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Physiological and Compositional Changes Associated with Maturation of 'Kerman' Pistachio Nuts[1, 2]

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Abstract. **As the pistachio (*Pistacia vera* L. cv. Kerman) nut matured, kernel moisture, respiration rate, and total protein content decreased, while kernel dry weight increased. At optimum maturity, ether-extractable fat and total sugar contents reached a peak. Either or both of these constituents may be useful as a maturity index, in addition to ease of hull separation, to determine optimum harvest date for pistachio nuts. Nut quality was acceptable for harvest during a 2- to 3-week period bracketing the time when the hull separates easily from the shell. Compositional analyses of hulls indicated some limitations on their potential use as animal feed.**

Pistachios have traditionally been deemed mature for harvest when the hull separates easily from the shell (12). Crane (5) studied the physiological changes associated with maturation and found pistachio nuts to be mature, based upon kernel dry weight, crude fat determination, shell dehiscence, and changes in shell color, within 1 week of the hull separating easily from the shell.

The purpose of this study was to develop a broader picture of the compositional changes associated with the maturation of 'Kerman' pistachio nuts by harvesting them at weekly intervals over a 6- to 7-week period bracketing the "normal" harvest date (based on ease of hull separation) and evaluating a variety of nut characteristics. These included fresh and dry kernel weights, kernel and hull moisture contents, shell and hull color, respiration rate and ethylene production of the nut. In addition, chemical constituents of the kernel, including ether-extractable fats, individual fatty acids, total proteins, total sugars, and reducing sugars, were analyzed. These data, therefore, provided information pertinent to selecting a harvest period that would insure optimum nut quality. We also report here on compositional changes in hulls and their potential use for animal feed.

Materials and Methods

'Kerman' pistachios were harvested weekly, for 6 weeks beginning August 15 during the 1978 season, and for 7 weeks beginning August 21 during the 1979 season, from Wolfskill Experimental Orchard, Winters, Calif. At each sampling date, 200 nuts were harvested from each of three 15-year-old trees chosen for the duration of the study. The pistachios were immersed in water; nuts lacking kernels floated to the surface and were discarded.

A sample of hulls plus shells (1978 season) and a sample of hulls alone (1979 season) from about 25 nuts were dried for 24 hr at 70°C in a vacuum oven to determine moisture content. Similarly, 25 kernels were dried, packaged in airtight, heat-sealable pouches, and stored at 0° for subsequent chemical analysis. Sampling during 1980 was limited to hulls of fresh pistachio nuts which were dried and stored until analyzed. Hull color was evaluated on 10 nuts from each tree using the Rd, a, and b modes of the Gardner Colorimeter Model XL-23 referenced on the green standard plate (Y = 44.1, X = 37.2, Z = 43.3). For shell color, 10 hulled nuts per replicate (tree) were similarly evaluated but the yellow reference plate (Y = 60.6, X = 59.2, Z = 42.4) was used to standardize the colorimeter. To monitor respiration and C_2H_4 production, 54 nuts from each tree were weighed, dipped in benomyl (1 g/liter) for decay control, air-dried for 1 hr, and held at 20° in 400-ml jars fitted with rubber stoppers and inlet and outlet tubes. A continuous air-flow rate of 65 ml/min was maintained using flow boards and capillary tubing. CO_2 and C_2H_4 production were monitored daily for 10 days using colorimetric (4) and flame ionization gas chromatographic techniques, respectively.

Samples of dried kernels and hulls (from 25 nuts, each) were ground to a fine meal in a coffee grinder (Braun, type 4-041). Aliquots of the meal were weighed into glass fiber extraction thimbles and oils were extracted into 35 ml ether during a 5-hr treatment in a reflux fat extractor. The thimble and residue were dried to constant weight in a vacuum oven (40°C) and low molecular weight sugars and phenolics were extracted with refluxing ethanol (80% v/v for kernels, 70% v/v for hulls) for 3 hr. The thimble and residue were again dried.

