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Emission of Far-infrared Ray in Packaging Paper

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ABSTRACT

The far-infrared ray (FIR) has been applied to various fields such as medical therapy, kitchen utensils, bath supplies, and so on. The FIR-emitting agent was used to make functional paperboards to have freshness-maintaining ability. The FIR-emitting agent was diluted with different concentrations at 0.5% starch solution, and the FIR-emitting solutions were coated on paperboards, i.e., liner. The more the concentration of the FIR radiating agent increased at 0.5% cationic starch solution, the higher FIR emissivity and emission power of paperboards increased. The corrugated boxes made of paperboards coated by the FIR-radiating agents at over 5% dilution concentration endowed mandarin oranges in the boxes with greater antimicrobial activity than those in boxes made of paperboards coated by the agent at below 5% concentration. In addition, it was ascertained that treatment of the FIR agents rarely affected strength properties of paperboards.

Keywords : *Far-infrared ray, FIR-emitting agent, paperboard, antimicrobial activity*

1. Introduction

In general, light industries have been known as a packaging-required industry but their slowdown in an economy will essentially lead to a structural turning point of corrugating paperboard industries. Therefore the packaging industry made a new paradigm for management innovation by introducing new facilities for various standardized packing in a few goods as well as for high value-added packaging products with fresh functions. It is not surprising that material costs of the corrugated packaging industry amount to over 70% of the total production cost differently from other manufacturing industries. This means that the packaging industry cannot be competitive in a market without improving a product quality with novel functionality.

For example, functional packaging paper (1) includes anti-oxidative corrugated boards, freshness-prolonging boards, slip-stop boards, and so on. In particular, as annual temperature rises, farmers have been in trouble in keeping freshness of stored fruits and vegetables during their distribution. Thus it is urgently required to make new paperboard products having functionality able to keep fruits and vegetables from their putrefaction during storage and distribution.

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Lots of works have been done to prolong freshness of fruits and vegetables in packing containers during distribution and storage. Unfortunately, most of the researches were not satisfactory in developing functional packaging materials, unlike storage methods such as controlled atmosphere (CA) or low-temperature storage (1).

In this study, inorganic materials emitting far-infrared ray were used to endow packaging boards with freshness-maintaining ability. The far-infrared ray has been rarely used in the field of packaging materials, differently from building materials, health products, household utensils, textiles, etc. The far-infrared ray (FIR) is known as an electromagnetic wave with a wavelength of 3㎛ to 1 mm, and falls within the outside of a red area in the light spectrum (2). The far infrared ray plays a great role in heating and energy saving through instantaneous heat transfer (3). Therefore the energy from the far infrared ray is absolutely essential and beneficial for human beings and all living things in the nature. In general, all of the naturals emit the far infrared ray but the wavelength in the center must be around 10㎛ for functionality such as antibiosis, de-odorization and prolonged freshness of fruits and vegetables. Particularly, feldspar porphyry containing verd antiques and amphiboles (or hornblende) emits over 90 per cent of the far infrared ray of the wavelength which ranges from around 8 to 11㎛.

If the objects emitting FIR are used in packaging materials like paperboard, goods in a packaging container can be distributed in good atmosphere. This will cause not only producers to keep their original profit safe just before selling their goods, but also consumers to get fresh goods in their hands.

The main drive for this investigation was possibility of providing new functionality like far-infrared radiation for paperboards used in a corrugated container. The functionality of the paperboards was assessed by measuring radiation energy ($W \cdot m^{-2} \cdot ㎛^{-1}$).

2. Materials and Methods

2.1 Application of materials radiating far-infrared rays

Inorganic materials emitting FIR chose functional materials in a liquid state manufactured from Korea Bion Co.. In order to maximize functional effects of paperboards including radiation of FIR and negative ion, natural minerals such as alumina silicate for antibiosis and deodorization and tourmaline for emitting negative ions were used together. For far infrared rays, highly concentrated alumina silica ($Al_2O_3SiO_2$) in a liquid state was mixed with other natural inorganic materials including selicite and titanium. Both negative ions and far infrared rays were also emitted from tourmaline which is a crystal silicate mineral compounded with elements such as aluminum, iron, magnesium, sodium, lithium, potassium. This material is liquefied by hydrogen polymerization and emits negative ions of over 500 ions/cc.

The functional materials were prepared by mixing of the highly concentrated liquids and tourmaline in a certain ratio. The functional materials were diluted in 0.5% cationic starch solution, as shown in Table 1, and were sprayed on paperboards.

