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Evaluating the Efficacy of Polyurethane Polymer as a Antimicrobial Agents Over Woods

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Abstract: *It is deal with a research paper, there has been a growing interest in using polymers with antibacterial and antifungal properties; therefore, the present review is focused on the effect of natural compounds on the antibacterial and antifungal properties of polyurethane (PUR). This is very important because materials and objects made with this polymer can be used as antibacterial and antifungal ones in places where hygiene and sterile conditions are particularly required and thus can become another possibility in comparison to commonly used disinfectants, which mostly show high toxicity to the environment and the human health. This topic also presents the possibilities of using natural extracts as antibacterial, antifungal, and antiviral additives, which, in contrast to the currently used antibiotics, have a much wider effect. The different kinds of fungi, but they cannot fight viruses; therefore, compounds of natural origin can find wide use as biocidal substances. Fungi grow in almost any environment, and they reproduce easily in dirt and wet spaces; thus, the development of antifungal polyurethane foams is focused on avoiding fungal infections and inhibiting growth. The ability of micro-organisms to grow on polyurethanes can cause human health problems during the use and storage of polymers, making it necessary to use additives that eliminate bacteria, viruses, and fungi.*

Keywords: polyurethane foams, antibacterial properties, natural additives

I. INTRODUCTION

Nowadays, disinfectants are mostly used for their cost-effectiveness and powerful outcomes, but these chemicals show high toxicity to the environment and human health. Such measures have many disadvantages, e.g., skin irritation on prolonged contact, possible bronchial irritation from inhalation, general caustic effects and corrosion of metals, product deterioration on standing, and others cause those other solutions are currently being sought. Natural antimicrobial additives can be successfully an alternative to chemical antimicrobials. Different kinds of plants, herbs, and spice extracts that have been used in natural medicine for many years have the greatest antimicrobial activity. The bio-resistance potential of clove, oregano, curcumin, cinnamon, birch juice, and thyme essential oils and components, cinnamaldehyde, eugenol, carvacrol, and thymol have been confirmed in the literature Liu Q., Meng X., et al. (2017) ; Burketova L. et al. (2015).

Many studies show that natural extracts with antibacterial properties can be successfully used as additives to polymers influencing their final properties. The most important feature of materials with antibacterial properties should be to inhibit the appearance, and growth of bacteria and preclude their cumulation. The largest amounts of the most popular bacteria, such as *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus*, appear on objects which are near to patients, such as bed rails and headboard, armchairs, and cabinets so there are other contact surfaces, from which bacteria can easily transfer to patients and their guardians and other employees (Liu Q., Meng X., et al., 2018). In the presented works, there are used as additives and modifiers of polyurethanes, which there are thoroughly researched and used as natural medicines daily.

There are no reports in the literature of the use of other toxic natural extracts as polyurethane modifiers. Before starting the study, data on the toxicity of the selected plant should be collected. If the plant is not toxic, continue testing if no toxicity data exist; appropriate determinations should be selected for the toxicity analysis. It is also important to develop and prepare a safety and toxicity protocol. Additionally, it should also be mentioned that the type of polymers used has significant importance in the search for final products that should mainly inhibit the growth of bacteria, fungi, and viruses..

It is effectual that the polymers selected to produce specific items should have a bacteriostatic activity to prevent the expansion of bacterial colonies in their proximity or work bactericidal and radiogenic impair nearby bacteria, by changing the course of their cell processes. Important characteristics to keep in mind are the yield and the type of surface to be used. The area with antibacterial features should be prepared with polymers which properties have a long useful time with contemporary high productivity of effect.

