METAL-INCORPORATED POLYESTER POLYOL AS ANTI-MICROBIAL AGENT FOR COATING APPLICATIONS

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The transformation of agricultural-based economy to an industrial-based economy in Malaysia has driven the growth of downstream oleochemical industries. Many derivatives from palm-based oleochemical materials have been aggressively produced and examined for their potential applications. One of which is polymer materials that have vast applications in the pharmaceutical, cosmetic, personal care, detergent and chemical industries.

Antimicrobial coating is a protective coating applied on a surface or product that help to kill, prevent, discourage or perform as a combination of the actions to reduce the growth of microorganisms such as germs, viruses, bacteria, fungi and molds and parasites. Antimicrobial coating also exhibits properties such as abrasion and scratch resistance, heat resistance, chemical resistance, adhesion promoting surfaces, *etc*. Antimicrobial coating has been modified to perform a dual role that is to protect human beings by reducing risk of infections from disease-causing microorganisms as well as protecting the surfaces of objects.

The major driving force for antimicrobial coating market is rapidly expanding for indoor air quality products. Increasing awareness about hospital-acquired infections is also expected to have positive impact on the growth of antimicrobial coating market. In addition, the rising use of additives and coatings in plastic packaging coupled with increasing demand of the products in different applications is expected to fuel the growth of this industry.

The present technology provides a polymer derived from an environmental-friendly source. Particularly, the polymer is polyester polyol synthesised from solvent-free polycondensation between a glycerol-based polyol and a carboxylic acid derived from palm oil derivatives. The polyester polyol incorporated with metal exhibits a microbial inhibiting property that could inhibit the growth of bacteria such as *Staphylococcus auerus*, *Escherichia coli* and *Pseudomonas aeruginosa* and fungus such as *Candida albicans*. The invention (*Figure 1* and *Table 1*) can act as anti-microbial agent in coating applications.

Figure 1. Metal-incorporated polyester polyol.

ANTIMICROBIAL ACTIVITIES

Broth Microdilution Analysis

Screening of the metal-incorporated polyester polyol polymer for antibacterial activity was carried out against *E. coli, S. aureus, P. aeruginosa, Bacillus subtillis* and *C. albicans* as test organisms since these are the most common nosocomial pathogens (Peleg and Hooper, 2010; Yassin and Ahmad, 2012; Jose and Sanchez, 1993). The results of the resazurin broth microdilution assay showed that

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TABLE 1. SPECIFICATIONS OF METAL-INCORPORATED POLYESTER POLYOL

Analysis items	Properties
Acid value (AV), mg KOH g^{-1}	15
Hydroxy value (OHV), mg KOH g^{-1}	350
Molecular weight (MW)	2 500-3 000
Appearance at 25°C	liquid
Metal content, %	5
Hydroxyl type	primary and secondary
Water, wt%	0.1% max

the metal-incorporated polyester polyol exhibited antimicrobial activity against all the four microbes except *B. subtilis* (*Table 2*).

Disk Diffusion Analysis

Figure 2 shows the antimicrobial activities of metal-incorporated polyester polyol coating film. Both B (standard control test drug) and C (metal-incorporated polyester polyol) disks showed enlarged zone of inhibition areas compared to A (polyester polyol) disk.

Disk diffusion method was used to determine the antimicrobial activity of the polyester polyol coating film. *Table 3* shows that the metal-incorporated polyester polyol coating have significant antimicrobial activity against *E. coli, S. aureus* and *C. albicans*. Disk diffusion test was not carried out against *B. subtillis* as the metal incorporated polyester polyol showed no antimicrobial activity against the species in previous resazurin broth microdilution assay.

