Greenaway, T. Scaysbrook, F. R. Whatley, Composition of propolis of Oxfordshire, UK and its relation to poplar bud exudate. *Z. Naturforsch*. **43c**, 301–304 (1988). DOI: 10.1515/znc-1988-3-423.

[17] V. Bankova, A. Dyulgerov, S. Popov, L. Evstatieva, L. Kuleva, O. Pureb, Z. Zamjansan, Propolis produced in Bulgaria and Mongolia: phenolic compounds and plant origin, *Apidologie* **23**, 79–85 (1992). DOI: 10.1051/apido:19920109.

[18] K. R. Markham, K. A. Mitchell, A. L. Wilkins, J. A. Daldy, Y. Lu, HPLC and GC-MS identification of the major organic constituents in New Zealand propolis, *Phytochemistry* **42**, 205–211 (1996). DOI: 10.1016/0031-9422(96)83286-9.

[19] A. C. H. F. Sawaya, D. M. Tomazela, I. B. S. Cunha, V. S. Bankova, M. C. Marcucci, A. R. Custodio, M. N. Eberlin, Electrospray ionization mass spectrometry fingerprinting of propolis, *Analyst*. **129**, 739–744 (2004). DOI: 10.1039/B403873H.

[20] W. Cao, J. Fu, Z. Suo, W. Chen, J. Zheng, A comparative study on chemical compositions of Chinese propolis and poplar resin, *Food Fermen. Indust*. **33**, 162–166 (2007).

[21] V. Bankova, G. Boudourova-Krasteva, J. M. Sforcin, X. Frete, A. Kujumgiev, R. Maimoni-Rodella, S. Popov, Phytochemical evidence for the plant origin of Brazilian propolis from Sao Paulo state, *Z. Naturforsch. C*. **54**, 401–405 (1999). DOI: 10.1515/znc-1999-5-616.

[22] E. W. Teixeira, G. Negri, R. M. S. A. Meira, D. Message, A. Salatino, Plant origin of green propolis: bee behavior, plant anatomy and chemistry, *eCAM*. **2**, 85–92 (2005). DOI: 10.1093/ecam/neh055.

[23] A. Daugsch, C. S. Moraes, P. Fort, Y. K. Park, Brazilian red propolis — chemical composition and botanical origin, *eCAM*. **5**, 435–441 (2008). DOI: 10.1093/ecam/nem057.

[24] C. Lotti, M. C. Fernandez, A. L. Piccinelli, O. Cuesta-Rubio, I. M. Hernandez, L. Rastrelli, Chemical constituents of red Mexican propolis, *J. Agric. Food Chem*. **58**, 2209–2213 (2010). DOI: 10.1021/jf100070w.

[25] A. L. Piccinelli, C. Lotti, L. Campone, O. Cuesta-Rubio, M. C. Fernandez, L. Rastrelli, Cuban and Brazilian red propolis: botanical origin and comparative analysis by high-performance liquid chromatography-photodiode array detection/electrospray ionization tandem mass spectrometry, *J. Agric. Food Chem*. **59**, 6484–6491 (2011). DOI: 10.1021/jf201280z.

[26] B. Trusheva, M. Popova, V. Bankova, I. Tsvetkova, C. Naydenski, A. G. Sabatini, A new type of European propolis, containing bioactive labdanes, *Rivista Italiana EPPOS*. **13**, 3–8 (2003).

[27] E. Melliou, I. Chinou, Chemical analysis and antimicrobial activity of Greek propolis, *Planta Med*. **70**, 1–5 (2004). DOI: 10.1055/s-2004-827150.

[28] M. P. Popova, K. Graikou, I. Chinou, V. S. Bankova, GC-MS profiling of diterpene compounds in Mediterranean propolis from Greece, *J. Agric. Food Chem*. **58**, 3167–3176 (2010). DOI: 10.1021/jf903841k.

[29] M. Popova, B. Trusheva, S. Cutajar, D. Antonova, D. Mifsud, C. Farrugia, V. Bankova, Identification of the plant origin of the botanical biomarkers of Mediterranean type propolis, *Nat. Prod. Commun*. **7**(5), 569–570 (2012).

[30] B. Trusheva, M. Popova, E. B. Koendhori, I. Tsvetkova, H. Naydenski, V. Bankova, Indonesian propolis: chemical composition, biological activity and botanical origin, *Nat. Prod. Res*. **25**, 606–613 (2011). DOI: 10.1080/14786419.2010.488235.

