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Minimizing photooxidation in pasteurized milk by optimizing light transmission properties of green polyethylene films

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ABSTRACT

The effect of different amounts of transmitted green light on photooxidation in pasteurized milk was studied. Five different green films produced with combinations of pigments and additives to minimize exposure to harmful wavelengths with regard to photosensitizers (400–450 and 600–650 nm) were evaluated. In addition, a non-colored transparent film and an orange film were compared with 1 selected green film. Pasteurized milk (3.9% fat) was packed in an air atmosphere and exposed to light for 14, 20, 26, and 32 h at 4°C under the different films. Samples stored in the dark were control samples. The results showed that the most-effective green film had low overall light transmission, and also almost completely blocked light wavelengths shorter than 450 nm and wavelengths longer than 600 nm, which prevented photooxidation of riboflavin and chlorophyllic compounds. Chlorophyll degradation was highly correlated with sensory properties (coefficient of determination = 0.80–0.94). To preserve milk quality, total blocking of all visible light would be preferable. If total blocking is not feasible, then light transmission for wavelength below 450 nm and above 650 nm should be minimized (e.g., less than 5%). The newly developed green film can be used as a prototype for protection of dairy products to reduce the degradation of photosensitizers.
Key words: milk, photooxidation, packaging, light transmission

INTRODUCTION

Light is well known for inducing chemical changes in food products and leading to formation of off-flavors and off-odors. Protection against photooxidation can be done by using light-blocking packaging materials. Complete blocking of all visible light by using black or opaque packaging is not always feasible because sometimes a desire exists to see the actual product through the packaging material. To design a transparent material with optimal protection properties, it is important to know the photochemical properties of the food products. For dairy products, these properties are quite well known, and based on this knowledge it is possible to suggest how transparent films can be optimized for extended shelf life.

Dairy products contain several photosensitizers (riboflavin, porphyrins, and chlorophyllic compounds) that absorb visible light in different wavelength regions (Wold et al., 2005). Riboflavin absorbs wavelengths below 500 nm, which means that it absorbs UV and blue light, whereas chlorophyllic compounds typically absorb light around 420 nm and above 600 nm. Protoporphyrin IX, present in milk, absorbs strongly around 400 to 420 nm and have many smaller absorption peaks throughout the visible region.

Wavelengths below 500 nm have been reported to degrade riboflavin and cause quality deterioration in dairy products (Bekbölet 1990; Bosset et al., 1994; Mortensen et al., 2004). Josephson (1946) reported that wavelengths below 500 nm degraded riboflavin the most, but that longer visible wavelengths (590–630 nm) induced the strongest formation of sunlight flavor in milk. Recently, Airado-Rodríguez et al. (2011) showed that milk exposed to wavelengths longer than 575 nm (orange light) induced significantly higher amount of sensory off-flavors than wavelengths shorter than 500 nm (blue light). This was explained by the photoactivation of tetrapyrroles absorbing in the red region (>600 nm). The tetrapyrroles typically absorb in the red region as well as in the blue and UV regions. However, milk also contains β-carotene, which will absorb much of the blue light and thereby reduce photooxidation by this wavelength region. The photosensitizers absorb relatively little between 500 and 600 nm. Thus, excluding the UV and blue light below 500 nm, and the red light longer than about 600 nm seems to be a feasible approach to avoid the worst photooxidation (Webster et al., 2009, 2011; Intawiwat et al., 2010, 2011; Airado-Rodríguez et al., 2011).

In many studies, green light (450–600 nm) has been shown to give the least-severe effect on photooxidation in dairy products (Hansen et al., 1975; Cladman et al.,

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1998; Wold et al., 2005, 2006b; Intawiwat et al., 2010). Green light is least absorbed by photosensitizers in dairy products and green films are, therefore, likely to give longer shelf life compared with blue or red films.