MARKET ANALYSIS

Global antimicrobial coating market was valued at around USD 2.10 billion in 2014 and is expected to reach USD 5 billion in 2020, growing at a compound annual growth rate (CAGR) of around 9% between 2015 and 2020 (Zion Research, 2016). In terms of volume, the global antimicrobial coating market stood at above 325 kilo tonnes in 2014. Key application markets for antimicrobial coating includes indoor air quality, mold remediation, medical/healthcare, antimicrobial textiles, construction, food and others. Indoor air quality dominated the global antimicrobial coating market in 2014. Medical or healthcare was the second largest application segment in the antimicrobial coating market in 2014. The antimicrobial textiles,

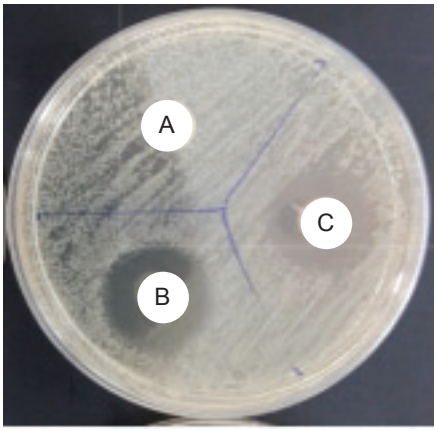

Figure 2. Example of disk diffusion method, where A - polyester polyol disk film; B - standard test drug; and C - metal-incorporated polyester polyol disk film.

TABLE 2. ANTIMICROBIAL ACTIVITIES OF METAL-INCORPORATED POLYESTER POLYOL (PP_m) BY RESAZURIN BROTH MICRODILUTION ASSAY

Code	*E. coli* (μg ml^{-1})		*S. aureus* (μg ml^{-1})		*P. aeruginosa* (μg ml^{-1})		*B.subtilis* (μg ml^{-1})		*C. albicans* (μg ml^{-1})	
	IC_{50}	IC_{90}	IC_{50}	IC_{90}	IC_{50}	IC_{90}	IC_{50}	IC_{90}	IC_{50}	IC_{90}
PP_m	ND	2 000	1 000	2 000	500	1 000	ND	ND	125	500

Note: IC = Inhibition concentration; ND = not detected.

TABLE 3. ANTIMICROBIAL ACTIVITY OF (A) POLYESTER POLYOL DISK FILM; (B) STANDARD TEST DRUG; AND (C) METAL-INCORPORATED POLYESTER POLYOL DISK FILM

Code	*E. coli*	*S. aureus*	*C. albicans*
A	-	-	-
B	+	++	+++
C	+	++	+++

Note: - : inactive (0-9 mm).
+ : mildly active (10-15 mm).
++ : moderately active (16-20 mm).
+++ : highly active (>21mm).

mold remediation, construction, food market witnessed a significant growth in the recent years and it is expected to persist in the coming years.

Antimicrobial coatings are widely used in plastic packaging, as these offer abrasion and scratch resistance, heat resistance and chemical resistance. With around 40% shares in total volume consumption, North America is the largest market for antimicrobial coating. In general, the demand for antimicrobial coatings has been the highest in North America. Asia-Pacific is the second largest market for antimicrobial coatings followed by Europe. Growing health awareness and changing consumers' behaviour are expected to drive the market over the forecast period.

ECONOMIC ANALYSIS

Polymer materials having antimicrobial properties, which can be produced from palm-based materials offers an opportunity to interested parties to venture into the antimicrobial coating market segment. The investment involved and payback period are as follows:

Capital investment = RM 905 000.
Operational cost = RM 1 330 000.
Production capacity = 144 t yr^{-1} @ 1000 kg per batch per day.
Payback period = 4 years.
Net present value (NPV) @ 10% = RM 1 075 000.
Internal rate of return (IRR) = 14%.
Cost price = RM 2000 per unit 250 kg.

POTENTIAL TAKERS

- Paint and coating industry players.
- Manufacturers of coating products.

BENEFITS OF THE PRODUCT/TECHNOLOGY

- The polymer coating materials contain more than 70% palm-based materials. These coating materials exhibit strong microbial inhibiting properties.
- The polymer materials offer huge market potentials in the niche antimicrobial coating market especially for indoor air quality products.
- The polymer are derived from an environmental-friendly source and synthesised from solvent-free reaction.

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