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The Effect of Antimicrobial Additive on Plastic Deterioration

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Abstract. The Covid-19 virus, which started in 2019 and has taken the whole world under its influence has negatively affected normal living conditions and accordingly, increased awareness to prevent anti-microbial diseases transmitted by contact. In almost all sectors, precautions have been taken considering the transmission of diseases by contact. As a requirement of our age, they enrich their product ranges by developing new methods and making innovations for companies whose sector is dominated by industrial locks, hinges, and handles, both in terms of hygienic product design and in terms of the raw material of the part used in production. For example, it is preferable that the products in the air-conditioning sector have anti-microbial properties. The evaluation of the effect of microorganisms on plastic raw materials and the determination of whether this effect causes future deterioration in plastic materials has been examined in our article. Currently, the products supplied to the sectors are products produced from raw materials such as PA6 GFR30, ABS, PA6, which are available on the market. It is aimed to provide anti-microbial properties of products in accordance with the needs of the sector and the era by changing the raw material used or adding additives in certain proportions to the raw material.

Introduction

Industrial polymers are common materials used in manufacturing o0f toys, packaging, and many households producing such as disposable plates, spoons, and forks. Plastic materials are easy to use and clean products. However, it is a suitable environment for bacterial growth in reuse because plastic can biodegrade and its carbon can be used as food by fungi and bacteria [1].

Bacteria and microbes on plastic products cause biological deterioration. Biodegradation is defined as the situation in which an undesirable change in the color, strength, or mass of the product occurs. Plastic products can be modified as antimicrobial with the additives used to prevent biological degradation. Antimicrobials are used in a wide range of plastic applications [2]. We can find the properties of these additives in the related standards like ISO 846 : 2019 Plastics — Evaluation of the action of microorganisms [3]. In the standard, the colonization of microorganisms on the surface of the plastic product, the deterioration of plastics that create a nutritious environment for microorganisms, and the biological deterioration of the product are examined. The function of the antibacterial additives is to prevent the growth of bacteria, mold, and pathogenic microorganisms by 99%.

Depending on the conditions of the pandemic process, studies have been initiated to make antimicrobial products for preference and to fulfill the supply of them on the market [4]. Locks, gaskets, handles, etc. used in the air handling unit sector. Studies are carried out on the condition that products such as products comply with the above-mentioned standard by using different raw materials or by adding additives to the raw material used. The antimicrobial additive material used because of the criteria provided by this standard reduces the proliferation of the organisms specified in the product and the biological deterioration of the plastic.

By using antibacterial additives, it is aimed to prevent the proliferation of microorganisms in the products, as well as to support the antibacterial feature by designing the environments where microorganisms can adhere and multiply, by designing such environments at a minimum level. The main points to be considered in terms of design can be considered as follows.

The part should not have indentations and protrusions that can create the necessary habitat for the reproduction and living of microorganisms such as water and dust. The surfaces should be as flat as possible, away from sharp recesses and sharp protrusions as much as possible. The recesses will create a suitable environment for the proliferation of microorganisms. Since there are no recesses and sharp surfaces that will create this environment, it will be ensured that water, dust, and similar substances that will cause the proliferation of microorganisms will not stick on the surface.

Sharp transitions should be avoided as much as possible. The examples we made are examples of the lever locks available in Mesan lock Inc. (Fig. 1). Sharp corners and lines may contain substances such as dust and dirt and may create an environment for the growth of microorganisms. However, the round design will keep the accumulation of such factors to a minimum due to its rounded lines. Accordingly, the new lever lock design we have designed has been optimally adapted to the above-mentioned features (Fig. 2).

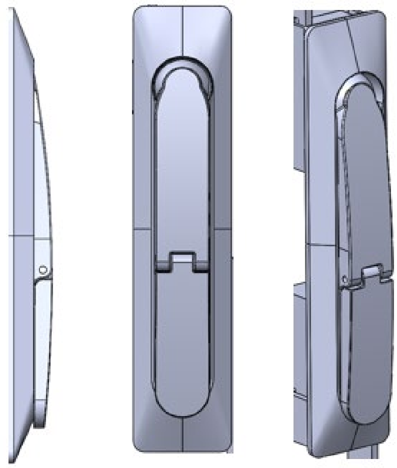

Figure 1. A Sharp Corner Designed Industrial Lock Inc.