Moreover, these polymers should show refractory to outside agents so that the process of leaching the antiseptic does not appear because of chemical or mechanical effects and it should also have the odds of constant bonding to different surfaces (Park D., Larson A.M., Klibanov A.M. et al. 2013) polyurethane foams are mainly used as insulation materials. Therefore, they should be resistant to viruses, bacteria and fungi. Commercial, synthetic compounds used as antimicrobial and antioxidant agents are mainly derived from phenol, and they are heavily toxic for human health. Nowadays, the tendency is to limit the use of synthetic additives, and replace them with the natural, bio-based antimicrobial and antioxidants additives that do not impact the human health. The application of natural compounds with an antimicrobial and anti-aging activity have been used in previous research. For example, Członka et al. (2020) studied the antioxidant and antimicrobial activity of polyurethane foams containing clove filler.

The obtained materials showed great antibacterial activity against selected bacteria, e.g., *E. coli* and *S. aureus*. Similar results were obtained in the case of polyurethane foams with incorporated nutmeg filler—the inhibitory zone of four bacterial strains (*E. coli*, *S. aurous*) significantly increased with the incorporation of nutmeg compound (Członka S., Strąkowska A., et al. (2020). The antimicrobial activity of cinnamon extract was also confirmed by Liszkowska et al.(2019) in the case of new materials based on cinnamon extract embedded in polyurethane matrices.

The presented results confirmed that the natural, antibacterial compounds can be incorporated into polyurethane foams and retain their inhibitory effect against microbial growth. Previous studies have shown that strong interfacial interaction, such as hydrogen bonding, can be easily formed between the additive molecules and isocyanate groups, leading to the formation of a cross-linked structure. It has been shown that the functional groups of natural additives can react with isocyanates even in the absence of catalyst leading to the formation of urea bonds Lee S.Y., et al. (2018). The impact of the addition of natural additives on the cross-linking density of polyurethane composites is presented .

Present study of polyurethane is widely used in the production of equipment that outright comes in contact with a person as medical application, Yeoh F.H., Lee C.S., et al. (2020) and others. Results in the literature indicate that the possibility and capacity of bacteria, viruses or fungi increasing on the surface of polyurethane can initiate a human health problem that arises during the use and storage of these materials.

A good example to raise antiseptic properties of polyurethane is to change them with the application of substances, which expose antimicrobial features like cinnamaldehyde (CA). Kucinska-Lipka and Feldman shown the synthesis of antibacterial porous structure of PUR matrices (MPTLs) in a shape of fine layers by applying solvent-casting/particulate-leaching method jointed with thermally initiated phase separation Feldman D.(2021). Furthermore, received MPTLs were modified with cinnamaldehyde at various percentage concentrations (0.5–5%) to create the best antimicrobial result of the CA applied into the MPTLs structure. Both unmodified and CA-modified MPTLs samples were defined by mechanical and physicochemical properties as well as by assessment of their antibacterial efficiency. The obtained results shown that the most important antibacterial effect of CA-modified MPTLs was received when the CA amount was 3.5% and it was between all concentrations used. All the described properties arise from the fact that the CA exhibits antibacterial, antifungal, and anti-inflammatory properties. CA in other words, cynamal, is the yellow liquid with an intensive and sweet-spicy flavor, with the group of aromatic aldehydes (Shreaz S., (2016). The greatest content of CA is the oil of *Cinnamomum zeylanicum* tree Kwon Y.S.(2016). Because of that CA has in its structure aldehyde groups show that it can be built in the chemical structure of such materials as polyurethane, chitosan, polylactide, cellulose, or alginates. The meaningful advantage of speaking in favor of this substance is the fact that it has been accepted as commonly safe and harmless by the Food and Drug Administration in the USA Nostro A., et at. (2012).

II. RESULT AND DISCUSSION

In another study, 2 wt.% of lavender functionalized with kaolinite (K) and hydroxyapatite (HA) were added to Polyurethane samples Członka S. et al.(2021). Thus, prepared lavender fillers were used as a reinforcing material in the synthesis of polyurethane foams. The reference foam was labeled as PUR_REF, whereas the polyu=urethane composites reinforced with non-functionalized lavender, lavender functionalized with kaolinite, and lavender functionalized with hydroxyapatite were labeled as PUR_L, PUR_L_K, and PUR_L_H, respectively.

