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PCA analysis on postharvest quality characterization of fenugreek depending on seed weight

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Abstract

In this study, the changes of quality characters of fenugreek according to thousand-seed weight (TSW) was examined and compared with Principal Component Analysis (PCA). Fenugreek seeds were separated into 5 different TSW ranges (W1, W2, W3, W4, W5). Different TSW had significant effects on crude protein content, palmitic, stearic, linoleic and linolenic acid contents and K, Ca and Mn contents. Linoleic acid had the highest content among fatty acid components. Increasing K and Mn contents and decreasing Ca contents were observed with increasing TSW. The highest values were obtained from W1 range in terms of crude ash and crude oil content, palmitic and linolenic acid, Ca, Mg, P, Na and S. At the end of the study, the W1 (10.00-13.00 g) range, which stands out in many quality features, can be recommended in fenugreek cultivation for high quality.

Keywords: Thousand-seed weight, Fenugreek, Fatty acids, Linoleic acid, Mineral composition

Introduction

Fenugreek is an annual medicinal and aromatic plant of *Fabaceae* family (Kaviarasan et al., 2007; Hassanzadeh et al., 2011). It has long been used as a traditional foodstuff (Pandey and Awasthi, 2015). Fenugreek plants have a gene center including South Europe, West Asia and Mediterranean basin (Tunçtürk and Çiftçi, 2011). Plant pods are about 15 cm long and include about 10-20 seeds in golden yellow color (Petropoulos, 2002; Pandey and Awasthi, 2015; Venkata et al., 2017). Plant seeds are used as spice or used in folk medicine (Gürbüz et al., 2000).

Protein, ash and oil contents are significant quality parameters of fenugreek plants. Fenugreek seeds contain about 27% protein, 3-4% ash, 8% crude oil and trace amounts of mucilage, trigonelline, diosgenin, choline, phytin, coumarin (Tunçtürk and Çiftçi, 2011). Besides high protein content, fenugreek seeds are also rich in calcium, iron and minerals (Pandey and Awasthi, 2015). Plant seeds constitute a good source of protein both in human and animal nutrition (Gökçe and Efe, 2016). Seeds are also rich in saturated and unsaturated fatty acids. Sulieman et al. (2008) reported that fenugreek plants contained around 43.2% linoleic acid, 22.0% linolenic acid and 16.7% oleic acid.

It was indicated in previous studies that several morphological characteristics (plant height, number of branches, number of pods, number of seeds per pod, pod length, seed weight) of fenugreek plants were closely related to seed yield (Sade et al., 1996; McCormick et al., 2009). A yield parameter, TSW is among the most significant ones of these characteristics. Since fenugreek plants are generally grown for their seeds, high seed yields are desired in fenugreek plants. Previous studies put forth direct and positive impacts of TSW on yield (Ayanoğlu et al., 2004; Fikreselassie et al., 2012; Gurjar et al., 2016).

Starting from the positive effect of TSW on seed yield, besides the treatments to increase TSW in field studies, laboratory studies are also needed to elucidate the effects of TSW on

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quality attributes. Therefore, in this study, after harvesting, the changes of quality characters of fenugreek according to TSW was examined and compared with PCA analysis.

Materials and Methods

Materials

Seeds of Gürarslan fenugreek cultivar were used in this study. Seeds were collected from the cultivar field in July 2018 and preserved in sacks until separation of them into different seed weight.

Determination of Thousand Seed Weight Ranges

Following the harvest, the seeds preserved in sacks were separated into five different TSW (g) ranges (W1, W2, W3, W4 and W5). Each range was formed in three replicates. For TSW, 1000 seeds were counted, weighed in a precise scale and expressed on dry matter in g. Resultant ranges are provided in Table 1 and average of replicates of ranges are provided in Table 2.

Table 1. Thousand-seed weight (g) ranges formed from fenugreek seeds

Thousand-seed weight ranges	
10.00-13.00	W1
13.01-16.00	W2
16.01-19.00	W3
19.01-22.00	W4
22.01-25.00	W5

For chemical composition, crude protein, ash and oil contents of the seed groups were determined by AOAC (1990). Crude protein content was determined from 0.2 g ground fenugreek seeds with the aid of Kjeldahl method. Resultant nitrogen content was multiplied by 6.25 to get crude protein content. Crude ash content of fenugreek seeks was determined from 1 g ground samples through ashing the samples in an ash oven at 550 ºC for 4 hours. For crude oil quantities, 3 g ground samples of each group were used. Samples were analyzed with petroleum ether in a device. Crude oil content was calculated over dry matter. Chemical composition analysis were replicated three times for each group and average of resultant measurements were expressed in % (Table 2).