Ether extractable fats were determined by drying aliquots (20% of total extract) of the ether extract in tared tubes in a stream of filtered air. Fatty acids were measured by gas liquid chromatographic (GLC) analysis of methyl esters produced by treatment of aliquots of the ether extract with methanol:benzene:H_2SO_4 (20:10:1) for 3 hr at 110°C in the presence of the antioxidant butylated hydroxytoluene (3). Margaric acid (C17:0) was used as internal standard. GLC analysis was performed on a Perkin-Elmer gas chromatograph fitted with columns (2 mm I.D. by 180 cm) packed with 5% DEGS-PS on 100/120 mesh "Supelcoport" (Supelco, Inc.). Oven temperature was maintained at 155°, injector and detector were held at 225°, and the flow rate of the N_2 carrier gas was 12 ml/min. Integration of chromatographic peaks was performed by a Perkin-Elmer Sigma 10 data system interfaced to the chromatograph flame-ionization detector.

Total sugars in ethanol extracts were measured using the anthrone test (6) with sucrose as a standard. Reducing sugars in extracts were measured using the method of Nelson (7) as modified by Somogyi (10) with glucose as a standard. GLC analysis of sugars was carried out on trimethylsilyl ethers (13) using columns (2 mm I.D. by 200 cm) of 3.8% SE-30 on Chromosorb W, 100/120 mesh (AW-DMCS).

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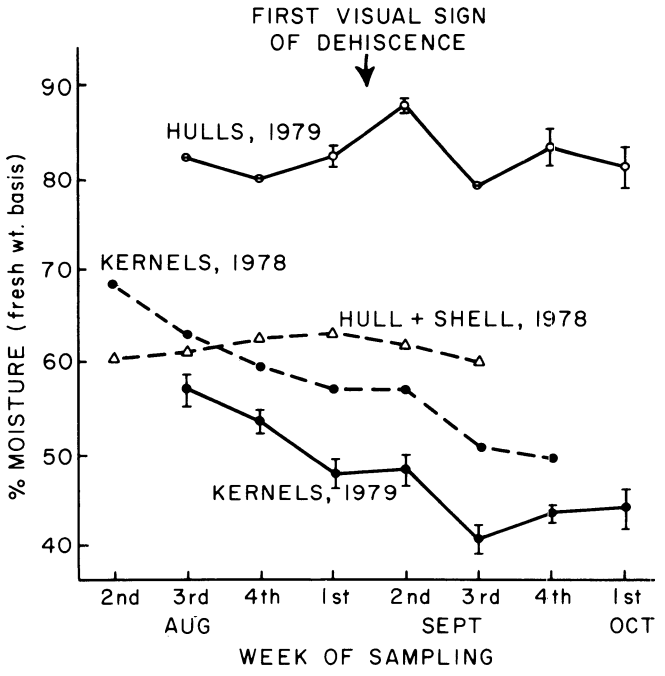

Fig. 1. Changes in moisture content (means of 3 replicates) of hull, shell, and kernel portions of 'Kerman' pistachio nuts during maturation. Vertical bars represent SD (not given for 1978 samples).

Total nitrogen was measured in the residues following ethanol extraction using the automated procedure of Carlson (2). Total protein was calculated by multiplying by 6.25.

Total phenols were measured in 70% ethanol extracts of hull meal using the Folin phenol reagent (8). Tannic acid was used as a standard. Carbohydrate analysis (noncellulosic neutral sugars, uronide, and cellulose) of the fiber remaining following ether and ethanol extraction of hull meal was carried out as described by Ahmed and Labavitch (1).

Results and Discussion

During both the 1978 and 1979 seasons, moisture content of the kernels decreased continually throughout maturation although there was generally some stabilization between the first and second weeks in September (Fig. 1). No clear trends were observed in moisture contents of the hull plus shell (1978) or hulls alone (1979). As kernel moisture decreased, kernel fresh and dry weights increased with maturation (Fig. 2). In 1978, kernel dry weight reached a peak on September 19, while during 1979, it peaked September 11.

Maturation-related changes in degree of greenness (−a) to redness (+a) of the hulls and in lightness (high Rd values) of the shell are illustrated in Fig. 3. During 1978, hull color showed little change from green to red as compared to the 1979 season in which hulls exhibited clear changes from green to red with maturation; the greatest change occurred during the second week in September. Shell color did not vary greatly in lightness during the 1979 season, but became lighter as the season progressed

