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Full Length Article

Comparative Nutritional Profiles of Various Faba Bean and Chickpea Genotypes

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Abstract

Grain legumes are important source of proteins and dietary minerals for humans. In this study, 40 faba bean and 28 chickpea genotypes were evaluated for their nutritional profile. We found that crude proteins ranged from 31.5–37.7% and 19.8–24.9% in faba bean and chickpea genotypes, respectively. Trypsin and chymotrypsin inhibitors varied from 2.24–2.77 and 0.35–0.70 trypsin inhibitory unit (TIU) mg^{-1}, respectively in faba bean genotypes; whereas, in chickpea genotypes, they ranged from 7.65–8.98 and 9.0–11.9 TIU mg^{-1}, respectively. Tannins in faba bean ranged from 12.2–16.2 mg 100 g^{-1}, while in chickpea they ranged from 4.11–4.94 mg g^{-1}. However, phytic acid ranged from 1.2–1.5 mg 100 g^{-1} in faba bean, while in chickpea it ranged from 6.10–6.98 mg g^{-1}. Total phenolic and total flavonoid contents ranged from 5.8–11.3 mg galic acid equivalents (GAE) g^{-1} and 0.08–0.16 mg quercetin equivalent (QE) g^{-1}, respectively in faba bean genotypes; whereas, in chickpea genotypes, these ranged from 1.5–2.5 mg GAE g^{-1} and 0.05–0.18 mg QE g^{-1}, respectively. In crux, some faba bean and chickpea genotypes could be potential donors for legume genetic improvement and incorporation of such legumes in human diets may improve the nutritional value of diet and can reduce malnutrition.

Keywords: Amino acids; Antioxidants; Crude protein; Minerals; Nutrition

Introduction

Human beings need a variety of complex mixture of organic compounds to meet the requirement for daily biological activities. In this regard, plant materials make a big portion of human diet and therefore their proximate composition and nutritive values are especially significant. Proteins, carbohydrates, fats and mineral nutrients are the major components of our diet as they provide energy and are important for growth and metabolism of body.

Grain legumes are important sources of food and feed proteins. Moreover, grain legumes also provide carbohydrates, dietary fiber, minerals and phytochemicals (Mitchell *et al*., 2009), which are necessary for proper body functioning. These grain legumes are well adapted in a wide range of climates and environmental conditions worldwide and are being consumed by millions across the globe. Among the grain legumes, faba bean (*Vicia faba* L.) and chickpea (*Cicer arietinum* L.) are the world leading grain legumes and are the used as rich source of proteins. Faba bean is a high yielding legume with good nutritional profile; being consumed by humans and livestock and it is the 6th major legume after soybean, peanut, beans, field pea and chickpea regarding worldwide production. However, presence of low amount of sulphur containing essential amino acids (methionine and cysteine) and ample amount of anti-nutritional factors like protease inhibitors, phytic acid, and tannins, limits its nutritive value (Crépon *et al*., 2010). Protein contents in faba bean varies significantly (27-34%) in different genotypes (Duc, 1997; Haciseferogullari *et al*., 2003); globulins (60%), albumins (20%) and glutelins (15%) being the predominant protein types (Hussein and Murtaza, 2006). It is also a good source of carbohydrate (50–60%), minerals and vitamins having quite low amount of lipids (Crépon *et al*., 2010). Faba bean grain is considered beneficial for human health due to its role in lowering of plasma LDL-cholesterol levels (Frühbeck *et al*., 1997), owing to the presence of several fibres, vitamins and minerals (Olaofe and Akintayo, 2000).

Chickpea is also a good source of proteins, carbohydrates (Chibbar *et al*., 2010), vitamins and minerals (Cabrera *et al*., 2003). It also contains several essential amino acids except sulphur containing amino acids *i.e.* methionine and cysteine. Starch is the main storage

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carbohydrate in chickpea followed by dietary fibre, oligosaccharides and simple sugars like glucose and sucrose (Chibbar *et al*., 2010). Fats are present in low amounts; unsaturated fatty acids like linoleic and oleic acid being predominant (Kaur *et al*., 2005). Chickpea grain is also a good source of important minerals like potassium, calcium, magnesium, phosphorus and important vitamins such as riboflavin, niacin, thiamin, folate and the vitamin A precursor, β-carotene (Cabrera *et al*., 2003). Besides this, chickpea grain also contains small amounts of alkaloids, tannins, phytic acid, saponins, phenolics and trypsin inhibitors (Roy *et al*., 2010). Chickpea grains have beneficial effects on some of the important human diseases like cardiovascular disease, type 2 diabetes, digestive diseases and cancer (Jukanti *et al*., 2012).

Although faba bean and chickpea are potential grain legumes for arid and semiarid regions; huge variation for nutritional composition and anti-nutritional factors exists among genotypes of both crops, which may be exploited to breed new genotypes of these crops with improved nutritional status. This study was, therefore, conducted to evaluate and compare the nutritional profiles, including antioxidants and anti-nutritional factors, of various faba bean and chickpea genotypes.

Materials and Methods

This study, consisted of forty faba bean and twenty eight chickpea genotypes, was conducted to examine the nutritional profile of these genotypes. The pedigree and origin of faba bean and chickpea genotypes used in this study are presented in Tables 1 and 2, respectively. These genotypes were grown at Dirab Experimental Research Station, Riyadh (24°43'34''N, 46°37'15''E), King Saud University, Riyadh, Saudi Arabia in randomized complete block design with three replications for field evaluation. Crop husbandry practices, recommended for the region, were followed during the crop growing season (Ammar *et al*., 2015). Harvested grains from these genotypes were used for appraisal of nutritional value and chemical composition.