Fatty Acid Composition

Fatty acid methyl esters for samples were prepared using 1-step extraction-transesterification process (Sukhija and Palmquist, 1988). In the study, the analysis was performed on a GC device (Schimadzu, GC 2010 plus) equipped with a FID (flame ionization detector) detector and column (a 100 m fused silica capillary column - i.d. 0.25 mm). Helium was used as the carrier gas. Fatty acid methyl esters were separated using a temperature gradient program (Chilliard et al., 2013) and the peaks were identified based on comparison of retention times with authentic standard (Supelco #37, Sigma, Supelco Inc., Bellefonte, PA, USA). Fatty acid composition analysis were repeated three times for each group and average of resultant values was expressed in % (Table 3).

Mineral Composition

Mineral composition of fenugreek samples was determined in an ICP OES spectrophotometer (Inductively Couple Plasma spectrophotometer) (Perkin-Elmer, Optima 4300 DV, ICP/OES, Shelton, CT 06484-4794, USA). 10 ml of a mixture of nitric + perchloric acid was added to 0.5 g of ground fenugreek seed and subjected to wet digestion until it had 1 ml of sample. After the digestion process, distilled water was added to the obtained solutions and readings were made on the ICP OES spectrophotometer to determine the mineral contents (Mertens, 2005). Mineral composition analysis were repeated three times for each range and resultant values were expressed in % (Table 4).

Statistical Analysis

All analysis were performed in three replicates. SPSS Statistics (version 17.0) for Windows was used for statistical analysis of the experimental data. Data were subjected to one-way analysis of variance (ANOVA) and significant means were compared with the aid of Duncan's multiple range test ($p < 0.05$). PCA analysis was performed using PAST (version 3.20) (Hammer et al., 2001).

Results and Discussion

TSW average of each range is provided in Table 2. Variance analysis for TSW revealed that the experimental ranges were significant and fenugreek seeds were separated into 5 different weight ranges. TSW varied between 11.96 - 23.01 g (Table 2). In previous studies, Tunçtürk et al. (2011) reported TSW as 18.5 g in the first year and as 18.0 g in the second year; Ayanoğlu and Mert (1999) reported TSW as between 12.23 - 18.58 g. Present findings on TSW thus comply with those earlier ones.

Chemical Composition

Results for chemical composition of fenugreek seeds are provided in Table 2. Variance analysis on investigated traits revealed that crude ash and oil contents of the ranges were not significantly different ($p>0.05$). Crude protein content of the ranges was found to be significant ($p<0.05$).

Crude protein contents of the TSW ranges varied between 20.43-24.91%, crude ash content varied between 3.20 - 3.50% and crude oil content varied between 2.81 - 3.88%. The greatest crude protein content was observed in W3 range and the greatest crude ash content and crude oil content were observed in W1 range (Table 2). The lowest crude protein and crude oil contents were observed in W4 range and the lowest crude ash content was observed in W5 range (Table 2).

In previous studies about chemical composition of fenugreek plants, Ali et al. (2012) reported protein content as 19.8% and ash content as 4%; Al-Jasass and Al-Jasser (2012) reported protein content as 12.91%, ash content as 4.23% and crude oil content as 4.51%; Sulieman et al. (2008) reported protein content as 25.0%, ash content as 3.0% and crude oil content as 8.4%; Acharya et al. (2006) reported protein contents as between 26.0 - 31.6%; Tunçtürk et al. (2011) reported protein content as 23.3% in the first year and as 23.2% in the second year. Niknam et al. (2004) reported protein content as 29.93% and Beyzi (2020) reported crude oil content as between 4.01-4.95%.

Table 2. Thousand-seed weight averages and chemical composition of experimental ranges

Characters	Ranges										*p*
	W1		W2		W3		W4		W5		
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	
TSWA (g)	11.96^{e}	0.21	14.83^{d}	0.86	17.68^{c}	0.57	20.22^{b}	0.35	23.01^{a}	1.28	*<0.05*
CP (%)	24.18^{a}	0.17	24.10^{a}	0.79	24.91^{a}	0.50	20.43^{c}	0.25	21.86^{b}	0.70	*<0.05*
CA (%)	3.50	0.55	3.43	0.43	3.23	0.28	3.35	0.40	3.20	0.18	*NS*
CO (%)	3.88	0.50	3.14	0.62	3.14	0.02	2.81	0.78	3.60	0.49	*NS*

TSWA: thousand-seed weights averages of ranges; CP: crude protein content; CA: crude ash content; CO: crude oil content; SD: standard deviation; a-b: different letters indicate differences in same raw at $p<0.05$; NS: not significant

Fatty Acid Composition

Results for fatty acid composition of fenugreek seeds are provided in Table 3. According to variance analysis on fatty acid composition, while the differences in linoleic, linolenic, palmitic, stearic acids and UFA/SFA content of the experimental ranges were significant ($p<0.05$), the differences in the other components were not found to be significant ($p>0.05$).