[31] M. Popova, R. Dimitrova, H. T. Al-Lawati, I. Tsvetkova, H. Najdenski, V. Bankova, Omani propolis: chemical profiling, antibacterial activity and new propolis plant sources, *Chem. Cent. J.* **7**, 158 (2013). DOI: 10.1186/1752-153X-7-158.

[32] M. do S. S. da Silva, A. M. das G. L. Citó, M. H. Chaves, J. A. D. Lopes, Triterpenóides tipo cicloartano de propolis de Teresina – PI, *Quim. Nova*, **28**, 801-804 (2005). DOI: 10.1590/S0100-40422005000500013.

[33] F. Li, S. Awale, Y. Tezuka, S. Kadota, Cytotoxic constituents of propolis from Myanmar and their structure-activity relationship, *Biol. Pharm. Bull.* **32**, 2075–2078 (2009). DOI: 10.1248/bpb.32.2075.

[34] S. Sanpa, M. Popova, T. Tunkasiri, S. Eitssayeam, V. Bankova, P. Chantawannakul, Chemical profiles and antimicrobial activities of Thai propolis collected from *Apis mellifera*, *Chiang Mai J. Sci.* (2015) (in press).

[35] S. K. Shalmany, M.Shivazad, The effect of diet propolis supplementation on Ross Broiler chicks performance, *Int. J. Poult. Sci.* **5**, 84–88 (2006). DOI: 10.3923/ijps.2006.84.88.

[36] P. T. Seven, I. Seven, Effect of dietary Turkish propolis as alternative to antibiotic on performance and digestibility in broilers exposed to heat stress. *J. Appl. Anim. Res.*, **34,** 193–196 (2008). DOI: 10.1080/ 09712119.2008.9706970.

[37] P. Tatli Seven, I. Seven, M. Yilmaz, U. G. Şimşek, The effects of Turkish propolis on growth and carcass characteristics in broilers under heat stress, *Anim. Feed Sci. Technol.* **146**, 137–148 (2008). DOI: 10.1016/j.anifeedsci.2007.11.003.

[38] U. T. Mahmoud, M. A. Abdel-Rahman, M. H. A. Darwish, T. J. Applegate, H-w. Cheng, Behavioral changes and feathering score in heat stressed broiler chickens fed diets containing different levels of propolis, *Appl. Animal Behav. Sci.* **166**, 98–105 (2015). DOI: 10.1016/j.applanim.2015.03.003.

[39] A. Daneshmand, G. H. Sadeghi, A. Karimi, A. Vaziry, S. A. Ibrahim, Evaluating complementary effects of ethanol extract of propolis with the probiotic on growth

performance, immune response and serum metabolites in male broiler chickens, *Livestock Science* **178**, 195–201 (2015). DOI: 10.1016/j.livsci.2015.04.012.

[40] M. A. M. Mahmoud, H. S. Abdel-Mohsein, M. R. F. Farghali, Antioxidant properties of Chinese propolis in Ross broilers exposed to heat stress in Egypt, *Open J. Vet. Med.* **5**, 197–209 (2015). DOI: 10.4236/ojvm. 2015.59027.

[41] C. Eyng, A. E. Murakami, I. C. Ospina-Rojas, R. B. Pedroso, T. G. V. Silveira, D. A. L. Lourenço, Efecto de la inclusión dietética de extracto etanólico de propóleos en la inmunidad de pollos de engorde [Effect of diet inclusion of ethanolic extract of propolis on broiler immunity], *Arch. Med. Vet*. **47**, 185–192 (2015). DOI: 10.4067/s0301-732x2015000200009.

[42] P. Haščík, J. Garlík, I.O.E. Elimam, V. Kňazovická, M. Kačániová, M. Šimko, M. Mellen, Meat performance of chickens Hubbard JV after application of propolis extract, *J. Microb., Biotechn. Food Sci.* **3**, 118–121 (2013).

[43] P. Haščik, I. O. Elimam, M. Kročko, M. Bobko, M. Kačaniová, J. Garlík, M. Šimko, A. A. Saleh, The influence of propolis as supplement diet on broiler meat growth performance, carcass body weight, chemical composition and lipid oxidation stability, *Acta Univ. Agric. et Silvic. Mendel. Brun*. **63**, 411–418 (2015). DOI: 10.11118/actaun 201563020411.

