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Total protein and amino acid compositions in the acorns of Turkish *Quercus* L. taxa

Tamer Özcan*
*Department of Biology, Division of Botany, Faculty of Science, Istanbul University, 34460 Istanbul, Turkey; *E-mail: tameroz@istanbul.edu.tr; phone: +90-212-4555700/26811; fax: +90-212-5226562*

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Abstract

Total protein content and level of 14 amino acid in mature acorns of 20 *Quercus* taxa from Turkey were studied. The range of total protein amounts between 2.75 and 8.44% were detected among taxa. Similar values in related species and variety level were observed. The amino acid profiles for each taxon were characteristically different and high variability of individual amino acid concentration was present at variety, subspecies and species levels. Different amino acid concentrations, relative percentages and critical values of some amino acids are thought to be additional considerable parameters for diagnosis of *Quercus*. Generally higher total quantity of amino acids in section *Quercus* and lower values in section *Ilex* were observed. When the essential and non-essential amino acids are expressed as a relative percent of total protein indicating quality of proteins, the ratios varied significantly among taxa ($p < 0.05$). But, no significant difference at section level were detected. Major amino acids were aspartic acid and glutamic acid showing the largest variations and the lowest levels were detected for methionine. Amino acid concentrations ranged from 1665 for aspartic acid to 13 mg/100 g dry wt. for methionine. All taxa had relatively higher amounts of leucin, lysin and valine than other essential amino acids. The highest quantity of protein and amino acids was recorded for *Q. infectoria* ssp. *boissieri* and the lowest for *Q. pontica*. The level of all essential amino acids in examined taxa was not sufficient compared to FAO scoring pattern for children (1985). But, threonine and valine in *Q. infectoria* ssp. *boissieri* and isoleucine in *Q. petraea* ssp. *iberica* show remarkable concentrations to the requirements. All examined essential amino acids among taxa generally provide adequate levels for adults according to FAO standard.

Introduction

Oaks include a wide genus of about 500 species of trees and shrubs in the Northern Hemisphere, exclusive of the Arctic; about half of these are in the New World. It was reported that *Quercus* as an extremely important genus for phytogeographer, forester and ecologist is one of the most problematical groups in the Turkish flora. Widespread hybridisation and introgression have much obscured specific limits (Browics 1982; Hedge and Yaltrk 1982; Yaltrk 1984). Eighteen species native for Turkey make large forests of 6.5 million ha in the Thrace and Anatolia totally with its subspecies, varieties and natural hybrids (Soykan 1969). Apart from a variety of hardwood for use in furniture and manufacturing, oak trees provide fodder for animals (acorns and leaves), cork for insulation and many other purposes such as erosion control, fuelwood, food for wildlife and wildstock. Acorns have been used as food by *Homo sapiens* for thousands of years virtually everywhere oaks are found (Bainbridge 1986; Lieutaghi 1998). They occur in the early town sites in the Zagros Mountains and at Catal Huyuk (6000 BC) and were a staple food for many people until after AD 1900 in Europe, Asia, North Africa, the Middle-East, and North America (Loudon 1844; Bishop 1891; Lefevbre 1900; Hedrick 1919; Brandis 1972; Bainbridge 1986). The Ch'i Min Yao Shu, a Chinese agricultural text from the sixth century recommends *Quercus mongolica* as a nut tree (Shen Han 1982). In Spain and Italy acorns provided 20% of the diet of many people just before the turn of the Century (Memmo 1894; Hill 1937). For many of the native Californians acorns made up half of the diet (Heizer and Elsasser 1980). Acorns are a perennial 'grain' crop that can play an important role in restoring degraded lands and feeding hungry and malnourished people. The sweet acorns from many species of oaks are edible raw, just as they are harvested (Michaux 1810; Loudon 1844; Hedrick 1919; Smith 1950; Ofcarcik et al. 1971; Bohrer 1972; Brandis 1972; Chestnut 1974; Coyle and Roberts 1975; Bainbridge 1984; Bainbridge and Asmus 1986). In some studies, nutritional value of the acorns including crude protein contents of *Q. kelloggii* (Duncan and Clawson 1980), *Q. alba* (Vogt and Cox 1970; Vogel 1990), *Q. incana* (Short 1976) were reported. *Quercus* acorns were declared to include many essential amino acids (Videl and Varela 1969; Luk'yanets 1978) and the quality of proteins as measured by the essential amino acid composition varied considerably among species (Boren et al. 1995). Acorns varieties of 12 oak species from Texas were analysed for chemical and physical properties including crude protein and the results at the variety and species level showed significant differences (Ofcarcik and Burns 1971). High nutritional qualities and the variations in the concentrations of amino acids and total protein percents in the acorns of 18 species were also reported from California and reported that minor deficiencies can probably be rectified with complementary legumes, fish, or meats (Bainbridge 1986). In the study on *Q. brantii* distributing in Zagros mountains, it was established that acorn have a very low crude protein and relatively high starch and crude fat content. Their amino acid composition is very poor; their protein contains very few sulphur containing amino acids. Amino acid contents of the acorns from different climates was also reported to be almost the same, although significantly different protein amounts were detected (Saffarzadeh et al. 1999). Proximate analyses have revealed chemical compositions of acorns to be similar to that of cereals (Wanio and Forbes 1941; Baumgras 1944). Amino acid analyses have suggested that acorn protein is more nutritious than that pecans (Racia et al. 1956). Starch is the main component of acorns, amounting to over 55% of the kernel (Saffarzadeh et al. 1999). The acorns are extremely important wildlife food, and are the primary overwintering food for a great many species of birds and mammals. They have been used for feeding livestock for many thousands of years. Most acorns, even without leaching, was reported be fed up to 20% of the ration of chickens (Weingarten 1958; Medina and Aparico 1965; Varela et al. 1965; Boza et al. 1966). *Q. infectoria* was favoured in Iraq where it was pollarded for better fodder production (Blakelock 1950). On the other side, acorns contain considerable amounts of tannin and other anti-nutritional substances. Given in large amounts they may be toxic. Poisoning of cattle has been recorded. Rations with containing over 25% acorn meal result in eggs with coloured yolks and low hatchability (De Boer and Bickel 1988). Some anti-nutritional factors in the acorns of *Q. brantii* from different climatic region were examined and declared that while tannin content of this species could lead to limitation and negative effect in animal nutrition, urease enzyme activity was almost negligible for human and animal consumption (Saffarzadeh 2000). Acorn of the white oak groups are only slightly bitter and, after leaching out tannin, the flour produced can be used for the baking of cakes and bread (Fernand and Kinsey 1943). The acorns of 18 species growing in Turkey are collected in the name of 'palamut' and three taxa especially, *Q. cerris* L., *Q. ithaburensis* Decne ssp. *macrolepis* (Kotschy) Hedge et Yalt. and *Q, robur* L. have utility in public medicine. Some species are also used as animal feed in Anatolia (Baytop 1999). Acorn of oaks having great importance for Turkey were not investigated previously in terms of its any chemical composition. The database of the nutrient compositions of these wild plant product is not present. In this work carried out for the first time in Turkey, total protein content and amino acid composition of the mature acorns of 20 *Quercus* taxa as alternative food reserve were studied in order to observe its different source potential for examined contents and provide some information for the essential amino acid requirements of FAO.