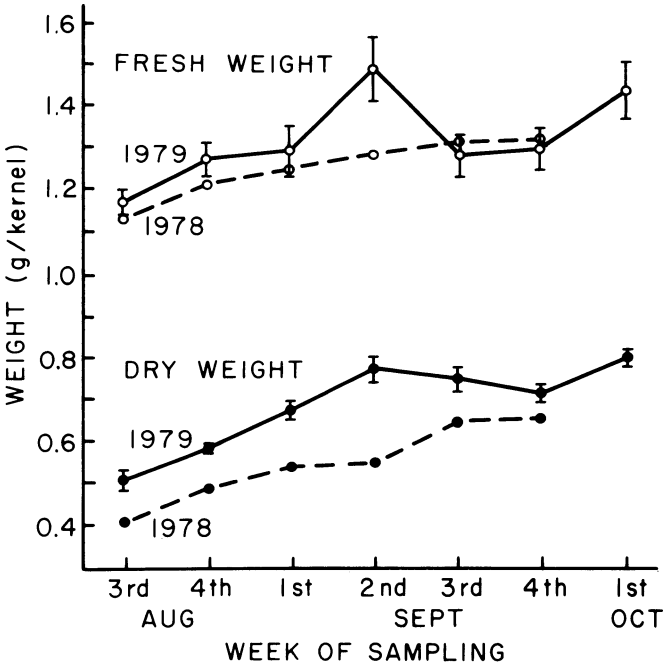

Fig. 2. Changes in fresh and dry weights (means of 3 replicates) of 'Kerman' pistachio nut kernels during maturation. Vertical bars indicate SD (not given for 1978 samples).

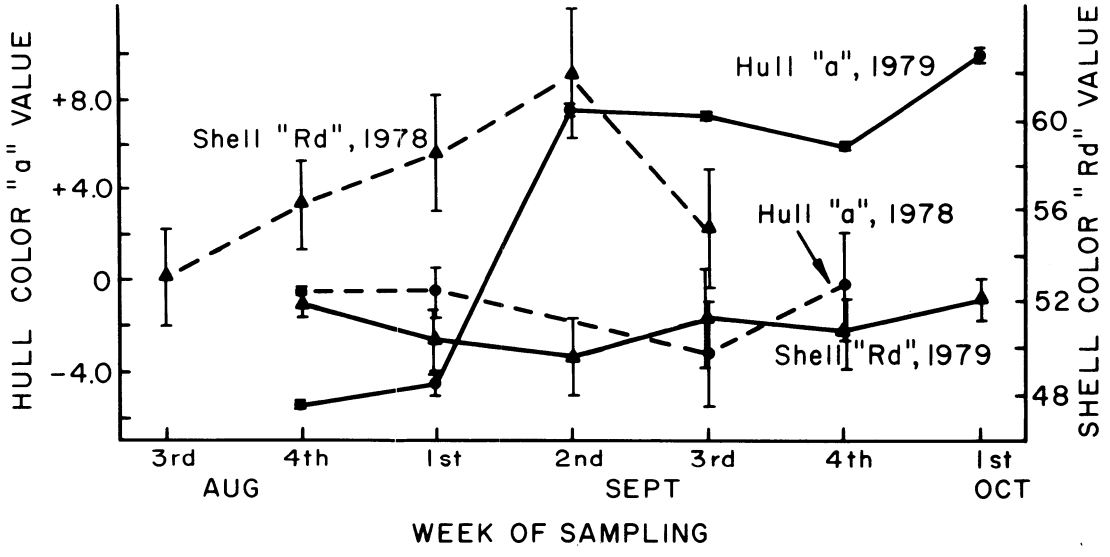

Fig. 3. Changes in hull and shell color (means of 30 replicates) of fresh 'Kerman' pistachio nuts during maturation. Vertical bars indicate SD.