[44] K. Kita, I. R. Ken, C. Akamine, W. Kawada, Y. Shimura, T. Inamoto, Influence of propolis residue on the bacterial flora in the cecum of Nanbu Kashiwa, *Japanese Poultry Sci.* **51**, 275–280 (2014) DOI: 10.2141/jpsa.0130137.

[45] R. F. Paludo, T. G. Petrolli, O. J. Petrolli, E. L. Fiorentin, D. Pavan, Effect of addition of green propolis in broiler chick diets on metabolizable energy utilization and hemathological parameters, *Enciclopédia Biosfera, Científico Conhecer – Goiânia,* **11**, 827–836 (2015).

[46] I. T. Tayeb, B. F. Sulaiman, Effect of propolis supplementation on productive performance in local quail, *IJAS* **4**, 621–627 (2014).

[47] P. T. Seven, The effects of dietary Turkish propolis and vitamin C on performance, digestibility, egg production and egg quality in laying hens under different environmental temperatures, *Asian-Australasian J Anim. Sci.* **21,** 1164–1170 (2008). DOI: 10.5713/ajas. 2008.70605.

[48] E. Scripnic, N. Eremia, Propolis extract used in incubation technology for hens eggs treatment**,** *Scientific Papers. Series D. Animal Science* **LVIII**, 330–333 (2015).

[49] C. C. B. F. Ítavo, M. G. Morais, C. L. Ramos, L. C. V. Ítavo, T. R. Tomich, J. A. da Silva, Green propolis extract as additive in the diet for lambs in feedlot, *Rev. Bras. Zootecn.* **40**, 1991–1996 (2011). DOI: 10.1590/S1516-35982011000900021.

[50] F. A. O. Baracho, G. F. da Silva, E. H. S. Rocha, J. M. D. Gomes, L. G. de Oliveira, L. T. A. dos Santos, F. A. de Souza, P. M. G. Beelen, Desempenho de cordeiros alimentados com Própolis Vermelha de Alagoas e monensina sódica [Performance of confined lambs fed with Brazilian Red Propolis and monensin sodium] XXV CONGRESSO BRASILEIRO DE ZOOTECNIA ZOOTEC 2015 *Dimensões Tecnológicas e Sociais da Zootecnia* Fortaleza – CE, 27 a 29 de maio de 2015. http://zootec2015.com.br/anais/Producao%20e%20Nutricao%20de%20Ruminantes/1555.pdf

[51] M. V. Valero, L. M. Zeoula, L. P. P. de Moura, J. B. G. C. Júnior, B. B. Sestari, I. N. do Prado, Propolis extract in the diet of crossbred (½ Angus *vs.* ½ Nellore) bulls finished in feedlot: animal performance, feed efficiency and carcass characteristics [Extrato de própolis na dieta de machos mestiços (½ Angus *vs.* ½ Nelore) não castrados terminados em confinamento: desempenho animal, eficiência alimentar e características de carcaça], *Semina: Ciências Agrárias, Londrina* **36**, 1067–1078 (2015). DOI: 10.5433/1679-0359.2015v36n2p1067.

[52] F. G. B. da Silva, S. M. Yamamoto, E. M. S. da Silva, M. A. Á. Queiroz, L. A.Gordiano, M. A. Formiga, Propolis extract and sodium monensin on ruminal fermentation and hematological parameters in sheep, *Acta Scientiarum. Animal Sciences Maringá* **37**, 273–280, (2015). DOI: 10.4025/actascianimsci.v37i3.25725.

[53] J. Li, I. H. Kim, Effects of *Saccharomyces cerevisiae* cell wall extract and poplar propolis ethanol extract supplementation on growth performance, digestibility, blood profile, fecal microbiota and fecal noxious gas emissions in growing pigs. *Anim. Sci. J.*, **85,** 698–705 (2014). DOI: 10.1111/asj.12195.

[54] T. Šegvić-Bubić, J. Boban, L. Grubišić, Ž. Trumbić, M. Radman, M. Perčić, R. Čož-Rakovac, Effects of propolis enriched diet on growth performance and plasma biochemical parameters of juvenile European sea bass (*Dicentrarchus labrax* L.) under acute low temperature stress, *Aquaculture Nutrition* **19**, 877–885 (2013). DOI: 10.1111/anu.12032.