Materials and Methods

The twigs of 20 *Quercus* taxa namely; *Q. pontica* C. Koch., *Q. robur* L. ssp. *robur*, *Q. hartwissiana* Steven., *Q. frainetto* Ten., *Q. petraea* (Mattuschka) Lieb. ssp. *petraea*, *Q. petraea* (Mattuschka) Lieb. ssp. *iberica* (Steven ex Bieb.) Krassiln., *Q. vulcanica* (Boiss. et Heldr. ex) Kotschy, *Q. infectoria* Olivier ssp. *infectoria*, *Q. infectoria* Olivier ssp. *boissieri* (Reuter) O. Schwarz, *Q. pubescens* Willd., *Q. virgiliana* Ten., *Q. cerris* L. var. *cerris, Q. cerris* L. var. *austriaca* (Willd.) Loudon, *Q. ithaburensis* Decne. ssp. *macrolepis* (Kotschy.) Hedge et Yalt., *Q. brantii* Lindl., *Q. libani* Olivier, *Q. trojana* P.B. Webb., *Q. ilex* L., *Q. aucheri* Jaub. et Spach, *Q. coccifera* L., bearing mature acorns collected from 5 to 6 individual trees living in their natural distribution areas in Marmara, north Anatolia, Aegea, Mediterranean region and south-east Anatolia of Turkey between August and October 2001. Collected specimens were made herbarium material by means of well-known method and determined with using the Flora of Turkey and identified specimens from Istanbul University, Faculty of Science (ISTF) and Faculty of Forestry (ISTO) herbarium. Voucher specimens were deposited in Botany section of Faculty of Science of the University. Mature acorns of each *Quercus* taxon were dehulled and the kernels (dicotyledons) were ground into meal and dried. Kjeldahl method (AOAC 1990) was used for analysing of total protein amount. Total nitrogen was determined by Kjeldahl analysis and converted to crude protein by multiplying the percent nitrogen by 6.25. The samples according to standard method were hydrolysed at 110 ± 1 °C with 6 N HCl for 24 h and amino acid composition of the samples were determined by Eppendorf LC 3000 amino acid analyser (EzChrom manual). All statistical analysis (for $p < 0.05$ significance level) were carried out by using a statistical package programme (SPSS ver.10.0). The results obtained were presented in two tables based on the taxonomical categories.

