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ORIGINAL PAPER

Amino acid profiles and protein quality of Siberian apricot (*Prunus sibirica* L.) kernels from Inner Mongolia

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Abstract Siberian apricot (*Prunus sibirica* L.) is a traditional nut tree species in East Asia and Siberia and is a possible contribution to healthy diets. However, it has attracted little research attention and information on the nutritional value of its kernel is limited. In this study, the profile, nutritional value and variation of amino acids were investigated in eight provenances. The kernels contained 29×10^{-2} g/g protein and were rich in glutamic acid (26.5%), aspartic acid (11.3%) and arginine (10.1%). They showed higher essential amino acids (EAA) than similar protein values for almonds. The variation coefficients of amino acids ranged from 3.8 to 43.7%, and the levels of seven amino acids were significantly different among the eight provenances. The proportion of essential amino acids to total amino acids and amino acid score were also quite different. Protein was negatively correlated with some amino acids and protein quality values. In conclusion, there were two superior provenances (Wanjiagou and Horinger County) with high EAA contents and protein quality, and could be used in the large-scale development of this species.

Keywords *Prunus sibirica* L. · Amino acids · Nutritional value · Diversity

Introduction

Over the last few decades, people have increasingly recognized that plant-based protein supplements are beneficial to cardiovascular and cerebrovascular health. The development and utilization of these resources have become important issues for study (Baskaran and Bhattacharaya 2004; Ganga et al. 2015). Plant-based protein is economical to produce and is of high nutritional value (Woolf et al. 2011). For example, walnut, pistachio, cashew and macadamia are popular nuts as high quality protein sources (Sousa et al. 2011). Apricot is an important fruit produced in temperate regions with rich, nutritious functional ingredients and include crude fat, protein and fiber, sugars, microelements, ascorbic acid, polyphenols and carotenoids (Tunçel et al. 1990; Ali et al. 2011; Fratianni et al. 2018). The protein contains four main molecular functions used to forecast potential health benefits according to the investigation of the proteome (Ghorab et al. 2018). The proteins of *Prunus armeniaca* L. and *Prunus dulcis* (Mill.) D.A. Webb, are rich in glutamic, arginine, aspartic acid and essential amino acids (Femenia et al. 1995; Sharma et al. 2010; Amirshaghaghi et al. 2017), with good physicochemical, thermal and emulsifying attributes (El-Aal et al. 1986). They are of benefit to human health and help

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decrease the risk of obesity, high blood pressure and high cholesterol. (Seker et al. 2010; Martínez et al. 2017; Liu et al. 2018). Apricot kernels also contain rich total oils and high percentages of monounsaturated fatty acids, and represent a potential source of edible oil and biodiesel (Wang 2013; Özcan et al. 2015). As consumer demand increases, it is increasingly necessary to develop more resources over large, suitable areas and to raise production levels.

Siberian apricot (*Prunus sibirica* L.) is widely distributed across northern and northeastern China, eastern Siberian, and Mongolia (Zhang and Zhang 2003). It is an ecologically and economically important species in the Yin Mountains and Greater Khingan Mountains of China, and is one several pioneer species for use as windbreaks in arid areas due to its adaptability to drought stress, poor soil fertility and cold waves or cold snaps. As a traditional dry fruit, the annual harvest of Siberian apricot is some 192,500 tons (Fan et al. 2016). The kernels are nutritive protein sources for daily diets and functional foods (Hoffman and Falvo 2004; Gu et al. 2016) and are increasingly popular in European and American cuisines.

Compared with *Prunus dulcis* and *P. armeniaca*, Siberian apricot attracted less research attention although there are approximately 1.7×10^6 ha of Siberian apricot forests in China (Fan et al. 2016). The forests are mostly in wild or semi-wild status and low yields and poor economic returns have seriously restricted the scale of Siberian apricot development and industrialization. Therefore, it is essential to collect and evaluate germplasm resources so as to identify elite germplasm for its sustainable development. Our previous study showed significant differences in content of crude protein levels among its provenances (Yin et al. 2017). The objective of this study is to evaluate the composition and nutritional value of amino acids of Siberian apricot kernels, and to determine variations among provenances. The study will greatly facilitate subsequent breeding of elite varieties and relevant industrialization of their high nutritional quality.