[55] J. Deng, Q. An, B. Bi, Q. Wang, L. Kong, L. Tao, X. Zhang, Effect of ethanolic extract of propolis on growth performance and plasma biochemical parameters of rainbow trout (*Oncorhynchus mykiss*), *Fish Physiol. Biochem.* **37**, 959–967 (2011). DOI: 10.1007/s10695-011-9493-0.

[56] N. S. Naghavi, F. Zeyghampoor, A. Nazari, E. Shams, Infectivity control of *Streptococcus iniae* isolated and detected from rainbow trout (*Oncorhynchus mykiss*) in Iran, by beehive propolis ethanol extract, *Indian Journal of Fundamental and Applied Life Sciences* **4**, 563–569 (2014).

[57] A. Tukmechi, F. Karimi Rad, F. Farrokhi, N. Agh, R. Jalili, The effects of short- and long-term diet supplementation with Iranian propolis on the growth and immunity in rainbow trout (*Oncorhynchus mykiss*)", *IJVR* **15**, 250–255 (2014).

[58] A. A. Abbass, A. M. El-Asely, M. M. M. Kandiel, Effects of dietary propolis and pollen on growth performance, fecundity and some hematological parameters of *Oreochromis niloticus. Turk. J. Fish. Aquat. Sci.* **12**, 851–859 (2012). DOI: 10.4194/1303-2712-v12_4_13.

[59] F. Meurer, M. M. da Costa, D. A. D. de Barros, S. T. de Oliveira, P. S. da Paixao, Brown propolis extract in feed as a growth promoter of Nile tilapia (*Oreochromis niloticus*, Linnaeus 1758) fingerlings, *Aquaculture Res.* **40**, 603–608 (2009). DOI: 10.1111/j.1365-2109. 2008.02139.x.

[60] E. Wafaa, I. Doaa, A. El-Murr, M. Rania, Effects of dietary inclusion of black cumin seeds, green tea and propolis extraction growth parameters, body composition and economic efficiency of Nile tilapia, *Oreo-*

chromis niloticus, *World J. Fish Mar. Sci.* **6**, 447–452 (2014). DOI: 10.5829/idosi.wjfms.2014.06.05.8632.

[61] M. E. Yonar, S. M. Yonar, A. Pala, S. Silici, N. S. Glam, Trichlorfon-induced haematological and biochemical changes in *Cyprinus carpio*: ameliorative effect of propolis, *Dis. Aquat. Organ.* **114**, 209–216 (2015). DOI: 10.3354/dao02866.

[62] S. Silici, N. A. Koç, F. Mutlu Sariguzel, O. Sagdic, Mould inhibition in different fruit juices by propolis, *Archiv für Lebensmittelhygiene*, **56**, 87–90 (2005).

[63] M. Makarewicz, I. Drozdz, T. Tuszynski, The effect of some bee products on microbiological stability of fresh fruit juices, *J. Health Sci.* **2**, 125–140 (2012).

[64] S. Silici, K. Karaman, Inhibitory effect of propolis on patulin poduction of *Penicillium expansum* in apple juice. *J. Food Process. Pres.* **38**, 1129–1134 (2014). DOI: 10.1111/jfpp.12072.

[65] A. Luis-Villaroya, L. Espina, D. García-Gonzalo, S. Bayarri, C. Pérez, R. Pagán, Bioactive properties of a propolis-based dietary supplement and its use in combination with mild heat for apple juice preservation, *Int. J. Food Microbiol.* **205**, 90–97 (2015). DOI: 10.1016/j.ijfoodmicro.2015.03.020.

[66] N. A. Montijo, A. F. Silva, G. H. G. Costa, O. E. Ferreira, M. J. R. Mutton, Yeast CA-11 fermentation in musts treated with brown and green propolis, *Afr. J. Microbiol. Res.* **8**, 3515–3522 (2014). DOI: 10.5897/AJMR2014.6937.

[67] M. J. R. Mutton, J. H. de Oliveira Filho, G. H. G. Costa, J. P. Roviero, L. Aline de Freita, Green and brown propolis: efficient natural biocides for the control of bacterial contamination of alcoholic fermentation of distilled beverage, *Food Sci. Technol. (Campinas)* **34**, 767–772 (2014). DOI: 10.1590/1678-457X.6469.

[68] S. Yang, L. Peng, Y. Cheng, F. Chen, S Pan, Control of citrus green and blue molds by Chinese propolis. *Food Sci. Biotechnol.* **19**, 1303–1308 (2010). DOI: 10.1007/s10068-010-0186-8.

