α- and γ-Tocopherol Content of Selected Foods in the Mexican Diet: Effect of Cooking Losses

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HPLC was used to determine α- and γ-tocopherol content in selected foods commonly consumed in the Mexican diet and to study losses due to cooking. Raw corn was high in total tocopherol content (8.1 mg/100 g), but processing into tortillas destroyed almost all of the tocopherols. Legumes were high in γ-tocopherol content. Almonds were high in α-tocopherol content with 22.3 mg/100 g and low in γ-tocopherol content (0.3 mg/100 g). Pecans showed the reverse trend with 0.7 mg/100 g of α- and 9.2 mg/100 g of γ-tocopherol. Peanuts had high levels of both α- and γ-tocopherol (8.2 and 7.9 mg/100 g, respectively). The cooking loss for most grains ranged from 22 to 55%, while that for legumes ranged from 9% for the garbanzo bean to 59% for the bayo bean. Vegetable oils were high in total vitamin E content and contributed the most vitamin E activity (1.3 mg/d), in the Mexican diet. Corn tortillas were low in vitamin E activity (0.03 mg/100 g) but due to their high intake in the Mexican diet, along with pinto beans, contributed to the total vitamin E intake. Neither diet met the recommended RDA intake; the high- and low-income diets provided 16.7 and 14.6%, respectively.

Keywords: α- *and γ-tocopherol; Mexican diet; cooking losses*

INTRODUCTION

Vitamin E is an important antioxidant in the diet. Studies have shown processing causes significant losses. α-Tocopherol is the primary E-vitamer with biological activity; however, the other vitamers have reduced activity. With the growing interest in the role of antioxidant vitamins in disease processes such as coronary heart disease and cancer (Knekt, 1994; Shibata et al., 1992), it is important to know the content of these vitamins in the diet and to be able to accurately assess their intake. Vitamin E is the major antioxidant nutrient that can protect cell membranes from oxidative damage (Burton et al., 1983). Many vitamin E content values have been either determined by nonspecific methods or calculated from information on other foods (Hogarty et al., 1989). α-Tocopherol is the primary vitamer with biological activity; however, the other vitamers have been shown to have decreased activity. γ-Tocopherol has 10% of the activity of α-tocopherol, and δ-tocopherol has 1% of the activity of α-tocopherol (National Academy of Sciences, 1989).

Many studies report values for unprocessed foods such as vegetables and fish or commercially prepared foods such as breakfast cereals or canned food items (Hogarty et al., 1989; Syvaoja and Salminen, 1985). Syvaoja et al. (1985) did include raw and pasteurized milk and raw and boiled eggs in their study. No significant losses in total tocopherol content were reported. It is assumed that vitamin E, being fat soluble, is not as severely affected by processing as water soluble vitamins. Losses in vitamin E content seem to be more closely associated with lipid degradation (Hakansson and Jagerstad, 1990), and factors that can affect this degradation include cooking temperatures, time, and exposure to light and oxidative conditions. Guzman and Murphy (1986) reported a loss of as much as 50% of the tocopherol content originally present in soybeans during processing of soybeans into tofu. Kodieck et al. (1959) reported 95% destruction of tocopherols in tortillas prepared from corn steeped in 1% lime water.

The purpose of this study was to determine the α- and γ-tocopherol content in selected foods commonly consumed in the Mexican diet and determine cooking losses.

MATERIALS AND METHODS

Sample Description. Twenty different food items, including two types of tortillas, were purchased from retail stores in Hermosillo, Sonora, Mexico, during the calendar year of 1997. The samples consisted of cereals and grains, tortillas, legumes, nuts, and oils. These foods were selected primarily because grains and legumes are the basic staples of the Mexican diet, and these 20 foods were considered the main potential contributors of vitamin E in the typical diet (Wyatt et al., 1995). Composite samples were prepared. Raw samples were ground in a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) by being passed through a 60 mesh sieve and immediately saponified and extracted. Samples requiring cooking were processed according to package instructions. Once the product was considered cooked, it was protected from light exposure, excess moisture was drained, and the product was air-dried at room temperature. The dried sample was ground to a fine powder with a mortar and pestle and then subjected to saponification and extraction. Two composite diet samples were also included in the study. These diets represent the typical diet for low- and high-income Mexicans. Each food item was prepared according to traditional receipes, weighed, and mixed to form a composite sample (Wyatt et al., 1995), and then a representative sample was taken for further analysis. Samples were analyzed in triplicate.

