

SMART PACKAGING FOR AGRICULTURAL PRODUCTS

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ABSTRACT

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This research deals with the development of smart packaging based on polypropylene-1wt% clay nanocomposites incorporated with silver nanoparticles at different contents (5, 10, 15, and 20 wt% in the clay). The masterbatch of nanocomposites was first prepared by a twin-screw extruder with plasma-assisted process and then further mixed with PP to reach the nanocomposites with 1 wt% of clay, followed by a blown film extrusion to a clear film for packaging application. The effects of silver nanoparticles on crystal structure, mechanical behavior, thermal properties, and gas permeability of the nanocomposite films were evaluated. The results revealed that the intercalated and partly exfoliated nanocomposite films were obtained. The presence of clay and silver nanoparticles had an adverse effect on the tensile strength and the percentage of elongation at break. However, an increase in the Young's modulus was obtained. This is deduced from the higher stiffness of the nanocomposite films. Furthermore, the existence of clay and these nanoparticles resulted in an increment in the percentage of crystallinity of the nanocomposite films, regarding the nucleating effect arising from the nanoparticles. The nanocomposite films also had higher thermal stability compared to neat PP film. With regard to an antifungal activity, the release of silver nanoparticles enabled the nanocomposite films to against *Colletotrichum gloeosporioides*. Only 5 wt% of silver nanoparticles in the clay presented the exfoliation structure of layered silicates in the matrix and concurrently manifested the potential in anti-anthraxnose activity. In addition to the aforementioned films, this work also fabricated the indicator film for fish freshness by tapping the potential of a natural dye from the sappan wood mixed with ethylene

vinyl acetate. In conclusion, the assembly of both films could afford to be a smart packaging for chilled fish storage. In particular, with potential use of this smart packaging, this film is capable of being applied for other categorizes of agricultural products, such as Nam-Dok-Mai mango, and Hom-Thong banana, etc.

บทคัดย่อ

ศาสตราจารย์ สุขจิต : บรรจุภัณฑ์ฉลาดสำหรับผลิตภัณฑ์ทางการเกษตร (Smart Packaging for Agricultural Products) อ. ที่ปรึกษา : รศ.ดร. รัตนาวรรณ มกรพันธุ์ 188 หน้า

งานวิจัยนี้มีเป้าหมายในการพัฒนาฟิล์มบรรจุภัณฑ์ฉลาดจากฟิล์มพอลิโพรพิลีนผสมด้วยปริมาณของอนุภาคนาโนเมตรของแร่ดินเหนียวเบนโทไนต์ 1 เปอร์เซ็นต์โดยน้ำหนักที่บรรจุปริมาณอนุภาคนาโนต่าง ๆ กัน เพื่อประโยชน์ด้านการซึมผ่านของก๊าซและการต้านเชื้อจุลินทรีย์ นาโนคอมพอสิตในงานวิจัยฉบับนี้ถูกเตรียมแรกเริ่มเป็นมาสเตอร์แบทช์โดยเทคนิคการผสมแบบสถานะหลอมเหลว โดยใช้เครื่องอัดรีดแบบสกรูคู่กอบรับการเข้าร่วมของเทคนิคพลาสมา จากนั้นจึงนำมาผสมกับพอลิโพรพิลีนอีกครั้งหนึ่งจนได้นาโนคอมพอสิตที่มีแร่ดินเหนียวเบนโทไนต์ 1 เปอร์เซ็นต์ และขั้นสุดท้ายคือการเป่าฟิล์มเพื่อบรรลุเป้าหมายในการนำไปใช้ในงานบรรจุภัณฑ์ งานวิจัยนี้มีการศึกษาผลของปริมาณของอนุภาคนาโนซิลเวอร์ (ปริมาณ 5 10 15 และ 20 เปอร์เซ็นต์โดยน้ำหนักเมื่อเทียบกับปริมาณแร่ดินเหนียวเบนโทไนต์) ต่อโครงสร้างทางผลึก สมบัติเชิงกล สมบัติทางความร้อน และประสิทธิภาพการซึมผ่านของก๊าซในฟิล์มนาโนคอมพอสิต จากการทดลองพบว่า การมีอยู่ของอนุภาคนาโนเบนโทไนต์และอนุภาคนาโนทำให้ฟิล์มนาโนคอมพอสิตมีโครงสร้างของนาโนคอมพอสิตแบบอินเตอร์คาเลตและเอกโฟลิเอทบางส่วน การยึดตัวก่อนแตกหักและความแข็งแรงต่อการดึงยึดลดลง แต่พบว่าค่ามอดูลัสของความยืดหยุ่นมากขึ้นซึ่งถึงความแข็งแรงเพิ่มขึ้นของฟิล์มนาโนคอมพอสิต อนุภาคนาโนซิลเวอร์ทำหน้าที่เสมือนเป็นสารก่อผลึก ทำให้ฟิล์มนาโนคอมพอสิตมีเปอร์เซ็นต์ความเป็นผลึกมากขึ้น และฟิล์มนาโนคอมพอสิตยังมีคุณสมบัติทนต่อความร้อนได้ดีขึ้น การซึมผ่านของไอน้ำและก๊าซออกซิเจนมีค่าน้อยสัมพันธ์กับปริมาณผลึกที่เพิ่มขึ้น จากการทดสอบการต้านเชื้อราแอนแทรกโนส *Colletotrichum gloeosporioides* พบว่าฟิล์มที่มีอนุภาคนาโนสามารถยับยั้งการเจริญเติบโตของเชื้อราได้ จากการทดลองทั้งหมด ผู้วิจัยสามารถสรุปผลการทดลองได้ว่าปริมาณอนุภาคนาโนซิลเวอร์เพียงปริมาณ 5 เปอร์เซ็นต์โดยน้ำหนักเมื่อเทียบกับปริมาณแร่ดินเหนียวเบนโทไนต์สามารถต้านเชื้อราชนิดนี้ได้ นอกจากนี้ยังมีการเตรียมฟิล์มเซนเซอร์สำหรับตรวจวัดความสดของเนื้อปลาโดยใช้พลาสติกเอธิลีน ไวนิลอะซิเตดผสมด้วยสีธรรมชาติจากฝาง ซึ่งมีคุณสมบัติการเปลี่ยนเฉดสีได้เมื่ออยู่ในภาวะกรดและเบส ทั้งนี้เมื่อนำฟิล์มสองส่วนมาประกอบกันจะช่วยเพิ่มประสิทธิภาพของฟิล์มบรรจุภัณฑ์ฉลาด ซึ่งสามารถนำไปใช้สำหรับการห่อหุ้มพลาสติกแช่แข็งได้