Materials and methods

Test materials were collected from the Siberian apricot provenance trial plantation at the Center for Forest Seed Breeding in Hohhot, Inner Mongolia (40°43′ N, 111°07′ E, 1050 m altitude). The trial of eight provenances was established with a 2 m × 3 m spacing in March, 2008. Selection of provenances was based on both kernel yields and crude protein levels determined in our previous study. Table 1 shows the family number, geographic location and main climatic factors of these provenances. The test kernels were collected randomly from four directions of each tree in August, 2015. The dried kernels without seed coats were ground into flour (filtered through a 60-mesh sieve), mixed equally for each tree, and stored at 4 °C for later use.

Amino acid analysis

The flour samples were tested in triplicate with each 100 mg sample hydrolyzed with 10 mL of 3 mol L^{-1} HCl in a long neck ampoule which was sealed and incubated in an oven at 110 °C for 24 h. The hydrolysate was diluted to 50 mL after filtration, and then 1 mL was sampled and dried on a nitrogen blowing instrument (ND200-1, Ruicheng Instrument Co., Ltd, Hangzhou, China) at 40 °C. The dried residue was dissolved in citrate buffer (pH 2.2) and filtrated through a 0.45 μm microporous membrane. Injected 20 μL of the filtrated solution into the automatic amino acid analyser (A300 membraPure, Germany) to estimate its amino acid profile against amino acid standards. The protein content is reported as percent of kernel flour, and amino acids are reported as grams per 100 mg of protein.

Evaluating nutritional value of protein

According to the FAO/WHO (1991) amino acid scoring pattern, nutritional parameters were calculated according to Bhat and Sridhar (2008), including fractions of essential amino acids (EAA), the proportion of EAA in total amino acids (E/T), the amino acid score (AAS), biological value (BV) and protein efficiency ratio (PER). The formula is:

$$\frac{E}{T}(\%) = \frac{E_{AA}}{T_A} \quad (1)$$

$$A_{AS}(\%) = \frac{E_{AA}}{E_{AAP}} \times 100 \quad (2)$$

where E_{AA} is the content of essential amino acids, T_A total amino acids, E_{AAP} the content of essential amino acids in the FAO/WHO (1991) scoring pattern.

The following regression equations were used to estimate predicted protein efficiency ratio (P-PER) according to Alsmeyer et al. (1974):

$$P{-}P_{ER1} = -0.684 + 0.456 \times L_{eu} - 0.047 \times P_{ro} \quad (3)$$

$$P{-}P_{ER2} = -0.468 + 0.454 \times L_{eu} - 0.105 \times T_{yr} \quad (4)$$

$$P{-}P_{ER3} = -1.816 + 0.435 \times M_{et} + 0.78 \times L_{eu} + 0.211 \times H_{is} - 0.944 \times T_{yr} \quad (5)$$

where L_{eu}, P_{ro}, T_{yr}, M_{et}, H are the contents of this amino acid.

The predicted biological value (P-BV) was calculated according to Morup and Olesen (1976):

Table 1 Sample information for eight provenances of Siberian apricot

Provenance	Family number	Latitude (N)	Longitude (E)	Annual air temperature (°C)	Annual sunshine duration (h)	Elevation (m)	Annual precipitation (mm)	Frost-free season (days)
HLRB	3	42°97′	122°35′	5.8	2889	308	452	148
BRB	3	43°25′	118°65′	4.9	2882	1100	358	121
HRMB	5	45°04′	121°28′	6.3	2900	876	355	122
JUB	5	44°55′	120°87′	6.6	2883	224	380	130
WJG	6	40°41′	111°09′	5.9	2872	1050	400	157
AHB	5	42°28′	119°87′	6.1	2800	575	407	140
LC	4	40°52′	112°48′	5.0	2900	1400	400	120
HC	10	40°23′	111°49′	6.2	2942	1160	393	118