Results

Analytical data derived from examined acorn samples show a considerable variation for crude protein and amino acid composition (Tables 1 and 2). Total protein amounts between 2.75 and 8.44% in studied taxa were obtained. The highest level of total protein was detected in *Q. infectoria* ssp. *boissieri*, while the lowest measurement value was observed in the acorns of *Q. pontica*. In the Flora of Turkey, oaks are divided into three distinct categories according to anatomical structures of their woods, maturing period of the fruits and the features of leaf and cork; white oaks (Section Quercus), red oaks (Section Cerris) and evergreen oaks (Section Ilex) (Yaltrk 1984).When the results obtained are evaluated on the basis of section, species, subspecies and variety levels, it is possible to observe differences and similarities in each taxonomic level. Average values of 5.11% in Section Quercus, 4.22% in Section Cerris and 3.35% in Section Ilex were detected. But difference at section level is not significant. Two subspecies of *Q. petraea* with the measurement values of 4.38 and 7.15%, and two subspecies of *Q. infectoria* having total percent of 6.61 and 8.44 in protein concentrations of their acorns from Section Quercus are considerable from the point of subspecific differences. On the other hand, very similar results for protein contents were obtained in two varieties of *Q. cerris* from Section Cerris. The largest variation in total protein percent in taxa from Section Quercus were observed. The closest values were examined in those of Section Ilex. Section Cerris has however moderate level of variation. Very similar results as close related species in *Q. brantii*, *Q. libani*, *Q. trojana*, but relatively higher value for *Q. ithaburensis* ssp. *macrolepis* from this section were determined.

On the other hand, considerable differences for each individual amino acid concentrations in the taxonomic categories were observed. High amount of total quantities of amino acids in Section Quercus, low values in Section Ilex and moderate levels in Section Cerris were detected generally for all amino acids. But, no significantly differences on both dry mass basis and relative percents of amino acids were calculated at section level. The average amino acid profile of the proteins in acorn kernels is given in both tables. Considerable differences in related species in addition to subspecific and

Table 1. Total protein percents, essential amino acid concentrations (mg/100 g dry wt.) expressed additionally as its relative percents in paranthesis for the acorns of examined taxa and comparison of the values with FAO/WHO/UNU (1985) estimates of amino acid requirements in children and adults.

Taxa/amino acid	thr	val	met	ile	leu	tyr	phe	lys	% protein
Section Quercus (averages)	**155 (3.03)**	**193 (3.77)**	**27 (0.52)**	**156 (3.05)**	**245 (4.79)**	**86 (1.68)**	**171 (3.34)**	**208 (4.07)**	**5.11**
Q. pontica	84 (3.05)	114 (4.14)	33 (1.20)	82 (2.98)	133 (4.83)	50 (1.81)	82 (2.98)	136 (4.94)	2.75
Q. robur ssp. *robur*	154 (2.48)	234 (3.38)	36 (0.52)	187 (2.70)	327 (5.28)	95 (1.53)	208 (3.36)	207 (3.34)	6.19
Q. hartwissiana	104 (1.98)	183 (3.45)	25 (0.47)	146 (2.78)	240 (4.57)	73 (1.39)	160 (3.04)	184 (3.50)	5.25
Q. frainetto	153 (3.65)	196 (4.67)	24 (0.57)	175 (4.17)	284 (6.77)	77 (1.83)	208 (4.96)	159 (3.79)	4.19
Q. petraea ssp. *petraea*	144 (3.28)	190 (4.33)	23 (0.52)	143 (3.26)	244 (5.57)	70 (1.59)	158 (3.60)	225 (5.13)	4.38
Q. petraea ssp. *berica*	185 (2.59)	226 (3.16)	23 (0.32)	204 (2.86)	264 (3.70)	120 (1.68)	212 (2.97)	280 (3.92)	7.13
Q. vulcanica	108 (3.19)	126 (3.66)	15 (0.43)	97 (2.81)	164 (4.76)	47 (1.36)	111 (3.22)	148 (4.30)	3.44
Q. infectoria ssp. *infectoria*	164 (2.48)	216 (3.26)	22 (0.33)	173 (2.61)	269 (4.06)	123 (1.86)	192 (2.90)	285 (4.31)	6.61
Q. infectoria ssp. *boissieri*	252 (2.98)	264 (3.12)	55 (0.65)	185 (2.19)	258 (3.05)	110 (1.30)	262 (3.10)	311 (3.68)	8.44
Q. pubescens	201 (4.86)	211 (5.10)	31 (0.75)	183 (4.43)	292 (7.07)	106 (2.56)	209 (5.06)	229 (5.54)	4.13
Q. virgiliana	156 (4.16)	163 (4.34)	13 (0.34)	141 (3.76)	219 (5.84)	75 (2.00)	159 (4.24)	120 (3.20)	3.75
Section Cerris (averages)	**140 (3.31)**	**168 (3.98)**	**34 (0.80)**	**129 (3.05)**	**193 (4.57)**	**09 (2.58)**	**145 (3.43)**	**221 (5.23)**	**4.22**
Q. cerris var. *cerris*	94 (3.07)	127 (4.15)	22 (0.71)	89 (2.90)	145 (4.73)	57 (1.86)	89 (2.90)	160 (5.22)	3.06
Q. cerris var. *austriaca*	172 (5.49)	156 (4.98)	26 (0.83)	138 (4.40)	114 (3.64)	92 (2.93)	153 (4.88)	210 (6.70)	3.13
Q. ithaburensis ssp. *macrolepis*	174 (2.72)	177 (2.77)	29 (0.45)	141 (2.21)	231 (3.62)	115 (1.80)	162 (2.53)	218 (3.41)	6.38
Q. brantii	143 (3.41)	185 (4.41)	64 (1.52)	155 (3.69)	251 (5.99)	208 (4.96)	158 (3.77)	214 (5.10)	4.19
Q. libani	145 (3.36)	172 (3.99)	20 (0.46)	111 (2.57)	212 (4.91)	79 (1.83)	165 (3.82)	307 (7.12)	4.31
Q. trojana	109 (2.56)	191 (4.49)	43 (1.01)	140 (3.29)	206 (4.84)	101 (2.37)	144 (3.38)	217 (5.10)	4.25
Section Ilex (averages)	**122 (3.64)**	**155 (4.62)**	**35 (1.04)**	**119 (3.55)**	**186 (5.55)**	**87 (2.59)**	**97 (2.89)**	**163 (4.86)**	**3.35**
Q. ilex	118 (3.63)	164 (5.04)	46 (1.41)	116 (3.56)	193 (5.93)	72 (2.21)	140 (4.30)	193 (5.93)	3.25
Q. aucheri	157 (4.25)	198 (5.36)	26 (0.70)	146 (3.95)	245 (6.63)	106 (2.87)	73 (1.97)	179 (4.85)	3.69
Q. coccifera	90 (2.87)	103 (3.29)	34 (1.08)	94 (3.00)	121 (3.86)	82 (2.61)	79 (2.52)	18 (3.76)	3.13
Range of variation	84–252	103–264	13–64	82–204	114–327	50–208	73–262	118–311	2.75–8.44
2–5 years	340	350	250[a]	280	660	630[b]	–	580	–
10–12 years	280	250	220[a]	280	440	220[b]	–	440	–
Adult (18 + years)	90	130	170[a]	130	190	190[b]	–	160	–

