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Fortification of Cheddar cheese with vitamin D does not alter cheese flavor perception

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ABSTRACT

Currently, dietary guidelines for vitamin D consumption are under review, considering new information that >50% of the US population is vitamin D deficient, and may lead to a recommendation of a higher dietary intake of this vitamin. Vitamin D fortification of cheese aims to improve the current availability of fortified dairy foods beyond liquid milk. However, cheese is susceptible to undesirable flavor changes during long-term cheese ripening, and cheese bacteria and enzymes may degrade added vitamins. To test the retention of vitamin D_3 in Cheddar cheese curd, cheese milk was fortified initially during manufacture at a level of 150 IU/serving, using commercial sources that contained vitamin D_3 in powder, oil, or emulsion form, with and without homogenization of the fortified milk. When fortification was done directly to the cheese milk, we found that more than 80% vitamin D_3 was retained in cheese curd, irrespective of homogenization or form of fortification. Further, Cheddar cheese was fortified with the emulsion form of vitamin D_3 directly in cheese milk at 200 and 400 IU/serving to test stability and flavor changes. Vitamin D_3 fortified in this manner was stable for up to 9 mo in Cheddar cheese. Consumer acceptance and descriptive analysis of flavor profiles of cheese were also conducted and showed that vitamin D_3 fortified cheeses were equally liked by consumers, and cheese taste and flavor remained unaltered with vitamin D_3 addition even after aging for 9 mo.
Key words: Cheddar cheese, vitamin D, flavor, retention

INTRODUCTION

Vitamin D is a class of fat-soluble vitamins widely recognized for its importance in skeletal health (Ceglia, 2009). The major forms of the vitamin class responsible for human health benefits are ergocalciferol (**D_2**) and cholecalciferol (**D_3**). These vitamin D forms are considered to be inactive until they are converted to their biologically active form, 1,25-dihydroxy vitamin D_3, in the liver or kidney (Holick, 1995), which then promotes calcium and phosphorous absorption and aids bone mineralization and muscle strength. More recently, vitamin D_3 has been shown to have preventive effects against certain types of cancer (Bouillon et al., 2006). This vitamin class' mechanism of action resembles that of hormones and, hence, the vitamin D class is collectively classified as a prohormone (Bikle, 1997).

Of the 2 biologically beneficial forms, vitamin D_3 is readily synthesized by the human body during exposure to sunlight of UV index >3 for 5 to 30 min (Holick, 1995), whereas vitamin D_2 is synthesized only by plants and fungi (Ricardo, 1986). In subtropical areas of the world, sunlight exposure alone is insufficient to produce adequate vitamin D throughout the year (Holick, 1995). Populations in these areas need a vitamin D-fortified diet to achieve adequate levels for health benefits, which, for dairy foods, has mainly been through fortification of fluid milk, in which 1 cup of milk provides 100 IU of vitamin D_3. Incidence of low serum vitamin D levels in young adults who were presumed to have a healthy diet has been observed to be more frequent than expected (Heidi Wengreen, Utah State University, Logan, personal communication). This observation was confirmed by a recent review of vitamin D deficiency prevalence in North America that recommended a 2.5-fold dietary increase to achieve adequate intake (Hanley and Davison, 2005).

In order to provide sufficient levels of serum vitamin D in North American adults, the dietary intake level of vitamin D for optimal health is currently under scrutiny. Initially, the vitamin D reference daily intake level was set at 400 IU in 1968 by the Institute of Medicine's Food and Nutrition Board (US FDA, 2007; Institute of Medicine, 2009). In 1999, the Food and Nutrition Board established a dietary reference intake level of 200 IU per day for people up to 50 yr of age and increasing amounts for older persons, assuming absence of adequate sunlight exposure (Institute of Medicine, Food and Nutrition Board, 1999). Research efforts that have since focused on vitamin D's biological role along with evidence from more recent clinical trials recommended

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a 2-fold higher level of intake, even for pediatric and adolescent populations (Holick, 2007; Vieth et al., 2007). In light of new evidence, the Food and Nutrition Board has recently designated an expert committee to revise the recommendations for vitamin D dietary intake levels (Institute of Medicine, Food and Nutrition Board, 2010).

