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Manufacturing of Low Lipid Meat Products Using Supercritical Carbon Dioxide Extraction

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Abstract

Supercritical fluid extraction (SFE) has great potential to modify animal products such as meats, shortenings, butter, eggs, and seafood to better fit current consumer preferences and recommended dietary guidelines. A substance enters the supercritical region when subjected to temperature and pressure above the critical point, which is 31°C and 1057 psi for carbon dioxide. The uniqueness of supercritical fluids lies in their gas-like diffusivities and liquid-like densities. This combination of physical properties and low critical temperature make CO_2 an ideal solvent for extraction of lipid material from temperature sensitive biomaterials. Therefore, there are two methods to make low lipid meat products. One is a way to extract lipid and cholesterol from meat products directly by supercritical carbon dioxide (SC-CO_2). Another is a way to make meat products using low cholesterol, low fat meat produced by SC-CO_2 extraction. Removal effectiveness of lipid seems to be much better to use the first method than the second method. However, applying SC-CO_2 extraction to meat or meat product, they show pale color and soft texture. Therefore, to control these weaknesses of SC-CO_2 extracted meat product, the second method is much effective to improve the quality of meat product and to be accepted by consumers.

Key words: SC-CO_2 extraction, meat products, low lipid and cholesterol

Introduction

Animal products contribute about 36% of the energy and 36~100% of the major nutrients available from foods. However, they also contribute more than half of the total fat, 75% of the saturated fatty acids, and all the cholesterol to the diet that may adversely affect an individuals health (Clarke, 1991). Despite the total nutritional value of meat products, consumers have been advised to lower their dietary fat and cholesterol levels to improve health (Nutritional Research Council Committee, 1988).

Supercritical fluid extraction (SFE) is a technique to use the solubility and selectivity of supercritical carbon dioxide (SC-CO_2) as a solvent, which is varied with the combination of temperature and pressure. SC-CO_2 has many desirable properties as a solvent for biomaterials including foods. It is widely available, nonflammable, non-toxic, and environmentally sound and considered as the replacement for hexane in traditional solvent extraction (Rizvi *et al.*, 1986). In addition, it is effective at relatively low temperatures and in certain cases does not cause extensive protein damage (Mansoori *et al.*, 1988). This is especially important in foods where proteins contribute extensively to nutrition and functionality. This also avoids thermal decomposition or oxidation of the product and retains the natural flavors.

SFE is just such a process and therefore has great potential to modify animal products such as meats, shortenings, butter, eggs, and seafood to better fit current consumer preferences and recommended dietary guidelines. Production of low lipid, low cholesterol meats using SC-CO_2, however, presents special problems not found in other systems. Cholesterol is distributed in the ratio of about 65 to 35 at the subcutaneous fat portions and lean portions of the meat matrix. Fresh meat has also high content of water and a minimum level of fat is necessary to ensure acceptable palatability. This has been

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determined to be as low as 3% for certain cuts of meat, with a suggested upper limit of 7.3%, based on acceptable palatability and health/nutrition concerns (Savell and Cross, 1988).

Literature search revealed that SC-CO_2 extraction from meat products has been studied very few. Yamaguchi *et al.* (1986) reported first that the extraction of oils from Antartic krill had been succeeded although it was not related to meat extraction within narrow concept. King *et al.* (1989) studied the extraction of fat from meat products such as comminuted meat, sausage, and ham and reported 96% lipid was removed from original content. Chao *et al.* (1991) carried out the experiment on the removal of lipid and cholesterol from ground beef and Wehling *et al.* (1992) showed it was possible that the lipid and cholesterol were successfully removed from dried ground beef. King *et al.* (1994) also showed the possibility that fat and cholesterol were removed from beef patties for hamberger. Kwon and Chao (1995) studied the moisture effect on the extraction of lipid and cholesterol from ground beef. Kwon (2000) also reported the possibility to make the low lipid, low cholesterol sausage from using the meat that was removed lipid and cholesterol by SC-CO_2 extraction.

Moisture Effect on the Extraction of Ground Beef

Effect of different moisture content on the extraction of lipid and cholesterol is shown in Table 1 when freeze-dried ground beef was applied at different extraction condition. The result shows that, at 345 bar, the lipid extracted decreased a little up to 7.5% moisture content and then remained constant extracted percentage as the moisture content increased, while the percentage of extracted cholesterol decreased gradually with increased moisture content. The ratio of extracted cholesterol to extracted lipid generally decreased with increased moisture content.

Even though cholesterol is a minor component in beef, it might be highly associated with triglycerides, especially short- and medium chain length triglycerides (Arul *et al.*, 1988). Shishikura *et al.* (1986) and Kwon (1993) also showed that the solubility of cholesterol was similar to the solubilities of trilaurin and trimyristin. These triglycerides have high affinity with CO_2 in 241 bar rather than 345 bar because they showed the higher selectivity with CO_2 at 241 bar than at 345 bar.

