Chemical Composition of Bitter and Sweet Apricot Kernels

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The chemical composition of bitter and sweet varieties of apricot (*Prunus armeniaca*) kernel was investigated. Oil, protein, soluble sugars, fiber (NDF and ADF), and ash contents in kernels were determined. Sweet apricot kernels were found to contain more oil (53 g/100 g) and less soluble sugars (7 g/100 g) than bitter kernels (43 and 14 g/100 g, respectively). No significant differences in the protein content were found in either variety. Oleic acid and linoleic acid are approximately 92 g/100 g of total fatty acids. Pectic polysaccharides, cellulose, and hemicelluloses (in decreasing amounts) were inferred to be their main component polysaccharides. Essential amino acids constitute 32–34 g/100 g of the total amino acids determined. Amygdalin content was very high (5.5 g/100 g) in bitter cultivars and was not detected in the sweet variety.

Keywords: *Apricot kernel; carboydrates; amino acids; fatty acids; mineral elements*

INTRODUCTION

Currently, large amounts of fruit seeds are discarded yearly at processing plants. This not only wastes a potentially valuable resource but also aggravates an already serious disposal problem. To be economically viable, however, both oil and meal from these fruit seeds must be utilized (Kamel and Kakuda, 1992).

Significant amounts of oil, edible protein, and fiber can be supplied by seed kernels obtained from an apricot fruit process. Current production of apricot fruit in Spain is about 160 000 tons per year, which represents 30 g/100 g of the EEC production (Escudero and Rodriguez-Navarro, 1990). This involves about 4000 tons of apricot kernels per year.

At present there is no systematic collection and utilization of this material; thus, a valuable product with a large industrial potential remains unexploited. Some of the seeds are difficult to collect because of the direct consumption of the fresh fruit by consumers, but the bulk of the fruit is used in food processing plants; i.e., the apricot kernels can be obtained as a byproduct from the many food companies that process apricots and are available at a very low cost.

To achieve the most economical and efficient utilization of these seeds, more information on the varieties, properties, and composition is required. Two main varieties of apricot kernels can be easily differentiated: sweet and bitter kernels.

Cyanogenic glycosides yielding hydrocyanic acid upon hydrolysis are widely distributed within approximately 150 plant species (Stoewsand and Anderson, 1973). Bitter kernels contain various levels of the toxic cyanogenic glycoside, known as amygdalin, depending on the specific cultivars. The presence of high levels of amygdalin in apricot kernels prevents its use as a food source, although it contains high levels of protein and carbohydrates (Khairy et al., 1975). Despite its known toxicity, this compound has been promoted as a cancer preventive. As a derivative of amygdalin, Laetrile has been advocated as an anticancer drug but has unproven efficacy (Miller et al., 1981).

Several studies have been conducted with a view to the removal of this toxic compound from apricot kernels; the physicochemical properties, the digestibility by different enzyme systems, and the functional properties of the amygdalin-free apricot kernel (Khairy et al., 1975; El-Aal et al., 1986a) have been investigated.

Tuncel et al. (1990) reported that 70 g/100 g of total cyanide was removed by the temper process. Bitter seeds contained antimicrobial substances that must be removed by leaching and boiling prior to temper fermentation. However, additional improvement of the detoxification process is required to obtain a completely safe product.

Although there is no general utilization of apricot kernels, usually the amount that is collected goes into the adulteration of both almond kernels and their oil (Aggarwal et al., 1974; Filsoof et al., 1976; Farines et al., 1986). Some procedures were investigated to detect the possible oil adulteration through the determination of tocopherols (Gutfinger and Letan, 1973).

The oil of apricot kernels has been used in Germany and the United States in preparing fixed oil and macaroon paste. Some uses of apricot kernel oil in cosmetics and for medical purposes were reported by Hallabo et al. (1975). The possibility of mixing crude edible oil with crude fruit seed oils, such as apricot kernel oil, and then processing the oil mixture by the conventional methods of refining and bleaching was analyzed by Helmy (1990).

El-Aal et al. (1986b) investigated the extraction, characterization, and evaluation of apricot kernel oil for use in preparing biscuits and cakes. Its effect on the acceptability of the product was evaluated organoleptically. El-Aal et al. (1986a) also reported that detoxified apricot kernel flour and protein isolates appear to be good sources of protein for food products. Godtfredsen et al. (1978) reported that apricot kernels play an important role in the industrial production of marzipan in some countries.