2.2 Functional paperboards

Paperboards were made from unbleached softwood kraft pulps beaten to 400 mL CSF according to TAPPI test method T200 and T205. The boards were made at an oven dry weight of 120 $g \cdot m^{-2}$. One side of the boards was coated with 5 g of the diluted functional materials, and each coated weight ($g \cdot m^{-2}$) at the respectively diluted concentration is shown in Table 1. The boards were used in measuring their emissivity of FIR, radiation energy and physical properties.

Emissivity of FIR and emission power were measured by FT-IR spectrometer (MIDAC 2400-C, USA) with a MCT detector in the Korea Far Infrared

Association. The emissivity of paperboards was obtained in the wavelength range of 5 to 20㎛ compared to the black body under the resolution of 8 cm^{-1} at 37℃.

Physical properties of the boards including tensile strength, tear strength, burst strength and bending stiffness were measured by TAPPI standard test method T220.

2.3 Freshness evaluation of fruits in boxes treated by functional materials

Functionality of corrugated boxes were given by spraying 0, 5, 30, and 50% functional materials diluted in 0.5% cationic starch solution on the inner liners. The boxes were used in assessing freshness of mandarin oranges (*Citrus unshiu*) during their storage at 20±2℃ and RH 65±2% for 15 days. The freshness of the oranges was evaluated by measuring a weight change and counting putrefied oranges.

3. Results and Discussion

Paperboards without treating functional materials emitted FIR but those applied at over 4 $g \cdot m^{-2}$ radiated more rays than the control one. It is interesting to note that untreated specimens emitted the FIR over 0.85. In general, all materials with emissivity over 0.85 are classified as materials emitting FIR. Even though all materials at over 273°K emit FIR, their emissivities are quite different according to their unique characteristics. As shown in Table 2, packaging paper without functional materials also showed a little higher emissivity than 0.85 but it is known that strong effects of FIR can be expected at the emissivity over 0.9. Therefore the application amount of the functional materials must be over 24 $g \cdot m^{-2}$.

In Fig. 1, it could be readily seen that treatment of the FIR-emitting materials greatly contributed to the increase of both the emission rate and the emission energy of FIR. With the increment of the diluted concentration of the FIR- emitting materials, the emissivity and the emission energy were simultaneously increased. Both emissivity and emission power were measured at 37℃. If packaging papers treated by the functional materials are exposed by any heating condition, their emissivity and emission power will increase with resonance occurring at a frequency of molecular motion by virtue of a frequency of FIR in a certain wavelength. Most of materials in our environment are in a low temperature range below 4 0℃, which leads to minor emission of FIR. Therefore it can be assumed that the paperboards with functional

Table 1. Mixing ratio of the functional materials

	The functional materials (%)*						
Dilution conc. (%)	**0**	**5**	10	20	**30**	40	**50**
Coated weight (g/m^2)	0	4	8	16	24	32	40

* diluted in 0.5% cationic starch solution, Bold:radiation energy of FIR was measured

Table 2. Emissivity and emission power of far-infrared ray from paperboards

Application amount(%)* of the functional materials	Emissivity of far-infrared ray at 5-20 ㎛	Emission power ($W \times m^{-2}$㎛ at 37 °C)
Control	0.887	3.42×10^2
5 (4 $g \cdot m^{-2}$)	0.897	3.46×10^2
30 (24 $g \cdot m^{-2}$)	0.901	3.47×10^2
50 (40 $g \cdot m^{-2}$)	0.903	3.48×10^2

