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Characteristics and composition of different seed oils and flours

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Abstract

The nutritional quality and functional properties of paprika seed flour and seed kernel flours of pumpkin and watermelon, and also the characteristics and structure of their seed oils, were studied. Paprika seed and seed kernels of pumpkin and watermelon were rich in oil and protein. All flour samples contained considerable amounts of P, K, Mg, Mn and Ca. Paprika seed flour was superior to watermelon and pumpkin seed kernel flours in contents of lysine and total essential amino acids. Antinutritional compounds, such as stachyose, raffinose, verbascose, trypsin inhibitor, phytic acid and tannins, were detected in all flours. Pumpkin seed kernel flour had higher values of chemical score, essential amino acid index and in-vitro protein digestibility than the other flours examined. The first limiting amino acid was lysine, for both watermelon and pumpkin seed kernel flours, but it was leucine in paprika seed flour. Functional properties were excellent in watermelon and pumpkin seed kernel flours and fairly good in paprika seed flour. Flour samples could be potentially added to food systems such as bakery products and ground meat formulations, not only as a nutrient supplement, but also as a functional agent in these formulations. Oil samples had high amounts of unsaturated fatty acids, with linoleic and oleic acids as the major acids. All oil samples could be fractionated into seven classes including triglycerides as a major lipid class. Data obtained for the oils characteristics compare well with those of other edible oils.

Keywords: Watermelon seed; Pumpkin seed; Paprika seed; Oil characteristics; Functional properties; Nutritional quality

1. Introduction

Recently, more attention has been focused on the utilization of food processing by-products and wastes, as well as under-utilized agricultural products. Obviously, such utilization would contribute to maximizing available resources and result in the production of various new foods. Simultaneously, a major contribution to avoiding waste disposal problems could be made.

The problems of industrial waste are becoming harder to solve, and much effort will be needed to develop the nutritional and industrial potential of by-products, waste and under-utilized agricultural products. Only a small portion of plant material is utilized directly for human consumption (El-Adawy, Rahma, El-Bedawy & Gafer, 1999). The remainder, or part of it, may be converted into nutrients for either food or feed, or into fertilizer; thus an important contribution to food resources or industrial products could be made (El-Adawy et al., 1999; Kamel, Deman & Blackman, 1982). For example, watermelon, pumpkin and paprika seeds, which remain in large quantities as waste products after the removal of the pulp, peel and flesh, could be used.

Pumpkin (*Cucurbita* sp.) and melon (*Citrullus* sp.) seeds are utilized directly for human consumption as snacks after salting and roasting, in Arabian countries (Al Khalifa, 1996). These seeds are excellent sources of protein (25.2–37%) and oil (37.8–45.4%; Lazos, 1986). Pumpkin seed oil has been produced in the southern parts of Austria, Slovenia and Hungary (Murkovic, Hillebrand, Winkler & Pfannhauser, 1996), while melon seeds are used for oil production at subsistence level in Nigeria (Akoh & Nwosu, 1992). Oils of pumpkin and melon seeds are used as cooking oils in some countries in West Africa and the Middle East (Girgis & Said, 1968; Kamel, Dawson & Kakunda, 1985; Sawaya, Daghir, & Khan, 1983). The kernels of pumpkin and melon seeds have been utilized as additives to some food dishes (Nwokolo & Sim, 1987). Several reports exist on the nutritive values of proteins and oils of melon and pumpkin seeds (Abd El-Aal & Rahma, 1988; Al-Khalifa,

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1996; Lazos, 1986; Nwokolo & Sim, 1987). However, very little information has been reported on the physicochemical and functional properties of pumpkin and melon seed proteins.

Paprika (*Capsicum annuum*) is widely used as a flavouring and for nutritional purposes. Paprika seeds are separated from the pods and discarded after eating or processing the flesh. A survey of the literature reveals only one paper (Domokos, Peredi & Bernath, 1993) on the fatty acid composition of Hungarian paprika seed oils. No literature data are available on the chemical and physical properties of paprika seed protein.

Therefore, the purpose of this work is to report the chemical composition and other characteristics of the oil and protein fractions of both watermelon and pumpkin kernels as well as paprika seeds. In addition, functional properties of seed proteins are also studied.