The sparsity of data in the literature on yields and physicochemical characteristics of apricot oils (Lotti et

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al., 1970; Gutfinger et al., 1972; Normakhmatov, 1973; Carpenter et al., 1976; Zuercher and Hadorn, 1976; Filsoof et al., 1976; Ermakov, 1980; Farines et al.,1986; El-Aal et al., 1986b; Kapoor et al., 1987; Kamel and Kakuda, 1992) and on the protein content and amino acid profile (Normakhmatov et al., 1973; Aggarwall et al., 1974; Gabrial et al., 1981; Javed et al., 1984; El-Aal et al., 1986a; Yurukov et al., 1988; Tuncel et al., 1990) and the lack of references on fiber (polysaccharide composition), soluble sugars, and ashes (mineral elements) stimulated this research.

The aim of this paper was to obtain a complete physical–chemical characterization of both bitter and sweet kernel varieties, thus elucidating the main compositional differences.

MATERIALS AND METHODS

Apricot Fruits. Apricot fruits (*Prunus armeniaca* L.) were collected from apricot fruit crops of Mallorca (Spain), covering the main production zones of the island.

Bitter and sweet seed kernels from 15 and 16 different crops, respectively, were analyzed for this study. Samples were collected from 10–15 trees in each crop. The collection extended from June to September during three consecutive years (1988–1990). Bitter kernels belong to the variety locally known as "canino" and sweet kernels to the variety "galta vermella"; both varieties comprise more than 98% of the total apricot fruit production cultivated in Mallorca.

Apricot Kernels. Stones from the apricot fruits were removed and individual stones were hammered to obtain the seed kernel in each case. The skin was removed and the kernels were homogenized and ground to particles <0.5 mm and then dried at 60 °C for 24 h. All analyses were performed in triplicate.

Determination of Moisture. Kernel moisture was determined gravimetrically by placing a small amount of specimen into an oven at 102 °C for 6 h or at constant weight.

Physical Characterization. Weight, length, width, and thickness of one seed/kernel were determined by taking the average measures of 30 seeds/kernels from each cultivar.

Extraction of Oil. Oils were extracted in Soxhlet extractors with ethyl ether and stored after solvent extraction at −5 °C.

Physicochemical Properties of Oil. Determinations of specific gravity, refraction index, unsaponifiable matter by the ethyl ether method, iodine value by the Hanus method, and the saponification values were all carried out following standard AOAC (1980) procedures.

Constituent Fatty Acids. The oils were saponified (Utrilla et al., 1976) and the methyl esters were extracted with diethyl ether. The esters were analyzed for their respective fatty acid compositions by GC on a Perkin-Elmer Sigma 3B series chromatograph using a stainless steel DEGS column. Nitrogen was used as a carrier gas. Detection was made by a flame ionization detector.

Determination of Protein. Nitrogen in defatted seed cakes was determined according to the Kjeldahl method, and the percentage of protein was calculated using the factor 6.25.

Determination of Total and Free Amino Acids. Analysis and quantitative determinations of total amino acids (Hill et al., 1979) were carried out on the acid-hydrolyzed samples using a Chromaspeck Rank-Hilger model autoanalyzer with a Biomex-DC 6A column. Free amino acids were extracted with a methanol–chloroform–water (60:25:15) mixture and analyzed on the automatic analyzer. Fluorescence detection was performed on the respective OPA derivatives.

Determination of Fiber (NDF and ADF). Determination of fiber was performed according to the methods described by Van Soest and Robertson (1979). Samples were treated with neutral and acid detergent solutions, respectively, to determine NDF and ADF contents. The hemicellulose content was determined as the weight loss of the NDF when treated with acid detergent.

Table 1. Physical Properties of Apricot Seed and Kernel

property	bitter kernel	sweet kernel
kernel percentage (of whole seed)	27.0 ± 0.3	31.9 ± 0.2
weight of 100 kernels (g)	48 ± 9	59 ± 6
seed length (mm)	21.7 ± 0.9	23.0 ± 0.9
kernel length (mm)	15.4 ± 0.9	16.6 ± 1.0
seed width (mm)	18.0 ± 1.0	18.3 ± 0.7
kernel width (mm)	11.4 ± 0.8	11.2 ± 0.6
seed thickness (mm)	11.4 ± 0.8	11.5 ± 0.6
kernel thickness (mm)	5.5 ± 1.1	6.5 ± 1.0

[a] Average value ± standard deviation.

