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Short communication

Natural variability in the nutrient composition of California-grown almonds

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ABSTRACT

The natural variability in nutrient composition among and within commercially important California almond varieties was investigated in a multi-year study. Seven major almond varieties (Butte, Carmel, Fritz, Mission, Monterey, Nonpareil and Sonora) were collected over three separate harvests and from various orchards in the north, central and south growing regions in California. Comprehensive nutritional analysis (20 macronutrients and micronutrients, 3 phytosterols) of 39 almond samples was carried out by accredited commercial laboratories. The macronutrient and micronutrient profiles obtained were notably similar for all the almond varieties in this study. The three-year mean contents of protein, total lipid, fatty acids (saturated, monounsaturated and polyunsaturated) and dietary fiber for these major varieties varied by no more than 1.2-fold. For individual nutrients, statistically significant variety, year and/or growing region effects were observed, which contributed to the natural variability in nutrient composition of the California almonds among and within varieties. Harvest year had a highly significant effect ($P < 0.01$) on the contents of total lipid, monounsaturated fatty acids and dietary fiber. Growing region had a significant effect ($P < 0.05$) on the content of ash and all minerals tested.
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1. Introduction

Almonds (*Prunus dulcis* (Miller) D.A. Webb; synonyms *Prunus amygdalus* Batsch and *Prunus communis* L.) and other tree nuts have a healthy nutrient profile, providing a nutrient-dense source of protein, monounsaturated fatty acids, dietary fiber, vitamin E, riboflavin and essential minerals in addition to phytosterols and polyphenols (Kendall et al., 2010; Richardson et al., 2009). Over the past 50 years, composition studies on almonds cultivated around the world have largely focused on individual nutrients (primarily lipids or fatty acids) in almond genotypes (varieties or cultivars and breeding selections) as well as limited studies on genetic and environmental factors influencing composition (Yada et al., 2011).

Variability in oil content and fatty acid composition, as well as tocopherol (vitamin E) content, has been shown to depend mainly on the almond genotype, but also may be affected by environmental factors that vary with orchard site and harvest year (Abdallah et al., 1998; Kodad et al., 2006, 2011b; Kodad and Socias i Company, 2008; López-Ortiz et al., 2008; Sathe et al., 2008). Composition variability in almond skins (seed coats) was investigated by Bolling et al. (2010), who found that the skins of major California almond cultivars had unique polyphenol profiles, and the polyphenol content (flavonoids and phenolic acids) varied 2.7-fold in samples collected over three harvest years.

Almonds are cultivated in many temperate and sub-tropical countries. The state of California in the United States is the major almond-producing region in the world, and presently accounts for about 80% of global almond production (shelled basis) (Almond Board of California, 2012; USDA-FAS, 2011). The commercial almond orchards are located throughout the north, central and south counties of the state's Central Valley. These orchards all receive supplemental irrigation and fertilization; however, soils, climates and cultivation practices can vary considerably. Pollination of the commercial almond orchards is carried out by managed honey bee populations. The honey bees must transfer pollen between almond trees of different varieties that are pollen compatible. For this reason, almond orchards have trees of at least two compatible varieties. In a typical orchard, rows of the main variety (e.g. Nonpareil) alternate with rows of one or more pollenizer varieties. Variety selection is based on many factors including field performance in specific growing regions, yields, disease resistance and marketability.

Over 30 almond varieties are grown commercially in California, and about ten major varieties account for most of the production (ABC, 2012). Nonpareil has consistently been the most important variety for both production and marketing due to its superior tree and nut characteristics. The majority of commercial almond

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varieties grown in California today are the descendants of two unrelated varieties – Nonpareil and Mission.

Differences among the commercial varieties in terms of physical characteristics, such as kernel shape, size, surface color and ease of blanching (for skin removal), are well established. The unique characteristics are fundamental to the marketing and usage of each almond variety. In contrast, differences in the nutrient composition profiles among these almond varieties have not been identified. Some variability in the contents of individual nutrients can be expected since almonds are natural products. Nutrient composition variability reflects genetic, environmental and analytical factors (Pennington, 2008). No previously published research has evaluated the influence of variety, harvest year and growing region on comprehensive nutrient profiles of major almond varieties. An understanding of the composition variability of California-grown almond varieties would be useful in product development and when compiling food composition data, and also for researchers evaluating storage or processing treatments and investigating the health benefits of almond consumption.

This study was part of a larger investigation to better understand the natural variability of the major almond varieties currently grown in California. In a previous paper the variability in the sensory characteristics of whole raw almonds, both among and within these major varieties, was established (Civille et al., 2010). The objective of the present study was to compare the nutrient profiles of the major almond varieties, and determine the variability in macronutrient and micronutrient composition among and within these varieties obtained from different growing regions in California over three normal harvest years.

