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Characterization of major and trace minerals, fatty acid composition, and cholesterol content of Protected Designation of Origin cheeses

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ABSTRACT

Cheese provides essential nutrients for human nutrition and health, such as minerals and fatty acids (FA). Its composition varies according to milk origin (e.g., species and breed), rearing conditions (e.g., feeding and management), and cheese-making technology (e.g., coagulation process, addition of salt, ripening period). In recent years, cheese production has increased worldwide. Italy is one of the main producers and exporters of cheese. This study aimed to describe mineral, FA, and cholesterol content of 133 samples from 18 commercial cheeses from 4 dairy species (buffalo, cow, goat, and sheep) and from 3 classes of moisture content (hard, <35% moisture; semi-hard, 35–45%; and soft, >45%). Mineral concentrations of cheese samples were determined by inductively coupled plasma optical emission spectrometry, and FA and cholesterol contents were determined by gas chromatography. Moisture and species had a significant effect on almost all traits: the highest levels of Na, Ca, and Fe were found in cheeses made from sheep milk; the greatest level of Cu was found in cow milk cheese, the lowest amount of K was found in buffalo milk cheese, and the lowest amount of Zn was found in goat cheeses. In all samples, Cr and Pb were not detected (below the level of detection). In general, total fat, protein, and minerals significantly increased when the moisture decreased. Buffalo and goat cheeses had the highest saturated FA content, and sheep cheeses showed the highest content of unsaturated and polyunsaturated FA, conjugated linoleic acid, and n-3 FA. Goat and sheep cheeses achieved higher proportions of minor FA than did cow and buffalo cheeses. Buffalo cheese exhibited the lowest cholesterol level. Our results confirm that cheese mineral content is mainly affected by the cheese-making process, whereas FA profile mainly reflects the FA composition of the source milk. This study allowed the characterization of mineral and FA composition and cholesterol content and revealed large variability among different commercial cheeses.
Key words: goat, sheep, conjugated linoleic acid (CLA), dairy products

INTRODUCTION

Cheese supplies essential nutrients for human nutrition in the form of proteins, bioactive peptides, AA, fat, fatty acids (**FA**), vitamins, and minerals (Walther et al., 2008; FAO, 2013). Cheese is suitable for lactose-intolerant individuals because, 94% of the lactose is washed out with the serum during cheese making, and the rest is fermented to lactic acid (Walther et al., 2008; Law and Tamime, 2011; FAO, 2013). Bioactive peptides, released from milk protein during cheese ripening, are multifunctional components with beneficial effects on cardiovascular, nervous, gastrointestinal, and immune systems (Korhonen and Pihlanto, 2006; Walther et al., 2008). Minerals and vitamins supplied by cheese are important for healthy bones and teeth (Walther et al., 2008; Bonjour et al., 2009). About 60 to 70% of Ca intake comes from milk and dairy products, with cheese being the main source in adults (Bonjour et al., 2009). Cheese usually contains between 20 and 35% fat, which contributes to the flavor and texture of the product (Walther et al., 2008). Specific SFA are involved in cell regulation and gene expression (Walther et al., 2008), n-3 FA produce anti-inflammatory eicosanoids (DeFilippis and Sperling, 2006), and CLA have shown health benefits (Walther et al., 2008). However, a detailed profile of mineral and FA contents, which could help consumers in purchasing decisions, is not listed on cheese labels.

Manufacturing cheese is a way to add value to raw milk and increase the shelf life of milk. Cheese composition depends on the milk's microbiological and chemical composition, the cheese-making technology, ripening time, and cheese factory conditions (De Marchi et al., 2008; Formaggioni et al., 2015). Milk protein and

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fat contents vary greatly according to species, breed, season, health status, stage of lactation, and animal diet (Palmquist, 2006; Martini et al., 2008; Walther et al., 2008; Bland et al., 2015). In addition, breed differences have been observed in milk for titratable acidity, freezing point, casein content, total Ca, total P, and colloidal P (Petrera et al., 2016). The pasteurization of the milk before cheese making could affect AA profile and vitamin content (FAO, 2013). The type of starter culture used might modify the total content of protein, fat, and ash, and FA profile of the cheese, due to the different activity and specificity of proteolytic and lipolytic enzymes (Taboada et al., 2015; Lešić et al., 2016). Because of dehydration, protein and fat contents increase during ripening time (Walther et al., 2008; Taboada et al., 2015), and dehydration also affects mineral concentration (FAO, 2013); for example, K and Mg concentration decreases and Se concentration increases during ripening (FAO, 2013). Demineralization of curd depends on the pre-acidification of milk, and the pH of whey at drainage (Lucey and Fox, 1993). However, the increase of some minerals is a result of the salt added during the manufacturing process, such as polyphosphates and NaCl (Bonjour et al., 2009).

