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Review

Thermal treatment of wood using vegetable oils: A review

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HIGHLIGHTS

- Effects of oil heat treatment on wood are reviewed.
- Advantages and disadvantages of using vegetables are discussed.
- Different types of treatment procedures are compared.
- Factors governing the treatment effectiveness are listed.
- Potential applications of oil heat treated wood are discussed.

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ABSTRACT

Wood is an ideal building material as it is renewable and green. However, low dimensional stability and durability might restrict its usage in structural application. Therefore, modification is needed to improve the aforementioned issues. As an environmentally friendly wood modification method, heat treatment of wood using oil as a heating medium has brought to researcher's attention to the fact that it might serve as an excellent treatment procedure in treating wood. This paper presents a review about the effects of oil heat treatment on the properties of wood such as colour stability, dimensional stability, mechanical strength and durability against termites and fungi as well as its potential to be used as construction and building materials. The pros and cons of using oil as a heating medium in wood treatment are discussed. This review shows discrepancies between the treatment methods or procedures and its resultant findings. Moreover, the effectiveness of the treatment is governed by several factors such as the type of oils used and wood species. The objective of the present paper is to conduct a review of the published literatures regarding the properties of wood modified by oil heat treatment and the results obtained were compared systematically.

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1. Introduction

As a renewable lignocellulosic material, wood is an ideal building material that is easy to work with and offers advantages such as high strength-to-weight ratio and lower processing energy. Unfortunately, dimensional instability is one of the major shortcomings of wood compared with synthetic materials coming from non-renewable resources. Dimensional stability is a vital criterion for the wood in use, especially for structural uses, as it will affect the wood performance in terms of visual and functionality. Apart from that, wood is also susceptible to a variety of deteriorating organisms, mainly Basidiomycota fungi (white rots and brown rots) and Ascomycota fungi that results in soft rot and stain. Other organisms such as termites, mold, bacteria, algae and lichens are also known to cause severe damages to wood [1]. Existence of these deteriorating agents on the wooden structure could cause financial loss and threaten users' health [2].

Treatments to reduce the hygroscopic behaviour of wood are therefore needed in order to improve its dimensional stability as well as resistance against biodeterioration agents. Thermal treatment, or heat treatment, is by far the most commercialised wood modification method. Heat treatment is typically performed at temperatures ranging from 180 °C to 260 °C, where lower temperatures did not cause any significant changes in the wood constituents while higher temperatures severely degraded the wood [3]. However, a widespread consensus has been reached among the researchers where the minimum temperature required to conduct thermal treatment on wood is 100 °C [4–6]. Nevertheless, some researchers believed that it is dependent on the wood species [7]. The effectiveness of thermal treatment on reduction in hygroscopicity of the wood was first proved by Tiemann [8], where 10–25% reduction in moisture sorption was obtained when the wood was subjected to steam at 150 °C for 4 h.

The underlying principle of thermal treatment is to convert the hydrophilic nature of wood to hydrophobic through thermal degradation of the polysaccharides, mainly thermally labile hemicellulose, in the wood cell wall [9,10]. The principle reason for the changes in wood properties is the alternations in wood chemistry as a result of exposure to high temperature [11]. Reduction in equilibrium moisture content (EMC) is the main observation in the heat treated wood as a result of thermal treatment and has been intensively studied and reported by several researchers [12–16]. Apart from that, improvement in decay resistance against biodeterioration agents such as fungi and termites is also one of the most prominent properties of heat treated wood [14–16]. Unfortunately, such improvement is usually accompanied by the decrement in mechanical strength as reported in several studies [3,17,18]. Heat treatment can be conducted in different treating media, for example, air, nitrogen and water. Each medium resulted in different extent of changes in the properties of treated wood.

Recently, heat treatment in oil has been proved to be an excellent approach to wood modification. Vegetable oils have long been used to protect woods from mold and fungi decay as well as to reduce its moisture accessibility owing to its non-toxicity and environmentally friendly nature [19]. Unsaturated oils can be oxidised when exposed to atmospheric oxygen leading to the formation of a protective layer on the surface of the wood [20]. Application of oil during heat treatment, or so-called oil heat treatment or oleothermal treatment is able to improve the properties of wood through synergetic effect of the oil and heat. Numerous studies regarding oil heat treatment of wood have been carried out by researchers around the world. However, the comparison between published literatures is difficult because the treatment procedures and parameters differ from one to another. Therefore, an integrated review on the subject is important.

A comprehensive review on wood modification by heat treatment has been done by Esteves and Pereira [21]. Reviews on thermal pretreatment methods of wood in order to produce wood composites with improved properties have been compiled by Pelaez-Smananiego et al. [22]. Several commercialised thermal modification methods on wood in Europe and its effects on the wood properties have been reviewed by Militz and Altgen [23]. Gerardin [24] reviewed different non-biocide alternatives for wood preservation where several thermal and chemical treatment methods have been discussed. Xie et al. [25] and Kocaefe et al. [26] reviewed the effects of various treatments, including heat treatment on the dimensional stability and mechanical properties of wood. Thermo-hydro (TH) and thermo-hydro-mechanical (THM) wood processes to produce environmentally friendly products and its recent development have been specifically discussed by Sanberg and Kutnar [27] and Sanberg et al. [28]. A review focused on the decay resistance of thermal treated wood has been carried out by Candelier et al. [29]. Nevertheless, to the authors' knowledge, a review on the effect of oil heat treatment on the properties of wood has yet to be done.

The objective of the present study is to conduct a systematic review of the published literature regarding the properties of wood modified by oil heat treatment and its potential uses as construction and building materials. The specific objectives of this review including: (1) discuss the pros and cons of using oil as a heating medium, (2) identify the types of different oil heat treatment and the factors that determine the effectiveness of the treatments, (3) assess the effects of oil heat treatment on the properties of wood, (4) compare the oil heat treatment with other heat treatment methods and (5) identify the potential applications of oil heat treated wood as building and construction materials.

2. Advantages and disadvantages of using oil as heating medium

Application of crude vegetable oils such as rapeseed, linseed or sunflower oil as heating medium in the heat treatment of wood can provide several advantages. Firstly, vegetable oils are good heating medium due to their ability to transfer heat to wood more readily and equally [30]. Moreover, oil can separate oxygen from wood during the treatment process and prevents the occurrence of oxidative process that leads to strength reduction in the treated samples [31]. Apart from that, the boiling points of many oils are