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Original Research Article

Comparison between Bio-PET and PET for food container

Kongpop Kaewmahit[1], Namphueng Ruengrit[2], Chutimar Deetuam[2], Pollawat Charoeythornkhajhornchai[1,*]

[1] *Department of Advanced Materials Engineering, Faculty of Engineering, Burapha University, Chonburi 20131, Thailand*

[2] *Toptrend Manufacturing Co., Ltd., Chonburi 20130, Thailand*

*** Corresponding author:** Pollawat Charoeythornkhajhornchai, pollawt.ch@eng.buu.ac.th

ABSTRACT

The environmental issue of single-use plastic is extremely discussed due to waste accumulation and the consumption of non-renewable resources. This study aims to investigate the properties of bioplastic compared to petroleum-based plastic. Two stages of stretch blow molding were used to fabricate polyethylene terephthalate (PET) and bio-polyethylene terephthalate (Bio-PET) bottles. The shelf life extension of chili sauce paste stored in PET and Bio-PET containers with an oxygen scavenger at 45 ℃ in an accelerated condition was investigated. After twelve weeks, the chili sauce paste stored in the container bottle was observed. PET and Bio-PET bottles without oxygen scavengers were also determined as a control for comparison. The result showed that both PET and Bio-PET bottles with oxygen scavengers could prolong the quality of chili sauce paste similarly, meaning that PET could be replaced by Bio-PET as a chili sauce paste container. Other properties, such as thickness gauge, color, leak test, drop test, and close-open force of the container bottle, were also verified to check the product quality standard.

Keywords: Bio-PET; oxygen scavenger; food container; shelf life

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1. Introduction

Petroleum-based plastic is commonly used for lightweight container products, especially in the food packaging industry. However, it has adverse environmental impacts and can cause the problem of waste accumulation and consumption[1–3]. Therefore, researchers have been interested in creating bioplastic and biodegradable plastic to address this issue. Polyethylene terephthalate (PET) is one of the polymers that can be converted to bioplastics known as bio-polyethylene terephthalate (Bio-PET), which has the same structure and qualities as PET[3]. It has a similar chemical structure, but it is synthesized synthetically from natural resources or bio-based feedstock to form bio-based purified terephthalic acid (Bio-PTA) and bio-based mono-ethylene glycol. The commercial Bio-PET consists of 30% bio-monoethylene glycol (Bio-MEG) and 70% purified terephthalic acid (PTA) from petroleum-based feedstock because the process of producing bio-based terephthalic acid still obstructs due to the difficulty of producing para-xylene from biomass[4,5]. The Bio-PTA could be synthesized with different methods, such as the iso-butanol method, the muconic acid method, the limonene method, or the furfural method[5–7] but it is still on the laboratory scale to the best of our knowledge. Thus, Bio-PET is usually used in the industry, and this work is produced by 30% Bio-MEG and petroleum-based purified terephthalic acid. Although Bio-PET is not regarded as a biodegradable or compostable plastic, it can be reusable, resulting in no release of carbon dioxide gas during combustion from the recycling process[8–10]. Biodegradable or compostable plastic means plastic that is composted by bacteria with the appropriate humidity and temperature after composting in the landfill[3,11–13]. Although bio-PET cannot be composted in landfills because its molecules cannot be degraded or cracked by bacteria consumption, it is also called bioplastic owing to being produced by natural resources. PET is the most popular plastic for food-preserved containers because it has excellent gas barrier performance, especially for the oxygen gas barrier. It has attracted a great deal of attention in the last decades, as it represents materials involved in the packaging of perishable foods, shelf life extension, and maintenance of food quality and safety. PET has become a dominant material for food packaging due to its good oxygen, moisture, and carbon dioxide barrier properties. It has an extremely low migration of monomers and the favorable recyclability of post-consumer packages[14]. However, increasing the PET barrier performance often becomes compulsory for oxygen-sensitive foods and beverage packaging. The small amount of oxygen in the packaging may disturb the product's taste and safety[15]. The development of active packaging, with the addition of oxygen scavengers (OS), represents an innovative and pursued strategy to fulfill more stringent barrier requirements[16,17]. The oxygen scavengers are used for oxygen gas adsorption above the air trap of food containers or oxygen gas that passes through the outside of the package into the foods and beverages inside the food container, which could extend the self-life and quality of the food from the oxidation reaction between oxygen gas and the food inside the food container[18–20]. Previous studies[21–23] found that the additional small amount of oxygen scavengers in PET food packaging resulted in prolonged food quality and its teste from food preservation caused by oxygen gas adsorption from oxygen scavengers. However, there was no research focused on investigating the performance of PET and Bio-PET with small amounts of oxygen scavengers for extending the self-life and quality of the food as a food container, to the best of our knowledge.