The proximate analyses for crude proteins, moisture, total ash and crude fat were carried out in triplicate using the methods described in AOAC (1990) and expressed in percentage. Mineral contents were determined following AOAC (2005) and expressed as mg/100 g seed. Carbohydrates were estimated by difference. Amino acid composition of both faba bean and chickpea genotypes was estimated by a gradient HPLC system LC-10AT vp (Shimadzu corporation, Kyoto, Japan) with auto injector (Gnanou *et al*., 2004). Data were processed using an integrator model Chromatopack-CR7-A (Shimadzu Corporation) and expressed as g/kg seed. Sulphur containing amino acids and trypotophan were determined following Shahidi *et al*. (1992).

The trypsin inhibitor activity assay, in both faba bean and chickpea grains, was carried out using benzoyl-DL-arginine-p-nitroanilide (BAPA) as synthetic substrate to estimate trypsin and chymotrypsin (Kakade *et al*., 1969), and were expressed as trypsin inhibitory unit/mg. Phytic acid analysis was performed using chromophore reagent (Mohamed *et al*., 1986) and the phytic acid contents were expressed as mg/100 g. Tannin contents were determined using vanillin–HCl method (Price *et al*., 1978) and were expressed as mg/100 g. Total phenolics were quantified by Folin-Ciocalteu method (Xu and Chang, 2007) and were expressed as mg gallic acid equivalent (GAE)/g. Colorimetric aluminum chloride method was used for flavonoid determination (Xu and Chang, 2007); total flavonoid contents were expressed as mg quercetin equilibrium (QE)/g. The ability of the samples to scavenge di (phenyl)-(2, 4, 6-trinitrophenyl) iminoazanium (DPPH) radicals was determined following protocol of Llorach *et al*. (2008) and was expressed as mg/g.

Statistical Analysis

Data of three separate determinations were statistically analysed for descriptive statistics using Minitab Statistical software.

Results

Proximate Composition

Faba bean contained higher average of total crude protein (33.5%) compared with chickpea (22%) (Table 3, 4). The crude protein composition of faba bean genotypes varied significantly and ranged from 31.5 to 37.7% in Goff1 and FLIP03-015FB, respectively (Table 3). The faba bean genotypes were categorized into three groups according to crude proteins values, (i) low crude protein (31–33%) containing 16 genotypes, (ii) medium crude protein (33–35%) containing 15 genotypes and (iii) high crude protein (< 35%) containing 8 genotypes (Table 3). The fat contents in faba bean genotypes ranged from 1.52 to 2.12% with overall mean value of 1.86% with no significant differences among genotypes (Table 3). Carbohydrate contents ranged from 42.7 to 49.3%, ash contents from 3.0 to 4.2% and moisture contents from 7.21 to 8% in various faba bean genotypes (Table 3). For chickpea genotypes, the crude protein varied from 19.8% in xO5TH33 genotype to 24.9% in xO5TH20 and xO5TH52 genotypes (Table 4). Moreover, crude fat contents ranged from 3.6 to 5.1%, carbohydrate contents from 63.0 to 69.7%. Likewise, moisture and ash content ranged from 7.1 to 7.9% and 2.7 to 3.9%, respectively in various chickpea genotypes (Table 4).

Minerals Analysis

The descriptive values of mineral contents of faba bean genotypes showed significant variation across tested genotypes (Table 5). The contents of calcium (Ca), manganese (Mg), copper (Cu) and zinc (Zn) were not

Table 1: Pedigree and origin of faba bean genotypes used in the study

Genotype	Pedigree	Origin	Genotype	Pedigree	Origin
WRB 1-3	White flower x ILB 1270-BC	UK	FLIP03-016FB	HBP/S0 F/2033 Fam. 76	ICARDA
WBR 2-7	White flower x ILB 1270 BC	UK	FLIP03-017FB	HBP/S0 F/2033 Fam. 81	ICARDA
WRB 1-4	White flower x ILB 1270 BC	UK	FLIP03-018FB	HBP/S0 F/2033 Fam. 42	ICARDA
WRB 1-5	White flower x ILB 1270 BC	UK	FLIP03-019FB	HBP/S0 F/2033 Fam. 45	ICARDA
WRB 2-1	White flower x ILB 1270 BC	UK	FLIP03-020FB	HBP/S0 F/2033 Fam. 70	ICARDA
FLIP03-001FB	Fam. 2-4-2 TW x ILB 938	ICARDA	FLIP03-021FB	Fam. 2-4-1 TW x ILB 938 BC	ICARDA
FLIP03-002FB	HBP/S0 F/2033, Fam. 46	ICARDA	FLIP03-022FB	Fam. 2-1-4 TW x ILB 938BC	ICARDA
FLIP03-003FB	HBP/S0 F/2033, Fam. 48	ICARDA	FLIP03-023FB	Fam. 2-2-1 TW x ILB 938BC	ICARDA
FLIP03-004FB	White flower x ILB 1270 BC	ICARDA	FLIP03-024FB	Fam. 2-1-2 TW x ILB 938BC	ICARDA
FLIP03-005FB	HBP/S0 F/2033, Fam. 91	ICARDA	FLIP03-025FB	HBP/S0C/03 Fam. 90	ICARDA
FLIP03-006FB	White flower x ILB 1270 BC	ICARDA	FLIP03-026FB	Fam. 2-4-3 TW x ILB 938	ICARDA
FLIP03-007FB	White flower x ILB 1270 BC	ICARDA	FLIP03-027FB	HPB/S0 F/2003, Fam. 8	ICARDA
FLIP03-008FB	HBP/S0 F/2033 Fam. 29	ICARDA	FLIP03-028FB	HBP/S0 C/2003, Fam. 51	ICARDA
FLIP03-009FB	HBP/S0 F/2033 Fam. 62	ICARDA	Reina Blanca	Cultivar (ILB 1270)	Spain
FLIP03-010FB	HBP/S0 F/2033 Fam. 2	ICARDA	Population 3	Selected from Yossef A'Sdek cv	Egypt
FLIP03-011FB	HBP/S0 F/2033 Fam. 32	ICARDA	Giza 40	Cultivar	Egypt
FLIP03-012FB	HBP/S0 F/2033 Fam. 51	ICARDA	Hassawi 1	Land races	KSA
FLIP03-013FB	HBP/S0 F/2033 Fam. 61	ICARDA	Goff1	Land races	KSA
FLIP03-014FB	HBP/S0 F/2033 Fam. 63	ICARDA	Gazira1	Land races	Sudan
FLIP03-015FB	HBP/S0 F/2033 Fam. 71	ICARDA	Triple White	Variety	Denmark