2. Materials and methods

2.1. Almond samples

Major almond varieties – Butte, Carmel, Fritz, Mission, Monterey, Nonpareil and Sonora – were chosen as the focus for this study. These have been among the top ten almond-producing varieties in California for many years and presently account for about 80% of the total commercial almond acreage (ABC, 2012).

Raw almonds harvested in 2005–2007 in the three growing regions (north, central and south) of California were purchased from various growers and handlers. Butte, Carmel and Nonpareil almonds were obtained from all three regions; for each variety, the almonds were sourced from the same orchard in each region for three years (Butte, Carmel, Nonpareil: $n = 9$). Fritz, Mission, Monterey and Sonora almonds were obtained only from the central region; for each variety, almonds were sourced from the same orchard in that region for three years (Fritz, Mission, Monterey, Sonora: $n = 3$). A total of 39 sample lots of almonds were included in the study: 13 lots of almonds were collected per harvest year, with 7 lots obtained from the central region and 3 each from the north and south regions per year.

All orchards were operated by independent commercial growers, each using their own orchard management practices as established for the characteristics of the site (climate, soil, etc.). Almonds from each harvest were initially stored by growers and handlers under their warehouse conditions (typically ambient). The raw (shelled) almonds were obtained in lots of ~23 or 91 kg (50 or 200 lb) and each lot represented an individual variety; lots were stored under ambient conditions prior to sampling. One 450-g sample of almonds was randomly removed from each lot and samples were submitted to commercial testing laboratories for complete nutrient analysis.

2.2. Analytical testing

Independent testing laboratories in the U.S. were contracted by the Almond Board of California to provide comprehensive nutrient analysis for all almond samples. These laboratories (Covance Laboratories Inc., Madison, WI; Medallion Labs, Minneapolis, MN) are accredited according to ISO/IEC 17025 standards of the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) for the majority of nutrient analyses carried out. In general, the laboratories used official methods of the Association of Official Analytical Chemists (AOAC), the American Association of Cereal Chemists International (AACC) and the American Oil Chemists' Society (AOCS), in accordance with the requirements of the almond samples. The analytical methods used at the time of the study are listed in Table 1.

Table 1
Methods used for nutrient analysis of almond samples.[a]

Component	Method reference
Ash	AOAC[b] 923.03. Ash of flour. [Gravimetry]
Dietary fiber, total	AOAC 991.43. Total, soluble, and insoluble dietary fiber in foods. [Gravimetry, enzymatic digestion]
Fat (total lipid, SFA, MUFA, PUFA)	AOAC 960.39. Fat (crude) or ether extract in meat. [Soxhlet extraction]
	AOAC 996.06. Fat (total, saturated, and unsaturated) in foods. [Gas chromatography]
	AOCS[c] Ce 1-62. Fatty acid composition by packed column gas chromatography.
Minerals (Ca, Cu, Fe, Mg, Mn, P, K, Zn)	AOAC 985.01. Metals and other elements in plants and pet foods. [ICP emission spectrometry]
Moisture	AOAC 925.09. Solids (total) and moisture in flour. [Gravimetry, vacuum oven]
Niacin	AOAC 960.46. Vitamin assays. [Microbiological assay]
	AOAC 944.13. Niacin and niacinamide (nicotinic acid and nicotinamide) in vitamin preparations. [Microbiological assay]
Phytosterols	AOAC 994.10. Cholesterol in foods. [Gas chromatography]
	AOAC 2007.03. Campesterol, stigmasterol, and beta-sitosterol in saw palmetto raw materials and dietary supplements. [Gas chromatography]
Protein	AOAC 968.06. Protein (crude) in animal feed. [Dumas method]
Riboflavin	AOAC 970.65 Riboflavin (vitamin B2) in foods and vitamin preparations. [Fluorometry]
	AOAC 981.15. Riboflavin in foods and vitamin preparations. [Fluorometry]
Sucrose	AOAC 982.14 Glucose, fructose, sucrose, and maltose in presweetened cereals. [High-performance liquid chromatography]
α-Tocopherol	AACC[d] Method 86-06.01 Analysis of vitamins A and E by high-performance liquid chromatography.
	Total tocopherols (internally developed high-performance liquid chromatography method; Cort et al., 1983)

[a] Methods in use by accredited commercial laboratories in 2005–2008; details on individual methods used by each laboratory are available from the authors.
[b] AOAC, Association of Official Analytical Chemists; http://www.aoac.org.
[c] AOCS, American Oil Chemists' Society; http://www.aocs.org.
[d] AACC, American Association of Cereal Chemists International; http://www.aaccnet.org.

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