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Study on laser perforated films as gas permeable packaging for confused flour beetle (*Tribolium confusum* Jacquelin du Val.) control inside food packaging

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ABSTRACT

Storage insect pests are a major threat for packaged foodstuffs and most packages have low permeability to the fumigant gases used for control. In this study, the effects of O_3 gas concentrations (50, 100, 150 ppm) in the atmosphere of 70% CO_2 on adults of Confused flour beetle placed inside three foodstuffs including; wheat (alive), wheat flour and rolled oats (inanimate) packed with laser perforated BOPP film with 80 μ width, were evaluated. The experiments performed at 25 ± 2 °C and 35 ± 5% r.h. with exposure period seven days. The results showed that the regression models between permeability index (PI) of Bopp film and insect mortality in three different foodstuffs and also empty packages were different. Regression model for packaged wheat was quadratic, for wheat flour and rolled oats was power and in empty packages, linear model was fitted with 95% confidence. The additive effect between O_3 and CO_2 gases on pest mortality placed in empty non-perforated film was found. Other results proved that the mean mortality in three products in the same condition is different and highest mortality was observed in wheat. Also, the interactions observed between factors at 0.05 level. Present study suggests laser perforated BOPP films as a proper packaging for inanimate products and non-perforated BOPP films for live products.

1. Introduction

The confused flour beetle, *Tribolium confusum* Du Val is one of the most serious pests of stored products worldwide. It causes damage to an extremely large variety of foodstuffs, and it is a very important pest on wheat flour and broken grain kernels. Moreover, this species is resistant to many residual pesticides and fumigants used for stored-product control (Abd El-Aziz and El-Saved, 2009; Rossi et al. 2010).

Food packaging as one of the most important parts of food industry is related with food security. Food packaging provides not only a method for transporting food safely, but extends product's self-life via preventing from harmful bacteria, contamination and degradation (Chin, 2010). Furthermore packaging can be security for food product, insect can enter goods during transportation, storage in the warehouse, or in retail stores, and also it is possible that the initial contaminants develop and destroy foodstuffs (Allahvaisi et al. 2010). Accordingly, the way, type of packaging can eliminate probable contamination of the food and prevent re-contamination, is one of the underlying subjects in packaging industry. When an infected packaging with an insect's life stage, enters into the warehouse, it can spread the contamination to other packages and in addition reducing food quantity, they annihilate quality.

In Europe, nearly 40% of all plastics are used in the packaging sector, and packaging is the largest sector of plastic's usage (Association of Plastics Manufacturers in Europe, APME). About 50% of Europe's food is packed in plastic packaging (British Plastics Federation, BPF) (Coles et al. 2003). Today, there are several popular types of polymers for foodstuff's packaging. Some of them have virtually no resistance to insects while others may be extremely resistant (Highland, 1981). Among these polymers, polypropylene has very low permeability against the pest insect (Allahvaisi et al. 2010). Orientation increases the versatility of PP film. Oriented PP film (OPP or BOPP) was the first plastic film to successfully replace regenerated cellulose film (RCF) in major packaging applications such as biscuit packing (Coles et al. 2003). In recent years, especially these films (BOPP) have become one of the most popular high-growth films in the world market (Lazic et al. 2010).

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In general, modified atmosphere packaging (MAP) is where a modified atmosphere is applied as the package is sealed and to retain the applied atmosphere, the very low permeability is required. On the other hand, today for fresh produce, films with relatively high oxygen transmission and suitable water vapor transmission rates are required (Winotapun et al. 2010). Laser perforation is the newer method to provide micro holes (Chow, 2003) that can increase gas permeability.

It is worth noting that of the 16 fumigants listed in common use, some 22 years ago by Bond (1984), only very few remain today (Navarro, 2006). Exposure of insects to toxic concentrations of atmospheric gases has been practiced for centuries and has been promoted in recent years as a bio-rational substitute for chemical fumigations (Sadeghi et al. 2011). Ozone, a powerful oxidant, has numerous beneficial applications and is very familiar to the food processing industry. This gas has regulatory acceptance by the Food and Drug Administration (USA), and the Environmental Protection Agency's (USA) MSDS defines it as “pure air” (Mason et al. 2006). CO_2 gas, is relatively safe to use, leaves no known residues, and readily penetrates packages of tightly compressed commodities (Keever, 1989).

When a product is packaged, it may be contamination and because percentage of insect's penetration can depend on the type of packaging material, finding the best wrapper for packaging is inevitable and purpose of this study. So, modified atmosphere system and BOPP film were applied due to least dangerous to storing agricultural products and maximum resistance to penetration by insect respectively.