[69] O. N. Manty, Efficacy evaluation of Iraqi propolis against gray mold of stored orange caused by *Penicillium digitatum*. *Plant Pathology Journal* **14**, 153–157 (2015). DOI: 10.3923/ppj.2015.153.157.

[70] O. N. Matny, S. H. S. Al-Warshan, A. M. Ali, Antifungal evaluation of Iraqi propolis against *Penicillium expansum* and mycotoxin production in apple, *Int. J. Curr. Microbiol. App. Sci.* **4**, 399–405 (2015).

[71] E. E. Candir, A. E. Ozdemir, E. M. Soylu, N. Sahinler, A. Gül, Effects of propolis on storage of sweet cherry cultivar Aksehir Napolyon, *Asian J. Chem.* **21**, 2659–2666 (2009).

[72] A. E. Özdemír, E. E. Çandir, M. Kaplankiran, E. M. Soylu, N. Şahínler, A. Gül, The effects of ethanol-dissolved propolis on the storage of grapefruit cv. Star Ruby. *Turk. J. Agric. For,* **34**, 155–162 (2010). DOI: 10.3906/tar-0902-50.

[73] B.-H. Mattiuz, M.-N. Ducamp-Collin, C. F. M. Mattiuz, C. Vigneault, K. M. Marques, W. Sagoua, D. Montet, Effect of propolis on postharvest control of anthracnose and quality parameters of 'Kent' mango, *Scientia Horticulturae* **184**, 160–168 (2015). DOI: 10.1016/j.scienta.2014.12.035.

[74] N. Zahid, A. Ali, Y. Siddiqui, M. Maqbool, Efficacy of ethanolic extract of propolis in maintaining postharvest quality of dragon fruit during storage. *Posth. Biol. Technol.*, **79**, 69–72 (2013). DOI:10.1016/j.postharvbio. 2013.01.003.

[75] N. Zahid, A. Ali, P. G.Alderson, M. Maqbool, S. Manickam, Dual mode of action of ethanolic extract of propolis (EEP) for the control of postharvest anthracnose in dragon fruits (Conference Paper). *Acta Horticulturae* **1012**, 711–718 (2013).

[76] A. Ali, C. K. Cheong, N. Zahid, Composite effect of propolis and gum arabic to control postharvest anthracnose and maintain quality of papaya during storage, *Int. J. Agric. Biol.* **16**, 1117–1122, (2014).

[77] E. Barrera, J. Gil, A. Restrepo, K. Mosquera, D. Durango, A coating of chitosan and propolis extract for the postharvest treatment of papaya (*Carica papaya* L. cv. Hawaiiana) [Un Recubrimiento de quitosano y extracto de propóleos para el manejo poscosecha de la papaya (*Carica papaya* L. *cv.* Hawaiiana)], *Rev.Fac.Nal.Agr*. **68**, 7667–7678 (2015). DOI: 10.15446/rfnam.v68n2.50982.

[78] G. A. Griffiths, U. Toshitaka, T. Fumihiko, H. Daisuke, Effect of vapors from fractionated samples of propolis on microbial and oxidation damage of rice during storage, *J. Food Eng*. **88**, 341–352 (2008). DOI: 10.1016/j.jfoodeng.2008.02.019.

[79] O. Kameyama, J. A. Junior, J. M. de Assis Teixeira, N. J. de Andrade, V. P. R. Minin,; L. dos Santos Soares, Propolis extract for sanitation and preservation of minimally processed carrot, *Revista Ceres*, **55**, 218–223 (2008). (*in Portuguese*)

[80] X. Feás, L. Pacheco, A. Iglesias, L. M. Estevinho, Use of propolis in the sanitization of lettuce. *Int. J. Mol. Sci.* **15,** 12243–12257 (2014). DOI: 10.3390/ijms150712243.

[81] C. A. Guginski-Piva, I. dos Santos, A. Wagner Júnior, D. W. Heck, M. F. Flores, K. Pazolini, Propolis for the control of powdery mildew and the induction of phytoalexins in cucumber [El propóleo para el control de oídio y la inducción de fitoalexinas en pepino], *Idesia* **33**, 39–47 (2015). DOI: 10.4067/s0718-34292015000100005.

[82] O. N.Matny, E. K. Abdul-Karim, R. A. Naemah, R. A. Al-Ani, Activity of propolis and *Boswellia* sp. resins extract against *Sclerotinia sclerotiorum* causative agent of white rot disease of *Phaseolus vulgaris* and *Daucus carota* under storage conditions, *J. Exp. Biol. Agric. Sci.* **2**, 65–71 (2014).