Analysis of Carbohydrate Composition. Alcohol-insoluble residue (AIR) was obtained as described by Selvendran and Ryden (1990). Monosaccharides were released from AIR preparations by hydrolysis with 1 M H_2SO_4 for 2.5 h and were also dispersed in 72 g/100 g of H_2SO_4, followed by dilution to 1 M (Saemen hydrolysis). Hydrolyzed monosaccharides were analyzed, as were their alditol acetates, by GLC. The alditol acetates were separated using a column of 3% OV225 on Chromosorb WHP 100/120 mesh with Ar as the carrier gas. Total uronic acid content was determined colorimetrically according to the Blumenkrantz and Absoe-Hansen (1973) method, after AIR was dispersed in 1 M H_2SO_4.

Determination of Soluble Sugars. Soluble sugars were determined as glucose according to the Haas colorimetric method, using anthrone as reactive and measuring the absorbances at 620 nm (Snell and Ettre, 1971).

Determination of Amygdalin. Determination of amygdalin was performed according to the acidic titration method (AOAC, 1980). Hydrolysis of the amygdalin molecule produces two glucoses, benzaldehyde, and CN^-, after hydrolysis in H_2O for 2 h, on $AgNO_3$. The titration of Ag^+ is based on the Volhard method.

Determination of Ash. Ash content was determined by overnight heating at 550 °C (AOAC, 1980).

Analysis of Mineral Elements. Determination of Ca, Mg, Fe, Cu, Zn, and Mn was carried out by absorption and that of Na and K by emission using a Perkin-Elmer 703 atomic absorption spectrophotometer. P was colorimetrically analyzed in the form of vanadium phosphomolybdate (AOAC, 1980).

Statistical Analysis. Analysis of variance (ANOVA) was performed on pooled data mainly for the independent variable, variety. As a minor variable cultivar was considered (Bisquerra, 1989; Best, 1990).

RESULTS AND DISCUSSION

Physical Properties and Moisture. Physical properties of the apricot seed and the apricot kernel regarding weight, length, width, and thickness, plus the kernel percentage (of whole seed), are listed in Table 1. Sweet and bitter kernels of apricots constituted a high proportion of their seeds (32 and 27 g/100 g, respectively). Values ranging between 21 and 38 g/100 g have been reported for bitter kernels, and values from 22 to 38 g/100 g for sweet kernels have been reported by Filsoof et al. (1976), Hallabo et al. (1975), and Ermakov (1980).

Morphologically, the kernel varieties studied can be differentiated by their physical properties, such as kernel percentage (of whole seed), kernel weight, kernel thickness, and kernel length ($P < 0.001$). Nevertheless, kernel width is not an appropriate variable to differentiate the two kernel varieties. On the other hand, seed parameters are not as significant as kernel parameters when it comes to differentiating both varieties.

Moisture values were 6.7 ± 2.1 and 5.4 ± 1.7 g/100 g for bitter and sweet apricot kernels, respectively. Moisture is not a good variable to differentiate the varieties due to its high variability for samples obtained from the same crop.

Table 2. Chemical Composition of Apricot Kernels (Percent Dry Matter)[a]