In fatty acid composition analysis, 8 components were identified. Linoleic acid had the highest content among these components. This component (linoleic acid) was followed by linolenic acid and oleic acid, respectively. Linoleic acid of TSW ranges varied between 43.85 - 46.02%, palmitic acid varied between 8.43 - 8.95%, stearic acid varied between 4.24 - 4.67% and linolenic acid varied between 26.47 – 28.04%. The greatest linoleic acid was observed in W4 range. The greatest palmitic acid was observed in W1 range and a regular decrease was observed in palmitic acid with increasing TSW. Contrary to palmitic acid, the greatest stearic acid content was observed in W5 range and a regular increase was in stearic acid with increasing TSW.

Among the insignificant fatty acids, the greatest oleic acid was observed in W2 range, arachidic acid in W5 range, eicosenoic acid in W3 range and behenic acid in W2 range. The UFA/SFA contents of experimental ranges varied between 5.62 – 5.86% with the greatest value in W4 range and the lowest value in W1 range (Table 3).

In previous studies about fatty acid composition of fenugreek plants, Bieńkowski et al. (2017) reported linoleic acid as 37.9%, α-linolenic acid as 28.2%, oleic acid as 13.3%, palmitic acid as 13.1%, stearic acid as 3.8%, arachidic acid as 1.4%. Ciftci et al. (2011) reported linoleic acid as between 45.1 – 47.5%, α-linolenic acid as between 18.3 – 22.8%, oleic acid as between 12.4 – 17.0%, palmitic acid as between 9.8 –11.2% and stearic acid as between 3.8 – 4.2%; Ali et al. (2012) reported palmitic acid as 10.5%, stearic acid as 6.5%, oleic acid as 20%, linoleic acid as 42.5%, linolenic acid as 18%, arachidic acid as 2% and behenic acid as 0.5%; Sulieman et al. (2008) reported average palmitic acid as 11.0%, stearic acid as 4.5%, oleic acid as 16.7%, linoleic acid as 43.2% and linolenic acid as 22.0%. Dinu et al. (2013) reported average palmitic acid as 8.77%, stearic acid as 3.71% and linoleic acid as 43.15%. Beyzi (2020) reported linoleic acid as between 39.62-43.68%, linolenic acid as between 26.11-29.89%, oleic acid as between 11.60-14.10%, palmitic acid as between 8.94-9.50% and stearic acid as between 4.67-5.55%.

Mineral Composition

Results for mineral composition of different weight ranges are provided in Table 4. Of the macro elements, the differences in K and Ca contents of the experimental ranges were found to be significant ($p<0.05$), but the differences in Mg, P, S and Na contents were not found to be significant ($p>0.05$). For micro elements, Mn was found to be significant ($p<0.05$), but Cu, Fe, Zn and B were not found to be significant ($p>0.05$).

K contents of the TSW ranges varied between 8908 - 10356 mg/kg. Increasing K contents were observed with increasing TSW and the greatest value was observed in W5 range. Ca contents varied between 1353 - 1897 mg/kg. Ca contents decreased with increasing TSW and the greatest value was observed in W1 range. Mn contents varied between 6.31 - 12.15 mg/kg. Mn contents increased with increasing TSW and the greatest value was observed in W5 range (Table 4). For insignificant minerals, the greatest Mg, P, S and Na contents were observed in W1 range, the greatest Cu content was observed in W5 range, the greatest Fe and Zn contents were observed in W4 range and the greatest B content was observed in W2 range.

In previous studies about mineral composition of fenugreek plants, Bouhenni et al. (2019) reported average Ca, K, Mg, P, S, B, Cu, Fe and Zn contents respectively as 1445, 10605, 1229, 5143, 2648, 11.8, 9.9, 91 and 30.9 mg/kg, Ali et al. (2012) reported average Ca, Cu, Fe, Zn, K, Mg, P, Na and Mn contents respectively as 226, 5.4, 11.6, 4.4, 1080, 78.4, 200, 290 and 1.6 mg/100 g; Al-Jasass and Al-Jasser (2012) reported K, Mg, Ca, Zn, Mn, Cu and Fe contents respectively as 603, 42, 75, 2.4, 0.9, 0.9, 25.8 mg/100 g.

