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Shelf life extension of sponge cake by active packaging as an alternative to direct addition of chemical preservatives

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A B S T R A C T

To extend the shelf life of sponge cake by an O_2 scavenger (OS) and an ethanol emitter (EE) as alternatives to chemical preservatives, sponge cake samples were packaged with an active packaging system and a high barrier pouch, polyvinylidene chloride (PVDC)-coated nylon or nylon. Effects studied included the initial rate of O_2 reduction, total O_2-scavenging capacity to maintain critically low O_2 concentration through storage, and effects of ethanol on microbial growth and evolution of headspace CO_2 and O_2. Active packaging system effectively extended mold-free shelf life of preservative-free cake from ~1 day (control) to more than 42 days. By significantly retarding microbial growth and activities, active packaging shifts the critical shelf life determination reaction to physicochemical deteriorations. OS retarded lipid oxidation and enhanced color stability of the cake. EE delayed staling. PVDC-coated nylon enhanced the efficiency of active packaging better than nylon. The combination of OS and EE synergistically delayed microbial spoilage as well as physical and chemical deteriorations. Application of active packaging systems is an effective alternative preservation technology for prolonging the shelf life of highly perishable sponge cake without the direct addition of chemical preservatives into the bakery formula.

1. Introduction

Sponge cake is conventionally made fresh daily due to its perishable nature. The mold-free shelf life of preservative-free bakery is limited to only a few days. Extending the shelf life of sponge cakes is challenging. Aside from rapid microbial degradations, a slower, complex set of deleterious physical and chemical changes associated with organoleptic characteristics also determines cake shelf life, which complicates efforts to extend both safety and quality. Crucial phenomena that lead to freshness loss of sponge cakes are staling and lipid oxidation (Del Nobile, Buonocor, Limbo & Fava, 2003). To increase shelf life and enhance safety, chemical preservatives are commonly employed. Recent food safety laws and regulations worldwide as well as consumer demand for organic and wholesome products with “clean” labels have shifted the burden of synthetic chemical preservatives away, and toward innovative packaging systems.

Modified atmosphere packaging (MAP) is one of the successful hurdle technologies that extend shelf life for many foodstuffs, including bakery products. MAPs of aerated bakery products are accomplished by gas flushing machinery that instills a desired gas mixture, i.e. elevated CO_2 for bacteriostatic and fungistatic activities and balanced N_2, into high-barrier polymeric packaging. Nevertheless, gas flushing can extend shelf life for only a few days. This is because the practice cannot sufficiently remove inherent O_2 occluded in the highly porous structure, in the void space between food particles, or dissolved O_2 within food components. Oxygen must be reduced to the critical levels necessary to suppress activity of aerobic microorganisms and remove ingress O_2 through packaging barriers over the storage time. In order to achieve a prolonged shelf life, headspace O_2 must be eliminated quickly and completely (Piergiovanni and Fava, 1997).

O_2 scavenger (OS) is an active packaging concept that selectively and actively decreases the level of free oxygen in a hermetically packaged food system. OS may prevent headspace O_2 from harboring aerobic microbial activities and reacting with food

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components, or may reduce oxygen permeation rates through container walls (Robertson, 2006). The key considerations when applying OS are scavenging capacity, packaging permeability, expected shelf life, activation mechanisms and rates of scavenging. Successful applications of OS have been demonstrated for extending shelf life of packaged bread (Salminen et al., 1996; Smith, Ooraikul, Koersen, Jackson, & Lawrence, 1986). Nonetheless, the reports on more complex systems, e.g. sponge cake, are limited. Furthermore, most studies focus on maintaining the reduced O_2 level during storage, with insufficient information on the effects of initial O_2 reduction rates.

Ethanol emitter (EE), from which ethanol vapor is deliberately control-released into the package headspace, is another choice for shelf life extension of food with a high water activity (a_w). The effect of ethanol as a preservative is based on ethanol's ability to lower a_w and function as antimicrobial agent (Kalathenos & Russell, 2003). Ethanol also demonstrated anti-staling properties in bakery products (Pafumi & Durham, 1987). EE can be used alone or in combination with OS to prevent the possible growth of anaerobic pathogens in the anaerobic environment (Latou, Mexis, Badeka, & Kontominas, 2010). Nonetheless, the effectiveness of EE as a preservative and an anti-staling agent is commonly restricted by its concentration, which is in turn limited by an ethanol odor threshold.

The initial O_2 reduction rate, total O_2-scavenging capacity and O_2 permeability of the barrier films were hypothesized to be the critical factors governing shelf life extension of packaged sponge cakes. Furthermore, a low concentration of ethanol is hypothesized to work synergistically with OS to prolong the shelf life of sponge cake at ambient conditions. EE should help suppressing proliferation of anaerobic microorganisms when OS reduces the headspace O_2 below 0.01% without contributing an unacceptable unpleasant odor. Therefore, the objective of this study was to extend shelf life of sponge cake by OS and EE as alternatives to direct addition of chemical preservatives.