In this work, both polyethylene terephthalate (PET) and bio-polyethylene terephthalate (Bio-PET) are formed in the same process to produce the 200 mL of food container. Then it was filled with chili sauce paste to observe the shelf-life extension. Other properties of the product bottle, such as color, leak test, drop test, and close-open force of the bottle product, were determined to be compared with our product quality standard. An oxygen scavenger was added to prolong the storage efficiency of the chili sauce paste bottle compared to the control without an oxygen scavenger.

2. Materials and methods

2.1. Materials

There were two types of plastic: virgin polyethylene terephthalate (PET, blow molding grade) and bio-polyethylene terephthalate (Bio-PET, blow molding grade), which were supported by Toptrend Manufacturing Co., Ltd., Thailand. An oxygen scavenger (oxygen absorber grade) was also supported by Toptrend Manufacturing Co., Ltd., Thailand. The plastic pellets were removed from moisture by being stored in the silo at 160 °C before being completely dried without moisture. The tensile strength of PET and Bio-PET ranged from 4.92 to 6.78 MPa, measured following ASTM D638 from the supplier. The supplier confirms that PET and Bio-PET have the same specification in thermal and mechanical properties because they have the same chemical composition and the same quality for polymerization under the same conditions. Bio-PET came from 30% bio-based alcohol produced by sugar cane, with further purification to convert it to monoethylene glycol (MEG) before reacting with terephthalic acid.

2.2. Stretch blow molding process

There were two different processing methods: one-stage stretch blow molding or one-time blow molding. The pellets were initially placed in the plastic hopper and dried for four hours at 160 °C to remove any moisture. The preform was then simultaneously injected and blown into a bottle. Another method was two-stage stretch blow molding. It was similar to the first one, except for the separated process of injection as a preform before being blown as a package. This work used both of these two processes to produce the bottom of the container for comparison.

2.3. Physical measurement

The two types of plastic, PET resin and Bio-PET resin, were compared in terms of their colors before and after they were molded as a bottle with and without oxygen scavengers. Comparisons of the colors of the PET and Bio-PET pellet products were done. The color of the plastic bottles with 2 wt% of the oxygen scavenger was also measured. Other properties, such as the wall thickness gauge, leak test, drop test, and close-open force of the bottle product, were also performed as standards for the product. The condition of the leak test was measured under 740 mmHg of water pressure for 10 min while the drop test was set up at 1 m above the semen floor. In addition, the close-open force of the bottle cap was 300 times per sample to observe any crack or fatigue after measuring by the machine. Finally, the oxygen transmission rate of the sampling bottle was investigated following ASTM F 1307-20 at 25 ± 2 °C and 60 ± 5% RH, which observed the oxygen permeability from the environment passing through the sealed package by using a coulometric sensor. The oxygen transmission rate is an important property that should be measured because it relates to the ability of chili sauce to be preserved.

2.4. Shelf life of chili sauce paste container measurement

Bottles containing the chili sauce paste made from PET and Bio-PET pellets with oxygen scavengers and the control bottles without oxygen scavengers were observed. The electromagnetism induction sealing machine was used to apply the bottle containing 200 mL of chili sauce paste under the aluminum foil, and it was kept in the catalytic incubator. Twelve weeks of testing at 45 °C of accelerating temperature with 7-day data intervals on the chili sauce container were compared. The standard of the chili sauce sampling was set at the container's head, middle, and bottom.