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Table 1. α- and γ-Tocopherols (mg/100 g Wet Weight) in Selected Raw Foods in the Mexican Diet

	% moisture	α-tocopherol	γ-tocopherol	total	vit E act.
grains					
rice	11.4	0.11 ± 0.02		0.11	0.11
oats	8.8	0.76 ± 0.11		0.76	0.76
corn	12.0	2.26 ± 0.17	5.80 + 0.37	8.06	2.84
wheat	9.8	1.57 ± 0.00		1.57	1.57
legumes					
beans, bayo	11.8		2.64 ± 0.32	2.64	0.26
beans, black	11.7		0.90 ± 0.04	0.90	0.09
beans, pinto	13.2	0.20 ± 0.04	2.06 ± 0.33	2.26	0.41
garbanzo	8.9	2.81 ± 0.02	7.29 ± 0.04	10.1	3.54
beans, faba	11.1	0.95 ± 0.09	5.22 ± 0.28	6.17	1.47
lentils	11.4	1.01 ± 0.03	4.66 ± 0.01	5.67	1.48
split peas	11.2	0.12 ± 0.01	4.65 ± 0.02	4.77	0.59
nuts					
almonds		22.32 ± 0.04	0.28 ± 0.01	22.60	22.35
peanuts		8.19 ± 0.02	7.93 ± 0.08	16.12	8.98
pecans		0.74 ± 0.06	9.19 ± 0.08	9.93	1.66
vegetable oils					
canola		14.73 ± 0.17	42.81 ± 1.7	57.54	19.01
sunflower		37.33 ± 0.14		37.33	37.33
corn		9.21 ± 0.34	53.48 ± 0.06	62.69	14.56
mixture		7.62 ± 0.37	49.51 ± 1.3	57.13	12.57

Moisture Determination. The moisture content in all samples was determined according to the Association of Official Analytical Chemists method, section 934.01 (1990). Data were expressed on a wet weight basis, and the dry weight was used to calculate cooking losses.

Saponification and Extraction. One gram of sample was saponified using the method of Carlson and Tabacchi (1986) and extracted with 25 mL of absolute ethanol following the method of Guzman and Murphy (1986), modified to give repeatable results with recoveries over 95% and a 2.6% CV. The sample was agitated for 30 min using a platform shaker (model G-33, New Brunswick Scientific Co., Inc., Edison, NJ); the suspension was filtered through Whatman filter paper no. 4, and the residue was re-extracted with 12.5 mL of ethanol for 1 h. The ethanol extracts were combined and evaporated in a Buchi rotary vacuum evaporator (Laboratoriums-Tech-Nik AG ch 9230 Flawil, Shweis, Switzerland) at 42 °C. The extract was rinsed with 3 portions of 6 mL each of hexane (Merck of Mexico) and filtered through anhydrous Na_2SO_4. The hexane was evaporated under vacuum at 35 °C. All solvents were HPLC grade, and extraction and saponification were carried out in the dark.

HPLC Analysis and Quantitation. The tocopherols were quantified using reverse-phase high-performance liquid chromatography, according to Supleco (1995). Separation of α- and γ-tocopherol was achieved by using a mobile phase of 2% water and 98% methanol with a flow rate of 1.5 mL/min. The column was a Supelcosil LC-18 column (250 mm × 4.6 mm, 5 μm) fitted with a Supleco guard column (Supleco, Inc., Bellefonte, PA). A Beckman HPLC system consisting of a model 126 pump and a Beckman UV−vis detector (model 168) equipped with a personal computer was used (Beckman de Mexico). The tocopherols were detected at 290 nm, and α-tocopherol acetate (T3001; Sigma Chemical Co., St. Louis, MO) was used as an internal standard. Standards of α- and γ-tocopherol (95% purity) (Sigma Chemical Co.) were used to establish retention times. The injections were repeated three times for each sample. The technique was verified using a certified standard (NBS 1563-2, NIST, Gaithersburg, MD). Recovery studies were performed by spiking with α- and γ-tocopherol before saponification.

All glassware was soaked overnight with a chromic acid solution and then throughly washed with deionized water to avoid contamination.

Vitamin E Activity. Vitamin E activity for the purpose of this study was expressed as milligrams per 100 g wet weight of α-tocopherol and 0.1 × mg/100 g γ-tocopherol (National Academy of Sciences, 1989). It is recognized that other isomers have activity, but these were not quantified in this study.