Using a packaging material with light barrier is one alternative to protect against photooxidation. Milk is commonly packed in transparent or translucent white plastic bottles. Coloring of transparent packaging materials can be used to protect and preserve food quality. Brown and green colored materials are used for packing light-sensitive products such as medicine, edible oils, and beer. Transparent packaging materials with different transmission properties, by using color pigments have been applied in the market. Traditionally, colored packaging materials are mostly used for design and to promote sale, and not for specific protection of food products by blocking certain harmful wavelength regions.

Some additives can be used to adjust light transmission properties of materials. Silver (Ag) has a specific absorption peak at 418 nm (He et al., 2002). Adding Ag into the material will reduce light transmittance at this wavelength close to chlorophyll absorption. Optical brightener absorbs UV light and it also emits light in the blue/white range of the spectrum, resulting in a whiter and brighter appearance of material (Intawiwat et al., 2012).

The purpose of this study was to investigate the effect of different green polyethylene films on photooxidation in pasteurized milk during light exposure. Because colored packaging materials have different optical properties, they might offer different degrees of protection of the food product. Regarding green films, we also compared the performance of one of the green films with a transparent non-colored film and a transparent orange film. The green film was selected based on providing overall better protection against photooxidation. A trained sensory panel evaluated the level of photooxidation. Fluorescence spectroscopy was used to measure the amount of protoporphyrin IX and chlorophyllic compounds and their degradation during light exposure of the milk.

MATERIALS AND METHODS

Experimental Design

Five different polyethylene films and 4 light-exposure times (14, 20, 26, and 32 h) were the parameters used to investigate the effect of different light-transmission properties of green films on photooxidation. There were 2 samples for each combination of films and exposure times. In addition to samples exposed to light, 2 samples were stored in the dark for 32 h as reference samples. In the study, 42 samples were evaluated [(4 light-exposure times × 5 films) × 2 replicates + 2 dark-stored samples].

After that, a green film, which tended to give overall good protection with regard to photooxidation, was compared with a non-colored transparent film and an orange film at 4 light-exposure times. A total of 26 samples were evaluated [(4 light-exposure times × 3 films) × 2 replicates + 2 dark-stored samples].

Each milk sample was mixed and poured in 2 white, high-density polyethylene (**HDPE**) trays. These 2 white trays were put into a black amorphous polyethylene terephthalate (**A-PET**)/polyethylene (**PE**) thermoformed tray for the same storage treatment. Of the 2 white trays, one was used for sensory analysis and the other was used for fluorescent spectroscopy. Samples used in this study are shown in Figure 1.

The samples were stored under air atmospheres and exposed to light at 4°C. The samples were analyzed immediately after light exposure. Sensory analysis was used to measure the formation of off-flavors and off-odors, whereas fluorescence spectroscopy was used to study the degradation of photosensitizers. Milk samples were named according to codes in Table 1.

Milk Samples

Pasteurized bovine milk with 3.9% fat content packed in gable-top cartons was obtained from a local dairy company (Tine SA, Oslo, Norway). The milk came from the same batch to obtain a fairly homogeneous set of samples. All milk was stored at 4°C in darkness before sample preparation.

Packaging Method and Sample Preparation

Milk from the cartons was blended to obtain a homogenous set of samples. Milk aliquots (230 mL), measured with sterilized graduated flasks, were placed in white HDPE trays (5.3 × 9.2 × 9.2 cm; Promens AS, Kristiansand, Norway). Two of the HDPE trays were packed in black A-PET/PE thermoformed trays. The A-PET/PE sheets were manufactured by Wipak Oy (Nastola, Finland) and thermoformed by JiHå Plast AB (Karlskoga, Sweden). The thermoformed trays (14.5 × 20.5 × 7.0 cm) were sealed with a top web consisting of PET/PE/ethylene vinyl alcohol (EVOH)/PE by using a tray-sealing machine (DYNO model 511 VG; Promens AS). OTR of sealed package (A-PET/PE tray and top web) was 0.23 ± 0.06 mL of O_2/package per day at 1 atm (at 23°C/50% relative humidity). The colored films were placed on the top of sealed packages (Figure 1). Samples were stored in an air atmosphere.