2. Materials and methods

2.1. Materials

One single batch of each mature fresh watermelon, *Citrullus vulgaris* (10 pieces), pumpkin, *Cucurbita pepo* (10 pieces) and paprika, *Capsicum annuum* (15 kg) were purchased from the local market (Shibin El-Kom city, Egypt) during the summer season of 1998.

2.2. Methods

2.2.1. Preparation of materials

Watermelons and pumpkins were cut by a sharp knife and the seeds were hand-collected from the gourd and washed by tap water, then sun-dried at ~30°C for one week. Dried seeds were shelled by cracking with a small iron rod and manually peeled to remove the kernels. Paprika seeds were collected by hand, after disrupting the paprika pods, and subsequently sun-dried at ~30°C for one week. Dried paprika seeds and seed kernels of both pumpkin and watermelon were crushed, then soaked, in petroleum ether (b.p. 40–60°C), at room temperature ~25°C for 36 h, with several changes of the solvent (8 times). Evaporation of petroleum ether was performed on a water bath and the oil samples produced were stored separately in a refrigerator inside a dark tight-stoppered glass bottle for oil analysis. The defatted flours were air-dried at room temperature (~25°C) and again ground to pass through a 60 mesh (British standard screen) sieve. The fine flour of each sample was put in an air-tight kilner jar and kept in a refrigerator until analysis.

2.2.2. Chemical analysis

Moisture (14.004), total ash (14.006), crude fibre (14.020), total fat (7.056) and total nitrogen (micro-Kjeldahl; 2.057) were determined according to the methods of AOAC (1990). Protein was calculated as N×5.3. N-free extract was calculated by difference.

2.2.3. Mineral contents

Samples were digested by concentrated nitric acid and perchloric acid (1:1, v/v). Total phosphorus was determined in the digested solution according to the method of Taussky and Shorr (1953). Na, Ca and K were estimated using an emission flame photometer (Model Corning 410), while Mg, Fe, Zn, Mn and Cu were determined using an atomic absorption spectrophotometer (Perkin-Elmer Instrument Model 2380), as described by El-Adawy et al. (1999).

2.2.4. Amino acids

Amino acids were determined using a Mikrotechna AAA 881 automatic amino acid analyzer according to the method described by Moore and Stein (1963). Hydrolysis of the flour samples was performed in the presence of 6 M HC1 at 110°C for 24 h. under nitrogen atmosphere. Sulfur-containing amino acids were determined after performic acid oxidation, as described by the method of Moore (1963). Meanwhile, tryptophan content was colorimetrically determined by the method of Miller (1967) after alkaline hydrolysis.

2.2.5. Antinutritional factors

Trypsin inhibitor activity was estimated according to the method of Kakade, Simons and Wiener (1969) using benzoyl-DL-arginine-P-nitroanilide hydrochloride as substrate. Total tannins (methods No: 9.098, 9.099, 9.100) were determined colorimetrically as described in AOAC (1990). The Wheeler and Ferrel (1971) procedure was followed for analysis of phytic acid, including determination of phosphorus by the method of Taussky and Shorr (1953). Flatulence factors (stachyose, raffinose and verbascose) were determined according to Tanaka, Thananunkul, Lee and Chichester (1975) using the TLC method.

2.2.6. In-vitro protein digestibility

This was determined as described by Salgó, Granzler and Jecsai (1984), by measuring the change in the sample solution pH after incubation at 37°C with trypsin-pancreatin enzyme mixture for 10 min.

2.2.7. Biological value

Biological values were determined on the basis of amino acid profiles. Chemical score of amino acids was calculated using the FAO/WHO (1973) reference pattern. Essential amino acid index (EAAI) was calculated according to Oser (1959) using the amino acid composition of the whole egg protein published by Hidvégi and Békés (1984). Protein efficiency ratio (PER) was estimated according to the following regression equation proposed by Alsmeyer, Cunningham and Happich (1974): PER = −0.468 + 0.454 (leucine)−0.105 (tyrosine).

2.2.8. Physicochemical characterization of oils

The specific gravity (using a 10 ml pycnometer at 25°C), refractive index (using Abbé refractometer at 25°C), free fatty acids (Ca 5a-40), acid value (Cd 3a-63), peroxide value (Cd 8-53), saponification value (Cd 3-25), iodine value (Cd 1-25) and unsaponifiable matter (Ca 6a-40) of the oil samples were determined according to AOCS (1973).

