J. Dairy Sci. 94:5760–5769
doi:10.3168/jds.2011-4226

Developing a strawberry yogurt fortified with marine fish oil[1]

J. D. Estrada,* C. Boeneke,† P. Bechtel,‡ and S. Sathivel*§[2]
*Department of Food Science, and
†School of Animal Sciences, Louisiana State University Agricultural Center, Baton Rouge 70803
‡USDA ARS, Subarctic Research Unit, University of Alaska–Fairbanks, Kodiak 99615
§Department of Biological and Agricultural Engineering, Louisiana State University Agricultural Center, Baton Rouge 70803

ABSTRACT

Fortified dairy products appeal to a wide variety of consumers and have the potential to increase sales in the yogurt industry and help increase intake of long-chain n-3 fatty acids. The objectives of this study were to develop a strawberry yogurt containing microencapsulated salmon oil (MSO; 2% wt/vol) and evaluate its characteristics during 1 mo of storage. Unpurified salmon oil (USO) was purified (PSO) and both USO and PSO were analyzed for peroxide value (PV), anisidine value (AV), total oxidation, free fatty acids (FFA), and moisture content. A stable emulsion was prepared with 7% PSO, 22% gum arabic, 11% maltodextrin, and 60% water. The emulsion was spray-dried to produce MSO. The MSO was added to strawberry-flavored yogurt (SYMSO) before pasteurization and homogenization, and a control (SY) without MSO was produced. Both yogurts were stored for 1 mo at 4°C and we determined the quality characteristics including acidity (pH), syneresis, thiobarbituric acid (TBA), fatty acid methyl ester composition, color, and lactic acid bacteria (LAB) count. The entire experiment was replicated 3 times. Total oxidation (unitless) of USO, PSO, and MSO was calculated to be 20.7 ± 1.26, 10.9 ± 0.1, and 13.4 ± 0.25, respectively. Free fatty acid contents were 1.61 ± 0.19%, 0.59 ± 0.02%, and 0.77 ± 0.02% for USO, PSO, and MSO, respectively. Eicosapentaenoic acid and docosahexaenoic acid were the predominant polyunsaturated fatty acids in MSO and in SYMSO, but neither was detected in SY. Fortification of SY with MSO had no significant effect on yogurt pH or syneresis. A decrease in concentration of lactic acid bacteria was observed during the storage of all yogurts. Thiobarbituric acid values significantly increased as storage time increased and SY had a significantly lighter (higher L*) and less yellow (lower b*) color than SYMSO. Although some slight differences were observed in the color and oxidation of SYMSO compared with SY, the study demonstrated that SY could be fortified with salmon oil.

Key words: marine fish oil, n-3, yogurt, microencapsulation

INTRODUCTION

Yogurt is a product made from heat-treated milk; it may also be homogenized before the addition of lactic acid bacteria (**LAB**) containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (US FDA-DHHS, 2011). According to the USDA National Agricultural Statistics Service (USD-NASS, 2008), 739,355,563 kg of yogurt were produced in the United States in 1998, and by 2008, annual production had increased 120% to 3.59 billion lbs. In 2009, production of yogurt totaled a record high 3.83 billion lbs. and it was the 12th straight year that yogurt production set a new record. According to Lempert (2009), yogurt was one of the 6 traditional snack categories that showed economic growth in 2009, while the NPD Group (2010), a market research company, announced recently that yogurt is among the top growing snack foods for children from 2 to 17 yr of age. The production of yogurt with microencapsulated marine n-3 fatty acids may be an alternative for the increasing market of health-conscious consumers and may contribute to an increase in n-3 consumption in the population. In a recent study, Blasbalg et al. (2011) quantified changes in the apparent consumption of n-3 and n-6 fatty acids in the United States during the 20th Century. The authors concluded that the increase in consumption of linoleic acid from soybean oil has decreased human tissue concentrations of eicosapentaenoic acid (**EPA**; 20:5 n-3) and docosahexaenoic acid (**DHA**; 22:6 n-3). It is known that the recommended intakes for n-3 fatty acids are not uniform (Whelan and Rust, 2006). In 2004, the International Society for the Study of Fatty Acids and Lipids (ISSFAL) recommended an intake of EPA and DHA of at least 500 mg/d (Cunnane et al., 2004).

Cardiovascular disease (**CVD**) is ranked as the number one killer in the United States. In 2010, the

Received January 31, 2011.
Accepted July 22, 2011.
[1]Approved for publication by the director of the Louisiana Agricultural Experimental Station as Manuscript Number 2011-237-6118.
[2]Corresponding author: ssathivel@agcenter.lsu.edu

total direct and indirect costs of CVD and stroke in the United States were estimated to be $503.2 billion (American Heart Association, 2010). Many scientific publications strongly suggest that regular consumption of significant amounts of polyunsaturated fatty acids (**PUFA**) rich in n-3 fatty acids can be highly effective in the prevention or treatment of CVD. Intake of PUFA is generally low in the diets of Western (developed) populations, and increased intake of these acids by supplementation of selected foods is recommended (Bauch et al., 2006). Salmon oil is a good source of PUFA, specifically EPA and DHA. Values reported by the USDA National Nutrient Database (USDA, 2009) indicate that 100 g of salmon oil contains 13.02 and 18.23 g of EPA and DHA, respectively.