HLRB Horqin left rear banner; *BRB* bairin right banner; *HRMB* Horqin right wing middle banner; *JUB* Jarud banner; *WJG* Wanjiagou, Tumotezuoqi; *AHB* Aohan banner; *LC* Liangcheng county; *HC* Horinger county

$$P\text{–}B_v = 10^{2.15} \times q_{L_{ys}}^{0.41} \times q_{(P_{he}+T_{yr})}^{0.60} \times q_{(M_{et}+C_{ys})}^{0.77} \times q_{T_{hr}}^{2.4} \times q_{T_{rp}}^{0.21} \quad (6)$$

$$q = \frac{E_{AA}}{E_{AAP}}, \quad E_{AA} < E_{AAP} \quad (7)$$

$$q = \frac{E_{AAP}}{E_{AA}}, \quad E_{AA} \geq E_{AAP} \quad (8)$$

where E_{AA} is the content of essential amino acids, E_{AAP} is the content of essential amino acids in FAO/WHO (1991) protein scoring pattern.

Statistical analysis

Variance analysis (ANOVA), multiple range test (LSD), correlation analysis and cluster analysis employed the SPSS 20.0 software.

Results

Amino acid composition

Table 2 shows the differences in amino acid composition and protein content among the eight provenances. The protein contents ranged from 23.2% in WJG to 31.3% in BRB with a mean of 29.0%, higher than common nut tree species such as *P. dulcis* (24.1%, Zhang et al. 2000), *P. armeniaca* (23.6–26.2%, Sharma et al. 2010) and *Juglans regia* L. (16.7%, Szetao and Sathe 2000). Siberian apricot kernels contained 18 different amino acids, among which glutamic, aspartic and arginine were the highest levels with means of 26.5×10^{-2} g/g, 11.3×10^{-2} g/g and 10.1×10^{-2} g/g, respectively. Methionine and tryptophan were limiting amino acids in all provenances with the lowest means of 0.5×10^{-2} g/g and 1.0×10^{-2} g/g, respectively. These were consistent with previous studies on *P. armeniaca* (Femenia et al. 1995) and *P. dulcis* (Amirshaghaghi et al. 2017).

The mean variation coefficient for 18 amino acids of all provenances ranged from 3.8% in leucine to 43.7% in cysteine (Table 2). Analysis of variance shows significant differences in the contents of seven amino acids among the provenances ($P < 0.01$). Glutamate and isoleucine were rich in all provenances except for HC (Horinger County) provenance. This provenance showed relatively high levels of serine (4.6×10^{-2} g/g), cystine (1.8×10^{-2} g/g) and tyrosine (3.1×10^{-2} g/g) but low amounts of aspartic acid (10.6×10^{-2} g/g), glutamic acid (24.8×10^{-2} g/g), valine (3.9×10^{-2} g/g) and isoleucine (3.2×10^{-2} g/g). The significant differences in amino acid levels among provenances provides an opportunity for selection and breeding of elite germplasm.

Evaluation of protein qualities

The nutritional quality of a protein is determined not only by its amino acid composition but also by the balance of essential amino acids (EAA). Plant-based proteins are robust markers for healthy diets but they are also deficient in several essential amino acids compared to animal-based proteins (Hoffman and Falvo 2004). Lysine and methionine are the first limiting amino acids in cereals and in legumes, respectively (Baptist 1954). According to FAO/WHO/UNU (1985) recommendations, Siberian apricot kernels were also deficient in lysine and methionine + cysteine, followed by threonine and tryptophan (Table 3). Deficiencies in lysine, methionine + cysteine and threonine have also been reported for *P. armeniaca* (Femenia et al. 1995) and *P. dulcis* (Amirshaghaghi et al. 2017). However, histidine, an essential amino acid for infants, was much higher in Siberian apricot kernels than reference almond,