2.2.9. Fatty acids

The methyl esters of crude oil were prepared according to Chalvardjian (1964), using a 1% of H_2SO_4 in absolute methyl alcohol. A Perkin-Elmer gas chromatograph (Model F22) with a flame ionization detector was used in the presence of nitrogen as a carrier gas. A glass column (2 m×2.5 mm), packed with Chrom Q 80/100 mesh at a temperature of 270°C, was used (El-Adawy et al., 1999). Standard fatty acid methyl esters were used for identification. The area under each peak was measured and the percentage expressed in regard to the total area as mentioned by El-Adawy et al. (1999).

2.2.10. Lipid classes

Lipid classes of the crude oils were separated by thin layer chromatography using precoated plastic sheets (POLYGRAM SilL G, 0.25 mm silica gel, made in Germany) according to the method of Mangold and Malins (1960).

2.2.11. Functional properties

Protein solubility in distilled water and 1.0 M sodium chloride solution was determined by the method described by Rahma and Narasinga Rao (1979). Water and oil absorption capacities were estimated according to Sosulski (1962) and Sosulski, Humbert, Bui and Jones (1976), respectively, and expressed as grams of water or millilitres of sunflower oil bound per g of flour. Foam capacity and foam stability were assessed according to the method of Lawhon, Rooney, Carter and Matti (1972) using 1% protein solution in a Braun blender at 1600 rpm for 5 mm. The percentage increase in foam volume was recorded as foam capacity. The change in volume of foam after 15, 30, 45 and 60 min of standing at room temperature (~30°C) was recorded as foam stability. Emulsification capacity (millilitres oil/g flour) was determined as described by Beuchat, Cherry and Quinn (1975). Emulsifying activity and emulsion stability were estimated by the method of Yasumatsu et al. (1972).

2.2.12. Statistical analysis

Results are expressed as the means of three separate determinations, except for the amino acid and fatty acid contents, as well as lipid classes, which were determined in duplicate. The data were statistically analyzed according to SAS (1985). Significant differences between any two means were determined at the 5% level.

3. Results and discussion

3.1. Chemical composition

Proximate compositions of watermelon and pumpkin seed kernels and paprika seed are presented in Table 1. Significant ($P \leqslant 0.05$) differences were observed among paprika seeds and seed kernels of pumpkin and watermelon in their contents of protein, oil, fibre, ash and N-free extract. Kernels of watermelon and pumpkin have high levels of protein (35.7–36.5%) and oil (50.10–51.01%); however, paprika seeds were still higher than many legumes in their protein (24.4%) and oil (25.91%) contents. This finding may focus interest on paprika seeds and seed kernels of both pumpkin and watermelon as high protein and oil sources in some food formulations. Paprika seeds had higher amounts of crude fibre (34.9%) and N-free extract (10.4%) than seed kernels of pumpkin and watermelon. Therefore, paprika seeds could also be considered as a good source of dietary fibre.

3.2. Minerals

Mineral contents of watermelon and pumpkin seed kernel flour and paprika seed flour are shown in Table 2. Paprika seed flour had a significantly ($P \leqslant 0.05$) higher

Table 1
Chemical composition of watermelon and pumpkin seed kernels and paprika seed (g/100 g dry weight sample)[a]

Component	Watermelon seed kernel	Pumpkin seed kernel	Paprika seed
Crude protein	35.7b	36.5a	24.4c
Crude oil	50.10b	51.01a	25.61c
Crude fibre	4.83b	4.43b	34.9a
Total ash	3.60b	3.21c	4.32a
N-free extract[b]	5.81b	4.88c	10.7a

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$).
[b] By difference.