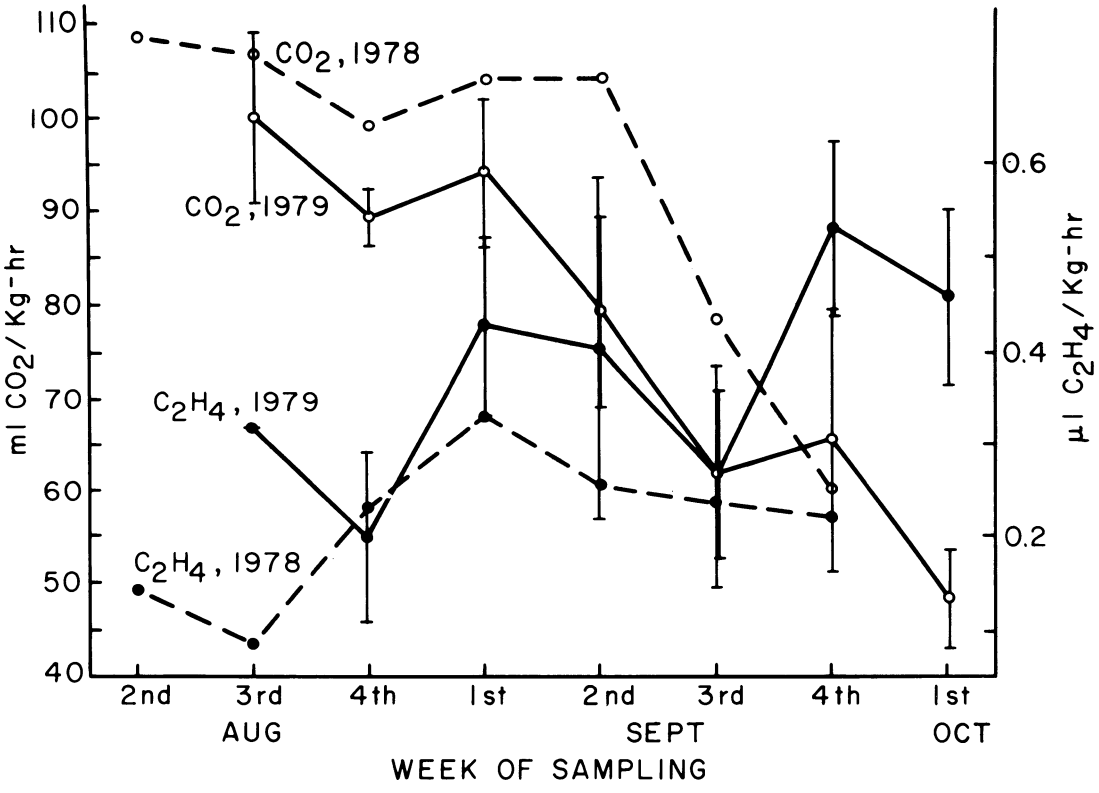

Fig. 4. Respiration and ethylene production rates (means of 3 replicates) of fresh 'Kerman' pistachio nuts during maturation. Data points represent "initial" measurements of ethylene and CO_2 (taken 24 hr after harvest and placement of nuts in jars). Vertical bars indicate SD (not given for 1978 samples).