Table 2 Amino acid compositions of kernels protein for eight provenances of Siberian apricot

Amino acids	HC	AHB	BRB	HRMB	HLRB	LC	WJG	JUB	Mean	CV (%)
Asp + Asn**	10.60 (0.38)c	11.41 (0.59)b	11.98 (0.21)ab	11.41 (0.14)b	11.05 (0.89)bc	12.47 (1.02)a	11.29 (0.77)b	10.62 (0.49)bc	11.25 (0.64)	5.69
Thr	2.82 (0.28)	2.68 (0.10)	2.59 (0.01)	2.71 (0.10)	2.61 (0.51)	2.53 (0.06)	2.85 (0.37)	2.69 (0.07)	2.71 (0.25)	9.23
Ser**	4.63 (0.20)a	4.55 (0.21)ab	4.31 (0.07)bc	4.71 (0.10)a	4.46 (0.14)ab	4.09 (0.03)c	4.20 (0.08)bc	4.43 (0.14)ab	4.55 (0.23)	5.05
Glu + Gln**	24.79 (1.14)b	26.81 (0.13)a	26.63 (0.09)a	26.58 (0.54)a	27.59 (0.58)a	26.54 (1.34)a	25.58 (1.57)ab	27.09 (0.26)a	26.50 (1.37)	5.17
Gly	5.5 0(0.45)	5.10 (0.21)	5.03 (0.06)	5.25 (0.03)	5.11 (0.27)	4.86 (0.38)	5.39 (0.45)	5.27 (0.16)	5.28 (0.41)	7.77
Ala	4.66 (0.22)	4.48 (0.09)	4.57 (0.03)	4.54 (0.27)	4.36 (0.38)	4.51 (0.06)	4.72 (0.18)	4.45 (0.07)	4.54 (0.20)	4.41
Cys**	1.75 (0.17)a	1.02 (0.08)b	0.85 (0.05)b	0.95 (0.14)b	1.03 (0.10)b	0.86 (0.03)b	1.12 (0.43)b	1.04 (0.07)b	1.19 (0.52)	43.70
Val**	3.94 (0.23)c	4.10 (0.35)bc	4.41 (0.07)ab	4.47 (0.07)ab	4.32 (0.41)ab	4.35 (0.51)ab	4.56 (0.14)a	4.39 (0.08)ab	4.34 (0.30)	6.91
Met	0.53 (0.08)	0.57 (0.02)	0.47 (0.11)	0.47 (0.03)	0.62 (0.07)	0.54 (0.03)	0.59 (0.28)	0.64 (0.06)	0.54 (0.09)	16.67
Ile**	3.17 (0.17)b	3.64 (0.08)a	3.58 (0.06)a	3.66 (0.07)a	3.57 (0.24)a	3.58 (0.06)a	3.62 (0.07)a	3.61 (0.01)a	3.53 (0.25)	7.08
Leu	6.99 (0.28)	6.73 (0.16)	6.79 (0.08)	6.71 (0.44)	6.66 (0.79)	6.78 (0.67)	6.99 (0.19)	6.75 (0.08)	6.84 (0.26)	3.80
Tyr**	3.06 (0.20)a	2.61 (0.01)b	2.62 (0.04)b	2.51 (0.03)b	2.71 (0.10)b	2.56 (0.10)b	2.62 (0.04)b	2.70 (0.03)b	2.70 (0.27)	10.00
Phe	5.35 (0.54)	5.70 (0.08)	5.61 (0.06)	5.69 (0.54)	5.63 (0.45)	5.50 (0.16)	5.74 (0.13)	5.68 (0.08)	5.63 (0.45)	7.99
His	2.82 (0.33)	2.66 (0.08)	2.75 (0.04)	2.68 (0.27)	2.71 (0.03)	2.69 (0.06)	2.88 (0.14)	2.78 (0.05)	2.76 (0.27)	9.78
Lys	2.86 (0.50)	2.95 (0.08)	2.80 (0.06)	2.84 (0.10)	2.95 (0.07)	2.72 (0.03)	3.32 (0.80)	3.05 (0.12)	2.95 (0.43)	14.58
Arg	10.10 (0.80)	10.36 (0.23)	10.41 (0.20)	10.06 (1.12)	10.3 (0.72)	10.71 (0.83)	9.86 (0.58)	9.08 (1.95)	10.11 (0.85)	8.41
Pro	4.96 (1.74)	3.66 (0.17)	3.66 (0.13)	3.79 (0.17)	3.33 (0.07)	3.71 (0.16)	3.69(0.09)	3.60 (0.13)	3.79 (1.52)	40.11
Trp	0.95 (0.05)	1.01 (0.01)	0.99 (0.01)	0.98 (0.71)	1.00 (0.03)	0.99 (0.03)	1.02 (0.03)	0.98 (0.01)	0.99 (0.05)	5.05
Protein	29.92 (4.45)	28.37 (100)	31.31 (0.51)	29.53 (0.71)	29.14 (1.21)	31.27 (0.84)	23.20 (4.96)	27.41 (2.47)	29.01 (4.30)	14.82