3. Results and discussion

3.1. Physical observation and physical measurement

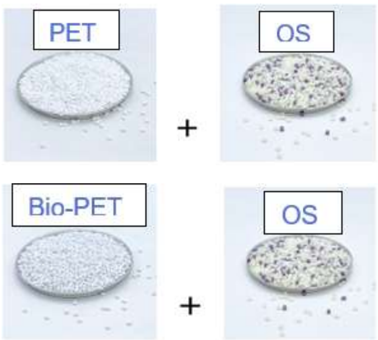
PET and Bio-PET container bottles with and without oxygen scavengers were compared side by side. PET and Bio-PET appear slightly different. The Bio-PET pigment has a little bluer color than PET, but it was blown into a container bottle with any distinctive color. **Table 1** shows that the Bio-PET pellet has a bluish tint compared to PET. However, the color aid did not change when the pellet was compounded and molded.

Table 1. Comparison of 150 mL bottle color between PET and Bio-PET bottles.

Plastic pellet	Bottle from one-step stretch blow molding
 	

The PET and Bio-PET incorporated with the oxygen scavenger are shown in **Table 2**. The packaging of Bio-PET with the oxygen scavenger is slightly yellower than that of PET with the oxygen scavenger bottles. This result shows the color of the Bio-PET bottles is stimulated to be slightly darker or yellower than PET bottles, but it could be acceptable for use.

Table 2. Comparison of 200 mL bottle color between PET with oxygen scavenger and Bio-PET bottles with oxygen scavenger.

Plastic pellets	Preform	Bottle from stretch blow molding
		

The physical test followed a standard test of the product from the company's specifications, including a wall thickness gauge, leak test, drop test, and open-close force as shown in **Table 3**. The result showed that both PET and Bio-PET passed all standards of testing necessary for use as a food container product. Moreover, the oxygen transmission rate of the sampling bottles of both PET and Bio-PET displayed similar values, with a slightly lower value for Bio-PET that was not significant for affecting the quality of preserving chili sauce in the bottle. This might be the key result for similar chili sauce preservation after testing due to the same performance of oxygen protection from the environment.

Table 3. Physical test of PET and Bio-PET for food container.

Testing method	PET	Bio-PET
Wall thickness gauge	√	√
Leak test	√	√
Drop test	√	√
Close-open force	√	√
Oxygen transmission rate (cc/day/package)	0.09825 ± 0.00615	0.07195 ± 0.00286

Note: Sampling the sample of at least 5 bottles per testing method.

3.2. Shelf life extension

Figures 1 and **2** show the shelf life test for PET and Bio-PET bottles with and without oxygen scavengers at 45 °C in an accelerating condition. The chili sauce paste started changing to a slightly dark color within six weeks, and the sauce emulsion appeared within 10 weeks. The shelf life of Bio-PET with oxygen scavengers was more prolonged compared to the control bottle without oxygen scavengers. As depicted in **Figure 2**, when an oxygen scavenger was added to PET and Bio-PET, the chili sauce paste revealed a longer effective performance, and the physical observation during storage in the bottle exhibited the same as week 12, thus it did not show in **Figure 1**. In addition, it was obvious from PET bottles and Bio-PET that oxygen scavengers might boost the food preservation performance because the color of the chili sauce paste in the bottle was unchanged. Bottles with oxygen scavengers can prolong their shelf life more than bottles without oxygen scavengers because the oxygen scavenger could adsorb the oxygen that might pass through from the environment into the inside of the bottle or it could adsorb the oxygen that might remain in the headspace of the bottle after the sealing and packing process[18,19]. The dark color of the chili sauce paste occurs from the oxidation reaction. The oxidation reaction occurs from the reaction of the chili sauce with the oxygen in the air and light in the environment. In addition, Bio-PET bottles have been used instead of PET bottles with the same performance due to the similar oxygen transmission rate as discussed earlier.