[83] M. V. Alvarez, A. G. Ponce, C. A. Mazzucotelli, M. R. Moreira, The impact of biopreservatives and storage temperature in the quality and safety of minimally processed mixed vegetables for soup, *J. Sci. Food Agric.* **95**, 962–971 (2015). DOI: 10.1002/jsfa.6770.

[84] M. V. Alvarez, G. Ponce, M. R. Moreira, Combined effect of bioactive compounds and storage temperature on sensory quality and safety of minimally processed celery, leek and butternut squash, *Journal of Food Safety* **35**, 560–574 (2015). DOI: 10.1111/jfs.12206.

[85] A. Ali, W. L. Chow, N. Zahid, M. K. Ong, Efficacy of propolis and cinnamon oil coating in controlling postharvest anthracnose and quality of chilli (*Capsicum annuum* L.) during cold storage, *Food Bioprocess. Technol.* **7**, 2742–2748 (2014). DOI 10.1007/s11947-013-1237-y.

[86] N. Sahinler, A. Gül, G. Çopur, Chemical composition and preservative effect of Turkish propolis on egg quality during storage, *Asian J. Chem.* **21**, 1877–1886 (2009).

[87] G. Copur, O. Camci, N. Sahinler, A. Gul, The effect of propolis egg shell coatings on interior egg quality, *Arch. Geflügelk*. **72**, 35–40 (2008).

[88] A. Aygun, D. Sert, G. Copur, Effects of propolis on eggshell microbial activity, hatchability, and chick performance in Japanese quail (*Coturnix coturnix japonica*) eggs, *Poult. Sci*. **91**, 1018–1025 (2012). DOI: 10.3382/ps.2011-01944.

[89] A. Aygun, D. Sert, Effects of prestorage application of propolis and storage time on eggshell microbial activity, hatchability, and chick performance in Japanese quail (*Coturnix coturnix japonica*) eggs, *Poult. Sci*. **92**, 3330–3337 (2013). DOI: 10.3382/ps.2013-03291.

[90] G. C. Akpinar, S. Canogullari, M. Baylan, S. Alasahan, A. Aygun, The use of propolis extract for the storage of quail eggs, *J. Appl. Poult. Res.* **24**, 427–435 (2015). DOI: 10.3382/japr/pfv043.

[91] J. X. De Carvalho, R. O. Suárez, F. Q. Mendes, R. V. De Barros Fernandes, M. C. Da Cunha, A. M. X. De Carvalho, Increased shelf life of eggs through the use of propolis, *Semina: Ciências Agrarias* **34**, 2287–2296 (2013). (*in Portuguese*) DOI: 10.5433/1679-0359.2013v34n5p2287.

[92] F. H. Ali, G. M. Kassem, O. A. Atta-Alla, Propolis as a natural decontaminant and antioxidant in fresh oriental sausage, *Vet. Ital*. **46**, 167–172 (2010).

[93] C. Gutiérrez-Cortés, H. Suarez Mahecha, Antimicrobial activity of propolis and its effect on the physicochemical and sensorial characteristics in sausages, *Vitae* **21**, 90–96 (2014).

[94] R. Casquete, S. M. Castro, S. Jácome, P. Teixeira, Antimicrobial activity of ethanolic extract of propolis in "Alheira", a fermented meat sausage, *Cogent Food & Agriculture* (2015). DOI: 10.1080/23311932. 2015.1125774.

[95] R. D. Vargas-Sánchez, G. R. Torrescano-Urrutia, E. Acedo-Félix, E. Carvajal-Millán, A. F. González-Córdova, B. Vallejo-Galland, M. J. Torres-Llanez, A. Sánchez-Escalante, Antioxidant and antimicrobial activity of commercial propolis extract in beef patties, *J. Food Sci*. **79**, C1499 – C1504 (2014). DOI: 10.1111/ 1750-3841.12533

[96] M. Kročko, M. Bobko, O. Bučko, M. Čanigová, V. Ducková, Sensory quality, colour and oxidative stability of cured cooked ham with propolis extract, *Potravinárstvo* **8**, 102–106 (2014). DOI: 10.5219/365.

[97] S. I. A. Hassanin, E.-S. A. El-Daly, Effect of propolis and garlic on Nile Tilapia *Oreochromis niloticus* fillets during frozen storage, *J. Arab. Aquacul. Soc.* **8**, 237–247 (2013).

