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Development of shelf stable chiffon cake using gamma irradiation

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ABSTRACT

Gamma irradiation combined with mild preservative was applied to extend the shelf life of chiffon cake stored at ambient temperature. Reduction of specific volume, hardness, springiness, chewiness and crumb yellowness was noticed after irradiation at 2–10 kGy, whereas crust yellowness and peroxide values increased. Panelists could detect a decline in chiffon cake qualities, especially odor and texture. Although overall acceptability scores significantly decreased ($p < 0.05$) at doses above 4 kGy, the scores did not differ significantly ($p \geq 0.05$) between 2 kGy and 4 kGy. Thus, a dose of 4 kGy was recommended for chiffon cake irradiation to encourage microbiological safety. Ordinary chiffon cake quickly spoiled due to mold growth while storing for 3 d. Calcium propionate at 3 g/kg could not prolong chiffon cake shelf life. This preservative had poor efficacy when employed with chiffon cake that had intermediate a_w of 0.85 and basic pH of 8.24. Gamma irradiation at 4 kGy, with or without 1.5 g/kg calcium propionate, effectively extended the shelf life of chiffon cake to 90 d without mold growth detection. However, storage of no longer than 75 d was recommended when oxidative rancidity was concerned. The ability of 4 kGy irradiation to decontaminate *Aspergillus flavus* was successfully assured.

1. Introduction

A change in consumer behavior from home cooking to purchasing ready meals has encouraged the continuous growth of bakery product markets. Bakery products are commonly packed in plastic bags after baking and cooling. The most widespread and important species, including *Penicillium, Aspergillus, Eurotium* and *Cladosporium,* usually access the product surface during the post-baking cooling, finishing and wrapping (Fustier, Lafond, Champagne, & Lamerche, 1998). Fungal growths differ among bakery products due to diverse nutritional compositions. Chiffon cake is made from wheat flour, water, vegetable oil, eggs, sugar, and baking powder. This cake contains plentiful nutrients and is classified as a product with intermediate moisture content. Few fungal genera dominate intermediate and low moisture foods and the most accountable species in microbiological deterioration are *Penicillium, Aspergillus,* and *Eurotium.* Environmental conditions which favor the growth of these fungi have been among the interests of many researchers (Abellana, Magri, Sanchis, & Ramos, 1999; Abellana, Sanchis, & Ramos, 2001; Fustier et al., 1998). The growth rate of these fungi on a sponge cake analogue depended on a_w and temperature. The minimum a_w values for growth of *Penicillium spp.* were between 0.85 and 0.90, whereas *A. flavus* was able to grow at an a_w value of 0.90 and a temperature above 15 °C (Abellana et al., 2001). Meanwhile, optimum growth of *Eurotium* spp. was at an a_w value of 0.90 and a temperature of 30 °C (Abellana et al., 1999). Thus, fungal growth of the three species could be prevented by keeping a_w <0.85.

Weak organic acids such as propionic, benzoic, and sorbic acids are usually used in order to suppress the growth of fungi and extend the shelf life of bakery products. Efficacy of weak acids was influenced by a_w and pH values of the products. These preservatives had poor efficacy in intermediate-moisture bakery products of high pH, such as egg-based cakes. Addition of weak acid preservatives at recommended concentrations of 2–3 g/kg was not useful when added to bakery products with near to neutral pH. However, they were effective in controlling fungi in sponge cake of pH 6.0, but only at low a_w of 0.80–0.85 (Guynot, Ramos, Sala, Sanchis, & Marin, 2002; Marin, Abellana, Rubinat, Sanchis, & Ramos, 2003).

Recently, consumers have been concerned about the use of

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chemical compounds in food products, with regard to health safety. Slight reductions in a_w and pH, as well as the control of storage conditions, were introduced in order to enhance preservative effect and reduce the use of preservatives (Marin et al., 2002). Gamma irradiation is an alternative technology for decontaminating food effectively. Microbial inactivation could be achieved by causing direct damage to nucleic acids and indirect damage from oxidative radicals originating from the radiolysis of water. Amounts of radiation energy needed to control microorganisms in food depend on the resistance and number of microorganisms, food composition, moisture content, irradiation temperature, presence of oxygen, and the frozen state of foods (Farkas, 2006). In bakery products, gamma irradiation can effectively eliminate fungi and their spores, as well as bacteria which frequently contaminate bread-making wheat flour (Arvizu et al., 2006). Bread made from irradiated wheat flour has a 50% longer shelf life than that of ordinary wheat bread. Fungal growth in bread and chapattis can be inhibited for several weeks after gamma irradiation (Urbain, 1986). Ready-to-eat shelf-stable bread (Bhoir, Muppalla, Kanatt, Chawla, & Sharma, 2015) and stuffed baked food (Kumar, Saxena, Verma, & Gautam, 2016) have been developed by employing high-dose radiation processing. Irradiation improves the microbiological and fungal quality of cookies (Rodrigues, Fanaro, Duart, Koike, & Villavicencio, 2012) as well. Irradiation of wheat flour affects physicochemical, dough and baking properties, but these effects are dose dependent (Arvizu et al., 2006). Therefore, this study aimed to determine optimum irradiation doses for chiffon cakes and consequently, apply irradiation combined with reduced preservative (calcium propionate) to decontaminate *A. flavus* and extend the shelf life of chiffon cakes stored at ambient temperature.