Effect of Shape on the Extraction of Dehydrated Beef

Table 2 shows the effect of freeze-dried beef shapes

Table 1. Effect of moisture content of freeze-dried beef on the extraction of lipid and cholesterol by SFE[1)]

Pressure (bar)	Moisture (%)	Lipid extracted (%)	Cholesterol[2)] extracted (%)	Ratio of [chol.] to [lipid]
138	7.5	68.0	17.0	25.0
241	7.5	97.3	71.5	73.4
	17.0	98.3	60.8	61.9
345	4.0	97.6	69.2	70.8
	7.5	93.3	67.9	72.8
	9.0	93.3	58.3	62.5
	14.5	94.6	55.3	58.5

[1)]SC-CO_2 extraction at 35°C
[2)]Cholesterol content is 56.4 mg/100 g of freeze-dried beef which equals to 100%.

Table 2. Effect of beef shapes on SFE efficiency of lipid and cholesterol from freeze-dried beef

Pressure (bar)	Temp. (°C)	Shape of beef	Moisture (%)	Cholesterol extracted (%)	Lipid extracted (%)
352	55	powder	1.9	55.9	75.8
	45	chunk	1.7	76.2	88.4
373	55	powder	1.4	87.8	95.8
	55	chunk	1.7	85.3	99.3
	45	chunk	1.7	84.6	99.4

on SFE efficiency of lipid and cholesterol. It can be observed that the amount of total lipid and cholesterol removed from sample increased with increased SC-CO_2 density, namely, increased extraction pressure and/or decreased temperature. The lipid components were extracted more easily from the chunks than from the powder. The irregularly shaped beef chunks do not pack as tightly in the extraction vessel as the powder particles, thereby providing less resistance to flow. When beef chunks were extracted at 373 bar, there were no statistically significant differences in the amounts of either cholesterol or lipid remaining in the products at either 45 or 55°C. It indicates that the higher temperature is not necessary to achieve effective removal of lipids from beef chunks. For the chunk product, the solubility of cholesterol in SC-CO_2 seems to be less sensitive to density differences that for the powder product. In the case of lower extracted cholesterol amount at 352 bar, decreasing the pressure may make penetration of the fluid into the bed of tightly packed powder particles more difficult. This factor may affect the extraction of cholesterol from powders to a greater degree than do the solubility differences that occur as the extraction pressure is changed.

Effect on the Color of Freeze-Dried Beef

When the freeze-dried ground beef was extracted with SC-CO_2, the color properties were changed (Table 3). The L value was significantly increased, while a_L and b_L values decreased significantly compared with the control color components. This change may be attributable to removal of pigments. However, a product with lighter color could be desirable as a protein source in various prepared foods.

Property Changes of Sausage Made from SFE Extracted Meat

After lipid and cholesterol extracted beef and pork were rehydrated, they were mixed with non-extracted meat for the manufacturing of frankfurter sausage. When the sausage was made from meat following by the sausage making procedure, the functional properties of sausage was altered according to the mixing ratio of fresh meat to SFE extracted meat (Table 4). As presentative properties of sausage quality, cook yield, water holding capacity ratio, and penetration test were carried out. These results show that the texture of sausage is softer and softer with increased mixing amount of SFE extracted meat. However, comparing with sensory evaluation (data not shown) which evaluated sausage color and taste, presence of off flavor, and overall acceptability, sensory panel showed there was no significantly different between control and extracted meat sausage with up to 50% mixing. Generally, the extracted meat sausage had slightly better scores for sausage taste and overall acceptability while slightly less scores for sausage color and off flavor than the control.

Extraction of Fat from Various Meat Products

Fat extracted results obtained on the meat products by SC-CO_2 are presented in Table 5. Results show that

Table 3. Effect of SC-CO_2 extraction on the color of freeze-dried beef

Condition (bar/)	L	a	b
Control	56.07	2.38	15.58
352/55	64.44	1.62	14.56
373/55	64.02	1.87	13.93

Table 4. Functional properties of the low lipid sausage made from SFE extracted meat

Ratio of fresh to extracted meat	Cook yield (%)	Water holding capacity ratio	Penetration test (g)
Control (100:0)	94.1	3.75	1965.7
70 : 30	93.7	3.63	1901.8
50 : 50	89.5	3.40	1788.2
30 : 70	82.6	2.88	1549.4

Table 5. Fat extraction results on various meat products

Sample type	Pressure (bar)	Sample weight (g)	Fat yield (g)	% Fat extracted
Link sausage	690	52.87	20.25	99.6
Luncheon meat	345	109.13	21.47	98.9
Smoked ham	345	169.47	7.35	96.6
Press ham	345	241.19	4.37	97.3

almost a 5-fold range in sample size can be processed by this extraction method. The corresponding fat yields for the quoted sample weights are more than adequate for subsequent analysis of trace analytes contained in these fat matrices. The degree of fat removal is impressive, as judged by the percentage of available fat extracted from the samples.

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