[98] H. S. Mahecha, Á. J. Toquica, A. C. D. Moreno, Physicochemical evaluation of Cachama fillets (*Piaractus brachypomus*) preserved with propolis during storage, *Rev. Fac. Nal. Agr*. **67**, 7229–7236 (2014). DOI: 10.15446/rfnam.v67n1.42653.

[99] S. Spinelli, A. Conte, L. Lecce, A. L. Incoronato, M. A. Del Nobile, Microencapsulated propolis to enhance the antioxidant properties of fresh fish burgers, *J. Food Process Eng.* **38**, 527–535 (2015), DOI: 10.1111/jfpe. 12183.

[100] M. Duman, E. Özpolat, Effects of water extract of propolis on fresh shibuta (*Barbus grypus*) fillets during chilled storage, *Food chem.* **189**, 80–85 (2015). DOI: 10.1016/j.foodchem.2014.08.091.

[101] S. M. Cottica, H. Sabik, D. Bélanger, H. J. Giroux, J. V. Visentainer, M. Britten, Use of propolis extracts as antioxidant in dairy beverages enriched with conjugated linoleic acid, *Eur Food Res Technol* **241**, 543–551 (2015). DOI: 10.1007/s00217-015-2483-1.

[102] E. Torlak, D. Sert, Effectiveness of chitosan-propolis coated polypropylene films against foodborne pathogens, *Int. J. Biol. Macromol.* **60**, 52–55 (2013). DOI: 10.1016/j.ijbiomac.2013.05.013.

[103] A. Ali, Y. Z. Wei, M. A. Mustafa, Exploiting propolis as an antimicrobial edible coating to control post-harvest anthracnose of Bell Pepper, *Packaging Technol. Sci.* **28**, 173–179 (2015), DOI: 10.1002/pts.2088.

[104] S. S. Costa, J. I. Druzian, B. A. S. Machado, C. O. de Souza, A. G. Guimarães, Bi-functional biobased packing of the cassava starch, glycerol, licuri nanocellulose and red propolis, *PLoS ONE* **9**, e112554 (2014). DOI: 10.1371/journal.pone.0112554.

[105] E. Mascheroni, V. Guillard, F. Nalin, L. Mora, L. Piergiovanni, Diffusivity of propolis compounds in polylactic acid polymer for the development of anti-microbial packaging films, *J. Food Eng*, **98**, 294–301 (2010). DOI: 10.1016/j.jfoodeng.2009.12.028.

[106] G. K. P. de Araújo, S. J. de Souza, M. V. da Silva, F. Yamashita, O. H. Gonçalves, F. V. Leimann, M. A. Shirai, Physical, antimicrobial and antioxidant properties of starch-based film containing ethanolic propolis extract, *Int. J. Food Sci. & Technol*. **50**, 2080–2087 (2015). DOI: 10.1111/ijfs.12869.

[107] S. Sharaf, A. Higazy, A. Hebeish, Propolis induced antibacterial activity and other technical properties of cotton textiles, *Int. J. Biol. Macromol.* **59**, 408–416 (2013). DOI: 10.1016/j.ijbiomac.2013.04.030.

[108] D. Abramiuc, L. Ciobanu, R. Muresan, M. Chiosac, A. Muresan, Antibacterial finishing of cotton fabrics using biologically active natural compounds, *Fibers and Polymers* **14**, 1826–1833 (2013). DOI: 10.1007/s12221-013-1826-4.

[109] J. I. Kim, H. R. Pant, H.-J. Sim, K. M. Lee, C. S. Kim, Electrospun propolis/polyurethane composite nanofibers for biomedical applications, *Mater. Sci. Eng. C* **44**, 52–57 (2014). DOI: 10.1016/j.msec.2014.07.062.

[110] E. Adomavičiūtė, S. Stanys, M. Žilius, V. Briedis, Formation and analysis of electrospun nonwoven mats from bicomponent PVA/aqueous propolis nano-microfibres, *Fibres & Textile East. Europe* **23**, 5(113): 35–41 (2015). DOI: 10.5604/12303666.1161754.

[111] C. Asawahame, K. Sutjarittangtham, S. Eitssayeam, Y. Tragoolpua, B. Sirithunyalug, J. Sirithunyalug, Formation of orally fast dissolving fibers containing propolis by electrospinning technique, *Chiang Mai Journal of Science* **42**, 469–480 (2015).