Table 2: Pedigree of chickpea genotypes used in the study

Genotype	Pedigree	Genotype	Pedigree
xO5TH13	(FLIP 97-90 x FLIP 97-126C) x FLIP 02-43C	xO5TH104	FLIP 01-28C X FLIP 00-06C
xO5TH15	(FLIP 97-165 x FLIP 97-28C) x FLIP 01-25C	xO5TH108	FLIP 01-16C X FLIP 00-14C
xO5TH20	(FLIP 98-160 x FLIP 95-68C) x FLIP 02-36C	xO5TH113	FLIP 98-113C X FLIP 0014C
xO5TH32	(S01169 x FLIP 97-90C)X FLIP 02-41C	xO5TH137	FLIP 98-178C X F5LM (5745)
xO5TH33	(S01172 X FLIP 97-91C)X FLIP 01-25C	xO5TH162	FLIP 00-14C X ICCV-92337
xO5TH35	(S01203 X FLIP 97-205C) X FLIP 01-29C	xO5TH172	FLIP 02-35C X ICCV-94304
xO5TH36	(S01205 X FLIP 97-229C) X FLIP 00-72C	xO5TH174	FLIP 00-14C X ICCV-92337
xO5TH37	(S01228 X FLIP 98-229C)X FLIP 01-28C	xO5TH182	ICCV 03301 X FLIP 00-14C
xO5TH43	(FLIP 87-59C X FLIP 99-34C) X FLIP 006C	xO5TH183	ICCV 03304 X FLIP 00-06C
xO5TH52	(ILC 5258 X S 01107)X FLIP 98-178C	xO5TH184	ICCV 03307 X FLIP 97-85C
xO5TH68	(Leb.Market-1X UC 15)X FLIP 02-35C	xO5TH193	ICCV 03109 X FLIP 97-85C
xO5TH71	(FLIP 93-93C X UC 27) X FLIP 00-6C	FLIP 82-150c	X79TH101/ILC 523 X ILC 183
xO5TH77	ILP 1929 X FLIP 00-14C	ILC 482	Long term check
xO5TH86	FLIP 86-6C X FLIP 00-14C	FLIP82-150C	X79TH101/ILC 523 X ILC 183

Table 3: Descriptive statistics of proximate composition (%) of faba bean genotypes

Protein	Number of genotypes	Moisture	Number of genotypes	Fat	Number of genotypes	Ash	Number of genotypes	CH_2O	Number of genotypes
<32	7(17.5)[*]	<7.3	10(25)	>1.7	5(12.5)	<3.5	8(20)	<43	2(5)
32-34	20(50)	7.3-7.4	18(45)	1.7-1.8	11(27.5)	3.6-3.9	16(40)	43-46	17(42.5)
34.1-36	11(27.5)	7.41-7.56	10(25)	1.81-2	14(35)	4-4.4	13(32.5)	46-48	18(45)
>36	2(5)	>7.56	2(5)	>2	10(25)	>4.4	3(7.5)	>48	3(7.5)
Min	31.5	Min	7.21	Min	1.52	Min	3	Min	42.7
Max	37.7	Max	8	Max	2.13	Max	4.8	Max	49.3
Mean	33.56	Mean	7.38	Mean	1.86	Mean	3.84	Mean	45.7
SD	1.472	SD	0.13	SD	0.15	SD	0.42	SD	1.8
CV	4.39	CV	1.78	CV	8.43	CV	11.05	CV	3.97

CH_2O = carbohydrates; CV = coefficient of variation; SD = standard deviation; Min = minimum value; Max = maximum value
[*]Values in parenthesis indicate the percentage of total genotypes used in the study

significantly different among genotypes; manganese (Mn), Cu and Zn were generally low than potassium (K) and Ca (Table 5). Potassium ranged from 699 mg/100 g in FLIP03-020FB genotype to 792 mg/100 g in FLIP03-028FB genotype (Table 5). Phosphorous (P) contents ranged from 63.6 mg/100 g in FLIP03-025FB genotype to 73.5 mg/100 g in Giza 40 genotype (Table 5). These were followed by Ca (33.9 to 39.3 mg/100 g), iron (Fe) (14.6–15.8 mg/100 g), Mg (7.4–8.2 mg/100 g), Zn (5.8–7.2 mg/100 g), Cu (2–2.9 mg/100 g) and Mn (2.1–2.8 mg/100 g). Iron content was not found significantly different among genotypes.