Table 2
Mineral composition of watermelon and pumpkin seed kernel flours and paprika seed flour (mg/100 g dry weight flour)[a]

Element	Watermelon seed kernel flour	Pumpkin seed kernel flour	Paprika seed flour
Copper	2.1b	1.7c	3.72
Zinc	10.6a	8.2b	6.7c
Iron	12.1b	10.9c	14.6a
Manganese	9.9a	8.9b	7.2c
Magnesium	542a	483b	396c
Sodium	33c	38a	37b
Calcium	150b	130c	163a
Potassium	1176b	982c	1214a
Phosphorus	1279a	1090b	989c

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$).

potassium, calcium, copper and iron content than pumpkin and watermelon seed kernel flours, while watermelon seed kernel flour had significantly ($P \leqslant 0.05$) more phosphorus, magnesium, manganese and zinc. However, all flours contained considerable amounts of minerals but only a low amount of copper. All flours are good sources of phosphorus, potassium, magnesium, manganese and calcium. Generally, these results were in good agreement with those reported by Lazos (1986) for pumpkin and watermelon seeds. However, no literature reports were found on mineral contents of paprika seed flour. Since some flours in the baking industry are deficient in some elements, in particular, calcium and iron, the fortification of flours with paprika seed flour as well as pumpkin and watermelon seed kernel flours, might improve their nutritional properties.

3.3. Amino acid composition

Amino acid composition of watermelon and pumpkin seed kernel flours and paprika seed flour are shown in Table 3. The amino acid profiles of watermelon and pumpkin seed kernel flours were similar or only slightly different. However, paprika seed flour is rich in total essential amino acids, lysine, threonine, total aromatic amino acids and tryptophan as compared with the FAO/WHO (1973) reference pattern and either watermelon or pumpkin seed kernel flour profiles. Paprika seed flour had less isoleucine, valine, sulfur-containing amino acids and leucine than the reference pattern. However, it is interesting that the paprika seed protein could complement these protein sources that are low in lysine and tryptophan. No reports were found on the amino acid profile of paprika seed protein. Watermelon seed kernel flour had more leucine, total aromatic amino acid and tryptophan, while both watermelon and pumpkin seed kernel flours had less lysine and leucine than the FAO/WHO (1973) reference pattern. Therefore, these seed kernel flours require supplementation with complementary protein if they are to be used as food sources. The earlier studies of Nwokolo and Sim (1987) reported that watermelon and pumpkin seed kernel flours were superior to soybean in their contents of all amino acids except lysine, which is in agreement with our findings.

Table 3
Amino acid compositions of watermelon and pumpkin seed kernel flours and paprika seed flour (g/l6 g nitrogen)[a]

Amino acid	Watermelon seed kernel flour	Pumpkin seed kernel flour	Paprika seed flour	FAO/WHO (1973)
Isoleucine	2.80	3.21	3.89	4.0
Leucine	7.70	6.49	5.03	7.0
Lysine	3.14	4.17	8.18	5.5
Cystine	1.39	1.17	1.67	–
Methionine	1.71	1.88	1.03	–
Total sulfur amino acids	3.10	3.05	2.70	3.5
Tyrosine	3.92	3.17	3.59	–
Phenylalanine	5.76	4.47	4.69	–
Total aromatic amino acids	9.68	7.64	8.28	6.0
Threonine	3.09	3.30	5.10	4.0
Tryptophan	1.15	0.86	1.22	1.0
Valine	3.98	4.71	4.45	5.0
Total essential amino acids	34.6	33.4	38.9	36.0
Histidine	3.21	3.26	1.48	
Arginine	18.6	19.0	8.65	
Aspartic acid	8.09	9.61	14.5	
Glutamic acid	15.6	17.3	15.8	
Serine	5.01	5.41	6.17	
Proline	4.12	3.37	4.82	
Glycine	5.66	4.32	4.39	
Alanine	5.07	4.24	5.32	
Total non-essential amino acids	65.6	66.6	61.2	

[a] Average of two determinations.

3.4. Fatty acid composition

Table 4 shows the fatty acid composition of crude oils of watermelon and pumpkin seed kernels and paprika seeds. There were wide variations in the contents of palmitic, stearic, oleic and linoleic acids among the oils studied, leading to differences in total saturated, total unsaturated, monounsaturated and polyunsaturated fatty acids. All oil samples had high amounts of total unsaturated fatty acids (which consisted mainly of linoleic followed by oleic and palmitoleic acid) representing 78.4% for watermelon seed kernel oil, 76.5% for pumpkin seed kernel oil and 82.5% for paprika seed oil. Paprika seed oil had the highest content of linoleic acid (67.8%) and the lowest amount of oleic acid (14.6%) of the kernel oils. The presence of high amounts of the essential linoleic acid suggests that these oils are highly