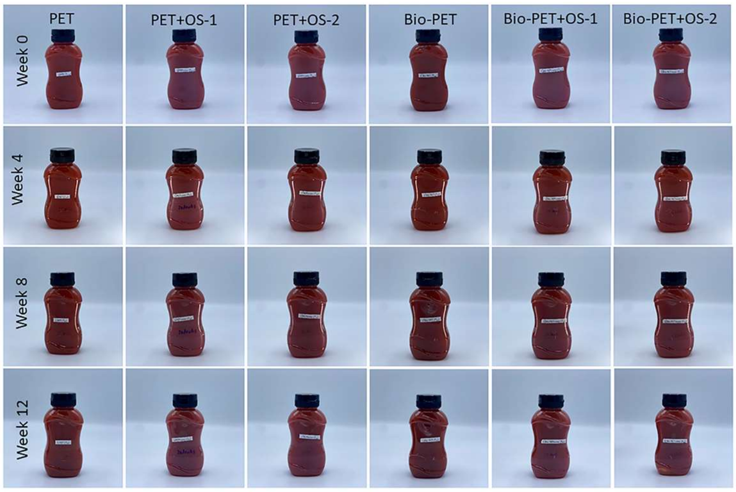


Figure 1. The storage shelf life test after packing 200 mL chili sauce paste in the bottles under accelerating conditions at 45 ℃.

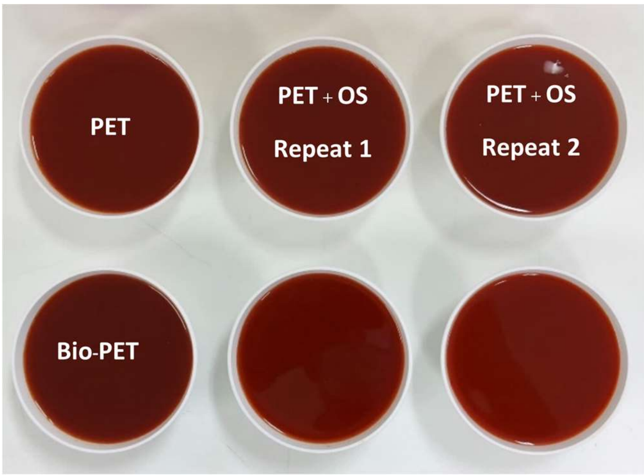


Figure 2. Color observation of chili sauce paste after shelf life test at accelerated conditions 45 ℃ of week 16.

4. Conclusion

Both container bottles of polyethylene terephthalate (PET) and bio-polyethylene terephthalate (Bio-PET) could be processed with the same condition, meaning that the Bio-PET bottle could be used to replace the PET bottle that was the petroleum-based plastic. The Bio-PET bottle also passed the company's standards, including the wall thickness gauge, leak test, drop test, and close-open force of the bottle cap, referring to the same qualities as the PET bottle. Thus, PET container bottles could be replaced by Bio-PET bottles without any issue of usage. Bio-PET bottle with oxygen scavenger exhibited a slightly darker color than the PET bottle, but it was clear after adding the blue aid color. Moreover, PET and Bio-PET bottles retained the color of chili sauce paste similarly due to the same oxygen transmission rate of the bottle container. In summary, the small amount of oxygen scavenger added enhanced the shelf life of chili sauce paste in the bottle container of both PET and Bio-PET, and the PET bottle was replaced by the Bio-PET bottle for the chili sauce container without any issue of usage.

Author contributions

Conceptualization, NR and CD; methodology, PC, NR and CD; validation, PC and CD; formal analysis, KK, NR and PC; investigation, KK; resources, NR and CD; data curation, KK; writing—original draft preparation, PC; writing—review and editing, PC; visualization, PC and CD; supervision, PC; project administration, CD; funding acquisition, PC. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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