Chickpea grains found to be a good source of macro elements (Ca, P and K) and moderate source of micro elements (Zn, Fe, Mn and Cu) (Table 6). Potassium and P ranged from 920–1097 mg/100 g and 232–273 mg/100 g, respectively. These were followed by Ca (180.9–196.4

Table 4: Descriptive statistics of proximate composition (%) of chickpea genotypes

Protein	Number of genotypes	Moisture	Number of genotypes	Fat	Number of genotypes	Ash	Number of genotypes	CH_2O	Number of genotypes
<20	2(7.2)*	<7.3	3(10.7)	<3.9	5(17.9)	<3	3(10.8)	<64	3(10.8)
20-22	5(18)	7.4-7.5	13(46.5)	3.9-4.4	14(49.9)	3-3.3	7(24.9)	64-67	10(35.5)
22-24	12(43)	7.6-7.7	9(32.2)	4.5-5	7(25)	3.4-3.7	12(42.8)	67-69	8(28.6)
>24.5	9(32.5)	>7.7	3(10.7)	>5	2(7.2)	>3.7	6(21.4)	>69	7(25)
Min	19.8	Min	7.1	Min	3.6	Min	2.7	Min	63
Max	24.9	Max	7.9	Max	5.2	Max	3.9	Max	69.7
Mean	23.093	Mean	7.5321	Mean	4.2893	Mean	3.4429	Mean	67.011
SD	1.542	SD	0.1867	SD	0.4483	SD	0.3543	SD	2.064
CV	6.68	CV	2.48	CV	10.45	CV	10.29	CV	3.08

CH_2O = Carbohydrates; CV = Coefficient of variation; SD = Standard deviation; Min = Minimum value; Max = Maximum value
*Values in parenthesis indicate the percentage of total genotypes used in the study

Table 5: Descriptive statistics of mineral contents (mg/100 g) of faba bean genotypes

Ca	Number of genotypes	P	Number of genotypes	K	Number of genotypes	Mg	Number of genotypes
<34	2(5)*	<64	2(5)	<721	4(10)	<7.5	2(5)
34-36	7(17.5)	64.3-69	17(42.5)	727-748	15(37.5)	7.5-7.7	18(45)
36.2-39	29(72.5)	69.1-72.9	18(45)	760-780	16(40)	7.8-8	18(45)
<39	2(5)	>73	3(7.5)	>780	5(12.5)	>8	2(5)
Min	30.65	Min	60	Min	699	Min	7.4
Max	39.3	Max	73.5	Max	792	Max	8.2
Mean	37.11	Mean	68.88	Mean	752.9	Mean	7.73
SD	1.71	SD	3	SD	22.54	SD	0.202
CV	4.63	CV	4.3	CV	3	CV	2.6
Fe	Number of genotypes	Mn	Number of genotypes	Cu	Number of genotypes	Zn	Number of genotypes
<14.9	5(12.5)	<2.3	2(5)	<2.2	5(12.5)	<5.9	2(5)
14.9-15.2	18(45)	2.3-2.4	16(40)	2.2-2.4	12(30)	5.9-6.4	20(50)
15.3-15.6	16(40)	2.5-2.6	15(37.5)	2.5-2.7	19(47.5)	6.5-6.9	15(37.5)
>15.6	1(2.5)	>2.6	7(17.5)	>2.8	4(10)	>7	3(7.5)
Min	14.6	Min	2.1	Min	2	Min	5.8
Max	15.8	Max	2.8	Max	2.9	Max	7.2
Mean	15.18	Mean	2.48	Mean	2.49	Mean	6.4
SD	0.287	SD	0.16	SD	0.233	SD	0.39
CV	1.8	CV	6.4	CV	9.3	CV	6.1

CV= coefficient of variation; SD = standard deviation; Min = minimum value; Max = maximum value; Ca = calcium; P = phosphorous; K = potassium; Mg = magnesium; Fe= iron; Mn = manganese; Cu = cupper; Zn = Zinc
*Values in parenthesis indicate the percentage of total genotypes used in the study

mg/100 g), Zn (5.1–6.9 mg/100 g), Mg (3.5–4.9 mg/100 g), Fe (2.4–3.9 mg/100 g), Mn (1.3–2.1 mg/100 g) and Cu (0.66–1.04 mg/100 g). The trend of concentration of various minerals in tested chickpea genotypes was K > P > Ca > Zn > Mg > Fe > Cu > Mn > Cu.

Amino Acids Analysis

Essentials amino acids (EAA) content of faba bean genotypes indicated that faba grains contained various EAA, *i.e.* leucine, isoleucine, lysine, methionine, phenylalanine, threonine, valine, tryptophan and tyrosine (Table 7). Arginine was the most abundant amino acids in most of the faba bean genotypes and ranged from 6.9 to 12.6 g/kg. Leucine, phenylalanine, valine, isoleucine, lysine and threonine were also the abundant amino acids in faba bean genotypes (Table 7). However, tryptophan and methionine were the lowest amino acids in faba bean grains (Table 7). Among non-essential amino acids, glutamic acid was the highest one, and varied considerably among genotypes (Table 7). Aspartic acid was second most abundant amino acid (Table 7). Other non-essential amino acids i.e. alanine, glycine, proline, serine and tyrosine were present in moderate amount and cysteine was the lowest one (Table 7).