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ABBREVIATIONS

ASTM	American Society for Testing and Materials
BEN	Pristine bentonite
<i>C. gleosporioides</i>	<i>Colletotrichum gleosporioides</i>
CMC	Carboxymethyl cellulose
EGMA	Poly (ethylene-co-glycidyl methacrylate)
EVA	Virgin ethylene vinyl acetate and ethylene vinyl acetate film
EVA-SAP-CMC	Composite of Ethylene vinyl acetate-Sappan-dyed carboxymethyl cellulose and indicator film of Ethylene vinyl acetate-Sappan-dyed carboxymethyl cellulose
EVA-1 wt%SAP-CMC	Ethylene vinyl acetate- 1 wt% of Sappan-dyed carboxymethyl cellulose
EVA-3 wt%SAP-CMC	Ethylene vinyl acetate- 3 wt% of Sappan-dyed carboxymethyl cellulose
EVA-5 wt%SAP-CMC	Ethylene vinyl acetate- 5 wt% of Sappan-dyed carboxymethyl cellulose
MBEN	γ -Methacryloxypropyltrimethoxysilane-modified bentonite
MSBEN	γ -Methacryloxypropyltrimethoxysilane-modified silver nanoparticles-loaded bentonite
MS5BEN	γ -Methacryloxypropyltrimethoxysilane-modified 5 wt% of silver nanoparticles-loaded bentonite
MS10BEN	γ -Methacryloxypropyltrimethoxysilane-modified 10 wt% of silver nanoparticles-loaded bentonite
MS15BEN	γ -Methacryloxypropyltrimethoxysilane-modified 15 wt% of silver nanoparticles-loaded bentonite
MS20BEN	γ -Methacryloxypropyltrimethoxysilane-modified 20 wt% of silver nanoparticles-loaded bentonite
OTR	Oxygen transmission rate
PP	Virgin polypropylene and neat polypropylene film
PPC-MPS	Polypropylene – 5 wt% of modified bentonite nanocomposites prepared by γ -methacryloxypropyltrimethoxysilane (MPS)

PPC-PLASMA	Polypropylene – 5 wt% of modified bentonite nanocomposites prepared by a plasma generator
PPC-0.1DCP	Polypropylene – 5 wt% of modified bentonite nanocomposites prepared by 0.1 phr of dicumyl peroxide (DCP)
PPBEN	Blown film of polypropylene – 1 wt% of modified bentonite nanocomposites
PPSBEN	Blown film of polypropylene – 1 wt% of modified silver nanoparticles-loaded bentonite nanocomposites
PPS5BEN	Blown film of polypropylene – 1 wt% of modified 5 wt% of silver nanoparticles-loaded bentonite nanocomposites
PPS10BEN	Blown film of polypropylene – 1 wt% of modified 10 wt% of silver nanoparticles-loaded bentonite nanocomposites
PPS15BEN	Blown film of polypropylene – 1 wt% of modified 15 wt% of silver nanoparticles-loaded bentonite nanocomposites
PPS20BEN	Blown film of polypropylene – 1 wt% of modified 20 wt% of silver nanoparticles-loaded bentonite nanocomposites
SAP-CMC	Natural dye powder prepared by natural dye from sappan wood and carboxymethyl cellulose
SBEN	Silver nanoparticles-loaded bentonite
S5BEN	5 wt% of silver nanoparticles-loaded bentonite
S10BEN	10 wt% of silver nanoparticles-loaded bentonite
S15BEN	15 wt% of silver nanoparticles-loaded bentonite
S20BEN	20 wt% of silver nanoparticles-loaded bentonite
TVBN	Total volatile basic amine
WVPR	Water vapor permeability rate