[a] Total amount of methionine and cysteine.
[b] Total amount of tyrosine and phenylalanin.

variety level were also detected for each amino acid concentrations. When the results are expressed as a percent of total proteins indicating quality of proteins, the ratios varied among taxa and sections. Significant differences were calculated on dry mass basis and relative percents of amino acids among taxa ($p < 0.05$). Two subspecies of *Q. petraea* and *Q. infectoria* and two variety of *Q. cerris* show generally different amino acid concentrations and the relative percentages. *Q. petraea* ssp. *iberica* show generally higher concentrations for each individual amino acid than ssp. *petraea* in accordance with its higher total protein percent. But, relative percent of all amino acids except for aspartic acid is remarkably high in *Q. petraea* ssp. *petraea*. Generally close values of the amino acid percentages between the subspecies of *Q. infectoria* and differently for leucine, aspartic acid and alanine were observed. *Q. infectoria* ssp. *boissieri* has higher values in the concentrations except for leucin, tyrosine and alanine than ssp. *infectoria*, as parallel with its higher total content of protein. The ratios of all amino acids except for valine and methionine show remarkable fluctations between two varieties of *Q. cerris*. Concentration and the relative percents of all amino acids out of leucin in *Q. cerris* var. *austriaca* were detected higher than var. *cerris*. Especially aspartic acid concentrations and its relative percents provide discriminative values between varieties and subspecies. In the related species having similar total protein percents, aspartic acid, glutamic acid, histidin, threonine in *Q. ithaburensis* ssp. *macrolepis*, serine, alanine, methionine, isoleucin, leucin, tyrosine in *Q. brantii*, glycine, lysine, phenylalanin in *Q. libani* and valin in *Q. trojana* have the highest quantities among each others. Valin, isoleucin, leucin, phenylalanin, serine show relatively similar

Table 2. Total protein percents, non-essential amino acid concentrations (mg/100 g dry wt.) and its relative percents in paranthesis for the acorns of examined taxa.