sample	oil	protein	sugars	NDF	ADF	ash	amygdalin
			Bitter Kernel				
bk-1	47.1 ± 1.2	25.2 ± 0.3	12.4 ± 0.5	6.6 ± 0.5	4.9 ± 0.2	2.4 ± 0.2	4.7 ± 0.3
bk-2	41.4 ± 0.6	28.8 ± 0.2	14.4 ± 0.8	7.1 ± 0.7	4.5 ± 0.2	2.3 ± 0.1	5.4 ± 0.5
bk-3	43.6 ± 0.7	27.5 ± 0.3	12.7 ± 0.6	8.3 ± 0.6	5.2 ± 0.2	2.2 ± 0.1	4.4 ± 0.7
bk-4	41.4.± 0.9	27.0 ± 0.2	14.5 ± 0.7	7.8± 0.3	6.7 ± 0.1	2.4 ± 0.2	5.3 ± 0.4
bk-5	40.8 ± 1.7	26.8 ± 0.2	14.2 ± 0.6	6.4 ± 0.6	5.0 ± 0.0	2.4 ± 0.1	5.9 ± 0.6
bk-6	46.9 ± 1.1	24.5 ± 0.1	13.7 ± 0.3	6.8 ± 0.8	4.5 ± 0.2	2.2 ± 0.2	4.6 ± 0.4
bk-7	43.3 ± 1.6	25.6 ± 0.1	12.4 ± 0.3	7.3 ± 0.5	5.4 ± 0.2	2.5 ± 0.2	4.5 ± 0.4
bk-8	43.9 ± 0.6	27.0 ± 0.1	14.7 ± 0.3	6.7 ± 0.8	4.5 ± 0.4	2.2 ± 0.1	5.0 ± 0.2
bk-9	40.2 ± 0.7	25.3 ± 0.3	15.1 ± 0.6	7.2 ± 0.4	5.7 ± 0.3	2.4 ± 0.2	5.5 ± 0.6
bk-10	43.2 ± 0.8	25.0 ± 0.3	15.4 ± 0.4	6.1 ± 0.5	4.8 ± 0.2	2.2 ± 0.2	5.3 ± 0.5
bk-11	42.9 ± 1.3	28.6 ± 0.4	11.3 ± 0.3	7.8 ± 0.4	6.0 ± 0.3	2.5 ± 0.1	6.2 ± 0.3
bk-12	46.0 ± 1.0	24.5 ± 0.3	12.9 ± 0.3	8.6 ± 0.1	6.9 ± 0.2	2.2 ± 0.0	4.6 ± 0.3
bk-13	41.1 ± 0.7	26.8 ± 0.2	14.5 ± 0.5	7.5 ± 0.1	5.9 ± 0.1	2.4 ± 0.0	5.1 ± 0.6
bk-14	47.2 ± 0.5	25.2 ± 0.1	13.7 ± 0.4	7.9 ± 0.2	6.9 ± 0.1	2.3 ± 0.1	5.6 ± 0.5
bk-15	46.3 ± 1.1	24.4 ± 0.1	16.3 ± 0.3	7.2 ± 0.1	7.2 ± 0.2	2.9 ± 0.0	5.8 ± 0.3
bk-16	39.7 ± 1.5	25.6 ± 0.2	20.2 ± 0.4	8.2 ± 0.4	7.0 ± 0.2	2.6 ± 0.1	4.4 ± 0.5
Av	**43.4 ± 2.6**	**26.1 ± 1.4**	**14.3 ± 2.0**	**7.3 ± 0.7**	**5.7 ± 1.0**	**2.4 ± 0.2**	**5.1 ± 0.6**
			Sweet Kernel				
sk-1	52.1 ± 1.0	24.5 ± 0.4	5.7 ± 0.6			2.4 ± 0.1	nd[b]
sk-2	53.7 ± 0.8	27.4 ± 0.4	6.2 ± 0.3			2.5 ± 0.2	nd
sk-3	52.2 ± 0.9	25.7 ± 0.2	5.2 ± 0.2	8.6 ± 0.6	3.7 ± 0.3	2.8 ± 0.2	nd
sk-4	54.4 ± 0.7	24.2 ± 0.3	6.1 ± 0.6	7.0 ± 0.7	4.9 ± 0.2	2.5 ± 0.1	nd
sk-5	53.1 ± 0.9	27.5 ± 0.5		7.2 ± 0.4	5.4 ± 0.1	2.9 ± 0.4	nd
sk-6	49.8 ± 2.1	27.1 ± 0.6				2.5 ± 0.1	nd
sk-7	51.4 ± 1.1	24.2 ± 0.2	7.9 ± 0.5		5.6 ± 0.5	2.8 ± 0.2	nd
sk-8	53.7 ± 0.6	26.4 ± 0.7	5.6 ± 0.4	6.8 ± 0.4	4.8 ± 0.1	2.6 ± 0.3	nd
sk-9	54.6 ± 0.5	23.5 ± 0.5	7.2 ± 0.2	7.7 ± 0.5	5.5 ± 0.1	2.6 ± 0.1	nd
sk-10	51.1 ± 0.9	22.9 ± 0.6	7.1 ± 0.3	9.5 ± 0.8	7.6 ± 0.2	2.0 ± 0.1	nd
sk-11	52.8 ± 1.1	29.3 ± 0.3	7.8 ± 0.3	6.6 ± 0.6	6.8 ± 0.1	2.6 ± 0.3	nd
sk-12	55.9 ± 1.2	25.8 ± 0.2	8.0 ± 0.2	7.0 ± 0.3	5.5 ± 0.1	2.6 ± 0.2	nd
sk-13	55.0 ± 0.9	26.3 ± 0.2	7.1 ± 0.2	6.6 ± 0.2	4.8 ± 0.2	2.8 ± 0.1	nd
sk-14	53.4 ± 1.2	24.2 ± 0.3	5.3 ± 0.6	6.4 ± 0.5	4.2 ± 0.1	2.4 ± 0.1	nd
sk-15	56.1 ± 0.7	22.4 ± 0.6	5.0 ± 0.3	9.0 ± 0.4	5.7 ± 0.2	2.6 ± 0.1	nd
Av	**53.3 ± 1.8**	**25.4 ± 1.9**	**6.5 ± 1.1**	**7.5 ± 1.1**	**5.0 ± 1.7**	**2.6 ± 0.2**	nd

