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A biological survey on the Ottoman Archive papers and determination of the D_{10} value

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ABSTRACT

The Ottoman Archives have one of the richest archive collections in the world. However, not all the archived documents are well preserved and some undergo biodeterioration. Therefore, a rapid and promising treatment method is necessary to preserve the collection for following generations as heritage. Radiation presents as an alternative for the treatment of archival materials for this purpose. In this study, we conducted a survey to determine the contamination species and the D_{10} values of the samples obtained from the shelves of the Ottoman Archives. The samples also included several insect pests collected at using a pheromone trap placed in the archive storage room. With the exception of few localized problems, no active pest presence was observed. The D_{10} values of mold contamination and reference mold (*A. niger*) were found to be 1.0 and 0.68 kGy, respectively. Based on these results, it can be concluded that an absorbed dose of 6 kGy is required to remove the contamination from the materials stored in the Ottoman Archives.

1. Introduction

Ottoman Archives comprise a rich collection containing more than 100 million documents which hold an important place in the documentation and writing of world history. In addition to recording history, they reveal the art of calligraphy and the inscriptions of Ottoman artists since the foundation of the Ottoman Empire. However, although the collection is well preserved, as with other cultural heritages consisting of natural different materials such as wood, silk and leather, they remain under attack by biodeteriorating agents, especially fungi and insects (Yoon et al., 2015; Marusic et al., 2016). Fungi, with their efficient degradative enzymes (cellulase), can destroy materials in a short time and hydrolyze a wide variety of polymers including cellulose (Adamo et al., 2003; Silva et al., 2006). Environmental conditions can encourage fungal growth, which is highly dependent on temperature and humidity, and result in fungal degradation. This situation not only creates a risk to human health but also causes the decay of valuable cultural heritage materials and documents (Tomazello and Wiendl, 1995). Therefore, preventing and inhibiting the biodegradation of these materials is a major task in the preservation of library and archive collections. Most of the techniques have been developed to reduce the threat of microorganisms against the conservation of valuable documents (Bicchieri et al., 2016). These techniques involve the use of toxic chemical fumigants, including methyl bromide and ethylene oxide. However, these fumigants have been banned in most countries due to their carcinogenic properties and destruction of the ozone layer (Silva et al., 2006). Thus, developing a new preservation technique is an ongoing objective of conservation sciences (Choi et al., 2012). Decontamination of fungi by ionizing radiation has emerged as a successful alternative to the use of fumigants (Pointing et al., 1998; Magaudda, 2004; Choi et al., 2012). The recovery of different types of materials contaminated with organisms through irradiation has been the subject of many studies carried out all over the world and has opened the way for obtaining necessary authorization for the commercial use of radiation treatment (Magaudda, 2004). As a decontamination technique, ionizing radiation is also used to control decaying microorganisms on organic materials such as paper and wood, which are major components of cultural heritage objects (Negut et al., 2012). It has been suggested that this technique is non-toxic and do not leave radioactive residues on objects.

With its high penetrating power, gamma radiation causes direct damage to cellular DNA through ionization and indirect damage to single and double-strand DNA through the radiolysis of cellular water and formation of active oxygen species, free radicals and peroxides. Gamma rays can quickly pass through materials without leaving any residue (Silva et al., 2006; Choi et al., 2012). The most important parameter in the irradiation process is the delivery of an accurate absorbed dose, which is determined through the D_{10} value. This value refers to the dose at which contaminants are reduced by a factor of ten; i.e., to 10% of the initial value. It depends on the initial level of

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contamination, the radiosensitivity of contaminating flora and the desirable reduction factor of biodeteriorating agents (Katusin-Razem et al., 2009). Using this value to determine the optimal dose of irradiation allows treating a large number of archival materials and objects in a short time and at a low cost. Recently, irradiation has been applied by several researchers for the disinfection of contaminated papers to demonstrate the applicability of this technology to archival materials (Silva et al., 2006; Magaudda, 2004).

The aim of this study was to investigate the effect of ionizing radiation on insect disinfestation in the Ottoman Archives, and to determine the D_{10} values of molds isolated from valuable archive documents and *A. niger* as a reference mold model to identify the accurate dose of radiation for the preservations of the materials against fungal and insect infestation.

2. Materials and methods

Radiation technology has been successfully used to decontaminate cultural heritage materials and it has been shown to have many advantages compared to alternative treatment techniques (Adamo et al., 2004). However, each material has specific characteristics and resistance to radiation. Therefore, this information should be obtained before the application. Since 2013, when the Ottoman Archives were relocated to the Kagithane district in Istanbul, all the materials have been kept under standard storage conditions for archives at 20 °C and 50% relative humidity. Under the specified conditions in the building, fertilization of the biodeteriorating agents is not possible. However, the removal of current load of bioburden contamination and insects (Fig. 1) from the archival materials remains crucial. After the treatment process, archival materials would survive unless the storage conditions are altered. Therefore, it is important to know the required dose of radiation before testing the materials. In the following sections, the results of a biological survey on the shelves of the Ottoman Archives and the optimal dose assessment are summarized.