Taxa/amino acid	asp	ser	glu	gly	ala	his	% protein
Section Quercus (average values)	**696 (13.62)**	**177 (3.46)**	**518 (10.13)**	**107 (2.09)**	**194 (3.79)**	**167 (3.26)**	**5.11**
Q. pontica	204 (7.41)	84 (3.05)	38 (8.65)	44 (1.60)	108 (3.92)	627(22.80)	2.75
Q. robur ssp. *robur*	524 (8.46)	173 (2.79)	686 (11.08)	122 (1.97)	227 (3.66)	140 (2.26)	6.19
Q. hartwissiana	517 (9.84)	111 (2.11)	525 (10.00)	90 (1.71)	169 (3.21)	113 (2.15)	5.25
Q. frainetto	454 (10.83)	168 (4.00)	589 (14.05)	80 (1.90)	194 (4.63)	82 (1.95)	4.19
Q. petraea ssp. *petraea*	564 (12.87)	164 (3.74)	470 (10.73)	109 (2.48)	179 (4.08)	114 (2.60)	4.38
Q. petraea ssp. *iberica*	1143 (16.03)	230 (3.22)	660 (9.25)	138 (1.93)	312 (4.37)	170 (2.38)	7.13
Q. vulcanica	311 (9.04)	120 (3.48)	309 (8.98)	60 (1.74)	142 (4.12)	72 (2.09)	3.44
Q. infectoria ssp. *infectoria*	1003 (15.17)	191 (2.89)	502 (7.59)	138 (2.08)	246 (3.72)	147 (2.22)	6.61
Q. infectoria ssp. *boissieri*	1665 (19.72)	282 (3.34)	689 (8.16)	187 (2.21)	168 (1.99)	159 (1.88)	8.44
Q. pubescens	737 (17.84)	247 (5.98)	592 (14.33)	119 (2.88)	202 (4.89)	121 (2.92)	4.13
Q. virgiliana	539 (14.37)	182 (4.85)	436 (11.62)	88 (2.34)	190 (5.06)	97 (2.58)	3.75
Section Cerris (average values)	**494 (11.70)**	**140 (3.31)**	**445 (10.54)**	**198 (4.69)**	**183 (4.33)**	**110 (2.60)**	**4.22**
Q. cerris var. *Cerris*	227 (7.41)	94 (3.07)	205 (6.69)	71 (2.32)	123 (4.01)	72 (2.35)	3.06
Q. cerris var. *austriaca*	386 (12.33)	189 (6.03)	381 (12.17)	101 (3.22)	182 (5.81)	108 (3.45)	3.13
Q. ithaburensis ssp. *macrolepis*	786 (12.31)	145 (2.27)	652 (10.21)	296 (4.63)	196 (3.07)	145 (2.27)	6.38
Q. brantii	638 (15.22)	162 (3.86)	353 (8.42)	164 (3.91)	248 (5.91)	106 (2.52)	4.19
Q. libani	482 (11.18)	123 (2.85)	564 (13.08)	325 (7.54)	203 (4.70)	107 (2.48)	4.31
Q. trojana	443 (10.42)	124 (2.91)	512 (12.04)	231 (5.43)	147 (3.45)	119 (2.80)	4.25
Section Ilex (average values)	**320 (9.55)**	**125 (3.73)**	**315 (9.40)**	**141 (4.20)**	**140 (4.17)**	**121 (3.61)**	**3.35**
Q. ilex	314 (9.66)	121 (3.72)	321 (9.87)	214 (6.58)	130 (4.00)	102 (3.13)	3.25
Q. aucheri	460 (12.46)	148 (4.01)	409 (11.08)	84 (2.27)	193 (5.23)	111 (3.00)	3.69
Q. coccifera	186 (5.94)	106 (3.38)	216 (6.90)	124 (3.96)	98 (3.13)	150 (4.79)	3.13
Range of variations	186–1665	84–247	205–689	44–325	98–312	72–170	2.75–8.44

Each value in the tables is the average of duplicate determinations.

concentrations apart from others. All amino acid percents except for histidine in these species are considerably different. It was observed differences of the concentrations and relative percents of amino acids in the other taxonomically related species, *Q. robur* ssp. *robur*, *Q. hartwissiana*, *Q. frainetto*, *Q. petraea* and *Q. vulcanica*. Aspartic acid and glutamic acid values especially have remarkable variations. Different amino acid profiles in three related species from Section Ilex were also observed. Nine amino acids were detected in the highest amounts in *Q. aucheri*, endemic for Turkey, but, methionine, phenylalanin, lysine, glycine in *Q. ilex* and histidine in *Q. coccifera* were found high. These related species have different percentage of amino acids generally, but high variations of the percents especially in aspartic acid, glutamic acid, glycine, leucine, phenylalanin and lysine were obtained. All values based on relative percents of amino acids among taxa except for *Q. pontica* and *Q. robur* ssp. *robur* are correlated significantly ($p < 0.01$). *Q. pontica* is significantly correlated positively with *Q. coccifera* only ($p < 0.05$) and *Q. robur* ssp. *robur* has no correlation significantly with all other taxa.

