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Short communication

Thyme essential oil for antimicrobial protection of natural textiles

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ABSTRACT

The study was aimed at increasing the resistance of lignocellulosic textiles to bacteria and mould action using a biocide of plant origin. The biocide used in the study was thyme essential oil. This kind of oil is characterized by low toxicity for humans and the environment. The antimicrobial efficiency of thyme essential oil applied to linen–cotton blended fabric and linen fabric was evaluated by determining bacterial growth, degree of mould growth, and their impact on fabric strength. Thyme essential oil applied as 8% concentration in methanol to linen–cotton blended fabric showed very high antibacterial and antifungal activity – no mould growth and no significant loss of breaking force were observed. Microscopic evaluation of the tested fabrics was also performed by Scanning Electron Microscopy. Applying the eco-friendly biocide to fabrics containing natural fibres in the finishing process produces antimicrobial barrier properties.

1. Introduction

Textiles that contain natural fibres, e.g. flax and hemp nonwovens, linen and cotton fabrics, find application both as finishing and insulation materials in automotive and construction industries and for medical, shoe lining and packaging products. Problems occur when these textiles are exposed to harmful external factors. High humidity and temperature and insufficient air circulation result in enhanced growth of microorganisms, especially moulds. Uncontrolled mould growth leads to complete degradation of natural textiles. Microorganisms, both moulds and bacteria, cause the degradation of cellulose, which is the main component of natural fibres such as flax and cotton. This leads to loss of strength and causes emission of odours, ultimately leading to worsening of the microbiological purity of the air. The process of microbiological degradation that occurs when the textile products are still in use could cause serious functional, aesthetic and hygienic problems because of textile deterioration, staining, discolouration and odour (Tomsic et al., 2007).

One of the methods of antimicrobial protection of lignocellulosic textiles is their finishing with the use of biocides. The choice of eco-friendly plant biocide for this study was dictated by pro-ecological trends and EU regulations. New regulations enforce the elimination of many commonly used biocides; EU Directive 98/8/EC considers the introduction of biocidal products to the market and the withdrawal of products based on substances exceptionally toxic to humans and the environment. Therefore, there is a growing demand for replacing old and not always environmentally safe compounds with new more ecological ones.

The essential oils, as plant products, are biodegradable, renewable in nature and safe for human health. Among natural biocides there are extracts and essential oils from different medicinal plants that are widely known for antibacterial and fungicidal properties, e.g. *Mentha piperita*, *Thymus vulgaris*, *Origanum compactum*, *Salvia officinalis*, *Artemisia absinthium*, *Lavandula angustifolia*.

Biocides of plant origin such as extracts and essential oils have become the focus of research in various branches of the economy (Marino et al., 2001; Rakotonirainy and Lavédrine, 2005; Rios and Recio, 2005; Gulluce et al., 2007; Rodriguez et al., 2007). These biocides are used in plant protection, food processing and the cosmetics industry as well as in the production of packaging, medical, finishing and insulation materials containing natural fibres. They are also used to preserve museum exhibits and antique book collections. Active substances (alkaloids, flavonoids, terpenes, tannins) that are present in essential oils such as those from thyme, oregano, clove, sage, chamomile and mint, have natural antimicrobial properties. Aromatic plants and their essential oils have been used since ancient times for their flavour and fragrances, as condiments or spices, in medicines, as antimicrobial/insecticidal agents, and to repel insects or protect stored products. These oils constitute an effective alternative to synthetic pesticides without producing adverse effects on the environment.

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Essential oils rich in phenolic compounds (carvacrol and thymol) are characterized by high antimicrobial activity, phytotoxic and insecticidal properties (Kordali et al., 2008). For example, bacteriostatic and fungistatic properties of the essential oil of *Thymus revolutus* are suspected to be associated with the main carvacrol content, which was found to have a significant antibiotic activity (Karaman et al., 2001). Bakkali et al. (2008) claim there are about 3000 essential oils known to science, of which 300 are of economic importance; they are complex natural mixtures which can contain about 20–60 components at high concentrations (20–70%) with other components present in trace amounts. For example, carvacrol (30%) and thymol (27%) are the major components of essential oil from *O. compactum* while menthol (59%) and menthone (19%) are the main components of essential oil from *M. piperita*. These major components determine the biological properties of essential oils. The influence of essential oils from sage, mint, hyssop, chamomile and oregano on the growth of Gram-negative and Gram-positive bacteria has been studied. Bacteriostatic activity was observed in case of sage, mint, chamomile and hyssop. Oregano oil shows both bacteriostatic and bactericidal activity, most likely due to its high content of phenolic compounds (Marino et al., 2001). Antifungal and antibacterial effectiveness of mint oil against food contaminants *Aspergillus* spp., *Penicillium* spp., *Escherichia coli*, *Bacillus* ssp. and *Staphylococcus aureus* have been reported (Karaman et al., 2001). Thyme essential oil may be recommended as a potential botanical preservative in eco-friendly control of biodeterioration of food commodities during storage (Kumar et al., 2008). Thyme oil completely inhibited the mycelial growth of *Aspergillus flavus* and exhibited a broad fungitoxic spectrum against eight different food contaminating fungi including *Aspergillus niger*, *Aspergillus fumigatus* and *Alternaria alternata*. The oil also showed significant antiaflatoxigenic efficacy as it completely stopped aflatoxin B_1 production by the toxigenic strain of *A. flavus*. On the basis of antifungal and antiaflatoxigenic activity, broad spectrum fungal toxicity, superiority over some prevalent synthetic fungicides and non-mammalian toxicity, thyme essential oil could thus be recommended as an ideal plant-based preservative for shelf life enhancement of stored food commodities. Essential oils should find a practical application in the inhibition of mycotoxin production in food products. Thyme oil inhibited the growth and alfatoxin production of the mould *Aspergillus parasiticus* (Rasooli and Owlia, 2005). Most of the antimicrobial activity (bactericidal and bacteriostatic properties) in essential oils from the *Thymus* genus appears to be associated with phenolic compounds, e.g. thymol and carvacrol (Rota et al., 2008).