RESULTS AND DISCUSSION

Cereal Grains, Legumes, Nuts, and Oils. Table 1 presents the α- and γ-tocopherol content (milligrams per 100 g) of unprocessed grains, legumes, nuts, and vegetable oils and their respective vitamin E activities. In the grain group, rice, corn, and wheat are the most commonly consumed grains in Mexico. Corn is primarily consumed in the form of tortillas and wheat in both tortillas and bakery products. Cereal grains are considered a good source of vitamin E in the diet. Piironen et al. (1986a) reported that up to 30% of the recommended dietary allowance of α-tocopherol equivalents comes from cereal products in Finland. Raw corn showed a high total tocopherol content (8.06 mg/100 g) with a relatively high γ-tocopherol content of 5.80 mg/100 g. McLaughlin and Weihrauch (1979) reported a total value of 5.81 mg/100 g in corn. The values reported in this study for oats and rice (0.76 and 0.11 mg/100 g, respectively) compare very favorably with the values reported by Piironen et al. (1986a). Neither study reported that γ-tocopherol was in these products. If one considers that a vitamin E activity of 2 or above would provide 20% of the RDA for adults, only raw corn would meet this criteria with a value of 2.84.

All of the legumes analyzed showed the presence of γ-tocopherol in relatively high levels, with the exception of black beans. Pinto beans are the most commonly consumed legume in Mexico and had a low α-tocopherol content (0.20 mg/100 g) compared to 2.81 and 1.01 mg/100 g in garbanzo beans and lentils, respectively. In the legume group, only garbanzo beans had a considerable vitamin E activity with a value of 3.54. McLaughlin and Weihrauch (1979) reported a total vitamin E activity of 1.40 mg/100 g for dry pinto beans and 1.27 for lentils.

In the nut group, almond kernels had a high α-tocopherol content with 22.32 mg/100 g and a lower γ-tocopherol content (0.28 mg/100 g), but this represents a considerable amount when compared to that of the other food groups. Piironen et al. (1986b) reported 26.44 mg/100 g for α-tocopherol and 0.76 mg/100 g for γ-tocopherol in almonds, which compares favorably with the results of this study. McLaughlin and Weihrauch (1979) also reported comparable values of 23.96 mg/100 g for α-tocopherol and 0.51 mg/100 g for γ-tocopherol. Pecan

Table 2. α- and γ-Tocopherols (mg/100 g) in Selected Cooked Foods in the Mexican Diet

	% moisture	α-tocopherol (wet wt)	γ- tocopherol (wet wt)	total	vit E act.	% cooking loss (dry wt)	% act. loss (dry wt)
grains							
rice	10.93	0.06 ± 0.00		0.06	0.06	42	42
oats	10.97	0.58 ± 0.00		0.58	0.58	22	22
corn	11.42	0.96 ± 0.07	3.26 + 0.11	4.22	1.29	48	55
wheat	12.64	0.69 ± 0.10		0.69	0.69	55	55
tortillas, corn	11.27		0.29 + 0.05	0.29	0.03		
tortillas, wheat	9.97	0.12 ± 0.00		0.12	0.12		
legumes							
beans, bayo	8.41		1.13 ± 0.07	1.13	0.01	59	60
beans, black	10.95		0.83 ± 0.02	0.83	0.08	12	10
beans, pinto	16.65	0.14 ± 0.01	1.66 ± 0.06	1.80	0.31	17	21
garbanzo	8.9	2.19 ± 0.04	6.75 ± 0.32	8.94	2.84	9	17
beans, faba	11.2	0.64 ± 0.06	3.01 ± 0.24	3.65	0.94	38	29
lentils	11.06	0.33 ± 0.05	2.90 ± 0.24	3.23	0.62	44	58
split peas	11.5	0.02 ± 0.00	2.46 ± 0.09	2.48	0.27	48	54

Table 3. α- and γ-Tocopherols (mg/100 g Wet Weight) in Typical Mexican Diets

diets	% moisture	raw α	γ	vit E act.	cooked α	γ	vit E act.
high income	82.0	0.19	0.09	0.20	0.06		0.06
low income	75.0	0.17	0.31	0.20	0.07	0.09	0.07

kernels showed the reverse trend with 0.74 mg/100 for α- and 9.19 mg/100 g for γ-tocopherol; McLaughlin and Weihrauch (1979) reported values of 1.24 and 18.62 mg/100 g, respectively. Fourie and Basson (1989) reported that α-tocopherol (28.4 mg/100 g of oil) predominated in almonds while γ-tocopherol was the primary form in pecans (12.3 mg/100 g of oil). The data from this study are consistent with these values. Peanut kernels had high levels of both α- and γ-tocopherol, 8.19 and 7.93 mg/100 g [compared to 8.33 and 8.04 mg/100 g (McLaughlin and Weihrauch, 1979)], respectively. Both almonds and peanuts were considered good sources of vitamin E on the basis of their vitamin E activities, 22.35 and 8.98, respectively.