It was noticed that the modification of lavender using a high-energy ball milling process influence the exterior morphology and size of filler particles. In 1, the morphology of non-functionalized lavender filler was shown, and the sample contained lavender particles between 950 nm and 3 µm with a medium value at ~1.5 µm. The application of the functionalization with kaolinite and hydroxyapatite caused the structure of lavender particles to become more uniform and smoother, whereas the average size of filler decreased to 712 and 615 nm, properly Członka S. et al.(2021).

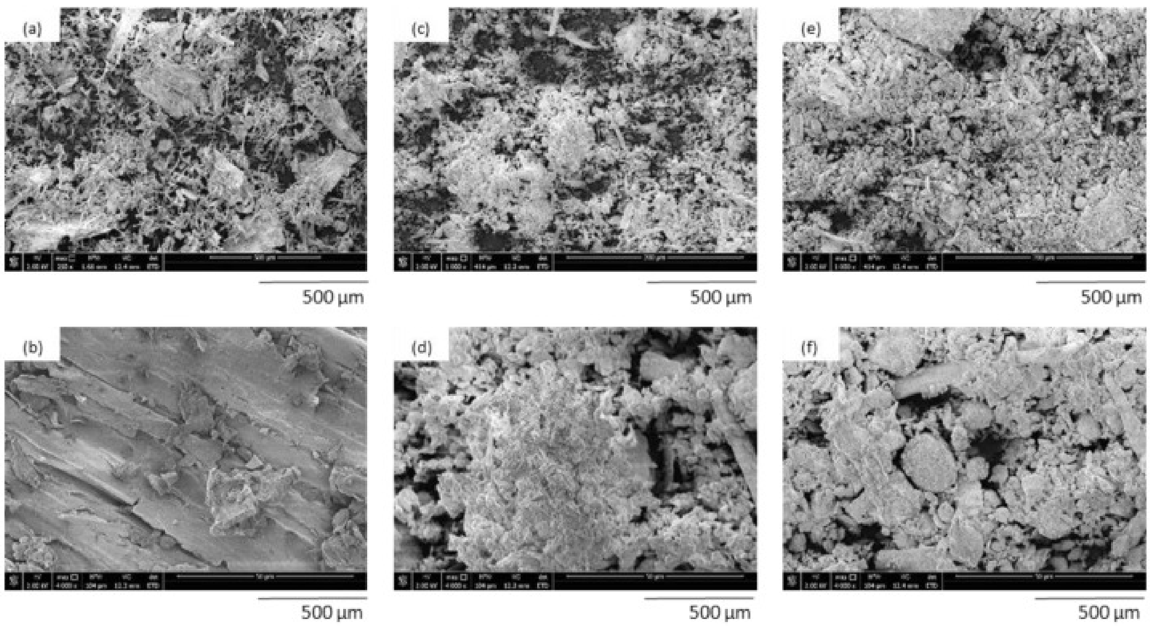

Figure 1 SEM images of lavender fillers: (**a**,**b**) non-functionalized lavender, (**c**,**d**) lavender functionalized with kaolinite, (**e**,**f**) lavender functionalized with hydroxyapatite. Adapted from Ref.

Considering the antibacterial and antioxidative properties of lavender Sienkiewicz M., (2014)and Subarnas A., (2010), kaolinite, and hydroxyapatite, the antibacterial properties of PUR composites filled with lavender fillers against *E. coli*, *S. aureus*, *B. subtilis*, *C. albicans*, and *A. niger* were evaluated (1). The obtained results confirmed the antibacterial activity of PUR composites against bacteria, but no activity against fungi was observed. The authors reported that a low antibacterial activity against fungi may relate to low concentration of lavender fillers in the PUR composites.

Table 1: Antibacterial properties of PUR composites against selected bacteria and fungi. [13].Open in a separate window + fights bacteria; − not fights bacteria.