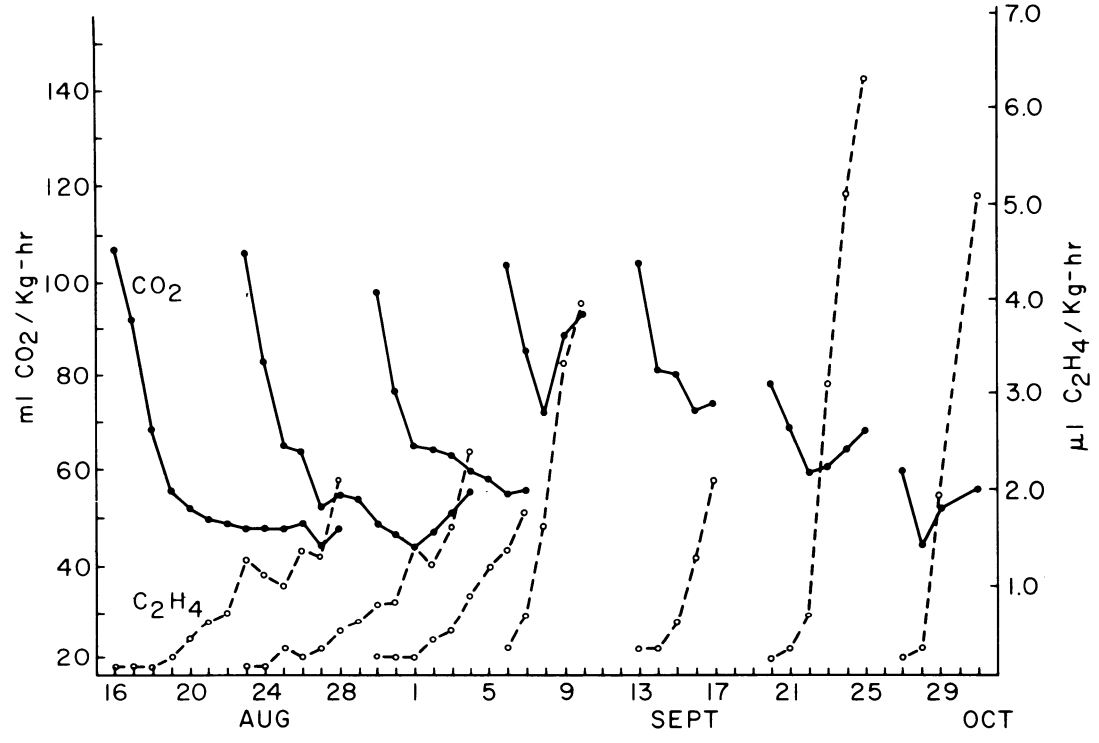

Fig. 5. Respiration and ethylene production rates (means of 3 replicates) of fresh 'Kerman' pistachio nuts, harvested at various maturity stages, during holding at 20°C for 10 days. The first point of each curve represents the measurement made 24 hr after enclosing nuts in jars. An indication of the variability in the data is given by the SD shown in Fig. 4.

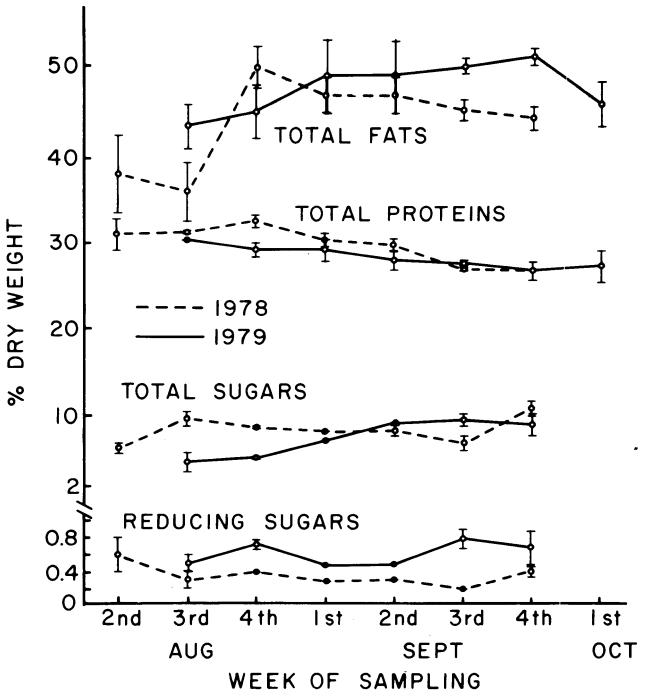

Fig. 6. Maturation-related changes in composition of pistachio kernels. Data are the means of 3 replicates. Vertical bars indicate SD.

during 1978, reaching a peak the second week in September, then dropping sharply. Because of these seasonal variations, it is not likely that color of hulls or shells can be used as an index of maturity.

Respiration rates declined with maturation (Fig. 4). Initial respiration rates were high (>90 ml CO_2/kg-hr) during the early part of the season and declined sharply after mid-September in 1978 and early September, 1979. Daily respiration readings during holding at 20°C for the 10 days following harvest also fell sharply regardless of harvest date (Fig. 5). Within 2 or 3 days of harvest, respiration rates dropped to 40–50% of the initial rates. During 1978, however, respiration rates of nuts harvested after mid-September dropped the first 4 days, then began to increase thereafter, perhaps due to decay incidence. As was reported by Toumadje et al. (11), initial C_2H_4 production rates were generally low (<0.06 µl/kg-hr). C_2H_4 production rate increased during the holding period at 20°, reaching as high as 5 µl/kg-hr, especially for samples picked during the latter part of the season. Usually within a day of this sharp increase in C_2H_4 production, mold (*Rhizopus* sp.) growth was evident. Whether fungal infection and C_2H_4 production were causally related was not examined.

Total fats increased with kernel maturation, peaking the fourth weeks of August and September in 1978 and 1979, respectively (Fig. 6). Individual fatty acid composition of the nuts remained fairly constant during both seasons (Table 1). Palmitic acid is the predominant saturated fatty acid, while oleic and linoleic acids are the main unsaturated fatty acids. Changes in the ratio of unsaturated to saturated fatty acids were small. Total protein content was highest during late August and declined thereafter. Total sugars increased markedly between the second and third weeks of August in 1978, while during the 1979 season, total sugar content increased steadily with maturation, reaching a peak the third week of September. Sucrose was the principal ethanol-soluble sugar in the pistachio kernel; the reducing sugars glucose and fructose made up only 5–7% of the total.

