Fat and Cholesterol Content of Beef Patties as Affected by Supercritical CO₂ Extraction


ABSTRACT

Beef patties (raw, raw freeze-dried, cooked, and cooked freeze-dried) were prepared for treatment with supercritical carbon dioxide extraction (SC-CO₂). Each type of patty was then assigned to one of four treatments: control, static extraction at 170 atm/50°C, dynamic extraction at 170 atm/50°C, and dynamic extraction at 544 atm/40°C. Freeze drying of the patties prior to SC-CO₂ extraction improved removal of fat and cholesterol. Freeze drying enhanced (P < 0.01) cholesterol extraction; however, precooking had limited effects (P > 0.05) on cholesterol extraction. Supercritical fluid extraction could be effective to reduce the fat and cholesterol content of preformed meat products, without requiring comminution of the sample.

Key Words: supercritical, carbon dioxide, extraction, beef, cholesterol

INTRODUCTION

CONSUMER CONCERN over dietary intake of fat and cholesterol is an important issue. Lowering fat content of meat products has been achieved commercially by trimming external fat from fresh meat and by use of added water or other components in processed products. However, substantially reducing the amount of cholesterol in fresh and processed products remains a challenge to the meat industry.

Supercritical carbon dioxide (SC-CO₂) extraction provides a potential method for substantial reduction of cholesterol from meat products such as ground beef patties. SC-CO₂ extraction was effective in removal of triglyceride-based oils from dehydrated ground fish muscle (Yamaguchi et al., 1986) and various oil seed flakes (Snyder et al., 1984; Pubols et al. 1985; List et al., 1989). SC-CO₂ is used commercially in decaffeination of coffee (Zosel, 1978) and processing of hops (Sharpe and Crabb, 1980). The feasibility of SC-CO₂ extraction for processing foods had been summarized by Rizvi et al. (1986).

SC-CO₂ extractions are performed under high pressure above the critical temperature of the solvent (31°C for CO₂). The intense pressure densifies the CO₂ which solubilizes a portion of the lipid components and removes them from the food matrix. Chao et al. (1991) achieved up to 40% reduction in cholesterol content of ground beef using SC-CO₂. However, such extractions had limited effects on fat extraction of meat products containing high levels of fat (Clarke, 1991). King et al. (1989) reported that reducing the water content of meat products made SC-CO₂ extraction much more efficient, resulting in almost complete delipidation at high pressures and SC-CO₂ flow rates. Research has also indicated that SC-CO₂ was very effective in reducing the cholesterol concentration and/or fat content of dehydrated beef powder (Wehling, 1991).

Demand for beef in the dehydrated form is relatively low, however. SC-CO₂ extraction may be more effective with precooked meat products because of their reduced moisture content compared to fresh products. In many countries, demand for convenient precooked products is increasing. A precooked convenience item low in cholesterol and fat may further increase the demand for such products by making them more attractive to diet-health-conscious consumers.

Limited research has been conducted on the effectiveness of SC-CO₂ in reducing fat and cholesterol content of precooked or fresh beef. Our objectives were to compare the effectiveness of SC-CO₂ in reducing cholesterol and fat content of precooked, fresh and dehydrated beef patties. Extraction conditions were chosen to maximize removal of cholesterol relative to fat (Chao et al., 1991) and to minimize thermal alteration of meat samples. In addition, relatively high flow rates were used in dynamic extractions to hasten processing.

MATERIALS & METHODS

Meat preparation

A meat block was formulated at 20% fat from lean (90% lean) and fat (50% lean) beef chuck trimmings. The composite meat sample had the proximate composition: moisture-63.1%, fat-20.1%, protein-20.4%, and ash-1.6%. Trimmings were coarse ground, mixed and reground through a 0.3 cm plate. Patties were formed using a commercial patty maker. Samples were prepared by removing a 5 cm core from the center of the patties (due to limited size of the extraction vessel).

Patties for the precooked treatments were cooked to internal temperature 70°C in a commercial convection oven and liquids liberated during cooking were allowed to drain from the patties. Temperature was monitored with copper-constantan thermocouples using a Campbell Scientific recorder. Half of both the precooked and raw patties were then freeze-dried in a commercial freeze-drier with a 5.5 m³ chamber (Vacudyne Corp., Chicago, IL; operating pressure <1 mm Hg; chamber condenser temp ~40°C), and all samples were vacuum packaged in Cryovac bags (W.R. Grace, Simpsonville, SC) and frozen (~34°C) for subsequent extraction.