A wide range of dairy and nondairy foods has been fortified with n-3 fatty acids. The main ways to deliver these fatty acids to foods are through direct addition of fish oil or algal oil and bio-delivery through meat and poultry products (Whelan and Rust, 2006). Most attempts to add DHA or EPA directly to foods have been unsuccessful because these fatty acids are unstable and rapidly give rise to a fishy odor and taste upon oxidation, making the food unpalatable. Microencapsulation is a process by which particles of sensitive materials are packed into a film of a coating material (Sathivel and Kramer, 2010), and this process could be used to decrease oxidation of salmon oil. The direct addition of microencapsulated salmon oil (**MSO**) to yogurt may not affect the original physical, chemical, and microbiological characteristics of the yogurt. Therefore, the objectives of this study were to develop a strawberry yogurt containing MSO (**SYMSO**; MSO at 2% wt/vol) and evaluate its physical, chemical, and microbiological characteristics during 1 mo of storage.

MATERIALS AND METHODS

Extraction and Purification of Oils

Salmon oil was obtained from fresh red salmon (*Oncorhynchus nerka*) heads kept refrigerated at 4°C. The salmon oil was extracted as described by Sathivel (2005), with modifications. The heads were weighed and ground using an industrial meat grinder (Northern Industrial, Burnsville, MN). The ground heads were cooked in 2-L beakers at 75°C for 30 min in a water bath (Lab-Line Instruments Inc., Melrose Park, IL) with constant electric stirring (model 5VB-C2, Eastern Mixers, Clinton, CT). The cooked, ground heads were centrifuged using a Beckman J2-HC centrifuge (GMI Inc., Ramsey, MN) at 7,957.6 × *g* for 30 min at 4°C. After centrifugation, unpurified salmon oil (**USO**) was collected and purified using chitosan, as described by Huang and Sathivel (2010). Chitosan bears hydroxyl and amino groups, which are excellent functional groups for use adsorbents for a variety of complex compounds (Quignard et al., 2000). Huang and Sathivel (2010) reported that chitosan could be used as an adsorbent for removal of FFA and peroxides from unpurified salmon oil. Five percent (wt/vol) shrimp chitosan was added to the USO and the mixture was stirred for 1 h at room temperature. Then, the mixture was centrifuged (23,385.6 × *g*) for 25 min at 4°C and purified salmon oil (**PSO**) was collected. The PSO was characterized and stored in a blast freezer at −20°C until use.

Preparation of MSO

Microencapsulated salmon oil was produced as described by Pu et al. (2011). A stable emulsion was prepared with a CPX-500 ultrasonic processor (Cole Parmer Instruments, Vernon Hills, IL) using the following ratio of components: 7% PSO:22% gum arabic:11% maltodextrin:60% water. The emulsion was spray-dried in a FT80 tall form spray drier (Armfield Ltd., Ringwood, UK) at an inlet temperature of 180°C to produce MSO.

Microencapsulation Efficiency and Encapsulation Yield

The method described by Wanasundara and Shahidi (1995) was used to determine the microencapsulation efficiency of MSO. One hundred grams of MSO was dissolved in 500 mL of a 0.88% (wt/vol) KCl solution. A few crystals of *tert*-butylhydroquinone and 1.5 L of a 2:1 chloroform:methanol solution were added. The mixture was centrifuged at 23,385.6 × *g* for 5 min at 4°C and transferred to a separatory funnel to separate the chloroform:methanol layer filtrate, which was collected in a round-bottomed flask for subsequent evaporation in a rotary evaporator (Buchi RE-121 Rotavapor, Flawil, Switzerland) at 40°C to reduce oxidation. The total oil (**TO**; %) of MSO was calculated gravimetrically.

To extract the surface oil (**SO**) from MSO, 2 g of the microencapsulated powder was mixed with 10 mL of hexane for 10 min. The mixture was filtered through Whatman 4 filter paper and washed with 4 × 10 mL of hexane. The filter paper containing the washed sample was oven-dried (VWR model no. 1330FM, Sheldon Manufacturing Inc., Cornelius, OR) at 70°C until hexane evaporation was complete and a constant weight was obtained. The SO (%) was calculated gravimetrically. The microencapsulation efficiency (*ME*) was calculated as follows:

$$ME = \frac{TO - SO}{TO} \times 100.$$