[a] Average value ± standard deviation. [b] nd, not detected.

Oil Fraction. Percentages of the lipidic fraction of the sweet and bitter kernels from the 31 crops of apricot studied are listed in Table 2. Oil content, the major fraction, was in the range 40–56 g/100 g. On average terms, sweet kerneled apricots containing 53 g/100 g of oil are a less valuable source for oil than bitter kerneled apricots containing 43 g/100 g. However, because of the economical value of the oil, and due to the high percentage values of oil content, they are both valuable as raw material for oil extraction. From a physiological point of view, and due to the high percentage values, the oil content is the most appropriate variable to differentiate ($P < 0.001$) both varieties of apricot kernel.

The authors found numerous references in the literature to the composition of the lipidic fraction for apricot kernels. Studies based on bitter varieties give results that range between 37 and 49 g/100 g for the oil fraction (Aggarwall et al., 1974; Hallabo et al., 1975; Kamel and Kakuda, 1992). Values for sweet varieties ranged from 42 to 58 g/100 g (Normakhmatov, 1973; Ermakov, 1980; Gabrial et al., 1981; Javed et al., 1984; El-Aal et al., 1986b). The findings in this study are in general agreement with these results.

However, Filsoof et al. (1976) reported that there were no differences between bitter and sweet apricot kernel varieties, with an oil content of approximately 50 g/100 g. Kappor et al. (1987) obtained values of up to 67 g/100 g for oil content in sweet varieties, and a lower value (30 g/100 g) was reported by Gutfinger et al. (1972) in a bitter variety. This wide range of values could be due to either interspecies variation or climatic conditions.

The sweet kernel oil percentage can be compared with that of almond oil (58 g/100 g), whereas bitter kernel oil is more similar to that of peach kernels (45 g/100 g) (Javed et al., 1984). According to the values provided by Saura-Calixto et al. (1982), sunflower oil (54 g/100 g), pine-seed oil (55 g/100 g), and peanut oil (49 g/100 g) contents are similar to those of sweet kernels; with dried fruit oils, such as walnut oil (67 g/100 g) and hazelnut oil (68 g/100 g), percentages are shown to be higher.

The degree of unsaturation and a measure of average molecular weight of the component fatty acids are reflected in the iodine and saponification values, respectively. The fact that these values are fairly close to each other, for both oils, indicates that these oils have a similar fatty acid makeup. Therefore, iodine values of the two oils suggest the oils as semidry.

The content of unsaponifiable matter is slightly high; values between 0.1 and 0.2 g/100 g are reported for the majority of vegetable oils (Saura-Calixto et al., 1985). It should be pointed out that values for physical and chemical characteristics of the studied oils are within the same range which is reported by Saura-Calixto et al. (1985) for almond kernel oil.

Fatty acid composition of the investigated oils is given in Table 3. As can be observed, the fatty acid compositions of the two oils were similar. However, sweet kernel oil contains more oleic acid and less linoleic acid than bitter kernel. The examined oils are very rich in unsaturated acids (oleic and linoleic acids represent about 93 g/100 g of total fatty acids in both oils), and the saturated fatty acid contents were low (approximately 6 g/100 g) for bitter and sweet kernels, with