In recent years, cheese production has increased worldwide, particularly in the European Union (+2.35%), United States (+2.83%), and Australia (+5.45%) (CLAL, 2016). Europe produces nearly 52% of the world's cheese (FAO, 2013) and, among European countries, Italy (1.009×10^6 t) is the third largest cheese producer after Germany (2.320×10^6 t) and France (1.779×10^6 t) (CLAL, 2016). A large amount of Italian milk production (11.633×10^6 t in 2014) is destined to cheese making (CLAL, 2016). About 80% of Italian cheeses are made from cow milk, and the remaining 20% are from sheep, goat, buffalo, and mixed milks. More than 40% of cheeses achieve the Protected Designation of Origin (**PDO**) according to European Regulation 1151/2012 (European Union, 2012; CLAL, 2016), and France, Italy, and Spain have the greatest number of PDO cheeses. For PDO cheeses, European and local legislation specify the rules for manufacturing process, from feeding and animal management to milk origin and aging, in order to protect the quality standard. Mozzarella, Grana Padano, Parmigiano Reggiano, Pecorino, Gorgonzola, and Provolone are the main exported Italian cheeses, with France, Germany, and the United States being the main destination countries (CLAL, 2016). Moreover, considering that the volume of milk destined for cheese manufacturing is growing worldwide in several European countries such as Italy, France, Ireland, and Estonia, several studies have been carried out on milk technological traits and the potential for their genetic improvement (Pretto et al., 2013; Tiezzi et al., 2013; De Marchi et al., 2014; Visentin et al., 2015).

To our knowledge, no studies have characterized the mineral, FA, and cholesterol contents of a wide range of commercial cheeses. Therefore, this study aims to describe and provide detailed information about minerals, FA, and cholesterol content of several PDO cheeses sourced from the Italian retail market.

MATERIALS AND METHODS

Sample Collection

A total of 133 cheeses were purchased from Italian stores from July to October 2015. Samples were randomly selected according to store availability and consumers' preferences. Cheeses produced using milk from more than one dairy species were not considered in the present study. Cheese varieties in the study included 11 PDO and 1 Traditional Specialties Guaranteed (**TSG**) cheeses made from cow milk, 1 PDO from water buffalo milk, 1 Robiola-type cheese from goat milk, and 1 Pecorino-type cheese from sheep milk (Table 1). In addition, 3 cosmopolitan cow milk cheeses (Cheddar, Maasdam, and pasta filata) were included as reference cheeses for the different moisture contents. The main characteristics of the 18 varieties of commercial cheeses included in the study are summarized in Table 1. A cheese variety could be prepared with milk from different dairy species, raw or pasteurized milk, whole or partially skim milk, and different ripening times (Table 1), conferring diversity within each type. Given that the present study was focused on commercial samples, specific feeding and animal management information was not available. However, PDO and TSG cheeses represent geographically linked production with specific animal production systems and requirements in terms of breed, diet, and farming conditions (Bertoni et al., 2001), and specific cheese manufacturing technologies regulated by the European Union and local authorities reported in public and approved guidelines. For example, for Parmigiano Reggiano PDO cheese, cows have to be fed primarily fodder from a defined geographical area and silages are forbidden (European Union, 2009). Cheese samples were transported in portable refrigerators at 4°C to the food laboratory of the Department of Agronomy, Food, Natural Resources, Animals and Environment of the University of Padova (Legnaro, Italy), and homogenized with a knife mill (Retsch Grindmix GM200; Retsch GmbH & Co, Haan, Germany) after removing 1.5 cm from the rind, when required. To prevent moisture loss, grated samples were kept at 4°C in sealed plastic bags until analysis, which was carried out within 24 h of sample delivery.