Table 4
Fatty acid compositions of watermelon and pumpkin seed kernel oils and paprika seed oil[a]

Fatty acid (%)	Watermelon seed kernel oil	Pumpkin seed kernel oil	Paprika oil
Myristic (C14:0)	0.11	0.17	–
Palmitic (C16:0)	11.3	13.4	13.8
Palmitoleic (C16:1)	0.29	0.44	0.12
Stearic (C18:0)	10.2	9.96	3.71
Oleic (C18:1)	18.1	20.4	14.6
Linoleic (C18:2)	59.6	55.6	67.8
Linolenic (C18:3)	0.35	–	–
Total unsaturated fatty acids	78.4	76.5	82.5
Total saturated fatty acids	21.7	23.5	17.6
Monunsaturated fatty acids	18.4	20.8	14.7
Polyunsaturated fatty acids	60.0	55.6	67.8

[a] Average of two determinations.

nutritious, due to their ability to reduce serum cholesterol. As all the oil samples examined are rich in both oleic and linoleic acids, they may be used as edible cooking or salad oils or for margarine manufacture. The major saturated fatty acids in crude oils of paprika seed and seed kernels, of both watermelon and pumpkin, were palmitic and stearic acids. The total saturated fatty acid contents of watermelon and pumpkin seed kernels were higher (21.7 and 23.7%) than paprika seed oil (17.6%). These results are confirmed by the findings of Al-Khalifa (1996) for pumpkin and watermelon seed oils and Domokos et al. (1993) for Hungarian paprika seed oils.

3.5. Lipid classes

The quantitative data of the individual lipid classes of crude oils of paprika seed and seed kernels of watermelon and pumpkin are shown in Table 5. Crude oils of paprika seeds and seed kernels of watermelon and pumpkin contained seven lipid classes which appeared on the thin-layer chromatogram in the following sequence order from the front to the base line: hydrocarbon, triglycerides, free fatty acids, steroids, diglycerides, monoglycerides and phospholipids. Triglycerides were the predominant lipid class in all oil samples (representing 94.2, 94.9 and 94.5% for crude oils of paprika seed and seed kernels of both watermelon and pumpkin, respectively), followed by free fatty acids, then monoglycerides. Free fatty acids, monoglycerides and hydrocarbon contents were high in paprika seed oil, but triglycerides and phospholipids contents were high in watermelon and pumpkin seed kernel oils. The presence of monoglycerides and free fatty acids in oil samples may be due to the partial enzymatic hydrolysis of reserve triglycerides during storage of the seeds. Aboul-Nasr, Ramadan and El-Dengawy (1997) reported that triglycerides were the major lipid fraction in pumpkin seed oil. No data on the lipid classes of paprika and watermelon seed oils were available in the literature for comparative purposes.

Table 5
The percentage of lipid classes of watermelon and pumpkin seed kernel oils and paprika seed oil[a]

Lipid classes (%)	Watermelon seed kernel oil	Pumpkin seed kernel oil	Paprika seed oil
Hydrocarbons	0.27	0.62	0.97
Triglycerides	94.9	94.5	94.2
Free fatty acids	1.41	1.44	1.48
Sterols	1.12	1.01	0.89
Diglycerides	0.35	0.39	0.30
Monoglycerides	0.98	0.93	1.35
Phospholipids	0.96	1.09	0.85

[a] Average of two determinations.

3.6. Physicochemical properties of crude oils

Some of the chemical and physical properties of the crude oils extracted from watermelon and pumpkin seed kernels and paprika seed are shown in Table 6. The specific gravity of paprika seed oil was lower than those of watermelon or pumpkin seed kernel oils, and the values compared well with the 0.91 and 0.928 values reported by Kamel et al. (1985) for watermelon oil and Al-Khalifa (1996) for pumpkin oil. All oil samples had relatively high iodine values, thus reflecting a high degree of unsaturation. Saponification values were higher (except paprika seed oil) than those reported in the literature for cottonseed oil (189–198) but lower than those for coconut oil (248–265; Codex Alimentarius Commission, 1982). Peroxide values, acid values and free fatty acids of all oil samples were similar. The Codex Alimentarius Commission (1982) stipulated a permitted maximum peroxide level of not more than 10 meq peroxide oxygen/kg oil, e.g. soybean, cottonseed, rapeseed and coconut oils. It also stipulated permitted maximum acid values of 10 mg KOH/g oil and 4 mg KOH/g oil for virgin palm oil and coconut oil, respectively. Watermelon and pumpkin seed kernel oils have less unsaponifiable matter than paprika seed oil and average values of refractive index and ester number were comparable to those reported by Lazos (1986),