Table 3. Physicochemical Properties and Fatty Acid Composition of Lipid Extracts from Apricot Kernels[a]

	bitter kernel	sweet kernel
refractive index (20 °C)	1.4680 ± 0.003	1.4665 ± 0.004
specific gravity (20 °C)	0.926 ± 0.009	0.919 ± 0.008
saponification number	190 ± 2	192 ± 2
iodine value	107 ± 2	104 ± 2
unsaponifiables (%)	0.70 ± 0.04	0.76 ± 0.05
fatty acids (%)		
C16:0	5.4 ± 0.2	4.9 ± 0.2
C16:1	1.0 ± 0.0_3	1.0 ± 0.0_4
C18:0	1.0 ± 0.0_2	0.8 ± 0.0_3
C18:1	63.4 ± 1.9	67.6 ± 1.6
C18:2	28.8 ± 1.1	25.3 ± 0.9
total unsaturated	93.2	93.9
total saturated	6.4	5.7

[a] Average value ± standard deviation.

palmitic acid as a major fatty acid. The high concentration of linoleic acid in apricot kernel oil makes this oil of high nutritional value as linoleic acid is one of the three essential fatty acids.

The figures obtained agree to a great extent with those reported by Lotti et al. (1970), Carpenter et al. (1976), Zuercher and Hadorn (1976), Farines et al. (1986), El-Aal et al. (1986a), and Kamel and Kakuda (1992). The fatty acid composition of apricot oil can be compared with that of almond oil (Saura-Calixto et al., 1985). Apricot and peach kernel oils approximately verge on the almond oil composition. Nevertheless, although it is of the same family, prune kernel oil has a slightly different fatty acid percentage (Javed et al., 1984).

The ability of some unsaturated vegetable oils to reduce the serum cholesterol level may focus attention on the apricot kernel oil due to its high unsaturated oil content.

Protein Content. Protein contents of the apricot kernels ranged from 22.4 to 29.3 g/100 g on a dry matter (Table 2). Sweet and bitter varieties of kernels were found to contain protein, 25.8 and 26.1 g/100 g as such, respectively. Statistical analysis showed that protein content is not an appropriate variable to differentiate the two varieties of apricot kernel.

Values given for sweet and bitter kernels are equivalent to 47 and 55 g/100 g of protein, respectively, on defatted kernels. These kernels thus are able to supply proteins in a concentrated form. Our results agree closely with those reported by Normakhmatov et al. (1973), Aggarwall et al. (1974), Gabrial et al. (1981), and Yurukov et al. (1988). However, higher protein contents (37–45 g/100 g) have been reported by several authors (Kapoor et al., 1987; Kamel and Kakuda, 1992).

The quality of proteins depends on the essential amino acid content and the amount of nitrogen in the nonessential amino acids. Table 4 lists the analysis results of total amino acids expressed in milligrams per 100 g of dry matter. As can be observed, the content of each amino acid is of the same order in both varieties.

The total amino acid anaylsis revealed that sweet and bitter kernel proteins contain all of the essential amino acids and many nonessential amino acids (Table 4). Essential amino acids comprise 32–34 g/100 g (weightwise) of the total amino acids determined. Glutamic acid is the most abundant, along with arginine and aspartic acid, these being the three major nonessential constituents; collectively they account for 45 g/100 g of the total amino acids cited. This result agrees with the previous work reported by Ekpenyong (1969) and Khairy et al. (1975).

Table 4. Total Amino Acids in Apricot Kernels[a] (Milligrams of Amino Acid per 100 g of Dry Matter)

amino acid	bitter kernel	sweet kernel
essential		
isoleucine	974 ± 48	1028 ± 42
leucine	1766 ± 71	1765 ± 81
lysine	742 ± 33	679 ± 37
methionine	152 ± 6	166 ± 8
cystine	118 ± 7	167 ± 6
phenylalanine	1518 ± 64	1412 ± 69
tyrosine	764 ± 43	777 ± 44
threonine	726 ± 29	726 ± 39
valine	1196 ± 45	1201 ± 55
nonessential		
arginine	2504 ± 107	2560 ± 135
histidine	606 ± 22	594 ± 30
alanine	1268 ± 70	1195 ± 51
aspartic acid	2602 ± 169	2362 ± 86
glutamic acid	5934 ± 237	5247 ± 236
glycine	1066 ± 51	994 ± 45
proline	1362 ± 64	1273 ± 50
serine	1038 ± 57	1111 ± 63
γ-aminobutyric acid	136 ± 5	100 ± 4
ornithine	trace	trace