Q. vulcanica, the other endemic species for Turkey show very low measurement values secondly from Section Quercus compared to *Q. pontica*. Amino acid concentrations in all taxa ranged from 1665 (mg/100 g dry wt.) for aspartic acid to 13 for methionine. While the lowest values in examined amino acids belong methionin, the highest ones were obtained from leucin among essential amino acids for all species generally. Lycine and valine have also higher values. On the other hand, the highest concentrations of aspartic acid and the lowest levels of histidin except for *Q. pontica* were observed among non-essential amino acids in examined species. The larger variations in the concentration of leucin (114–327), lycine (118–311), phenylalanine (73–262), aspartic acid (186–1665) and glutamic acid (205–689) were detected. Total quantity of protein and amino acids in *Q. infectoria* ssp. *boissieri* is higher than the other taxa. The most similar values to this taxon were obtained from subspecies *infectoria*. *Q. pontica* has contrarily lowest total protein and amino acid contents except for histidine. The concentrations of leucine, lycine, valine, aspartic acid and glutamic acid in all taxa show relatively higher values. The extremely high values were obtained from *Q. petraea* ssp. *iberica* and two subspecies of *Q. infectoria* for aspartic acid. Aspartic acid (5.94–19.72) and glutamic acid (6.69–14.33) are highly variable concentrated non-essential amino acids as the basis of relative percents. Leucine and lysine among essential amino acids are also relatively variable in their percents. It was obtained remarkable high ratios from *Q. cerris* var. *austriaca* for threonine and serine, *Q. pubescens* for leucine, *Q. brantii* for tyrosine, *Q. libani* for lysine and glycine, *Q. infectoria* ssp. *boissieri* for aspartic acid and *Q. pontica* for histidine.

The amounts of all essential amino acids from examined taxa are not sufficient compared to FAO reference values for preschool child. But, threonine and valine in *Q. infectoria* ssp. *boissieri* and isoleucine in *Q. petraea* ssp. *iberica* show considerable concentrations. On the other hand, the levels of threonine, valine, isoleucine, leucine, lysine, tyrosine and phenylalanin in the acorns of all taxa generally show adequate patterns for the requirements of adults (FAO/WHO/UNU 1985). Additionally, *Q. pubescens* for threonine, *Q. robur* ssp. *robur*, *Q. petraea* ssp. *iberica*, *Q. infectoria* ssp. *infectoria* and *Q. pubescens* for valine, *Q. robur* ssp. *robur*, *Q. infectoria* ssp. *boissieri*, *Q. pubescens*, *Q. frainetto*, *Q. infectoria* ssp. *infectoria* for isoleucin, *Q. robur* ssp. *robur* for leucin, *Q. infectoria* ssp. *boissieri* for phenylalanin and lysine and *Q. libani* for lysine respectively have also very close values for amino acid requirements of FAO.

Discussion

Oaks are divided into two subgenera: Lepidebalanus (white oaks) and Erythrobalanus (black oaks). These subgenera differ in several ways, but most importantly for seed considerations. They differ in time required for fruit maturation, chemical composition of their stored food reserves and degree of dormancy (Bonner and Vozzo 1987). The chemical composition of seeds is determined ultimately by genetic factors and hence varies widely among species and their varieties and cultivars (Bewley and Black 1994). Considerable differences in section, species and subspecies levels for total percent of protein and close values in related taxa were observed in this work. In a study to determine extent of variation in nutrient content, annual growth stems of *Q. gambelii* from nine geographic area in Colorado was analysed for dry matters including crude protein and reported that coefficients of variation among area were less than 10% in this species (Roland et al. 1981). It was declared that no significant diversity within the population of the same species, however xerophytic species within a genus contain higher protein and amino acid contents (Amer and Sheded 1998). In the study on *Q. brantii* from Zagros mountain, crude protein percents of acorns proved lowest (3.7) in those from the tropical climate and highest (4.3) from cold climate (Saffarzadeh et al. 1999). Difference was reported to be significant. Percent of total protein for the same species was detected as 4.19% from south-east Turkey in this study.