Data expressed as $\times 10^{-2}$ g/g protein are the average (standard deviation) of populations studied

Asp + Asn Aspartic acid + asparagines; *Thr* threonine; *Ser* serine; *Glu + Gln* Glutamic acid + glutamine; *Gly* glycine; *Ala* alanine; *Cys* cysteine; *Val* valine; *Met* methionine; *Ile* isoleucine; *Leu* leucine; *Tyr* tyrosine; *Phe* phenylalanine; *His* histidine; *Lys* lysine; *Arg* arginine; *Pro* proline; *Trp* tryptophan; *HC* Horinger county; *AHB* Aohan banner; *BRB* Bairin right banner; *HRMB* Horqin right wing middle banner; *HLRB* Horqin left rear banner; *LC* Liangcheng county; *WJG* Wanjiagou, Tumotezuoqi; *JUB* Jarud banner

**Represents significant difference at 0.01 levels in analysis of variance, different small letters indicate significant differences between values in the same row at 0.05 level according to least-significant difference (LSD) tests

Table 3 Essential amino acid compositions of Siberian apricot kernel protein and reference proteins ($\times 10^{-2}$ g/g protein)

EAAs	HC	AHB	BRB	HRMB	HLRB	LC	WJG	JUB	Mean	Almond[a]	Soybean[b]	Egg[c]	FAO/WHO[d]
Thr	2.81	2.68	2.59	2.71	2.61	2.53	2.76	2.69	2.71	2.64	3.76	4.68	3.40
Val	3.93	4.09	4.41	4.47	4.32	4.35	4.53	4.39	4.34	6.06	4.59	6.78	3.50
Met + Cys	2.28	1.59	1.31	1.42	1.65	1.41	1.70	1.67	1.72	2.07	2.92	6.64	2.50
Ile	3.18	3.63	3.58	3.66	3.57	3.58	3.62	3.61	3.53	3.51	4.62	5.28	2.80
Leu	7.03	6.73	6.79	6.71	6.66	6.78	6.94	6.75	6.84	6.68	7.72	8.76	6.60
Phe + Tyr	8.41	8.30	8.23	8.20	8.34	8.06	8.36	8.38	8.33	7.34	6.08	9.08	6.30
Lys	2.79	2.94	2.79	2.84	2.95	2.72	3.13	3.04	2.95	1.69	6.08	6.98	5.80
Trp	0.93	1.00	0.99	0.98	1.00	0.99	1.01	0.98	0.99	2.50	3.39	1.46	1.10
His	2.76	2.66	2.75	2.68	2.71	2.69	2.84	2.78	2.76	1.93	2.50	2.25	1.90
E/T* (%)	26.60	27.35	27.21	27.53	27.35	26.99	28.67	27.80	26.96	30.07	37.82	–	–
AAS* (%)	100.86	95.62	94.22	95.61	96.02	93.80	99.94	97.24	99.13	116.68	143.75	164.43	–
P-BV	46.27	35.58	27.52	33.03	34.01	27.52	48.98	37.51	42.17	31.01	74.62	21.69	–
P-PER1	2.27	2.22	2.24	2.20	2.20	2.23	2.33	2.22	2.26	1.99	2.61	–	–
P-PER2	2.38	2.31	2.34	2.31	2.27	2.34	2.43	2.31	2.36	2.31	2.91	–	–
P-PER3	1.58	1.78	1.79	1.82	1.66	1.86	2.02	1.77	1.66	1.63	4.09	–	–