Table 5. Free Amino Acids in Apricot Kernels[a] (Milligrams of Amino Acid per 100 g of Dry Matter)

amino acid	bitter kernel	sweet kernel
essential		
isoleucine	17.9 ± 0.9	17.1 ± 0.9
leucine	27.1 ± 1.6	22.7 ± 1.0
lysine	10.5 ± 0.5	8.4 ± 0.5
methionine	6.7 ± 0.3	5.9 ± 0.3
cystine	1.4 ± 0.0	2.1 ± 0.1
phenylalanine	37.5 ± 1.8	34.2 ± 1.7
tyrosine	18.5 ± 0.9	20.7 ± 1.2
threonine	32.9 ± 1.8	22.9 ± 1.3
valine	36.3 ± 2.3	33.3 ± 1.4
nonessential		
arginine	29.8 ± 1.4	25.5 ± 1.3
histidine	9.9 ± 0.5	6.6 ± 0.2
alanine	78.4 ± 2.8	45.9 ± 2.2
aspartic acid	89.1 ± 4.0	54.1 ± 2.4
glutamic acid	142.0 ± 7.0	113.8 ± 6.0
glycine	16.1 ± 0.9	20.4 ± 0.5
proline	48.5 ± 2.0	50.7 ± 3.0
serine	25.7 ± 1.3	29.4 ± 1.4
γ-aminobutyric acid	78.6 ± 3.0	151.8 ± 7.0
asparagine	411.4 ± 21	131.0 ± 6.0
glutamine	29.0 ± 1.4	24.2 ± 1.1
α-aminobutyric acid	8.2 ± 0.4	9.0 ± 0.5
β-alanine	3.5 ± 0.1	4.7 ± 0.1
1-methylhistidine	trace	trace
ornithine	trace	trace

[a] Average value ± standard deviation.

The low methionine levels reported for both varieties tally with those reported by Javed et al. (1984). Due to these low values, blended with other vegetable protein or other meals, they could prove necessary for food purposes. Since tryptophan is destroyed by acid hydrolysis, it is not included in the table. According to the previously cited paper, this amino acid is present in a quantity of 0.07 g/ 100 g of defatted cake.

It should be pointed out that the results reported by Soler et al. (1989) for the total amino acid composition in almond kernels were almost identical to the total amino acid figures obtained for apricot kernels.

No references were found regarding the determination of free amino acids in apricot kernels. Free amino acid results are listed in Table 5. The free amino acid total values were very low, approximately 0.7 and 1.1 g/100 g on a dry matter basis for bitter and sweet varieties, respectively. The asparagine content was the main difference between varieties, 36 g/100 g of total free amino

Table 6. Carbohydrate Composition from Apricot Kernel AIR[a] (Micrograms of Anhydrosugar per Milligram of AIR)

component	bitter kernel	sweet kernel
rhamnose	13.2 ± 0.4	14.2 ± 0.3
fucose	5.4 ± 0.1	5.8 ± 0.1
arabinose	179.9 ± 3.2	181.0 ± 4.1
xylose	49.7 ± 1.9	51.2 ± 2.1
mannose	13.8 ± 0.5	13.2 ± 0.7
galactose	38.5 ± 1.4	36.2 ± 1.1
glucose	171.6 ± 2.2	133.6 ± 1.7
glucose (1 M)	10.4 ± 0.5	8.3 ± 0.3
uronic acid	53.3 ± 1.6	50.0 ± 1.2
total sugar	536	493

[a] Average value ± standard deviation.

acids for bitter kernels and only 16 g/100 g for sweet kernels. As amino acids that do not usually form part of the protein, the free presence of α- and γ-aminobutyric acid should be noted. Also, traces of ornithine from a decomposition of glutamic acid were found.

Fiber (NDF and ADF). The shell from the apricot seed was the main source of fiber. A study about chemical composition of this part of the seed has already been reported by the authors (Cañellas et al., 1992).

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) results are listed in the overall composition table (Table 2). NDF values ranged from 6.4 to 8.6 g/100 g for bitter kernels and from 6.4 to 9.5 g/100 g for sweet kernels. These percentages approximately comprise the content of cellulose, hemicelluloses, and lignin present in the kernels. Hemicellulose contents obtained from the difference between NDF and ADF gave values from 1.5 to 2.5 g/100 g for both sweet and bitter kernels. Pectic polysaccharides are underestimated using the NDF method, as this material is dissolved during the NDF procedure.