On the other hand, the global amino acid composition of a protein, although a cruder variable than sequence, is nevertheless informative and has been correlated with protein structural class (Ojasso and Dore 1996). Comparing with above study, our values on *Q. brantii* for amino acid amounts show parallel results generally. Slightly higher values than that of Saffarzadeh et al. (1999) for methionine, tyrosine, lysine, aspartic acid, serine, alanine and histidine, and lower ones for other amino acids were detected. Due to the very low crude protein content of acorns, the total quantity of amino acids in the same study was reported to be very low, approximately half that of corn. Bolton et al. (1976) stated that the amino acid composition of unfractionated leaf protein is controlled by genetic rather than by environmental factors. It may be expressed that composition of amino acids show the basis for a structural protein taxonomy well related to the biological classification. Different amino acid profile reflect the specific characteristics of a protein. Variation of protein amino acid profile from high taxonomic categories to cultivars in different plant groups were reported to have taxonomically intelligible patterns (Watson and Creaser 1975; Yeoh et al. 1984; Yeoh et al. 1986; Brown and Jeffrey, 1992; Amer and Sheded 1998; Pedo et al. 1999; Cook et al. 2000; Liang et al. 2001). It was reported that proteins having great diversity and different pathways in any plant groups as characteristic macromolecules in taxonomy are reserved in embriyonic or extraembriyonic tissuse of the seeds in different taxa as different amounts and genetically controlled, little effected from environmental conditions in maturing period (Hawkes 1967; Bewley and Black 1994). Valuable informations with comparing the protein contents of homolog organs of different plant taxa could be provided in taxonomical studies (Hawkes 1967). In a few investigations carried out on the proteins of different tissues of *Quercus* from taxonomical point of view, electrophoretic differentiations, inheritance of isoenzymes and allozyme characterisation (Bordacs and Koranyi 1993; Müller-Starck et al. 1996; Toumi and Lumaret 2001) in addition to distribution of chloroplast DNA variation in *Q. robur* and *Q. petraea* were tested (Cottrell et al. 2002). But no any study on amino acid profiles of acorns in taxonomy of *Quercus* at specific or infraspecific levels and its taxonomical utility has been published. *Quercus* acorns were declared to include many essential amino acids (Videl and Varela 1969; Luk'yanets 1978) and the quality of proteins as measured by the essential amino acid composition varied considerably among species (Boren et al. 1995). Acorns varieties of 12 oak species from Texas were analysed for chemical and physical properties including crude protein and the results at the variety and species level showed significant differences (Ofcarcik and Burns 1971). High nutritional qualities and the variations in the concentrations of amino acids and total protein percents in the acorns of 18 species were also reported from California (Bainbridge 1986). The compositions and the amounts of amino acids as stable and reliable parameter giving more specific information for any protein in the solution of taxonomical problems have significant importance. Re-organisation and analyses of extensive published data on protein amino acid compositions of cereal grains and dicotyledonous leaves have elicited taxonomically intelligible patterns. In the study on 12 ecologically different *Senna* populations representing four species, protein and amino acids content were determined in order to study the relative similarity and ecological variation among the studied samples. The results revealed that no significant diversity within the population of the same species, however, interspecific variations are notable (Amer and Sheded 1998). It was reported the morphological descriptors and amino acid composition analysis to be complementary methods for the characterisation of cultivars (Pedo et al. 1999; Asensio et al. 2002). Contrarily, four different cultivar samples of *Lupinus albus* seeds were studied for chemical contents including amino acid composition and concluded that amino acid profile of four samples of lupin seeds were similar (Moss et al. 2001). The amino acid composition of the total protein fraction in cereal grains is strongly influenced by the nature of the major storage proteins (Bewley and Black 1994). In cereal grains, leucine and alanine levels are lower in festucoids than in other grasses, while those of lysine and glycine are higher. Chloridoid grasses, in the middle of grass classifications, have intermediate levels of leucine and alanine. In dicotyledone leaves there is patternisation of quantitative data on isoleucine, lysine, cystine, phenylalanine, alanine, aspartic acid, glutamic acid, glycine and serine. It was reported that protein from *Q. rotundifolia* and *Q. suber* from Spain seems to have a similar amino acid profile, however glycine and proline concentrations were higher and arginine content lower in the protein from the acorn of *Q. rotundifolia* (Nieto et al. 2002). In this study, generally higher amino acid concentrations as average values in Section Quercus than other two section except for tyrosine, lysine and glycine are considerable. However, moderate levels in Section Cerris and lowest values in Section Ilex were observed. Striking fluctuations in the amino acids are thought to reflect different structures and taxon specific characteristics of the proteins. Significantly differences at variety and subspesific levels especially in addition to interspecific variations were detected from the points of dry mass basis and relative percents implying its diagnostic utility. All individual amino acid except for histidine in related taxa *Q. ithaburensis* ssp. *macrolepis*, *Q. brantii*, *Q. libani*, *Q. trojana* show different relative percents. But, some close values may be explained with phylogenetic affinity (Hedge and Yaltrk 1982). The lowest total protein and amino acid contents and highest histidine values were examined in *Q. pontica*, deciduous tall shrub, that is a relict species, varying little in its characters and quite distinct among all other Turkish oaks on account of leaf characteristics (Hedge and Yaltrk 1982). On the other side, concentrations and relative percents of nine amino acid in *Q. aucheri* that is endemic according to Flora of Turkey show considerable higher values compared to other two species from Section Ilex.

Q. coccifera has generally lowest concentrations from same section. Varying proportions of these amino acids at lower and higher taxonomic categories generally may account for the distinct nature of the proteins. Stability and percents of the variations of these parameters are needed to determine for a species from different localities. However, amino acid contents of the acorns from different climates in the study on *Q. brantii* distributing in Zagros mountains was reported to be almost the same, although significantly different protein amounts were detected (Saffarzadeh et al. 1999). The stage of maturity of the acorns is the other factor showing final contents of the specimens. It is probable that highly variable concentrations of some amino acids may be of significance for delineations of *Quercus* at specific and infraspecific level especially as a diagnostical parameter. Differences of the concentrations in addition to relative percents and critical values of amino acids may reflect some qualities of proteins in individual taxa of *Quercus*. Leucine, aspartic acid and alanine are considerable parameters for delineations of both subspecies of *Q, infectoria*. Generally, aspartic acid concentrations and its relative percents provide some discriminative values at variety and subspecific level.