Other than fish and marine products, foods normally consumed by humans are low in vitamin D_3 content and need fortification to adequately supplement our daily needs. Fish contains approximately 120 to 500 IU of vitamin D_3 per 3-oz serving (Holden, 2009), almost 50 to 200% of the recommended daily intake level, as opposed to <25% in unfortified grains, meats, vegetables, and breakfast cereal. Unfortified whole milk and cheese provide only 1% of the daily value of vitamin D (Holden, 2009), which is insufficient for proper nutrition. Among dairy foods, cheese is widely consumed in various forms across different populations of the United States. Cheddar cheese is rich in vitamins A and B (Holden, 2009), and fortification with vitamin D_3 would increase its acceptance as a nutritious food that is rich in protein, vitamins, and minerals. Cheese can be relatively easily fortified with vitamin D_3 to provide up to 100% daily value in the diet, as it has a higher milk fat content than liquid milk, which aids inclusion of fat-soluble vitamins.

Effective retention in curd and long-term stability of vitamin D_3 in cheese are essential for uniform nutrient delivery to the consumer. Previous studies show that about 85 to 90% of added vitamin D is effectively retained in Cheddar cheese (Kazmi et al., 2007; Wagner et al., 2008), except in one study (Banville et al., 2000) that reported recovery ranging between 40 and 50%. The differences in retention between studies are likely due to different forms of vitamin D used for fortification. However, approximately 90% retention has been achieved and suggests that fortification of cheese is feasible.

The ability of bacteria to metabolize vitamin D_3 is uncharacterized but may contribute to a reduction of fortified vitamin D_3 levels. Additionally, the physicochemical environment of cheese, such as lower pH, higher salt, longer storage, and further thermal processing, may also reduce the stability of added vitamin D. However, vitamin D_3 appears to be stable in cheese during both short-term (Banville et al., 2000) and long-term storage (Kazmi et al., 2007; Wagner et al., 2008). Upreti et al. (2002) reported a 25% reduction in vitamin D_3 content during thermal treatment of processed cheese at 232°C/5 min, whereas Wagner et al. (2008) reported no thermal loss in Cheddar cheese for the same heat treatment. Hence, stability to thermal treatment varies by type of cheese and manufacturing conditions, whereas storage appears to have no effect on vitamin D_3 stability in cheese.

The inclusion of a novel chemical component may affect cheese flavor, which is a complex attribute that arises from a variety of volatile and nonvolatile organic compounds (Mulder, 1952; Fox and Wallace, 1997). These compounds are produced by enzymes of bacteria that degrade casein into peptides and amino acids and further metabolize the amino acid substrates into compounds that contribute to cheese flavor (Fox et al., 1995). Lipolysis and subsequent release of fatty acids that are further metabolized by bacteria also play a role in cheese flavor. Physicochemical alterations to cheese such as age, temperature, pH, salt level, and redox potential all cumulatively influence bacterial metabolism and consequently the types of compounds produced. Any external component added may modify one or more of these physicochemical attributes and eventually influence cheese flavor.

Only a limited number of studies have documented the effect of vitamin D fortification on cheese flavor. These efforts mainly addressed successful cheese fortification using different methods for retaining fortified components and for providing even distribution in cheese curd (Wagner et al., 2008). Banville et al. (2000) found the flavor perception of vitamin D-fortified Cheddar cheese to be similar to that of unfortified cheese flavor at 2 mo of aging. Upreti et al. (2002) reported similar results for fortified processed cheese. However, to our knowledge, the effect of vitamin D_3 fortification on flavor acceptability of cheese during long-term aging (>3 mo) has not been documented.

In this study, our objectives were to identify vitamin D retention in cheese curd with minimal loss using commercial sources, select an appropriate source of vitamin D for fortification, and further study whether vitamin D is lost during cheese aging.

MATERIALS AND METHODS

Preliminary studies were conducted to determine vitamin D retention in cheese curd, followed by a long-term aging study to understand scalability and vitamin D stability during aging. In order to understand the role of vitamin D_3 in altering cheese flavor, we fortified Cheddar cheese with vitamin D_3 at 2 different levels, 200 and 400 IU/serving. Four trials were conducted on separate days using 10-kg batches of milk to make vitamin D-fortified cheeses for preliminary studies. Each batch of cheese milk was individually fortified with the respective source of vitamin D on the day of manufacture. Long-term aging cheeses including controls were manufactured in 2 replicates on different days with different batches of milk. In all stages of the study, vitamin