Table 6
Physicochemical characteristics of watermelon and pumpkin seed kernel oils and paprika seed oil[a]

Property	Watermelon seed kernel oil	Pumpkin seed kernel oil	Paprika seed oil
Refractive index (25°C)	1.4696a	1.4706a	1.4715b
Specific gravity (25°C)	0.919a	0.917a	0.912a
Acid value (mg KOH/gm oil)	2.82a	2.88a	2.96a
Saponification value (mg KOH/g oil)	201b	206b	168c
Ester value (mg KOH/g oil)	194b	203a	165c
Iodine value (g I/100 g oil)	115b	109c	131a
Peroxide value (meq O_2/kg oil)	3.40a	3.60a	3.21a
Free fatty acid (%) as oleic acid)	1.41a	1.44a	1.48a
Unsaponifiable matter (%)	0.93b	0.85	1.46a

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$).

Badifu (1991) and Al-Khalifa (1996). It is notable that there are no data in the literature on the chemical and physical properties of paprika seed oil for comparison results.

3.7. Antinutritional factors

Antinutritional factors of watermelon and pumpkin seed kernel flours, as well as paprika seed flour, are shown in Table 7. There were significant ($P \leqslant 0.05$) differences between watermelon and pumpkin seed kernel flours, in their contents of antinutritional factors. However, a significant ($P \leqslant 0.05$) difference was observed between paprika seed flour and both watermelon and pumpkin seed kernel flours in their contents of antinutritional factors. The highest level of phytic acid was noticed in pumpkin and watermelon seed kernel flours (2.37 and 2.63 g/100 g sample, respectively), while the highest levels of tannins (0.48 g/100 g sample), trypsin inhibitor (1.96 TIU/mg protein), raffinose (0.79 g/100 g), stachyose (0.92 g/100 g) and verbascose (0.66 g/100 g) were found in paprika seed flour. To the best of our knowledge there are no data reported in the literature regarding the antinutritional factors in watermelon, pumpkin and paprika seed flours.

Table 7
Antinutritional factors of watermelon and pumpkin seed kernel flours and paprika seed flour (g/100 g dry weight flour)[a]

Antinutritional factors	Watermelon seed kernel flour	Pumpkin seed kernel flour	Paprika seed flour
Raffinose	0.32b	0.29b	0.79a
Stachyose	0.67ab	0.52b	0.92a
Verbascose	0.26b	0.23b	0.66a
Phytic acid	2.63a	2.37a	1.98b
Tannins	0.24b	0.17b	0.48a
Trypsin inhibitor (TIU/mg protein)	1.46b	1.39b	1.96a

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$).

3.8. In-vitro protein digestibility and biological values

In-vitro protein digestibility and biological values of watermelon and pumpkin seed kernel flours, as well as paprika seed flour, are shown in Table 8. In-vitro protein digestibility was significantly ($P \leqslant 0.05$) different for all flours. Pumpkin seed kernel flour had the highest in-vitro protein digestibility (90.0%), followed by watermelon seed kernel flour (87.91%), then paprika seed flour (72.7%). The low digestibility of paprika seed flour could be attributed to higher contents of trypsin inhibitor and tannins than other flours. Aw and Swanson (1985) found that tannins adversely affect the nutritive value of black bean by decreasing the proteolytic enzyme digestibility. Oyenuga and Fetuga (1975) found the in-vitro protein digestibility of melon seed protein to be in the range 91–93%, which is comparable to soybean meal but less than whole hen's egg protein (98.8%).