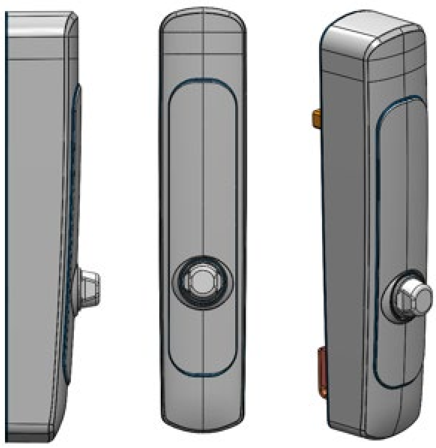

Figure 2. A Round Corner Designed Industrial Lock Inc.

Our aim in this work is to offer a product in compliance with antimicrobial standards by choosing the appropriate additive to the plastic raw material ensuring optimum mixing.

Antimicrobial Additive. Products made from Plastic materials are easy to clean and use. However, it is a suitable environment for bacterial growth in reuse. There is a general belief in society that plastic materials are not hygienic products. Therefore, it is aimed to give antibacterial properties to plastic products by using additives. Antimicrobial additives are auxiliary materials that enable the final product to have antimicrobial product properties by adding a certain amount into the plastic products currently used and dispersing them homogeneously. Thanks to these additives, the formation of bacteria and fungi on the product are prevented by 99% [5]. Heavy metals including silver, zinc, copper, mercury, tin, lead, bismuth, cadmium, chromium, and thallium among the metallic elements have antibacterial capabilities, and the exchange with these metals endows inorganic polymers like zeolites and zirconium with antibacterial activity [6]. Silver-supported zirconium phosphate or silica gel's antibacterial properties aren't brought on by the release of silver ions, but rather by the catalytic action of silver, which causes oxygen to be activated [7, 8]. Silver is the most widely used technology as an antibacterial agent in the world due to its historical success, broad performance spectrum, many materials and applications suitability for use are the main factors.

The additive brought to a surface during the production process includes the specific antimicrobial active, such as silver, and can be formulated as a concentrated powder, liquid suspension or masterbatch pellet, depending on the target material and production process.

In this study, an additive containing 15% granular glass with silver ions concentration, which was added to the PA6 GFR 30 raw material, was used. The additive material was turned into masterbatch pellets and mixed homogeneously in PA6 GFR 30.

Case Study

This study, it is aimed to add a certain number of additives to the plastic raw materials, which are most widely used in industrial lock sectors, to gain antimicrobial properties. This experiment was performed in accordance with ISO 846 : 2019 Plastics - Evaluation of the action of microorganisms standard procedure A, including identification, and visual and microscopic evaluations.

Before the PA6 GFR 30 raw material entered the test environment, the test samples were prepared by mixing the antimicrobial additive in certain percentages homogeneously with the raw material. Then, PA6 GFR30 material, which added a certain percentage of antimicrobial additives, was tested. We can consider the experiment in two stages. The first of these stages is the growth test, that is, the test in which the resistance of the raw material against mold is examined and the resistance tests against bacteria.

Experiment 1 Fungal-Growth Test. Before starting the experiment, the surfaces of the prepared test samples were cleaned with 70% ethanol, and then the microbes detailed below were exposed and their incubation periods were observed. The observation period for this experiment was 4 weeks. As the first, Aspergillus Niger van Tieghem's characteristics are given in Table 1. As the second, Penicillium funiculosum's characteristics are given in Table 2. Additionally, Paecilomyces variotii's and Trichoderma virens‘s characteristics are given in Table 3. Finally, Chaetomium globosum's characteristics are given in Table 4.

Table 1. Aspergillus Niger van Tieghem's characteristics [9].

Product Category	Fungi
Strain Designation	4247 [AM 324, CBS 131.52, CBS 769.97, DSM 1957, IFO 6341, IMI 45551, J. Friedrich A98, KCC F-0086, NRRL 334, QM 324, QM 458, Steinberg, TC 215-4247, WB 334]
Type strain	No
Genome sequenced strain	Yes

Table 2. Penicillium funiculosum's characteristics [9].

Product Category	Fungi
Strain Designation	IMI 114933 [CBS 631.66, CEB 3296.31, IAM 7013]
Type Strain	Yes
Classification	Fungi, Dikarya, Ascomycota, Pezizomycotina, Eurotiomycetes, Eurotiomycetidae, Eurotiales, Trichocomaceae, Talaromyces

Table 3. Paecilomyces variotii's and Trichoderma virens's characteristics [9].

Category	Fungi
Strain Designation	T-1 [CBS 430.54, DSM 1963, IAM 5061, IFO 6355, IMI 45553, NRRL 2314, QM 365]
Type Strain	No
Classification	Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Hypocreaceae, Trichoderma

Table 4 . Chaetomium globosum's characteristics [9].