On the other hand, nutritive potential value of acorns has significant importance as a relatively rich sources of some amino acids. Particular focus is given to the lysine requirements of adults, since this indispensable amino acid is most likely to be limiting in the cereal-based diets characteristic of populations in large areas of the developing world (Young and Pellett 1990; Hoshiai 1995). Considerable amount of lysine were observed in *Q. infectoria* ssp. *boissieri*, *Q. libani*, *Q. infectoria* ssp. *infectoria* and *Q. petraea* ssp. *iberica* respectively. It was declared that total seed protein in barley is reported to be quantitatively inherited (Olsen 1974) and high lysine content is due to the recessive monogenic effect (Karlsson 1972). On the other hand, proline, glycine, arginine and lysine amino acids were reported to be accumulated in xerophytic species than mesophytic ones (Amer and Sheded 1998). High glycine and lysine content generally in two subspecies of *Q. petraea* and *Q. infectoria*, *Q. ithaburensis* ssp. *macrolepis*, *Q. libani*, *Q. brantii*, *Q. trojana* and *Q. pubescens* having xeromorphic structure were detected in this study. Remarkable higher lysine contents in *Q. petraea* ssp. *iberica*, *Q. infectoria* ssp. *infectoria*, *Q. infectoria* ssp. *boissieri*, *Q. libani* comparing to corn and *Q. petraea* ssp. *petraea*, *Q. pubescens*, *Q. ithaburensis* ssp. *macrolepis*, *Q. brantii*, *Q. trojana* in addition to above species than sorghum were measured. It was obtained similar values from *Q. cerris* var. *austriaca* and *Q. infectoria* ssp. *boissieri* with sorghum and wheat individually for lysine (Saffarzadeh et al. 1999). Lysine concentrations of all taxa except for *Q. pontica*, *Q. vulcanica* and *Q, coccifera* could be favourably compared with FAO scoring patterns for adults. Additionally, both subspecies of *Q. infectoria*, *Q, libani* and *Q. petraea* ssp. *iberica* have remarkably higher concentrations. Regarding taxa may be evaluated as a favourably sources for this essential amino acid. Detected histidine concentration in *Q. pontica* show considerably higher level compared to with some cereal grains. Moreover, higher aspartic acid levels from *Q. petraea* ssp. *iberica* and both subspecies of *Q. infectoria* than maize, barley and oats were observed (Bewley and Black 1994; Saffarzadeh et al. 1999). Acorns examined here generally deficient in sulphur containing amino acids and have high concentrations of aspartic acid and glutamic acid in all taxa. The levels of threonine and valine in *Q. infectoria* ssp. *boissieri* showing the highest total quantity of protein and amino acids generally and isoleucin in *Q. petraea* ssp. *iberica* is adequate according to FAO reference values (1981). Many taxa examined here show very close values of essential amino acids compared to the requirements, expressing valuable nutritious potential of this product. Acorns are also valuable feed for domestic animals and birds, and wildlife. In oak species, acorns constitute an important source of mast for many small birds and mammals in some Arizona locations. Acorns are utilized by the collared peccary, wild turkey, numerous rodents such as Abert's squirrel, geese, grouse, quail, scrub jays, and many other birds (Van Dersal 1940; Pase 1969; Cable 1975). Scrub jays and many rodents collect and cache acorns of shrub live oak, thereby aiding in seed dispersal (Pase 1969). Mule deer, white-tailed deer, and cattle also consume acorns during the fall (Pase 1969; McCulloh 1973; Urnes and McCulloch 1973; Cable 1975). In a study to evaluate the usefulness of *Quercus* acorns as an alternative energy source for growing lambs, the low cost of acorns compared with barley suggest that substitution of acorns for barley at maximum level of 24% would be economically advantageous (Al Jassim et al. 1988). The results on amino acid availability and energy value of acorn in the Iberian pig support that the acorn is an excellent source of available energy, but supplies low quantities of a protein with a poor biological quality and lysine is the first limiting amino acid in acorn (Nieto et al. 2002).

The various species of *Quercus* can tolerate a very wide range of climatic and soil conditions, including very hot or cold climates, highly saline or alkaline soil, and wet or intermittently flooded ground. Acorns as a native wild product which does not need specific culture conditions could provide new food sources for some regions particularly during the time of drought that lead to poor cereal harvests. Although no single plant would provide humans with adequate levels of all essential amino acids, these product can be prepared with other foods and contribute useful amounts of the amino acids to the diet. Some specimens herein can be compared favourably with the FAO standard. Information on the nutritional value of the acorns of *Quercus* taxa having large distributions in Anatolia will be of use in determining which plants should be preferentially utilized and conserved to benefit the overall nutrition of the rural populations especially. The challenge is primarily to alert foresters, farmers and the food industry to the potential use of acorns. Detailed economic analysis of acorn harvesting and processing in Turkey is also needed.

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