Essentials oils from medicinal plants and their active substances have not previously been used in antimicrobial protection of textiles. The objective of this study was to evaluate the ability of thyme essential oil from *T. vulgaris* to inhibit growth of microorganisms, especially mould fungi, on fabrics containing natural fibres.

2. Materials and methods

2.1. Thyme oil

Thyme essential oil was obtained from Avicenna-Oil® Company, Wroclaw, Poland (Member of IFEAT). The chromatographic profile of tested shows major components to be Thymol 32.0%, p-Cymene 25.0%, Carvacrol 3.8%, Borneol 3.1%.

2.2. Test fabrics

- Linen–cotton blended fabric (55% linen and 45% cotton) characterized by surface mass at 360 g/m^2 and abrasion resistance (measured with *Martindale* device) – over 40,000 cycles.
- 100% linen fabric characterized with surface mass at 150 g/m^2 and abrasion resistance – 4000 cycles.

Before testing fabrics had been washed in order to remove possible finishing agents applied during production and all other residues from the surface.

2.3. Application

Thyme essential oil is readily soluble in methanol. It was applied as 5, 8 and 12% concentrations in methanol at 1.2 ml per 1 g of dry fabric using the padding method. The padding was carried out using the Mathis 2-Roll Laboratory Padder. This equipment allows an accurate control of the padding degree (100%), applying the thyme oil uniformly on the fabric surface. The reference samples were treated with methanol only. After padding, tested samples of fabrics were dried at ambient temperature.

2.4. Mould and bacterial strains

2.4.1. Mould strains

A. niger van Tieghem, *Chaetomium globosum* Kunze, *Gliocladium virens* Miller, *Paecilomyces variotii* Bainier and *Penicillium ochrochloron* Biourge.

2.4.2. Bacterial strains present on human skin

Corynebacterium xerosis PCM555, *Bacillus licheniformis* Łock 0808, *Micrococcus luteus* Łock, *Staphylococcus haemolyticus* PCM 2113, *S. aureus* ATCC 6538 as Gram positive bacteria and *E. coli* ATCC 10536, *Klebsiella pneumoniae* PCM 555, *Pseudomonas aeruginosa* Łock 0885 as Gram negative ones. All microorganisms originated from the Pure Culture Collection of the Institute of Fermentation Technology and Microbiology, Technical University of Łodz, Poland.

2.5. Test methods

2.5.1. Antifungal test

Determination of the resistance of tested fabrics to the mould action was conducted according to Standard EN 14119:2003. Agar medium pH 6.0–6.5 was used with the following composition: $NaNO_3$ 2.0 g; KH_2PO_4 0.7 g; K_2HPO_4 0.3 g; KCl 0.5 g; $MgSO_4 \cdot 7H_2O$ 0.5 g; $FeSO_4 \cdot 7H_2O$ 0.01 g; distilled water to 1000 ml; agar 20.0 g and glucose 20.0 g. The protected and unprotected samples of linen–cotton blended fabric and linen fabric were exposed to the action of a mixture of the following mould fungi: *A. niger*, *Ch. globosum*, *G. virens*, *P. ochrochloron*, *Pa. variotii*. For each fungus the spore concentration was determined with the use of a Thom chamber at about 10^6 spores ml^{-1}. During preparation of the final spore mixture for inoculation, the same amounts of each spore suspension were mixed together. The test samples were placed on agar medium and inoculated with a suspension of testing fungi. They were incubated at 29 ± 1 °C and 90% RH for 4 weeks. After the tests, evaluation of antifungal properties was performed on the basis of visual assessment by determination of mould growth and change of breaking force.

The rating system for mould growth was as follows:

0 – no visible growth evaluated microscopically
1 – no visible growth evaluated with naked eye but clearly visible microscopically
2 – growth visible with naked eye, covering up to 25% of tested surface
3 – growth visible with naked eye, covering up to 50% of tested surface