* Dilution ratio of the functional materials in 0.5% cationic starch solution

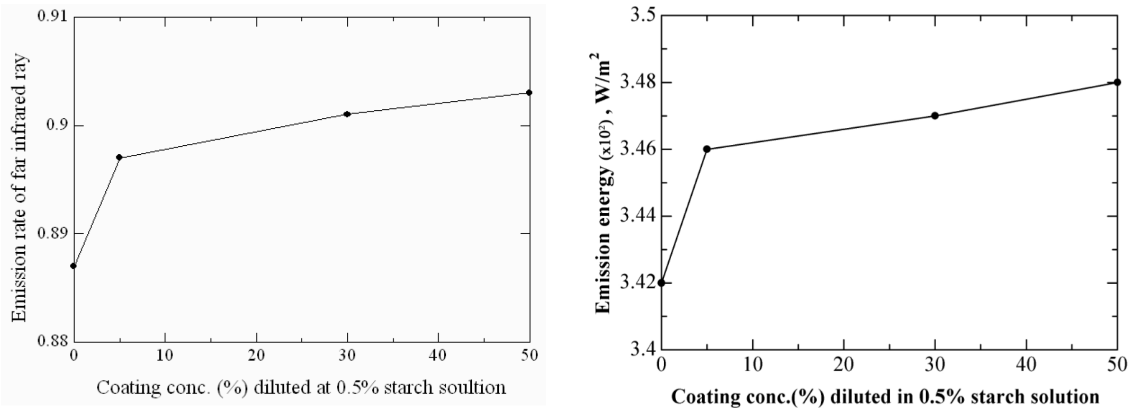
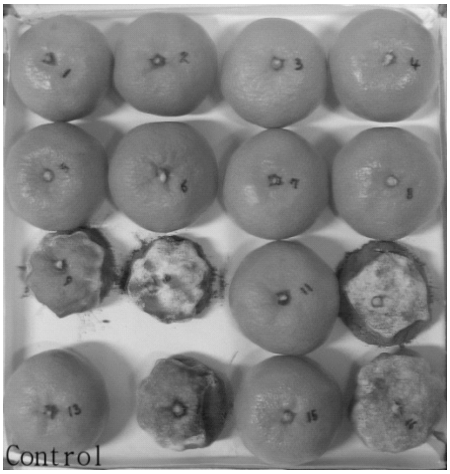


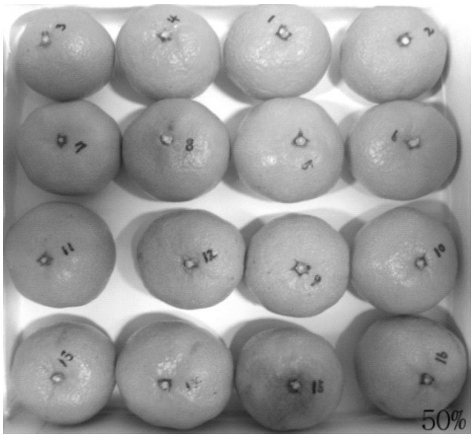
Fig. 1. Emissivity and emission power of far-infrared ray from packaging paper.



(A)Control

(B)5%

(C)30%



(D)50%

Fig. 2. Mandarin oranges stored in boxes treated with different amounts of FIR-emitting materials (note: the concentration based on oven-dried weight).

materials will be forced to emit a low amount of FIR in room temperature. However, even the paperboards without any treatment emitted FIR over 0.8 at 37℃, and thus could be regarded as FIR-emitting boards.

Considering a wavelength range of light, FIR has a low sterilizing power due to its lower energy level than a UV ray. In general, it is known that UV light has the most effective sterilizing power, together with the shortest wavelength based on the electromagnetic spectrum. On the other hand, it is expected that FIR has an indirect sterilizing effect with its thermal energy emitting under high room temperature in addition to environmental change for microbial activity under its emission.

Fig. 2 shows putrefied mandarin oranges stored at 20±2℃ and RH 65±2% for 15 days. The oranges stored in untreated and 5% treated corrugated boxes were severely decayed, and had a putrefying ratio of 25% respectively. Their shapes were completely deformed and covered by rot fungi, and finally got crushed. The oranges stored in boxes treated with 30% of FIR-emitting chemicals had a putrefying ration of about 13%, which was much lower than that in untreated and 5% treated boxes. The high emission of FIR was known to decrease cluster size of water molecules (4) as well as to improve antioxidant activity (5). In particular, FIR radiation onto the peels of mandarin oranges might liberate and activate covalently bound compounds with antioxidant activities (6). The little emission of FIR from untreated and 5% treated boxes hardly seems to liberate activating compounds in orange peels, and thus leads to rare freshness-maintaining ability of the boxes due toshortage of activating force by FIR.