2. Materials and methods

2.1. Sample preparation and storage

Preservative-free sponge cakes were freshly baked by the commercial five-star ranking One Tambon One Product (OTOP) bakery (Trang, Thailand). The cake batter consisted of egg (50% w/w), sugar (13%), wheat flour (17%), whole milk (10%) and butter (10%). The round cake was 150 mm in diameter and 40 mm in height. The samples had average weight of 230 g and average total volume of 685 cm^2, calculated using cross-sectional tracings of cake (Cloke, Davis, & Gordon, 1984).

Two types of barrier gusset pouches ($180 \times 30 \times 250\ mm^3$) were used: (1) a 2 μm polyvinylidene chloride (PVDC)/14 μm nylon/44 μm cast polypropylene (CPP) (Knylon type) and (2) a 15 μm nylon/65 μm linear low density polyethylene (LLDPE) (nylon type) (Huhtamaki (Thailand) Limited). The O_2 transmission rate (OTR) of PVDC-coated nylon and nylon are 6.73 ± 0.05 and 66.03 ± 0.81 cc/m^2.day, respectively. The OX-TRAN® 2/21 ST modular system (MOCON Inc., Minneapolis, MN, U.S.A.) was used to measure OTR according to standard method ASTM D3985-05 (ASTM 2001) at 23 °C, 0% relative humidity (RH) and 1 atm partial pressure difference. The water transmission rate (WVTR) of Knylon and nylon are 0.02 ± 0.01 and 3.88 ± 0.01 g/m^2.day, respectively. The water vapor transmission rate (WVTR) was determined according to ASTM E398-0324 (ASTM 2003) using a PERMATRAN-W® model 398 (MOCON Inc., Minneapolis, MN, U.S.A.). Testing was performed at 23 °C and at a 90%–10% RH gradient.

To study the effect of OS and EE on shelf life of sponge cake, OS BestKept® (Alpine Foods Co., Ltd., Bangkok, Thailand) with an O_2-scavenging capacity of 400, 200 or 100 ml; and EE MaxxLive® (Alpine Foods Co., Ltd., Thailand) of size 1.5 g were used as detailed in Table 1. EE consists of food grade ethanol (55% w/w) and water (10%) encapsulated in carrier powder (35%). The size calculation of EE is based on product weight, a_w and required shelf life. The recommended effective size is 4.6 g due to the high a_w and weight of the sample. Nonetheless, the testing size was selected using results from preliminary sensory evaluation. The pouches were hermetically sealed and packaged in a retail carton ($180 \times 180 \times 60\ mm^3$). The samples were stored at ambient conditions; 30 ± 2 °C and 60 ± 10% relative humidity (RH) and monitored by Flashlink® electronic data loggers (model 20207, Delta Trak, California, U.S.A.) for 42 days.

2.2. Headspace gas analysis

Headspace gas composition in the packaged sample was measured by a CO_2/O_2 MAP headspace gas analyzer, Model 900141(Bridge Analyzers, Inc., California, U.S.A.). An optical oxygen sensor (Wonder sensor™, PowderTech Co., Ltd., Kawashiwa-shi, Japan) was also used to monitor headspace O_2.

2.3. Ethanol content

Ethanol content was measured using Agilent 7697A headspace sampler and Agilent 7890B gas chromatograph system equipped with a 5977A MSD mass spectrometry (Agilent Technologies, California, U.S.A.). The Agilent J&W HP-INNOWax capillary column (30 m × 0.25 mm i.d. x 0.25 μm film thickness) was used at helium flow rate of 1 ml/min. The oven temperature was initially set at 40 °C for 5 min, and then increased to 150 °C at 90 °C/min for 1 min. The ethanol content (% by volume) was calculated using the external standard method.

2.4. Microbial analyses

Total plate count (TPC) and yeast and mold count (YM) were determined according to FDA's Bacteriological Analytical Manual (FDA-BAM, 2001). At the end of the storage period, *Clostridium perfringens* and *Bacillus cereus* were tested (ISO 7937: 2004 and ISO7932: 2004, respectively). Mold-free shelf life was considered as the time period from packaging to the day when visible microbial growth was observed in any sample for the first time.

2.5. Color

The color of the cake crumb and crust was evaluated using a

Table 1
Active packaging and barrier film treatments for shelf life extension of sponge cake.

Sample	Active packaging	Laminated film
Control	n/a	KNylon
OS400/K	O_2 scavenger 400 ml	KNylon
OS200/K	O_2 scavenger 200 ml	KNylon
OS100/K	O_2 scavenger 100 ml	KNylon
OS400 + EE/K	O_2 scavenger 400 ml + Ethanol emitter	KNylon
OS200 + EE/K	O_2 scavenger 200 ml + Ethanol emitter	KNylon
OS100 + EE/K	O_2 scavenger 100 ml + Ethanol emitter	KNylon
OS400/N	O_2 scavenger 400 ml	Nylon
OS200/N	O_2 scavenger 200 ml	Nylon
OS100/N	O_2 scavenger 100 ml	Nylon
OS400 + EE/N	O_2 scavenger 400 ml + Ethanol emitter	Nylon
OS200 + EE/N	O_2 scavenger 200 ml + Ethanol emitter	Nylon
OS100 + EE/N	O_2 scavenger 100 ml + Ethanol emitter	Nylon