Thr Threonine; *Val* valine; *Met + Cys* methionine + cysteine; *Ile* isoleucine; *Leu* leucine; *Phe + Tyr* phenylalanine + tyrosine; *Lys* lysine; *Trp* tryptophan; *His* histidine; *E/T* proportion of total essential amino acids to the total amino acids in the protein; *AAS* amino acids score; *P-BV* predicted biological value; *P-PER* predicted protein efficiency ratio; *EAAs* essential amino acids; *HC* Horinger county; *AHB* Aohan banner; *BRB* Bairin right banner; *HRMB* Horqin right wing middle banner; *HLRB* Horqin left rear banner; *LC* Liangcheng county; *WJG* Wanjiagou is Tumotezuoqi; *JUB* Jarud banner

*Significant differences among treatments at 0.05 levels

[a]Popular nut protein sources of *Prunus* (Zhang et al. 2000)

[b]Common plant-based protein sources (Bhat and Sridhar 2008)

[c]Common animal-based protein sources (Friedman 1996)

[d]FAO/WHO/UNU (1985) suggested pattern of amino acid requirements for preschool child (2–5 years)

soybean, egg white and FAO recommendations (Table 3). The kernel content of phenylalanine + tyrosine (8.3×10^{-2} g/g) was also higher than reference almond, soybean and FAO recommendations (Friedman 1996; Zhang et al. 2000; Bhat and Sridhar 2008). In general, the content level of most EAAs in Siberian apricot kernels, except for valine, methionine + cysteine and tryptophan, were higher than those for almond, a popular nut in diets and in the food processing industry. Therefore, Siberian apricot kernels are a good source of plant-based protein with high levels of balanced amino acids.

Amino acid contents were further used to determine nutritional characteristics for predicting protein quality (Table 3). The E/T ratios in all provenances was lower than those of soybean (37.8%) and FAO/WHO (1991) criterion (36.0%) and similar to almond (30.1%). The amino acid score (AAS) of 93.8–100.9% for all provenances was similar to almond (116.7%), while it was lower than those of soybean seeds (143.8%) and egg white (163.4%). The AAS of the HC (Horinger County) provenance was the highest while its E/T ratio was the smallest, showing limited but high quality essential amino acids. Generally, protein is poor quality if its efficiency ratio (PER) is below 1.5, intermediate quality between 1.5 and 2.0, and good to high-quality above 2.0 (Friedman 1996). P-PER (predicted protein efficiency ratio) values of Siberian apricot kernels (1.7–2.4) were similar to those of almond (1.6–2.3). There were small differences between Siberian apricot kernels (2.3, 2.4) and soybean seed (2.6, 2.9) in $P\text{-}PER_1$ and $P\text{-}PER_2$ respectively. The highest P-PER (2.0–2.4) was observed in the WJG (Wanjiagou) provenance, while the lowest P-PER (1.7–2.3) was in the HLRB (Horqin Left Rear Banner) provenance. The biological value was correlated to the EAA supply which was used to measure utilization efficiency of protein ingestion (Hoffman and Falvo 2004). The mean P-BV (predicted biological value) of 42.1 was higher than that for almond (31.0) and egg white (21.7), but lower than soybean (74.6) and wheat (61.6) (Friedman 1996). The highest P-BV was in the WJG provenance (49.0) and the lowest for the BRB and LC provenances (27.5).