Product Category	Fungi
Strain Designation	QM 459 [1042.4, CBS 148.51, CBS 161.52, CEB 1218.1, CEB 1218.2, CECT 2701, DSM 1962, IFO 6347, IMI 45550, MUCL 1984, NRRL 1870, UPSC 3159, VTT D-81079]
Type Strain	No
Genome Sequenced Strain	Yes

During this 4-week period, mold resistance of the above-mentioned Fungi was observed in the piece. This process is illustrated visually. In the image you see on the left, there is an antimicrobial added plastic sample sent before the test starts. On the right, there is a sample image that has not changed at all (that is, it passed the test and gave a positive result) as a result of the 4-week test period (Fig. 3).

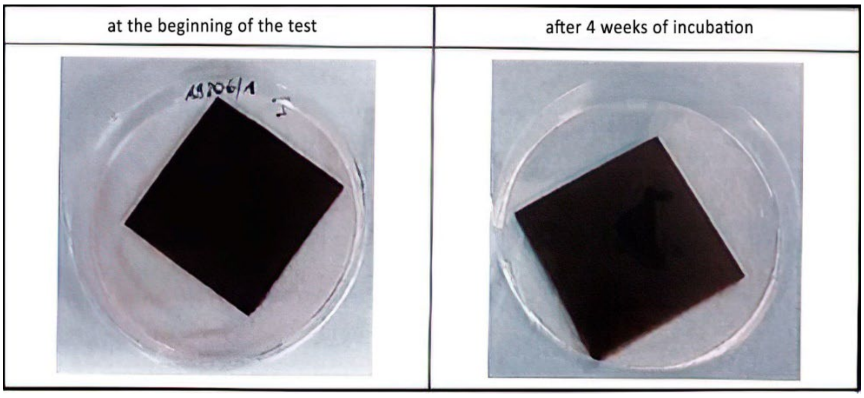

Figure 3. Fungal-Growth Test Illustration.

The meanings of the intensity grades used for the evaluation of mold growth are given in Table 5.

Table 5. Intensity Grade Evaluations [10].

Intensity	Evaluation
0	no growth visible under microscopic inspection
1a	no growth visible with the naked eye, but growth clearly visible under the microscope, up to 25 % of the sample surface overgrown
1b	no growth visible with the naked eye, but growth clearly visible under the microscope, up to 50 % of the sample surface overgrown
1c	no growth visible with the naked eye, but growth clearly visible under the microscope, more than 50 % of the sample surface overgrown
2	growth visible with the naked eye, up 25 % of the sample surface overgrown
3	growth visible with the naked eye, up 50 % of the sample surface overgrown
4	considerable growth, more than 50 % of the sample surface overgrown
5	strong growth, whole sample surface overgrown

The findings found as a result of the mold resistance test (growth test) are detailed as follows. It was observed that the raw material prepared with the additive did not show any change in color or structure compared to the uninoculated sterile sample and control samples. No mold formation could be detected on the sample surface, even under microscopic examination. The growth density was determined as “0”. Overall evaluation growth intensity is also determined as “0”.

Experiment 2 Bacteria Resistance Test. The test is done according to above mentioned “Plastics -evaluation of the action of microorganisms” standard, procedure C, including identification, visual and microscopic evaluation [3]. For this experiment, the surface of the test pieces was cleaned again with 70% ethanol.

Material prepared with the additive did not show any change in color or structure compared to the uninoculated sterile sample and control samples. No mold formation could be detected on the sample surface, even under microscopic examination. The growth density was determined as “0”.

As a result of our experiments, it was observed that the optimum ratio determined for the PA6 GFR30 raw material piece with antimicrobial additives **was 6** %.

Summary

Microbe growth and raw material degradation create problems in many sectors. For this reason, antimicrobial additives are gaining value day by day. With the spread of the coronavirus around the world, customers' interest in antimicrobial products is increasing. As this need for customers increased, companies started to add antimicrobial additives at certain rates to their products. In this study, we examined the effect of 6% antimicrobial additive added to PA6 GFR30 raw material by observing bacteria and mold formations. According to the results of our mold and bacteria growth experiments, no mold or bacteria growth was observed in the handle lock products produced in our company as a result of mixing the masterbatch containing 15% silver ion glass powder with 6% PA6 GFR30 raw material. Companies producing antimicrobial products with PA6 GFR30 raw material will increase their costs and produce inefficiently because of using more than 6% additives. Therefore, it is important for engineers to make decisions based on the results we have shown in our study. By making design improvements and adding additive raw materials to the products in the right ratio, it is possible to stop the reproduction of microbes and ensure that they do not stick to the surfaces 100%.

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