2. Materials and methods

2.1. Chiffon cake making process

Chiffon cake was prepared from wheat flour (213 g), egg white (330 g), egg yolk (170 g), vegetable oil (133 g), sugar (258 g), salt (1 g), baking powder (4 g), and vanilla powder (7 g). After the egg yolk, vegetable oil, sugar, salt, wheat flour, baking powder, and vanilla flavor were well mixed, the dough was rested. The egg white was beaten and sugar was added when egg foam was observed. The egg white mixture was poured onto the rested dough and rapidly mixed. The dough was put in a grease-painted aluminum pan and subsequently baked in an electric oven (180 °C) for 15 min, rested for 5 min, removed from the pan and cooled for 1 h. The chiffon cake was cut into 4 × 2 × 2 cm pieces, packed in sealed polypropylene plastic bags (six pieces per bag), and kept at ambient temperature (25 ± 5 °C) before the experiments.

2.2. Gamma irradiation

Test batches of chiffon cake were irradiated at the Office of Atomic Energy for Peace, Thailand, using a Co-60 source with Gammacell-220. The dose rate was 0.16 kGy/min. Absorption of ionizing radiation was checked by ferrous sulfate and ceric sulfate dosimetry. The irradiation doses were 0, 2, 4, 6, 8 and 10 kGy. After irradiation at an ambient temperature (25 °C), samples were taken and kept for 24 h before determination of the chiffon cakes' qualities.

2.3. Combination of gamma irradiation and mild preservative

Calcium propionate (CAP) was used as preservative. Permissible level of CAP in bakery products is 3 g/kg (European Union, 1995). Four treatments were designated: ordinary chiffon cake (untreated), chiffon cake irradiated at a predetermined optimum dose, chiffon cake added with 3 g/kg CAP, and chiffon cake added with 1.5 g/kg CAP and irradiated at a predetermined optimum dose. Chiffon cakes were prepared using the previously explained process. Based on a total weight of ingredients, CAP was added to the dough before baking in order to provide final concentrations of 1.5 g/kg and 3 g/kg. After cutting and packing all the chiffon cakes in plastic bags, some of the untreated chiffon cakes and chiffon cakes added with 1.5 g/kg CAP were irradiated at a predetermined optimum dose. All chiffon cake samples were stored at ambient temperature (25 ± 5 °C) for 3 months. Microbiological qualities and peroxide values were monitored during storage.

2.4. Inoculation, incubation, and assessment of Aspergillus flavus growth

The *Aspergillus flavus* inoculum was prepared by growing the isolate in Potato Dextrose Agar (Sigma-Aldrich Co., St. Loius, USA) for 3 d at 30 °C to obtain sporulating cultures. Fungal spores were collected in sterile bottles containing 0.5 g/L Tween-80. Spore concentration was measured with a haemocytometer and adjusted approximately to 10^4 spores/mL.

Pieces of untreated chiffon cake, chiffon cake added with 1.5 g/kg CAP, and chiffon cake added with 3 g/kg CAP were sealed in aluminum foil and autoclaved at 121 °C for 15 min. Each chiffon cake piece was inoculated with 1 mL of spore solution, using a sterile needle, and packed separately in a sealed sterile plastic bag. Each 20-piece batch of chiffon cake was used for one of the four treatment batches: (1) ordinary chiffon cake (untreated), (2) chiffon cake irradiated at a predetermined optimum dose, (3) chiffon cake added with 3 g/kg CAP, and (4) chiffon cake with 1.5 g/kg CAP added and irradiated at a predetermined optimum dose. All treatments were performed in duplicate. Growth of *A. flavus* on chiffon cake was monitored daily during the 10 d of storage at ambient temperature (25 ± 5 °C). A piece of chiffon cake was supposed positive when more than 1% of the total surface area was covered with fungi. From a total of 20 chiffon cake pieces, the number of pieces covered with *A. flavus* during storage at ambient temperature (25 ± 5 °C) for 10 d was recorded and the percentage reported.

2.5. Analysis of chiffon cake qualities

Water activity (a_w) was measured with an a_w meter (LabMaster-a_w, Novasina, Switzerland). Chiffon cake samples were analyzed for pH using a pH meter (Eutech pH 700, Eutech Instruments Pte Ltd., Singapore). To determine the specific volume, the chiffon cake sample was first weighed, and the volume of the sample was then measured using the rapeseed displacement method. Specific volumes were reported as mL/g. The chiffon cakes' color of crust and crumb was measured in terms of L* from white (L = 100) to black (L = 0), a* from red (+a*) to green (-a*), and b* from yellow (+b*) to blue (-b*), using a C.I.E. LAB Color Meter (Color Guide Gloss, BYK Gardner GmbH, Germany). The texture of chiffon cake was assessed. Chiffon cake pieces with 20 mm thickness were subjected to Texture Profile Analysis, using a Texture Analyzer (TA 500, Lloyd Instrument, UK) with cylindrical compression probe (diameter 37.5 mm), 500 N load cell and crosshead speed of 2 mm/s. The probe was moved downward to 50% of the sample height and subsequently, hardness, cohesiveness, springiness, chewiness and adhesiveness were determined from the force deformation curve. To determine the Peroxide Value (PV), 10 g of chiffon cake was extracted with chloroform/ethanol (2:1 v/v) and the solvents were removed under rotary evaporation to leave an oil. This oil (5 g) was added with 30 mL of acetic acid/chloroform (3:2 v/v) and 0.5 mL of saturated potassium iodide solution. It was vigorously mixed for