Effect of Fat Substitute and Plum Extract on Radiation-induced Hydrocarbons and 2-Alkylcyclobutanones in Freeze-dried Beef Patties

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Abstract

The effect of adding 10% fat substitute (10%F) or 2% plum extract (2%P) on the formation of hydrocarbons and 2-alkylcyclobutanones (2-ACBs) in freeze-dried beef patties, irradiated (IR) at 44 kGy, and freeze-dried irradiated cooked beef patties was investigated. Hydrocarbons, such as C\textsubscript{16:3}, C\textsubscript{16:2}, C\textsubscript{17:2}, and C\textsubscript{17:1}, were detected only in irradiated samples and their concentrations were high in the order of 2%P+IR, IR and 10%F+IR. Only irradiated beef samples produced 2-ACBs (2-DCB, 2-TCB, 2-TeCB), and their amounts were high in reverse order. The addition of fat substitute or plum extract did not help in reducing hydrocarbons and 2-ACBs in the freeze-dried irradiated cooked beef. However, the amounts of radiation-induced hydrocarbons and 2-ACBs in all irradiated beef patties even at 44 kGy were too small to be of concern for human consumption.

Key words: freeze-dried beef, irradiation, hydrocarbons, 2-alkylcyclobutanones, additives

Introduction

Space foods have been developed since astronaut John Glenn, the first American to orbit the Earth, has taken foods to the weightless conditions of the earth orbit. Dehydrated, retorted, and irradiated foods are consumed for space missions, and the critical factors for designing space foods include light weight, high quality, and long shelf-life. International Space Station (ISS) and planetary outpost missions have 9 mon, 1 year, and 3-5 years of shelf-life requirements for the foods in shuttle, respectively. Another important requirement for space foods is improved mouth feel and taste (Kloeris, 2001). Reduction of fat content in hamburgers without compromising desirable quality characteristics is important to ensure that the products are acceptable to NASA astronauts as well as other consumers. The drastic reduction of fat content from beef, however, can result in a product with an unpalatable mouth-feel. Fat substitute (Fantesk\textsuperscript{TM}, Heritage Fare Technology, USA), a uniformly-dispersed oil phase (10 to 50 µ droplets) within a carbohydrate matrix (Garzon et al., 2003), and plum extract puree added in meat products can eliminate this quality defect. Fat substitute, Fantesk\textsuperscript{TM}, is reported to bind moisture and maintain the desirable texture and mouth-feel that consumers expect in a juicy hamburger. Also, addition of fat substitute to ground beef can reduce fat content in hamburger patties without compromising mouth-feel (Garzon et al., 2003). This reduction in fat content may also decrease the extent of off-odors generated from lipid oxidation during irradiation and storage. Plum extract contains humectants such as sorbitol, which binds moisture and thus has a potential to alleviate the dry mouth-feel in low-fat meat products (Anon, 1998). The addition of plum extract to low-fat ground beef has enabled the production of hamburgers with similar mouth-feel and texture to those with high-fat beef patties (Anon, 1998). Keeton et al. (2001) reported that moisture retention of hamburgers added with plum puree was improved by 15.8% in precooked patties when reheated to 102°C and held warm for up to 4 h. More importantly, plum extract

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contains antioxidants (Núñez de Gonzalez et al., 2008). Therefore, it can reduce the development of off-odors due to lipid oxidation in meat products that form during irradiation and storage.

Irradiation produces a characteristic odor, which negatively influences the consumer acceptance (Lee et al., 2003). The principle of electron beam irradiation is that a stream of high-energy electrons propelled from an electron gun is absorbed by materials in which the radiation energy converts water molecules to reactive ions or produces free radicals (Woods and Pikaev, 1994; Josephson and Peterson, 2000). Hydroxyl radicals from ionizing irradiation can increase lipid oxidation (O’Connell and Garner, 1983; Thakur and Singh, 1994). Fat and myoglobin that is oxidized by the free radicals in irradiated meat can cause color changes, rancidity, and off-odor in meat (Murano, 1995).

The radiation processing of food is accepted in over 50 countries and commercially implemented in about 40 countries as a mean of enhancing hygienic quality, extending shelf-life and reducing incidence of food-borne diseases (IAEA, 2008). At the same time, demands for reliable detection methods for irradiated foods are growing to help educate consumers and promote international trade of foods (Morehouse and Ku, 1993; Lee et al., 2000; Hwang et al., 2001; Chung et al., 2002; Kwon et al., 2003). Food irradiation is acknowledged as a safe process to improve food quality by reducing microbial contamination. However, the toxicological potential of 2-alkylcyclobutanones (2-ACBs), radiolytic derivatives of triglycerides found exclusively in irradiated foods, is a concern for some consumers (Thakur and Singh, 1994).

The objective of this study was to determine the effect of the fat substitute Fantesk™ and plum extract on the formation of radiation-induced hydrocarbons and 2-ACBs in freeze-dried, irradiated (44 kGy), or freeze-dried and irradiated cooked beef patties typically used by NASA astronauts.

**Materials and Methods**

**Reagents**

Hydrocarbon and 2-alkylcyclobutanone standards were purchased from Fisher Scientific (USA). Florisil was heated at 550°C overnight to remove contaminants, cooled in a desiccator, and deactivated by adding 3% water prior to use.

**Sample preparation**

Eight raw beef top rounds were obtained from the Meat Laboratory at Iowa State University 6 d post-slaughter. Two top rounds were pooled and treated as a replication. Each round was trimmed off any visible fat and connective tissues, and each replication was ground separately through a 3-mm plate twice. Fat substitute (Fantesk™, Heritage Fare, Ltd, USA) was obtained from the Heritage Fare Ltd. (USA) and plum extract puree was obtained from the California Plum Board (Sunsweet Growers Inc., USA). Plum extract was dissolved in distilled water prior to use. Fresh ground beef (80% lean) was used to prepare hamburger patties for control (no fat substitute or plum extract added) and 90% lean meat was used for 10% fat substitute or 2% plum extract treatments. For 10% fat substitute treatment, fresh raw beef and the fat substitute were ground through a 3-mm plate separately, and then the ground beef and fat substitute (10% of meat) were mixed for 3 min in a bowl mixer (Kitchen Aid, Inc., USA). For the plum extract treatment, plum extract (2% of meat weight) was dissolved in 4 vol. of distilled water, added to ground beef (90% lean), and mixed for 3 min in a bowl mixer (Kitchen Aid, Inc.) to ensure uniform distribution of plum extract. The mixtures were chilled and patties (110 g) were prepared using an automatic patty machine.

Patties were cooked in an electric oven at 175°C to an internal temperature of 75°C and cooking yield was determined. Internal temperatures of meat during cooking were monitored with thermocouples connected to digital read-out devices. All the cooked meat patties were vacuum-packaged in high-oxygen-barrier bags (nylon/polyethylene, 9.3 mL O₂/m²/24 h at 0°C; Koch, USA) immediately after cooking to minimize oxidative changes during handling and storage. The cooked beef patties were frozen, freeze-dried (FD), irradiated (IR), or freeze-dried and irradiated (FD+IR). Freeze-drying of patties was done using a Virtis freeze-dryer (Ultra-35, 8 shelf unit, Virtis Inc., USA). Samples for freeze-drying were held at -20°C in a walk-in freezer prior to loading. Temperature of the freeze-dryer shelves was held initially at < 0°C until a vacuum reading of < 100 millitorr was achieved (approximately 1 h after loading) and then raised to 26°C for the duration of the run. After freeze-drying, patties were individually...