Table 3. Fatty acid composition of the thousand-seed weight ranges

Fatty acid composition (%)		Ranges										
		W1		W2		W3		W4		W5		
		Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	*p*
C16:0	Palmitic acid	8.95^{a}	0.14	8.75^{a}	0.08	8.72^{a}	0.24	8.44^{b}	0.03	8.43^{b}	0.12	*<0.05*
C18:0	Stearic acid	4.24^{b}	0.05	4.25^{b}	0.07	4.35^{b}	0.09	4.36^{b}	0.10	4.67^{a}	0.15	*<0.05*
C18:1	Oleic acid	12.47	0.18	12.63	0.54	12.28	0.30	12.48	0.54	12.56	0.05	*NS*
C18:2	Linoleic acid	43.85^{c}	0.15	44.28^{c}	0.40	45.35^{ab}	0.25	46.02^{a}	0.06	45.07^{b}	0.71	*<0.05*
C18:3	Linolenic acid	28.04^{a}	0.24	27.65^{ab}	0.36	27.16^{bc}	0.29	26.47^{d}	0.36	26.94^{cd}	0.49	*<0.05*
C20:0	Arachidic acid	1.26	0.02	1.25	0.01	1.08	0.18	1.19	0.07	1.31	0.05	*NS*
C20:1	Eicosenoic acid	0.53	0.02	0.52	0.01	0.62	0.21	0.46	0.02	0.56	0.01	*NS*
C22:0	Behenic acid	0.66	0.04	0.67	0.10	0.44	0.21	0.59	0.08	0.46	0.01	*NS*
SFA		15.11		14.92		14.59		14.57		14.87		*NS*
UFA		84.89		85.08		85.41		85.43		85.13		*NS*
UFA/SFA		5.62^{b}		5.70^{ab}		5.85^{a}		5.86^{a}		5.73^{ab}		*<0.05*

SD: standard deviation; $^{a-b}$: different letters indicate differences in same raw at $p<0.05$; NS: not significant; SFA: sum of saturated fatty acids; UFA: sum of unsaturated fatty acids

Table 4. Mineral composition of the thousand-seed weight ranges

Mineral composition (mg/kg)	Ranges										
	W1		W2		W3		W4		W5		
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	*P*
Macro minerals											
K	9779^{ab}	363.67	8908^{b}	1007.83	9943^{a}	137.96	10166^{a}	194.69	10356^{a}	339.00	*<0.05*
Ca	1897^{a}	40.43	1668^{b}	259.31	1512^{bc}	18.21	1431^{c}	46.42	1353^{c}	68.13	*<0.05*
Mg	992	26.94	862	106.69	904	55.79	904	34.63	880	8.16	*NS*
P	5605	116.56	5007	498.80	5526	453.99	5143	211.78	5216	221.04	*NS*
S	2080	245.57	1823	139.12	2075	133.13	2068	182.38	1917	242.79	*NS*
Na	166.15	10.17	148.29	23.60	149.17	9.71	155.71	4.75	147.33	12.30	*NS*
Micro minerals											
Cu	17.88	0.60	19.12	1.10	18.25	1.49	18.50	0.97	20.35	0.37	*NS*
Fe	62.91	4.53	72.81	15.24	73.48	4.17	78.88	13.51	60.23	9.56	*NS*
Zn	24.77	7.05	22.19	2.53	24.73	5.04	30.83	14.08	22.00	2.96	*NS*
B	1.29	0.13	1.48	0.25	1.15	0.13	1.21	0.04	1.17	0.25	*NS*
Mn	6.31^{c}	0.77	9.23^{b}	2.44	9.67^{b}	0.38	10.33^{ab}	0.88	12.15^{a}	0.83	*<0.05*

SD: standard deviation; $^{a-b}$: different letters indicate differences in same raw at $P < 0.05$; NS: not significant

Principal Component Analysis (PCA)

The eigenvalue and variability values resulting from the PCA analysis were given in Table 5. According to PCA analysis, the first two PCs explained 67.52% of the total variance. PC1 explained 42.50%, PC2 25.02%, PC3 19.26% and PC4 13.22% of the total variance. In Eigenvalue values, PC1 was 9.775, PC2 5.754, PC3 4.430 and PC4 3.041 (Table 5). It can be said that W1 range was separated from other TSW ranges since it located in a separate location (Fig. 1). The highest values were obtained from W1 range in terms of crude ash and crude oil content, palmitic and linolenic acid, Ca, Mg, P, Na and S (Table 2,3,4). For this reason, W1 range can be recommended in fenugreek cultivation for high quality.