All of the vegetable oils analyzed had high total vitamin E content and activity. Sunflower oil was the only oil that did not contain γ-tocopherol. Bauernfeind (1980) showed that α-tocopherol is the primary tocopherol in sunflower oil, and McLaughlin and Weihrauch (1979) reported values of 59.50 mg/100 for α-tocopherol and 3.54 mg/100 g for γ-tocopherol. All of the other oils, canola, corn and a commercial mixture showed high levels of both α- and γ-tocopherol with the γ-tocopherol level being higher. Hogarty et al. (1989) reported 2.9 ± 0.45 mg/100 for of α-tocopherol and 33.3 ± 0.36 mg/100 g for γ-tocopherol in corn oil. The values in this study are slightly higher for both vitamers with 9.21 ± 0.34 mg/100 g for α-tocopherol and 53.48 ± 0.06 mg/100 g for γ-tocopherol and compare more favorably with the values reported by McLaughlin and Weihrauch (1979) of 14.26 and 64.90 mg/100 g, respectively. Hogarty et al. (1989) reported a similar pattern in margarine made from corn oil. Oils with a high total tocopherol content have a high γ-tocopherol content, and this probably says something about the stability of this compound.

Table 2 presents the α- and γ-tocopherol contents of cooked grains and legumes, including values for corn and wheat flour tortillas and losses due to cooking, defined as differences in total vitamin E between the raw and cooked state, calculated on a dry weight basis to eliminate any effect of moisture differences. In the grain group, oats showed less cooking loss, 22% compared to the other grains that had losses from 42 to 55%. Oats had a lower vitamin E activity loss (defined as differences in total vitamin E activity from the raw to cooked state) of 22%, while corn and wheat showed losses of 55%. Corn tortillas had a small amount of γ-tocopherol (0.29 mg/100 g) which reflects the high γ-tocopherol content found in the raw corn kernel. Kodicek et al. (1959) reported 95% destruction of the tocopherols in corn when it was steeped in 1% lime water for making the dough for tortillas. Wheat flour tortillas contained only 0.12 mg/100 g for α-tocopherol.

In the legume group, garbanzo and black and pinto beans showed low cooking losses, ranging from 9% for garbanzo to 17% for pinto beans. These low losses reflect the stability of γ-tocopherol with respect to cooking treatments. The other items in the legume group showed cooking losses ranging from 38 to 59%. With regard to the loss of vitamin activity by cooking, black beans showed a low loss of 10% and garbanzo beans 17%, again reflecting the stability of γ-tocopherol. All of the other legumes experienced higher cooking loss in vitamin E activity, ranging from 21 to 60%, with the highest in loss of 60% in bayo beans. Guzman and Murphy (1986) reported a 47% loss of vitamin E activity in processing soybeans to tofu. These high losses are due to the sensitivity of α-tocopherol to heat treatment, which has a higher biological activity.

Diets. The α- and γ-tocopherols contents, obtained by analysis, in typical Mexican diets for high- and low-income adults are presented in Table 3. As reported elsewhere (Wyatt, 1998), the basic ingredients and energy in the Mexican diet are pinto beans and corn and wheat flour tortillas. As income improves, the diet becomes more varied and includes more animal products, dairy products, and fresh fruits and vegetables. The high-income diet has 97.6 g/d of fat and the low-income diet 89.0 g/d. Thirty-two percent of the calories in the high-income diet comes from fat and 30% in the low-income diet. Using a database, Nutritionist IV (1996), only the α-tocopherol content of the two diets was calculated for the cooked diet. The high-income diet was expected to have 0.17 mg/100 g for α-tocopherol and 0.10 mg/100 g for the low-income diet. The analyzed values of 0.06 and 0.07 mg/100 g for α-tocopherol for the high- and low-income diets, respectively, were lower than the calculated values. This is highly possible as the temperature and time of cooking for each of the

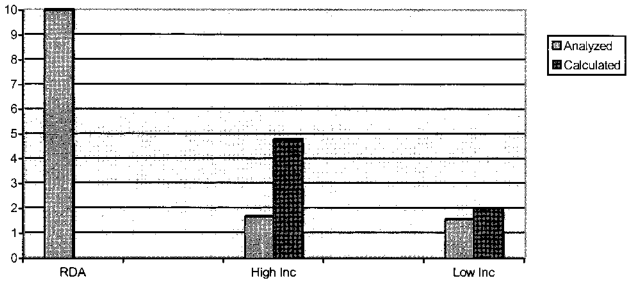

Figure 1. RDA (milligrams per day) for adult men and vitamin E activity of Mexican diets for low- and high-income adults

foods could vary significantly. It has been shown that many factors can affect the retention of α-tocopherol which can produce differences in values obtained under different conditions. The cooking loss in the vitamin E activity was 69% for the high-income diet and not significantly different ($p = 0.001$) from the value of 64% for the low-income diet.