Chickpea genotypes contained leucine, isolucine, lysine, methionine, phenyl alanine, threonine, valine, tryptophan and histidine as essential amino acids (Table 8). Arginine was found to be most abundant amino acid in most of the chickpea genotypes. This was followed by leucine, lysine phenylalanine, threonine, valine, isoleucine and tyrosine, respectively (Table 8). Tryptophan and methionine were the limiting amino acids in chickpea genotypes. Among non-essential amino acids, glutamic acid and aspartic acid were the abundant. Other non-essential amino acids *i.e.* alanine, glycine, proline, serine and histidine were present in moderate amount and cysteine was the limiting.

Antioxidant Analysis

The total phenolic contents of various faba bean genotypes

Table 6: Descriptive statistics of minerals contents (mg/100 g) of chickpea genotypes

Ca	Number of genotypes	P	Number of genotypes	K	Number of genotypes	Mg	Number of genotypes
<184	6(21.6)*	<240	4(14.3)	<1000	4(14.4)	<4	5(17.9)
185-190	10(36)	240-255	12(42.9)	1000-1040	9(32.3)	4.1-4.4	7(25)
190-195	9(32.3)	256-270	11(39.4)	1041-1080	13(46.7)	4.5-4.7	8(28.5)
>195	3(10.8)	>270	1(3.6)	>1080	2(7.2)	>4.7	8(28.6)
Min	180.9	Min	232	Min	920	Min	3.8
Max	196.4	Max	273	Max	1097	Max	4.9
Mean	188.75	Mean	253.36	Mean	1034	Mean	4.4571
SD	4.51	SD	10.67	SD	45.2	SD	0.3595
CV	2.39	CV	4.21	CV	4.37	CV	8.06
Fe	Number of genotypes	Mn	Number of genotypes	Cu	Number of genotypes	Zn	Number of genotypes
>2.6	4(14.3)	<1.5	5(17.8)	<0.80	5(17.9)	<5.5	3(10.8)
2.6-3	14(50.1)	1.5-1.7	12(42.8)	0.82-0.90	11(39.3)	5.6-6.2	13(46.4)
3.1-3.6	8(28.5)	1.8-2	10(35.7)	0.91-0.99	7(25.1)	6.3-6.7	9(32.2)
>3.6	2(7.2)	>2	1(3.6)	>100	5(17.9)	>6.7	3(10.7)
Min	2.3	Min	1.3	Min	0.66	Min	5.1
Max	3.9	Max	2.1	Max	1.04	Max	6.9
Mean	2.9429	Mean	1.6893	Mean	0.8804	Mean	6.1286
SD	0.4185	SD	0.2149	SD	0.0995	SD	0.4681
CV	14.22	CV	12.72	CV	11.3	CV	7.64

CV= coefficient of variation; SD = standard deviation; Min = minimum value; Max = maximum value; Ca = calcium; P = phosphorous; K = potassium; Mg = magnesium; Fe = iron; Mn = manganese; Cu = cupper; Zn = zinc
*Values in parenthesis indicate the percentage of total genotypes used in the study

Table 7: Descriptive statistics of amino acid contents (g/kg) of faba bean genotypes

Thr	Number of genotypes	His	Number of genotypes	Met	Number of genotypes	Lys	Number of genotypes	Arg	Number of genotypes
<3.3	5(12.5)	<3	5(12.5)	<1	12(30)	<3.6	6(15)	<8	2(5)
3.3-3.9	22(55)	3-3.5	19(47.5)	1-1.2	15(37.5)	3.6-4.2	14(35)	8.5-9.9	16(40)
4-4.9	11(27.5)	3.6-4.2	14(35)	1.3-1.5	11(27.5)	4.3-5	18(45)	10-11.7	18(45)
>4.9	2(5)	>4.4	2(5)	>1.6	2(5)	>5.1	2(5)	>12	4(10)
Min	3	Min	2.3	Min	0.7	Min	3.2	Min	6.9
Max	5	Max	4.7	Max	1.7	Max	5.7	Max	12.6
Mean	3.845	Mean	3.465	Mean	1.15	Mean	4.1725	Mean	10.118
SD	0.5272	SD	0.5132	SD	0.2572	SD	0.5991	SD	1.257
Leu	Number of genotypes	Ile	Number of genotypes	Phe	Number of genotypes	Trp	Number of genotypes	Val	Number of genotypes
<5	1(2.5)	<3.5	3(7.5)	<4.5	10(25)	<1.3	3(7.5)	<3.6	8(20)
5.4-6.7	13(32.5)	3.5-4.2	21(52.5)	4.5-5.2	10(25)	1.3-1.4	25(62.5)	3.7-5.2	17(42.5)
7-7.8	22(55)	4.3-5.1	13(32.5)	5.6-6.1	14(35)	1.5-1.6	11(27.5)	5.3-6	10(25)
>7.9	4(10)	>5.2	3(7.5)	>6.2	6(15)	>1.6	1(2.5)	>6	5(12.5)
Min	4.6	Min	3.2	Min	4.2	Min	1.2	Min	3.3
Max	8.1	Max	5.6	Max	6.6	Max	1.7	Max	6.4
Mean	6.942	Mean	4.185	Mean	5.265	Mean	1.395	Mean	4.705
SD	0.835	SD	0.5912	SD	0.822	SD	0.1131	SD	1.019