Sample	**Bacteria**		**Fungi**		
	E. coli	***S. aureus***	***B. subtilis***	***C. albicans***	***A. niger***
PUR_REF	−	−	−	−	−
PUR_L	+	+	+	−	−
PUR_L_K	+	+	+	−	−
PUR_L_HA	+	+	+	−	−

Furthermore, the effect of fillers modified with lavender on mechanical properties was defined by examination the compressive strength ($\sigma_{10\%}$), flexural strength (σ_f), and impact strength (σ_I). The results clearly showed that the application of non-functionalized and functionalized lavender fillers influences the value of $\sigma_{10\%}$. When the reference sample is compared, $\sigma_{10\%}$ increased by ~7, ~15, and ~17%, for PUR composites reinforced with non-functionalized lavender, lavender functionalized with kaolinite, and lavender functionalized with hydroxyapatite, respectively.

An analogy trend was observed in the case of $\sigma_{10\%}$ measured perpendicular to the direction of the foam expansion—the value of $\sigma_{10\%}$ increased by ~8, ~18, and ~16% for with non-functionalized lavender, lavender functionalized with kaolinite, and lavender functionalized with hydroxyapatite, respectively.

Research author for the purpose of securing of seeming density on the mechanical characteristics of polyurethane samples specified the compressive strength as well. In accordance with the show results, the mechanical strength of polyurethane composites little increased—the specific strength (measured parallel) measured for PUR_REF was 6.5 MPa kg^{-1} m^{-3}, whereas due to the application of lavender fillers, the value increased to 6.8, 7.1 and 7.3% for with non-functionalized lavender, lavender functionalized with kaolinite, and lavender functionalized with hydroxyapatite, respectively.

Furthermore, the amplification effect of lavender modified fillers was also proven by the σ_f and σ_I results. Analyzing the PUR_REF foam, the application of non-functionalized lavender filler causes growth the value of σ_f by ~5%, and the use of lavender filler functionalized with kaolinite and hydroxyapatite enhanced the value of σ_f by ~9 and ~12%. A very similar trend was visible for σ_I. Better results were observed for PUR samples reinforced with lavender filler functionalized with kaolinite and hydroxyapatite—the value of σ_I increased by ~4 and ~7%, respectively.

III. CONCLUSION

Polyurethanes are one of the common polymeric materials with great control over their physicochemical features based on chemical composition. The properties of polyurethanes enable them to obtain their various forms and to be applied in universally accessible products where are required conveniences, durability, warmth, and sound isolation.

Advisable research of scientists indicated that the chemical inclusion of modifying substances with assured antibacterial and antifungal properties into nonmodified polyurethane formulations enable obtain of antimicrobial products. The scientific description confirmed that the use of an antibacterial modifier can change the rheological behavior, cellular structure, and further mechanical properties of polyurethane materials.

Naturally occurring antimicrobials have gained attention among researchers and material manufacturer due to their safety, easily accessible and nontoxic status. Natural additives as extracts are easy to obtain from various plants.

Fruit, vegetables, herbs, and spices have been found to be rich sources of aldehydes, ester terpenoids, phenolics, and sulfur-containing compounds. These natural occurring agents commonly found in roots, flowers, leaves, seeds and bulbs and in other parts of the plants. These substances are produced in defensive mechanism and are helpful for inactivation or inhibition of many microorganisms (bacteria, yeast and molds) and there have not harmful impacts on human health.

The natural antimicrobial substances used so far as additives to polyurethanes, we consider that the presented results prove that it can be potential strategy or candidate to be further applied extensively. The possibility of using such additives is confirmed not only by the fact of their effectiveness, but also the nature of their origin, the possibility of using, in many cases, bio-waste with antimicrobial properties. There are many natural antibiotics in nature; thus, further research should be carried out in this field because there are few such additives to polyurethanes described so far.

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