Biological value computations depend, in large measure, on the relative proportions of the essential amino acids (El-Adawy et al., 1999). Based on chemical score, the first and second limiting amino acids were lysine and isoleucine, respectively, for seed kernel flours of watermelon and pumpkin, while they were leucine and total sulfur amino acids, respectively, for paprika seed flour. Kamel et al. (1985) reported that the first limiting amino acid was lysine in watermelon and pumpkin seed flours. It is interesting to improve and increase the biological value of wheat flour by blending with paprika seed flour. However, paprika seed flour had a lower PER and higher EAAI than either watermelon or pumpkin seed kernel flour.

3.9. Functional properties

Table 9 shows the functional properties of watermelon and pumpkin seed kernel flours and paprika seed flour. No significant ($P \leqslant 0.05$) differences were observed among the flour samples in their protein solubility index in distilled water and 5% sodium chloride. However, protein solubility index of all flour samples in sodium chloride were higher than in distilled water. This could be due to the fact that distilled water extracts only

Table 8
In-vitro protein digestibility and biological value computations of watermelon and pumpkin seed kernel flours and paprika seed flour[a]

Method of evaluation	Watermelon seed kernel flour	Pumpkin seed kernel flour	Paprika seed flour
In-vitro protein digestibility (%)[a]	87.9b	90.0a	72.7c
Chemical score (%)	57.1	75.8	71.9
First limiting amino acid	Lysine	Lysine	Leucine
Second limiting amino acid	Isoleucine	Isoleucine	
Essential amino acid index	58.8	85.4	67.3
Protein efficiency ratio	2.62	2.15	1.77

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$).

Table 9
Functional properties of watermelon and pumpkin seed kernel flours and paprika seed flour[a]

Functional properties	Watermelon seed kernel flour	Pumpkin seed kernel flour	Paprika seed flour
Protein solubility index (%) in			
Distilled water	23.9a	24.3a	24.9a
Sodium chloride (5%)	78.0a	79.7a	78.8a
Water absorption capacity (g H_2O/g flour)	2.55a	2.51a	2.10b
Fat absorption capacity (ml oil/g flour)	3.89a	3.85a	3.10b
Emulsification capacity (ml oil/g protein)	98.2a	98.5a	51.2b
Emulsification stability (%)	44.1a	43.9a	18.6b
Emulsification activity (%)	60.0a	59.2a	41.7b
Foam capacity (% volume increase)	18.1a	18.2a	12.8b
Foam stability (ml) at			
15 min	15.2±1.3	15.9±1.4	10.5±1.2
30 min	12.8±1.1	13.5±1.3	8.4±1.2
45 min	9.9±1.2	10.1±1.3	6.1±1.1
60 min	8.5±1.1	8.6±1.2	5.5±1.2

[a] Means in the same row with different letters are significantly different ($P<0.05$).

albumin, while sodium chloride extracts and solubilizes albumin and globulin. Watermelon and pumpkin seed kernel flours had significantly ($P \leqslant 0.05$) higher water and fat absorption capacities, emulsification properties and foam capacity than paprika seed flour. All flour samples absorb more fat than water. However, the water absorption capacities of flour samples were quite high compared to other vegetable proteins (1.38 g H_2O/g peach kernel flour; Rahma & Abd El-Aal, 1988). These two properties may give an advantage to these flours in some bakery products, as meat replacers and as thickening agent in soups. Emulsification properties (capacity, stability and activity) of watermelon and pumpkin seed kernel flours were fairly high compared to other vegetable proteins (Abdel-Nabey, Attia, & Amin, 1999), which may be of interest in sausage and other comminuted meat products. The foaming properties of the flours were poor and this may be due to the lower solubility of the flour proteins in water at natural pH. Therefore, addition of sodium chloride or sugars to water may improve foaming properties of these flours, by increasing the ionic strength and solubilized protein.

4. Conclusion

Watermelon and pumpkin seed kernels and paprika seed could be utilized successfully as sources of edible oils and of protein for human consumption. In addition, paprika seed could be considered as a good source of dietary fibre. Because of their high contents of unsaturated fatty acids, watermelon, pumpkin and paprika seed oils might be acceptable substitutes for highly unsaturated oils. Seed kernel flours of watermelon and pumpkins as well as paprika seed flour, have great potential for addition to food systems, not only as nutrient supplements but also as functional agents. Finally, the utilization of these seeds for oil and protein production could provide extra income and at the same time help to minimize waste disposal problems.

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