2. Material and methods

This study was carried out at Department of Plant Pest and Disease, Razavi Khorasan Research Center for Agriculture and Natural Resources during the years 2012–2013. Different concentrations of O_3 and CO_2 gases was tested on packages made of laser perforated BOPP films with 80 μ width containing wheat, wheat flour and rolled oats, and the best gas mixture was selected. This gas mixture was treated on the eight treatments, including seven laser perforated films (LPFs), a non-perforated film and control treatment.

2.1. Insect

Confused flour beetle was collected from a flour silo in Mashhad (36°20′N 59°35′E), a city in Iran. Cultures were established and maintained on healthy uncontaminated food at 25 ± 2 °C and 65 ± 5% r.h. in plastic bottles and were closed with pieces of muslin cloth fixed by rubber bands. Rearing medium used was composed of wheat flour with 5% yeast (Childs and Overby, 1983). All insects were cultured under moderately crowded conditions to ensure proper development and equal size of the resultant adults.

2.2. Supply of gases

Ozone gas was generated by ozone Generator, Ozonica series, Oz 100 model (WWW.ozoneab.com/), that generate 100 g/hour ozone from purified oxygen with four reactors. Purified oxygen produce by oxygen generator, LFY-I-5F–W model, provided by Longfei Group Co. Ltd., and produce purified oxygen 93% ± 3% with flow rate 0–5 L/min. Specified O_3 concentration Was measured based on the volume of the chamber and the default generator. A local factory supplied CO_2 gas needed inside cylinders of 40 kg with 99.9% purity.

2.3. BOPP film

We laminated two BOPP film rolls with 40μ width together and produced film 80μ. Then cut rolls to size 60 × 100 cm. Afterward, perforated them with Golden Laser Machine, JG-13090DT model produced by China with distances 0.75, 0.8, 1, 2, 3, 4 and 5 cm and 200 ± 25μ hole's diameter, and made the packages to size 20 × 30 cm by plastic press machine.

2.4. Bioassay

At the first, the packages 20 × 30 cm were filled with 1 kg of wheat, wheat flour and rolled oats separately. Then a cage (Petri with a diameter of 10 cm) containing 40 adults *T. confusum* 12 ± 4 day old and 3 g food was entered into each package and sealed with a plastic press machine. Three packages from each of the treatment of LPFs and foodstuffs was performed, then transferred into chamber 70 × 120 × 180 cm and placed horizontally at the bottom it and the chamber closed tightly. Afterward, CO_2 gas was injected into the upper left, and air exited from the bottom right until concentration of CO_2 was 40% or 70% and in the final step, we injected O_3 gas daily at a specified time and every day on reaching the specified concentration, ozone injection was stopped. A total, in each experiment seven injections with equal doses during seven days performed. During CO_2 injection and until 1 h after O_3 injection, the system was circulated. During experiments, upper surface of packages exposed chamber atmosphere. Exposure period was considered 7 day at 25 ± 2 °C, 35 ± 5% r.h. After exposure period, the specimens were transferred to a clean jar containing 3 g of food with the same condition. Mortality rates of the insects were recorded 6 h after termination of the treatment.

Preliminary dose-mortality tests to determine a range of doses that produce 25–75% mortality at the lowest and the highest doses were done, respectively (Robertson et al. 2007). Afterward, the interaction of two gases on mortality obtained. Final experiment performed in two parts. At the first, we consider relationship between permeability index (PI) of BOPP film with the formula (Area of all of micro-holes on package/Area of package) × 1000 and mortality rate (MR) of adult insect and another part; treatments were compared for each factor separately and interactions between factors was evaluated.

2.5. Complementary experiments

We performed two complementary experiments for elected treatments, including test of confused flour beetle penetration inside and outside packaging and test of adult emergence from immature stages in a gas treatment. The first experiment for adults was conducted in two parts. At first, the starved insects were placed around packages containing 3 g of foodstuffs and then, the starved insects were entered into packages while on the outside there were foodstuffs. For the test of adult emergence, a sample containing 100 g of rearing medium containing eggs, larvae and pupae of confused flour beetle randomly selected and placed into the packages containing wheat, wheat flour and rolled. After fumigation (70% CO_2 + 150 ppm O_3), the samples were transferred to a clean jar and held at 25 ± 2 °C and 60 ± 10% r.h. for eleven weeks. During this period of incubation, every week, the number of adults emerged, recorded and was removed from the container. The experiment was replicated three times and results were pooled.

2.6. Data analysis

Experiments were performed by a completely randomized design using factorial experiment. All of data were analyzed with