2.1. Sampling of insect infestation

As one of the biodeteriorating agents, an insect survey was conducted at the archive storage. Despite the presence of several footprints of insects on the surface of the archival materials, there was no sign of an active insect infestation. Therefore, after a careful consideration of the most encountered insect pest species in archives (Querner, 2015), pheromone traps (XLure MST) were used to collect samples for a long-term survey. This trap is generally used in the pest monitoring programs of museums and archives, which are suspected of being damaged by a potential pest hazard (Anonymous, 1998). As indicated by the name, a pheromone trap uses pheromones to lure insects. This trap is very sensitive; so, it can attract insects at very low densities. It is often used to detect the presence of exotic pests, or for sampling, monitoring, or determining the first appearance of a pest in an area. It contains a mix of three insect pheromones and two food attractants in addition to plant extracts and a purified hydrocarbon thixotropic agent for the attraction and containment of target insects. It can also be used in various conditions including areas of high dust.

In this study, a total 37 pheromone traps were used. Each trap was placed on one corner of each storage room in March 2016 and all the traps were replaced in May 2016. The trapped insects were collected with the help of fine-tip flexible forceps and placed into Eppendorf tubes containing 70% ethanol.

2.2. Sampling of microbial contamination

Thirty-eight samples were collected using the sterilized cotton swaps method from the documents stored in the Ottoman Archives. The samples were inoculated on a potato dextrose agar (PDA, Merck) to obtain colonies with mature fruiting bodies or a reproductive structure. The inoculated plates were incubated at 28 °C for 72 h. *A. niger* strain obtained from the culture collection of Ankara University, Turkey was used as a reference mold to investigate the inactivation of molds by irradiation. *A. niger* was grown on PDA and incubated at 28 °C for 72 h. After incubation, a molds cocktail and *A. niger* suspensions were prepared separately. The molds cocktail and *A. niger* spores suspensions (1 mL) harvested from the Petri dishes by washing with maximal recovery diluent (MRD, Merck) on the magnetic stirrer were immediately transferred to sterilized Whatman paper (2×2 cm^2 in size) in separate sterilized Petri dishes for further analyses. The samples were dried at the room temperature overnight.

2.3. Gamma irradiation

Each sample was irradiated by a cobalt-60 irradiator (Ob-Servo Sanguis Co-60 irradiator, 12,000Ci maximum activity, Hungary) at doses of 0, 1, 2, 2, 3, 4, 5, and 6 kGy at a dose rate of 1.95 kGy/h at the room temperature. The absorbed dose was measured with Harwell Gammachrome YR™ dosimeters (Chromwell, UK). The change in absorbance was measured at 530 nm using UV–visible spectrophotometry. After irradiation, the samples were transferred to the laboratory and microbiological analyses were performed in duplicate.

2.4. Determination of the D_{10} value

To enumerate molds cocktail and *A. niger* on the Whatman paper after irradiation at different doses, 0.2 g of Whatman paper was aseptically placed into a sterilized Erlenmeyer flask containing 9.8 mL of MRD and stirred on a magnetic stirrer for 2 min. The homogenized samples were serially diluted with MRD. The diluent (1 mL) was placed in Petri dishes and the PDA medium was poured onto the inoculated Petri dishes, which were then incubated at 28 °C for 72 h. After this process, colonies were manually counted. The D_{10} value was determined from the slope of survivors versus the dose plot, which was determined after counting the number of colony-forming units per gram of sample (CFU/g) for the treatments.

3. Results and discussion

3.1. Insect disinfestation

A few insects were collected from the 37 traps throughout the survey period. Regarding observations, the most important species were found to belong to the order of Collembola (springtails) as shown in Fig. 2a. Springtails are an indicator of a moisture problem but are not considered as an archive or museum pest (Eckstein and Bacharach, 2014; Jacobs, 2010). These insects commonly consume fungal hyphae and spores, but are also known to feed on plant material and pollen, animal remains, colloidal materials, minerals, and bacteria (Chen et al., 1996; Hopkin, 1997). Controlling the population of springtails requires changing relative humidity since they cannot survive or reproduce under dry conditions (Townsend, 2016; Robinson, 2005).

Anobium punctatum (De Geer) (Coleoptera: Anobiidae) is an insect species seen in the woods. It was found in one of the storage rooms containing a few wooden boxes and paper waste (Fig. 2b and c), (Robinson, 2005; Hutton, 2008). This genus of insects damages the wooden staff, frames, furniture, small wooden materials, books, toys, bamboo materials, furnishing and building mainframes made of wood in archives and museums (Campbell et al., 1989). The holes created by adult insects on the object can be seen with the naked eye. Under favorable conditions, adults continue their invasion with an increasing damage by leaving their eggs on the same material. The larvae feed themselves by opening tunnels and fill them with stones, and sawdust makes it easy to observe pest presence by leaking into the environment (Eckstein and Bacharach, 2014).

A part of the insect belonging to Coleoptera order but without its