All values are means of triplicate determinations; Ala = alanine; Gly = glycine; Leu = leucine; Iso = isoleucine; Phe = phenylalanine; Try = Tryptophan; Tyr = tyrosine; Val = valine; Pro = proline; Ser = serine; Thr = threonine; Glu = glutamic acid; Asp = aspartic acid; His = histidine; Cys = cysteine; Met = methionine; Lys = lysine; Arg = arginine; SD = standard deviation; Min = minimum value; Max = maximum value
*Values in parenthesis indicate the percentage of total genotypes used in the study

ranged from 5.84 in WRB 1-4 genotype to 11.43 mg GAE/g in Hassawi 1, respectively (Table 9). Faba bean genotypes were categorized into three groups depending on their phenolic content as low (<6 mg GAE/g), moderate (6–10 mg GAE/g) and high (>10 mg GAE/g) (Table 9). On the other hand, there was no significant difference in total flavonoid component (TFC) among faba bean genotypes and this ranged from 0.08 to 0.16 mg QE/g in various genotypes. The di(phenyl)-(2,4,6-trinitrophenyl) iminoazanium (DPPH) values of faba bean ranged from 0.62 in WRB 1-5 and FLIP03-002FB to 2.27 mg/g in Hassawi 1 (Table 9).

Different genotypes of chickpea also exhibited difference in total phenolics component (TPC). The TPC of chickpea genotypes ranged from 1.50 to 2.59 mg GAE/g, TFC from 0.057 to 0.181 mg QE/g and DPPH activity of chickpea genotypes ranged from 0.276–0.398 mg/g (Table 10). The chickpea genotypes xO5TH13 contained the lowest amount of TPC (1.5 mg GAE/g) while the genotype xO5TH33 contained the maximum TPC (2.59 mg GAE/g) (Table 10). The genotypes xO5TH193 contained the highest TFC (0.18 mg QE/g), while the genotype xO5TH172 contained lowest TFC content (0.057 mg QE/g) (Table 10). DPPH activity was highest in genotype xO5TH33 (0.39

Table 8: Descriptive statistics of amino acid contents (g/kg) of chickpea genotypes

Thr	Number of genotypes	His	Number of genotypes	Met	Number of genotypes	Lys	Number of genotypes	Arg	Number of genotypes
<3.60	4(14.8)	<2.5	5(18)	<1.30	8(28.6)	<6.00	4(14.4)	<10	2(7.2)
3.61-3.83	14(51.8)	2.53-3.26	11(39.5)	1.3-1.49	9(32.3)	6-6.4	10(36)	10-10.5	12(42.7)
3.84-3.98	7(25.9)	3.28-3.80	8(28.7)	1.52-1.78	10(35.9)	6.4-6.65	11(39.5)	10.6-11	11(39.2)
>4	2(7.4)	>3.8	4(14.4)	>1.8	1(3.6)	>6.69	3(10.8)	>11	3(10.7)
Min	3.21	Min	2.25	Min	1.17	Min	5.8	Min	9.36
Max	4.02	Max	3.9	Max	1.78	Max	6.79	Max	11.2
Mean	3.7532	Mean	3.066	Mean	1.43	Mean	6.3782	Mean	10.23
SD	0.1836	SD	0.558	SD	0.1846	SD	0.2443	SD	0.4
Leu	Number of genotypes	Ile	Number of genotypes	Phe	Number of genotypes	Trp	Number of genotypes	Val	Number of genotypes
<6.88	4(14.4)	<3.00	6(21.5)	2(7.2)	2(7.2)	<0.92	2(7.2)	<3	4(14.3)
6.93-7.2	12(43)	3-3.4	9(32.3)	9(32.4)	9(32.4)	0.95-1	6(21.4)	3-3.5	10(35.5)
7.22-7.5	9(32.2)	3.5-3.8	11(39.5)	13(46.7)	13(46.7)	1-02-1.05	11(39.2)	3.54-3.82	12 (43)
>7.5	3(10.8)	>3.8	2(7.2)	4(14.4)	4(14.4)	>1.05	9(32)	>3.89	2(7.2)
Min	6.45	Min	2.39	Min	4.72	Min	0.9	Min	2.9
Max	7.78	Max	3.91	Max	5.93	Max	1.1	Max	3.96
Mean	7.1775	Mean	3.3893	Mean	5.2893	Mean	1.0246	Mean	3.455
SD	0.2933	SD	0.4015	SD	0.4118	SD	0.0549	SD	0.3062

All values are means of triplicate determinations; Ala = alanine; Gly = glycine; Leu = leucine; Iso = isoleucine; Phe = phenylalanine; Try = Tryptophan; Tyr = tyrosine; Val = valine; Pro = proline; Ser = serine; Thr = threonine; Glu = glutamic acid; Asp = aspartic acid; His = histidine; Cys = cysteine; Met = methionine; Lys = lysine; Arg = arginine; SD = standard deviation; Min = minimum value; Max = maximum value
*Values in parenthesis indicate the percentage of total genotypes used in the study

Table 9: Descriptive statistics of antioxidants in faba bean genotypes

TPC (mg GAE /g)	Number of genotypes	TFC (mg QE /g)	Number of genotypes	DPPH (mg/g)	Number of genotypes
<6	1(2.5)*	<0.1	12(30)	<1	10(25)
6-8	10(25)	0.1-0.12	18(45)	1-1.5	19(47.5)
8-10	25(62.5)	0.13-0.15	8(20)	1.6-1.7	8(20)
>10	4(10)	>0.15	2(5)	>2	3(7.5)
Min	5.843	Min	0.083	Min	0.626
Max	11.432	Max	0.168	Max	2.276
Mean	8.474	Mean	0.11595	Mean	1.3218
SD	1.241	SD	0.02272	SD	0.4307