Table 5. Eigenvalue and variance values formed as a result of PCA analysis

	Eigenvalue	Variability (%)
PC1	9.775	42.50
PC2	5.754	25.02
PC3	4.430	19.26
PC4	3.041	13.22

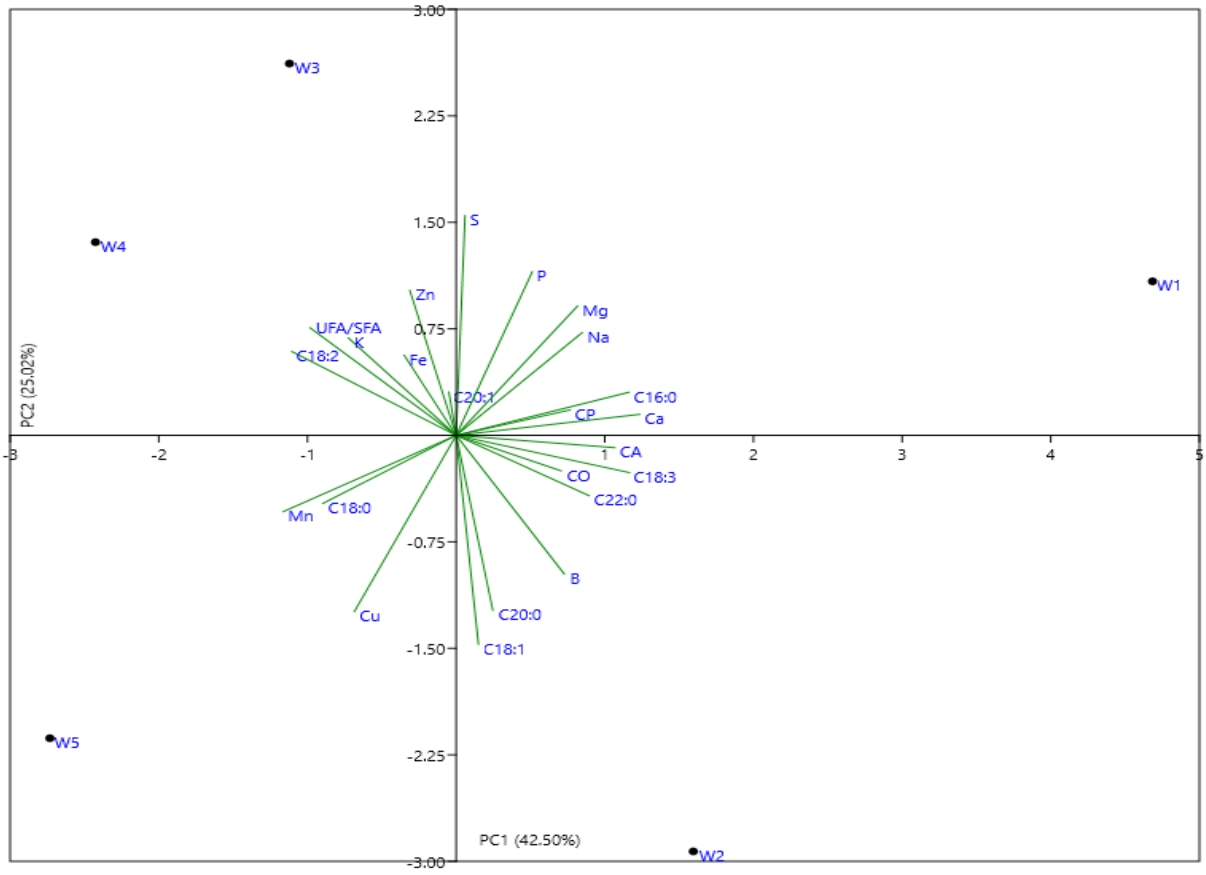

Figure 1. PCA graph of quality characteristics of fenugreek depending on thousand-seed weight; UFA: sum of unsaturated fatty acids; SFA: sum of saturated fatty acids; CP: crude protein content; CA: crude ash content; CO: crude oil content

Conclusion

In this study, the changes of postharvest quality characters of fenugreek according to TSW was examined and compared with PCA analysis. Different TSW had significant effects on crude protein content, palmitic, stearic, linoleic and linolenic acid contents and K, Ca and Mn contents. In this study, it has been determined that PCA analysis can be used for classification according to the quality characteristics of fenugreek depending on TSW. At the end of the study, the W1 (10.00-13.00 g) range, which stands out in many quality features, can be recommended in fenugreek cultivation for high quality.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

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Data availability

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Consent for publication

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