Variance analysis showed significant differences of the E/T ratios and AAS among eight provenances. As a whole, Siberian apricot kernels were a good source of protein for human consumption with high nutritional quality. The WJG and HC provenances had higher E/T, AAS, P-BV and P-PER, indicating that they had the best protein quality. The correlation analysis between protein quality and essential amino acids had positive implications for the evaluation of provenances. Kernel protein content was significantly negatively correlated with lysine, tryptophan, histidine, E/T, AAS, P-PER$_3$ ($p < 0.01$) and P-BV ($p < 0.05$). This suggests that it is difficult to consider high content and quality of protein at the same time within the provenances. It may be of great potential to aggregate both elite traits by subsequent hybridization.

Clustering of provenances

Based on the essential amino acid (EAA) contents and protein quality parameters, Siberian apricot provenances were divided into four groups by the between-group linkage method (Fig. 1). Group A and B contained the WJG and HC provenances, respectively. They both had higher essential amino acid contents and quality protein. Group C consisted of the AHB, HLRB, HRMB and JUB provenances with medium essential amino acid content and protein quality. Group D had BRB and LC provenances with lower threonine, methionine + cysteine, phenylalanine + tyrosine, lysine, AAS and P-BV.

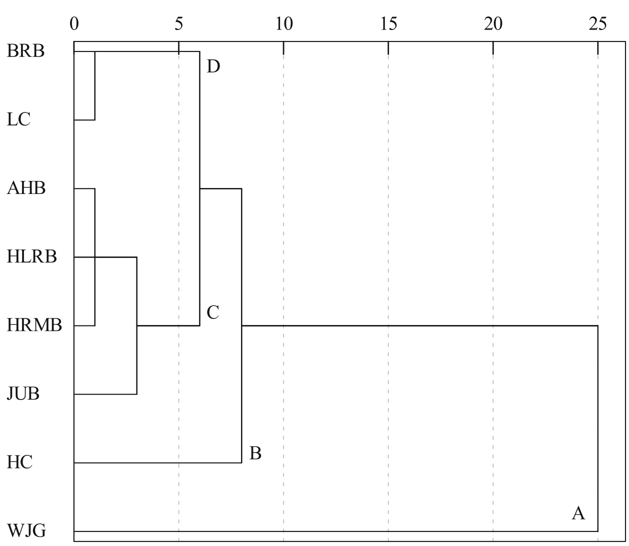

Fig. 1 Clustering of provenances based on the essential amino acids content and nutritional characteristics. (BRB is Bairin Right Banner; LC is Liangcheng County; AHB is Aohan Banner; HLRB is Horqin Left Rear Banner; HRMB is Horqin Right Wing Middle Banner; JUB is Jarud Banner; HC is Horinger County; WJG is Wanjiagou, Tumotezuoqi)

Conclusion

Siberian apricot kernels were rich in glutamic, aspartic and arginine, and deficient in lysine, methionine + cysteine, threonine and tryptophan. They had higher essential amino acid levels than almonds. Significant differences in the contents of seven amino acids and two nutritional parameters were found among the eight provenances. WJG and HC provenances had the highest amino acid levels and quality protein and are recommended for large scale plantings. Overall, Siberian apricot kernel protein showed balanced composition and high nutritional value and the rich variations of amino acids among provenances provides a good potential for selection and breeding of elite varieties and to further facilitate the development of Siberian apricot.

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