Sugars in the alcohol-insoluble residue (AIR), obtained from defatted kernels, were released by two hydrolytic procedures which helped to distinguish the sugars from noncellulosic polysaccharides and cellulose (Selvendran et al., 1989). It can be inferred from Table 6 that the cell walls of sweet and bitter apricot kernels mainly contain cellulose and pectic polysaccharides, in addition to considerable amounts of xylose (hemicelluloses polysaccharides).

The cellulose content appears to be slightly higher in the bitter variety. The occurrence of cellulose is deduced from the fact that the bulk of the glucose could only be released after Saeman hydrolysis. Glucose released with 1 M sulfuric acid accounted for 7 g/100 g of the total glucose. The presence of pectic polysaccharides, mainly arabinosic, can be inferred from the relatively large amounts of arabinose as well as uronic acids, galactose and rhamnose. The xylose component is likely to have arisen from the hemicellulose polysaccharides such as arabinoxylans or xyloglucans.

Although no data were found on the sugar composition of apricot kernels, the reported results are comparable to the almond carbohydrate composition found by Englyst et al. (1988), in which arabinose and cellulosic glucose are the main monosaccharides.

Soluble Sugars and Amygdalin. Results provided in the overall composition table (Table 2) show that the percentage of soluble sugars is significantly higher for bitter kernels ($P < 0.001$). As the Antrona method was used to determine soluble sugars as glucose, the difference between varieties may be due to the hydrolysis of glucoses from amygdalin molecules.

Table 7. Mineral Elements[a] (Milligrams per 100 g of Dry Matter)

	bitter kernel	sweet kernel
potassium	616 ± 11	567 ± 9
phosphorus	93 ± 3	105 ± 2
calcium	141 ± 3	145 ± 4
magnesium	209 ± 5	186 ± 5
sodium	8.8 ± 0.4	6.8 ± 0.4
zinc	5.1 ± 0.1	3.2 ± 0.1
iron	2.7 ± 0.1	2.6 ± 0.1
copper	$1.6 \pm 0.0_4$	$0.8 \pm 0.0_2$
manganese	$0.5 \pm 0.0_1$	$0.6 \pm 0.0_1$

[a] Average value ± standard deviation.

As seen in Table 2, the amygdalin content of the 16 bitter kernel crops ranged from about 4.5 to 6.5 g/100 g on a dry matter basis. It should be pointed out that these values are similar to the highest amygdalin values found in the literature for apricot kernel (Voldrich et al., 1989), and higher than the amygdalin contents reported by Stoewsand et al. (1975), Briggs and Yuen (1978), Mandenius et al. (1983), and Stosic et al. (1987).

Tasting the kernels showed that only those in which amygdalin was not detected (Table 2) were sweet, while the other kernels had a very strong, bitter flavor. Bitterness has been shown to be due to the relatively large amounts of amygdalin (Stoewsand et al., 1975). Bitter apricot kernels could be used as a source to obtain this compound due to the high amygdalin content. Therefore, bitter apricot kernels must be detoxified before being used for either feeding or food purposes. Amygdalin content found in bitter crops is equivalent to a cyanide content of about 240–350 mg/100 g of dry matter. Ingested cyanide salts have a minimum lethal dose of about 2–4 mg/kg of body weight. Several cases of cyanide poisoning by apricot kernel consumption were reported by Lasch and El Shawa (1981).

Development and cultivation of sweet apricot kernel crops would decrease health hazards and increase the marketability of this byproduct.

Mineral Elements. Apricot kernels have an ash content ranging between 2.0 and 2.9 g/100 g (Table 2). Similar values have been reported by Hallabo et al. (1975), Kapoor et al. (1987), and Yurukov et al. (1988). There are many factors which may affect the concentration of various elements in plants. These include the nature of the element, its content and form in the soil, the soil type and pH, the crop variety, proximity to external sources of pollution, and many other factors.

As can be observed in Table 7, the mineral element compositions are similar for both varieties of kernel, the greatest absolute difference being in potassium. This element together with phosphorus, magnesium, and calcium, accounts for 1100–1200 mg/100 g, which represents about 40 g/100 g of the ashes in both varieties. The other essential elements, iron, manganese, copper, and zinc, account for 7–9.5 mg/100 g. Higher concentrations of iron, manganese, and zinc were reported by Furr et al. (1979).

The high quantity of potassium, phosphorus, magnesium, and calcium, together with the small proportion of sodium plus the content of the essential elements iron, manganese, copper, and zinc allows the apricot, as well as the almond, to be considered as an excellent source of bioelements (Saura-Calixto et al., 1982).

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