Extraction apparatus

The extractions were performed on the apparatus shown in Fig. 1. Carbon dioxide from a cylinder was fed through an electronic flow meter (Model D12 H-SF, Micro Motion, Inc., Boulder, CO) that monitored the mass of CO₂ used during extraction. The CO₂ then

Fig. 1.—SC-CO₂ meat extractor.
flowed to a gas booster compressor (Model AGT-62/152, Haskel Eng. Corp., Burbank, CA). After pressurization, the fluid was introduced into a double ended, 2L extraction vessel (316 stainless steel pressure rated at 720 atm) with dimensions: 15.2 cm o.d., 7.6 cm i.d., 45.7 cm length (Autoclave Engineers, Erie, PA). Extraction pressure was set to the desired value by adjusting the air intake valve setting to the flow of a gas booster compressor (Model AGT-62/152, Haskel Eng. Corp., Burbank, CA). After pressurization, the fluid was introduced into a double ended, 2L extraction vessel (316 stainless steel pressure rated at 720 atm) with dimensions: 15.2 cm o.d., 7.6 cm i.d., 45.7 cm length (Autoclave Engineers, Erie, PA). Extraction pressure was set to the desired value by adjusting the air intake valve setting to the Parker, 1991).

RESULTS & DISCUSSION

ALL OF THE HAMBURGERS were weighed before and after extractions. All meat patties retained their shape when removed from the extraction vessel and holding trays. The lipid extract was also collected after SFE from the receiver vessel. The fatty extract was brown in color and had a rich meaty aroma. Static extractions of the hamburger patties resulted in a 23 and 13% weight loss on the raw and cooked patties, respectively. Static extraction of the freeze-dried analogues yielded a 4 and 2% reduction in weight, respectively. Approximate initial weight of both the raw and cooked hamburgers was 40–41g. Freeze-dried patties averaged 17–19g. From these results, apparently static extraction was not effective for removal of lipid material, primarily due to the limited amount of CO₂ used and the low solubility of fat in SC-CO₂ (0.2 wt %) under these conditions (Friedrich et al., 1982). Collection of the lipid extract was difficult under these conditions, since upon decompression, most of the solubilized lipid precipitated on the extraction vessel wall or in the interconnecting tubing. Dynamic extraction, using slightly different conditions (170 atm/40°C), gave similar weight losses for hydrated patties (Fig. 3). However, the freeze-dried patties lost more weight in the dynamic mode than in the static mode, indicating a greater amount of lipid material had been extracted. The CO₂ supply to the extractor was continually replenished. Lipid could also be collected in the receiver using this mode of extraction, ranging from a total of 3.0 g from three raw hamburger patties in one experimental run to 7.6 g for the dynamic extraction of three cooked hamburgers.

Dynamic extraction at 544 atm and 40°C showed greater weight losses in the meat patties, particularly for those that were freeze-dried before extraction. Weight losses for raw,
freeze-dried patties were about 35 wt % and for the cooked, freeze-dried patties, 27 wt %. For these two cases, total fat extracted from each run on the three patties, yielded over 8 g of collected fat per extraction. Note that the quantity of CO2 used in both dynamic extractions corresponded to two volumetric turnovers of CO2 in the extractor vessel.

The effects of SC-CO2 extraction on the proximate analysis of the extracted hamburgers were compared (Tables 1 to 3). Some general trends for each type of beef patty are apparent from Table 1. Higher extraction pressures seemed to increase the protein content due to reduction in fat and moisture content. Cholesterol content was also reduced at higher CO2 pressures, with exception of the raw hamburger. This confirmed the observations of King, et al. (1989) that lipid extraction was inhibited by moisture in the meat matrix.

Differences in percentage of fat and cholesterol as a function of extraction conditions for each patty type, (moisture-retained and dry basis) were also compared (Table 2). Differences tended to substantiate trends noted in Table 1. The large reduction in cholesterol content of the cooked, freeze-dried patties was probably due to denaturing of the protein and membranes, which would allow more of cholesterol to be removed. The interrelationship between all of the meat treatments and the extraction conditions could be statistically related through the use of contrast analysis. Precooking significantly increased (P < 0.01) protein and ash content (Table 3) and decreased (P < 0.01) percentage fat. Freeze drying enhanced (P < 0.01) cholesterol extraction, but had no effect on sample fat, protein, or ash content. Clarke (1991) and Wehling (1991) also reported SC-CO2 was effective in reducing cholesterol content of freeze dried meat products.

The contrast of control vs extracted (both static and dynamic) was not significant (P > 0.05) for cholesterol but was significant (P < 0.05) for fat and ash content. The contrast of extraction pressure was significant (P < 0.01) for sample fat, protein, and ash content and was not significant (P > 0.11) for cholesterol reduction. The contrast of raw vs cooked was significant (P < 0.01) for difference in cholesterol content on a dry matter (DM) and moisture-retained (MR) basis (Table 3). Freeze drying increased (P < 0.01) the difference in percentage fat on a moisture-retained basis greater (P < 0.05) the difference in percentage cholesterol on a moisture-retained basis. Differences in percentage cholesterol were not significant (P > 0.05) for the contrast of control vs extraction, but the difference in percentage fat was greater (P < 0.05) for extracted samples. The contrast of extraction pressure was significant (P < 0.01) for differences in percentage fat on a MR and DM basis.

CONCLUSION

FREEZE-DRYING was an effective means of enhancing extraction of cholesterol using supercritical CO2. However, the effects of precooking meat patties on cholesterol extraction were limited. A process which combines freeze drying with supercritical fluid extraction could produce a very lean meat product.
REFERENCES


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