SD = standard deviation; Min = minimum value; Max = maximum value; TPC= total phenolic component; TFC = total flavonoid component; DPPH = di(phenyl)-(2,4,6-trinitrophenyl) iminoazanium
*Values in parenthesis indicate the percentage of total genotypes used in the study

Table 10: Descriptive statistics of antioxidants in chickpea genotypes

TPC (mg GAE /g)	Number of genotypes	TFC (mg QE /g)	Number of genotypes	DPPH (mg/g)	Number of genotypes
<1.7	7(25)*	<0.05	1(3.6)	<0.29	7(25)
1.79-1.98	10(35.8)	0.06-0.07	19(67.9)	0.29-0.31	11(39.3)
2-2.7	9(32.4)	0.08-0.09	5(17.8)	0.32-0.36	7(24.9)
>2.28	2(7.2)	>0.09	3(10.7)	<0.36	3(10.7)
Min	1.507	Min	0.057	Min	0.276
Max	2.595	Max	0.181	Max	0.398
Mean	1.925	Mean	0.07825	Mean	0.31629
SD	0.2673	SD	0.02379	SD	0.03431

SD = standard deviation; Min = minimum value; Max = maximum value; TPC= total phenolic component; TFC = total flavonoid component; DPPH = di(phenyl)-(2,4,6-trinitrophenyl) iminoazanium
*Values in parenthesis indicate the percentage of total genotypes used in the study

mg/g), while lowest in xO5TH68 (0.27 mg/g) (Table 10).

Antinutritional Factors

Faba bean trypsin inhibitor activity level ranged from 2.24–2.77 trypsin inhibitor units (TIU)/mg with average value of 2.50 TIU/mg (Table 11). Genotype WBR 2–7 had the highest trypsin inhibitor activity level followed by genotypes FLIP03-015FB, FLIP03-001FB, FLIP03-012FB and FLIP03-002FB (Table 11). However, genotypes WBR 1-3, Gaziral, Triple weight, FLIP03-027FB, FLIP03-026FB and FLIP03-025FB showed lower TIU values. Chymotrypsin inhibitor activity level ranged from 0.35 in FLIP03-017FB to 0.70 TIU/g in Reina Blanca (Table 11). Phytic acid values in faba bean genotypes ranged from 1.23 in WRB 2-1 to 1.55 mg/100 g in FLIP03-023FB genotype with average value of 1.35 (Table 11).

Trypsin inhibitory activity level of the chickpea genotypes ranged from 7.65 in xO5TH32 to 8.89 TIU/mg in xO5TH52 with average of value of 8.33 TIU/mg (Table 12). Chymotrypsin inhibitor activity level ranged from 9.0 in xO5TH32 and xO5TH108 to 11.9 TIU/g in xO5TH174 genotype (Table 12). Tannins content ranged from 5.9 mg/g in genotype xO5TH52 to 4.94 mg/g in genotype xO5TH86 (Table 12). Similar to trypsin inhibitor level, tannins content of chickpea genotypes had a very narrow range. Chickpea genotype xO5TH37 showed the highest phytic acid value *i.e.* 6.98 mg/g, while genotypes FLIP 82-150c, xO5TH36 and xO5TH33 showed the lowest phytic acid value *i.e.* 6.10 (Table 12).

Discussion

This study demonstrated that faba bean and chickpea genotypes vary in their nutritional status, which might be used as selection criteria to breed new genotypes of both

Table 11: Descriptive statistics of antinutritional factors in faba bean genotypes

Trypsin (TIU/mg)	Number of genotypes	Chymotrypsin (TIU/mg)	Number of genotypes	Tannin (mg/100 g)	Number of genotypes	Phytic acid (mg/100 g)	Number of genotypes
<2.31	4(10)*	<0.4	8(20)	<13	12(30)	<1.3	8(20)
2.33-2.48	17(42.5)	0.41-49	14(35)	13-14.8	13(32.5)	1.3-1.39	22(55)
2.51-2.7	15(37.5)	0.5-0.6	12(30)	15-15.9	13(32.5)	1.4-1.5	7(17.5)
>2.7	4(10)	>0.6	6(15)	>15.9	2(5)	>1.5	3(7.5)
Min	2.24	Min	0.35	Min	12.2	Min	1.23
Max	2.77	Max	0.7	Max	16.2	Max	1.55
Mean	2.5	Mean	0.49	Mean	14.16	Mean	1.35
SD	0.13	SD	0.09	SD	1.25	SD	0.08

SD = standard deviation; Min = minimum value; Max = maximum value; TIU = trypsin inhibitory unit

*Values in parenthesis indicate the percentage of total genotypes used in the study

Table 12: Descriptive statistics of antinutritional factors in chickpea genotypes

Trypsin (TIU/mg)	Number of genotypes	Chymotrypsin (TIU/mg)	Number of genotypes	Tannin (mg/g)	Number of genotypes	Phytic acid (mg/g)	Number of genotypes
<7.8	5(17.9)*	<9.3	5(17.8)	<4.3	4(14.4)	<6.12	6(21.4)
7.85-8.56	10(35.9)	9.3-10.2	11(39.3)	4.3-4.5	9(32.2)	6.12-6.14	12(42.9)
8.6-8.78	9(32.3)	10.3-11	10(35.5)	4.6-4.8	11(39.5)	6.15-6.17	8(28.5)
>8.8	4(14.4)	>11	2(7.2)	>4.8	4(14.3)	>6.90	2(7.2)
Min	7.65	Min	9	Min	4.11	Min	6.1
Max	8.98	Max	11.9	Max	4.94	Max	6.98
Mean	8.33	Mean	10	Mean	4.55	Mean	6.19
SD	0.46	SD	0.76	SD	0.22	SD	0.21