Though Crane (5) found nuts to be of highest quality within a 1-week period coinciding with ease of hull separation from the shell, we found that harvesting nuts within a 2- to 3-week period around the time of easy hull separation did not result in significant changes in nut composition. In contrast, pistachios sampled before or after this 2- to 3-week period were deficient in total fat and total sugar contents. Further, harvesting before this period resulted in lower yields, while later harvests resulted in lower total protein content. Since ether-extractable fat content and total sugar contents exhibited abrupt changes just prior to the harvest period, monitoring these constituents may be useful as maturity indices to determine optimum harvest date for pistachio nuts. Determination of soluble solids content using a hand refractometer can be used as an indicator of sugar content in fresh nuts in the orchard. However, determination of oil content will require a laboratory procedure.

Chemical constituents in pistachio hulls were analyzed to pre-

Table 1. Changes in fatty acid content (percent of total fats, mean of 3 replicates) of 'Kerman' pistachio kernels during maturation and senescence. Refer Fig. 6 for maturation-related changes in total fat composition.

		Week of sampling							
		August			September				October
Fatty acid	Season	2nd	3rd	4th	1st	2nd	3rd	4th	1st
Palmitic acid	1978	12.3	11.8	12.2	11.9	11.1	10.8	11.9	—
	1979	—	10.7	10.6	10.7	10.9	10.6	10.8	11.0
Stearic acid	1978	1.1	1.0	1.5	1.3	1.3	1.1	1.2	—
	1979	—	0.6	0.7	0.6	0.5	0.6	0.6	0.6
Total saturated	1978	13.4	12.8	13.7	13.2	12.4	11.9	13.1	—
	1979	—	11.3	11.3	11.3	11.4	11.2	11.4	11.6
Oleic acid	1978	49.7	50.5	51.1	51.4	54.4	53.2	52.1	—
	1979	—	49.0	50.3	50.0	50.0	50.2	50.3	50.6
Linoleic acid	1978	35.7	35.7	34.2	34.4	32.2	34.0	33.8	—
	1979	—	39.2	37.9	38.2	38.1	38.1	37.8	37.3
Linolenic acid	1978	1.1	1.0	1.0	1.0	1.0	0.9	1.0	—
	1979	—	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total unsaturated	1978	86.5	87.2	86.3	86.8	87.6	88.1	86.9	—
	1979	—	88.7	88.7	88.7	88.6	88.8	88.6	88.4

Table 2. Composition of hulls from 'Kerman' pistachio nuts harvested at weekly intervals during the latter portion of the 1980 season. All data presented are means of 3 replicates and are expressed on the basis of the dry weight of unextracted hull meal.

	Week of sampling					
	August	September				October
Component	4th	1st	2nd	3rd	4th	1st
Ether-soluble fat (%)	3.7	4.4	4.0	5.9	4.1	5.5
70% ethanol-soluble material (%)	36.1	43.5	30.7	42.1	32.8	38.9
Total soluble sugar (%)	3.6	4.4	3.7	4.4	3.4	3.1
Total phenolics (%)	6.3	6.9	5.3	6.9	5.8	7.4
Insoluble residue (%)	60.2	52.1	65.4	52.1	63.2	55.5
Total protein (%)	4.7	4.7	6.3	4.7	5.6	5.1

liminarily assess the value of the pistachio hull as livestock feed. Our data (Table 2) are interpreted in relation to a published study of almond hulls (9) which are currently used for dairy cattle feed in California. The 2 hull types have similar fat and protein contents. In contrast, soluble sugars, which are a good indicator of the nutritive value of hulls (9), are 6 to 7 times more prevalent in the almond hull. While sucrose is by far the dominant soluble sugar in almond and pistachio kernels, in the hull tissues of these nuts fructose and glucose predominate. The sugar components of the fiber present in the insoluble residues of extracted pistachio hull material were quite similar to the constituents in almond hull fiber.

The soluble sugar data suggested that pistachio hulls would be less useful as feed than almond hulls. This point is strengthened by our data for total soluble phenolic materials. Use of almond hulls as feed is restricted (25% of total ration, maximum) because of their content of phenolic materials which inhibit the activity of rumen microbes. Phenolic content of pistachio hulls is 5 to 7 times that of almond hulls. While the effects of phenolics on rumen microbes will vary with the compound in question this suggests that the pistachio hull would likely not be suitable as animal feed.

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