Fig. 3 shows the effect of the FIR-radiation agent on strength properties of paperboards. The FIR-radiation agent was diluted at 0.5% solution of cationic starch. That is, the increased concentration of the FIR-radiation agent implies the decrease in cationic starch. In general, it is simple to assume that FIR-radiation materials do not influence paper strength. However, it is expected that cationic starch solution as a diluting agent can contribute to the increase in paper strength. Tensile strength and bending stiffness of paperboards started to increase with addition of the FIR-radiating agents at 5-10% concentration, and thereafter decreased up to the level of untreated boards. The initial increase of the strengths might be caused by more amount of starch compared to the starch solution at over 10% concentration, which could be regarded as surface sizing effect. Fortunately, the FIR-radiating agent did not express any negative effect of strength properties of paperboards in spite of surface coating of excessive concentration. Fig. 4 shows the SEM images of the surfaces of paperboards with and without treatment of

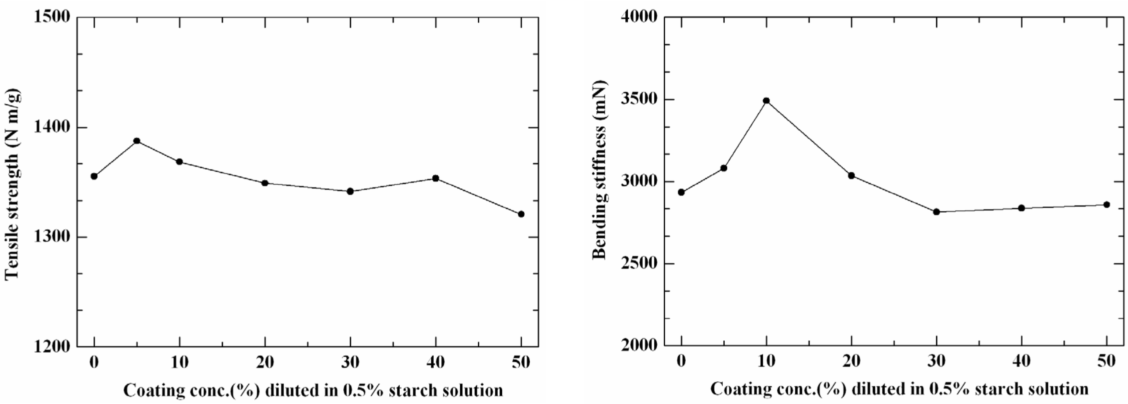


Fig. 3. Effect of FIR-radiating materials on strength properties of paperboards.

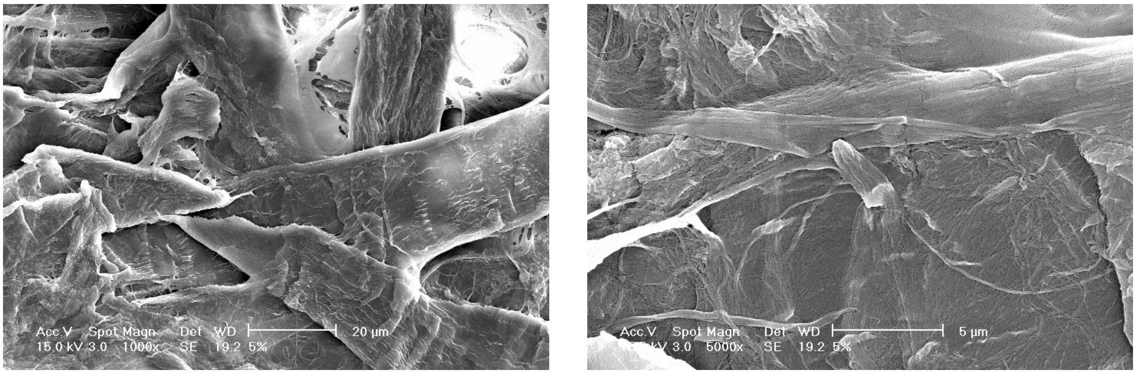


Fig. 4. SEM images of paperboards without (left) and with (right) the FIR-emitting agent.

the FIR-radiating agent. Differently from the surface of the non-treated specimen, the surface of the treated one was coated with the solution of the FIR-radiating agent. Finally it was confirmed that the FIR-radiating agent could contribute to antimicrobial activity of corrugated boxes without deterioration of strength properties.

4. Conclusions

The FIR-emitting agent was diluted with different concentrations at 0.5% starch solution, and the FIR-emitting solutions were coated on paperboards, i.e., liner. The more the concentration of the FIR radiating agent increased at 0.5% cationic starch solution, the higher FIR emissivity and emission power of paperboards increased. The corrugated boxes made of paperboards coated by the FIR-radiating agents at over 5% dilution concentration endowed mandarin oranges in the boxes with greater antimicrobial activity than those in boxes made of paperboards coated by the agent at below 5% concentration. In addition, it was ascertained that treatment of the FIR agents rarely affected strength properties of paperboards.

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