SD = standard deviation; Min = minimum value; Max = maximum value; TIU = trypsin inhibitory unit

*Values in parenthesis indicate the percentage of total genotypes used in the study

these crops with improved nutrient profile. The variability in chemical composition among faba bean genotypes might be due to variations in genetic background and/or origin of that specific genotype (El-Saber, 2010). Moreover, there was also a considerable difference in the nutritional profile of the various chickpea genotypes and most of chickpea genotypes appeared to be good source of protein, ash, fat and carbohydrates as was observed in a previous study (Costa *et al*., 2006). Taken together, proximate composition of faba bean and chickpea grains were found to vary according to genotypes and some genotypes proved to be good sources of nutrition. The remarkably high level of protein, carbohydrate and ash in some genotypes underlines their importance as sources of vital nutrients, which may be considered in future breeding programs.

All living organisms require minerals to activate their enzymes, hormones and other molecules that play an important role in the growth, various functions and maintenance other life processes. In the present study we observed that both faba and chickpea genotypes had high levels of mineral contents (calcium, iron, copper, zinc, potassium and magnesium) which may provide a sufficient amount of minerals to meet the human mineral requirement, RDA (Recommended Dietary Allowance) (NRC/NAS, 1989) and to prevent malnutrition.

Likewise, amino acid composition normally reflects the nutritive value of particular protein source (Bodwell *et al*., 1980). Essential amino acid contents of faba bean genotypes indicated that faba grains contained various EAA (leucine, isoleucine, lysine, methionine, phenylalanine, threonine, valine, tryptophan, tyrosine, methionine and cysteine) and there was a considerable difference among faba bean genotypes. This variation in amino acid composition among various genotypes may be due to environmental growth conditions or genotypic differences among faba bean genotypes. Chickpea genotypes also contained EAA like leucine, isoleucine, lysine, methionine, phenyl alanine, threonine, valine, tryptophan and histidine, which proved that chickpea grains are also a good source of these EAA.

The total phenolic contents (TPC) and total flavonoid contents (TFC) can be used as key marker of the antioxidant activity in functional foods and natural phenolics make use of their beneficial health effects mainly through their antioxidant activity (Fang *et al*., 2002). These phenolic compounds have ability to act as free radical scavengers and metal ions chelators (Naczk and Shahidi, 2004). We observed significant differences among faba bean genotypes for phenolic compounds and antioxidant activities. The results strongly suggest that faba bean genotypes may serve as an excellent dietary source of natural antioxidant for disease prevention and health promotion. Therefore increase consumption of faba grains can reduce the risk of cardiovascular disease and some types of cancer. Similarly chickpea genotypes also exhibit the variability in total phenolic content and showed lower phenolic contents than faba bean genotypes. However, most of genotypes showed higher TPC as described by Xu and Chang (2007), which may be considered in future breeding programs.

Anti-nutritional factors determined in this study are protease inhibitors (trypsin and chymotrypsin) tannin and phytate or phytic acid in faba bean and chickpea and these inhibitors and tannins may account for the decrease in digestive utilization. There exists considerable differences among tested genotypes in TIU and thus, genetic selection could greatly reduce trypsin inhibitor level. Phytic acid can form complex with protein and minerals that lead to reduction of protein solubility and minerals availability due to their negative charges. In order to utilize legume grains effectively as human food, it is essential to inactivate or remove these anti-nutritional factors. There are several methods of processing bean, which include soaking, cooking, autoclaving, roasting, germination and fermentation. Generally, adequate heat processing inactivates the trypsin and chymotrypsin (Osman *et al*., 2002). Heat stable compounds in cereal and legumes such tannins and phytates are easily removed after germination (Reddy *et al*., 1985) and fermentation (Osman, 2004). However recent studies have identified certain anti-nutritional compound may have beneficial effect on human health after adequate processing procedures (Roy *et al*., 2009).

Overall, 40 faba bean and 28 chickpea genotypes were categorized into three groups as low, medium and high quality genotypes according to their nutritional profiles. Based on genotype wise nutritional status, the best 5 genotypes were selected from each crop. the selection criteria included protein content (higher than 25% in faba bean genotypes and 20% in chickpea genotypes), iron and zinc, more than 3 mg/100 g and 6 mg/100 g, respectively The upper limits for trypsin and chymotrypsin inhibitors were established as lower than 3 TIU/mg protein based on the average of the respective values found for the genotypes studied. Overall, the five best performing genotypes exhibited better value for nutritional contents among faba bean were FLIP03-015FB, FLIP03-007FB, FLIP03-012FB, Giza40 and Triple White and among chickpea were xO5TH20, xO5TH52, xO5TH193, xO5TH15 and xO5TH108. The grains of those faba and chickpea genotypes contain appreciable amount of proteins, fat, carbohydrate, mineral elements, polyphenols and generally low level of anti-nutritional factors which may be included in daily diet or these genotypes can be used in future breeding programs.

In crux, faba bean and chickpea genotypes have differential grain nutrient profile, which can positively contribute to the nutrient requirements of human diet. The genotypes also have high anti-oxidants activities hence may be of great medicinal value and much beneficial health attributes. Some faba bean and chickpea genotypes showed superiority in most of the chemical components. These genotypes could be used as protein and antioxidant sources to curtail the protein deficiency problems in human diet. These genotypes are further suggested for use in genetic improvement programs.

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