One interesting observation in the cooked low-income diet is the presence of γ-tocopherol, although the amount is small. Bieri and Evarts (1974) stated the increased use of vegetable oils, such as soybean oil, was responsible for the higher γ-tocopherol content in diets. In the case of the low-income diet in this study, this phenonemon is attributed to the high consumption of corn tortillas. As explained earlier, corn kernels and corn oil were the only items in their respective group showing γ-tocopherol content, and because of its resistance to cooking temperatures, what little was there is carried over into the composite diet sample. This is more obvious if one looks at the data expressed on a dry weight basis. The low-income diet, in its raw state, had 0.67 mg/100 g of for α- and 1.25 mg/100 g for γ-tocopherol or 87% more γ- than α-tocopherol. In the cooked state, it had 0.26 mg/100 g for α- and 0.34 mg/100 g for γ-tocopherol or 30% more γ- than α-tocopherol.

Figure 1 presents the RDA for adult men of 10 mg/d (National Academy of Sciences, 1989) and the vitamin E activity contribution of the diets for high- and low-income adults. As can be seen from the figure, neither diet meets the recommended intake. The high-income diet provides 16.7% of the RDA for vitamin E and the low-income diet 14.6%. The calculated intake using the data obtained from a database (Nutritionist IV, 1996), taking into consideration the α-tocopherol content only, would provide 47.8% of the RDA for the high-income diet and 20% for the low-income diet. Other studies reporting vitamin E intakes used frequency questionnaires and estimated intakes with databases. These studies report values higher than those found in this study. Databases often over estimate intakes (Mendez and Wyatt, 1995). Bolton-Smith et al. (1991) reported a value of 7.6 mg of vitamin E/d for smokers and nonsmokers in Scotland. In the CARDIA study, McDonald et al. (1991) reported 8−12 mg of vitamin E/d for men and women. These values come closer to meeting the recommended RDA of 10 mg/d than the values obtained in our study.

Figure 2 presents the vitamin E activity of various food items in the diet for low-income Mexican adults. Vegetable oils, due to their high content (13 mg/100 g), contribute the highest intake of 1.26 mg of vitamin E/d. Pinto beans are very low in vitamin E activity (0.31 mg/100 g), but due to their high intake in the Mexican diet (217 g/d), their contribution represents the next highest intake of 0.67 mg/d, followed by corn tortillas at 0.38 mg/d. The average consumption of corn tortillas in the Mexican diet is 128 g/d.

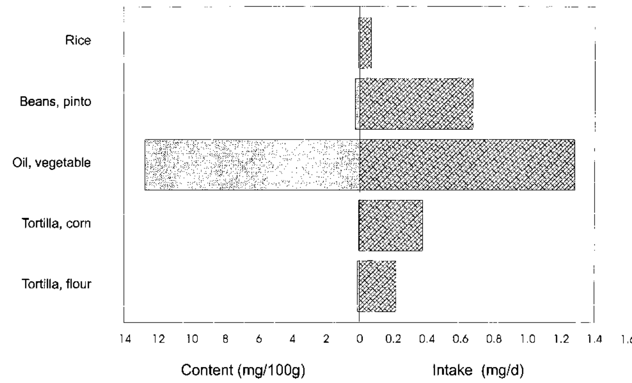

Figure 2. Vitamin E activity of selected foods in the low-income Mexican diet.

CONCLUSIONS

On the basis the data of this study, it was shown that legumes were high in vitamin E with the garbanzo bean containing the highest amount. γ-Tocopherol is predominant in this group and is fairly resistant to cooking losses. In the grain group, corn was a significant source of vitamin E; however, the tocopherols were almost completely destroyed in the making of tortillas. Both nuts and vegetable oils represent a good source of vitamin E. Pinto beans, corn tortillas, and wheat flour tortillas are the major energy sources in the Mexican diet. These items, along with vegetable oil, contribute the most vitamin E to the diet. Due to the high level of consumption of these items, and the predominance of γ-tocopherol over α-tocopherol in these food items, the γ-vitamer level is higher than that of the α-vitamer in the diet. The low-income diet, in its raw state, had 87% more γ- than α-tocopherol and cooked 30% more γ- than α-tocopherol.

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