[112] A. S. Fouda, A. Hamdy Badr, Aqueous extract of propolis as corrosion inhibitor for carbon steel in aqueous solutions, *African J. Pure Appl. Chem.* **7**, 350–359 (2013). DOI: 10.5897/AJPAC2013.0524

[113] F. Kheiri, R. E. Sabzi, E. Jannatdoust, H. Sedghi, Acetone extracted propolis as a novel membrane and its ap-

plication in phenol biosensors: the case of catechol, *J. Solid State Electrochem*. **15**, 2593–2599 (2011). DOI: 10.1007/s10008-010-1250-2.

[114] S. I. Drapak, A. P. Bakhtinov, S. V. Gavrylyuk, Z. D. Kovalyuk, O. S. Lytvyn, The formation of organic (propolis films)/inorganic (layered crystals) interfaces for optoelectronic applications, *Superlatt. Microstruc.* **44**, 563–570 (2008). DOI: 10.1016/j.spmi.2007.12.019.

[115] V. Brus, L. Pidkamin, M. Ilashchuk, P. Maryanchuk, Propolis films for hybrid biomaterial-inorganic electronics and optoelectronics, *Applied Optics* **53**, B121-B127 (2014). DOI: 10.1364/AO.53.00B121.

[116] V. T. Perchyonok, T. Souza, R. Felliti, S. Zhang, S. Grobler, Bio-functional nanodiamond restorative materials containing bio-additives: *In vitro* approach, *Open Journal of Stomatology* **5**, 117–126 (2015). DOI: 10.4236/ojst.2015.55017.

[117] C. G. Woo, J.-S. Kang, H.-J. Kim, Y.-J. Kim, B. Han, Treatment of air filters using the antimicrobial natural products propolis and grapefruit seed extract for deactivation of bioaerosols, *Aerosol Science and Technology* **49**, 611–619 (2015). DOI: 10.1080/ 02786826.2015.1054983.

[118] B. Han, J.-S. Kang, H.-J. Kim, C.-G. Woo, Y.-J. Kim, Investigation of antimicrobial activity of grapefruit seed extract and its application to air filters with comparison to propolis and shiitake, *Aerosol and Air Quality Research* **15**, 1035–1044 (2015). DOI: 10.4209/aaqr. 2014.09.0208.

[119] A. S. Morsy, Y. A. Soltan, S. M. A. Sallam, M. Kreuzer, S. M. Alencar, A. L. Abdalla, Comparison of the *in vitro* efficiency of supplementary bee propolis extracts of different origin in enhancing the ruminal degradability of organic matter and mitigating the formation of methane, *Animal Feed Sci. Technol.* **199**, 51–60 (2015). DOI: 10.1016/j.anifeedsci.2014.11.004.

[120] A. Salatino, É. W. Teixeira, G. Negri, D. Message, Origin and chemical variation of Brazilian propolis. *Evidence-based Complementary and Alternative Medicine*.;**2,** 33–38 (2005). DOI: 10.1093/ecam/neh060.

[121] R. Silva-Carvalho, F. Baltazar, C. Almeida-Aguiar, Propolis: A complex natural product with a plethora of biological activities that can be explored for drug development, *Evidence-Based Complementary and Alternative Medicine*, **2015**, Article ID 206439, 29 pages, (2015). DOI: 10.1155/2015/206439.

[122] M. M. Tajkarimi, S. A. Ibrahim, D. O. Cliver, Antimicrobial herb and spice compounds in food, *Food Control* **21**, 1199–1218 (2010). DOI: 10.1016/j. foodcont.2010.02.003.

[123] B. Nanditha, P. Prabhasankar, Antioxidants in bakery products: a review, *Crit. Rev. Food. Sci. Nutr.* **49**, 1–27 (2009). DOI: 10.1080/10408390701764104.

[124] M. Carocho, M. F. Barreiro, P. Morales, I. C. F. R. Ferreira, Adding molecules to food, pros and cons: A review on synthetic and natural food additives, *Comprehensive Reviews in Food Science and Food Safety*, **13**, 377–399 (2014). DOI: 10.1111/1541-4337.12065.

[125] J. M. Fuentes-Alventosa, S. Farris, F. Li, L. Piergiovanni, E. Mascheroni, New active packaging materials based on propolis, *Italian Journal of Food Science*, **24**, 133–136 (2012).