World Applied Sciences Journal 15 (9): 1225-1233, 2011
ISSN 1818-4952

Nutritional and Chemical Evaluation for Two Different Varieties of Mustard Seeds

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Abstract: The objective of this work was to determine the physicochemical properties of yellow and brown mustard seeds with regards to its contents of different nutrients and as well to determine its contents of allyl isothiocyanate. Also, to determine the functional properties of prepared mustard meals. The obtained results showed that the yellow and brown mustard seeds contained a higher amounts of both protein (ranged between 32.48 to 36.37%) and oil contents (ranged from 31.78 to 36.32%), also, they contained an adequate percentages of ash and dietary fiber. Furthermore, the investigated mustard seeds containing a considerable amount of allyl isothiocyanate, which was a higher amount as three times or more (479 mg/100g WT) in brown mustard seeds than that found in yellow mustard seeds (148 mg/100g WT). In addition, all indispensable amino acids were found in both yellow and brown mustard seeds in high amounts, which were contained a higher exceptionally contents of aromatic amino acids (Phenylalanine and tyrosine), amino acids-containing sulfur (Methionine and cystine), leucine, valine and lysine. Moreover, yellow and brown mustard seed oils were contained higher amount of erucic acid (23.90-37.89%). Also, considerable amounts of four major unsaturated fatty acids; oleic, linoleic, linolenic and gadoleic acids were present; whereas, oleic acid was the prevalent unsaturated fatty acids, followed by linoleic and linolenic acids. The results also showed that the mustard seed proteins, generally, had good functional properties, especially brown mustard seed protein, which having better functional properties such as protein solubility, emulsion capacity and stability, foam expansion and stability when compared with yellow mustard protein.

Key words: Mustard Seeds * Amino Acids * Fatty Acids * Functional Properties

INTRODUCTION

The mustard plant belongs to the *Cruciferae* (*Brassicaceae)* family. Mustard used in food is often a mixture of seeds from two or more species of *Brassicaceae*, for example, *Sinapis alba L.* (white or yellow mustard), *Brassica nigra* (black mustard) and *Brassica juncea L.* (Brown or oriental mustard). Mustards are functional foods having beneficial physiological effects in humans. *Sinapis alba* can be used as a source for a wide range of active components including isothiocyanates, phenolics, dithiolthiones and dietary fiber [1]. Flour from the yellow species (*Sinapis alba*) is used most commonly in Europe, while oriental mustard (*Brassica juncea*) is used most commonly in the United States and Japan. Mustard consumption in different countries varies according to local food habits [2]. Mustard is principally grown as a source of condiment for the spice trade. *Sinapis alba* is commonly known as "white" or "yellow" mustard and contributes a "hot" principle which results in a sensation of sweetness and warmth. *Brassica juncea*, commonly called "brown" or "oriental" mustard, contributes the "pungent" principle [3]. Mustard plant at different types have been widely cultivated and used as spice, medicine and a source of edible oil since ancient times [4]. The mustard seed is rich in protein. The protein is of excellent nutritional quality, being rich in lysine with adequate amounts of sulfur-containing amino acids-limiting amino acids in most of the cereals and oilseed proteins [5]. The use of protein rich full-fat or defatted flour shows promise in improving the nutritive value of the final product as well as optimum utilization of the flour. Protein fortification of food is of current interest because of increasing consumer's awareness towards health and quality of food [6]. Mustard is used on some meat products, such as hotdog and burger,

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but is very often an added ingredient in sauces, salads and other foods; for example, mayonnaise, salad dressing, barbecue and related products as well as ketchup, may contain mustard. Mustard is also used in various traditional remedies to stimulate appetite and as a laxative, expectorant and antiseptic agent for the treatment of various gastrointestinal, respiratory and skin diseases [2, 7]. The mustard plant, mainly the seeds, contain special compounds namely glucosinolates. These compounds characterize this flavour of mustard and mustard products. The main glucosinolate compound found in mustard is sinigrin, but it contains other glucosinolate compounds, such as sinalbin and glucobrassicin. Glucosinolates are degraded into isothiocyanates by enzymatic action of plant specific myrosinase or intestinal flora in the body. It appears that significant portion of the chemopreventive effects of isothiocyanates may be associated with the inhibition of the metabolic activation of carcinogens by cytochrome P450s, coupled with strong induction of detoxifying and cellular defensive enzymes. Sinigrin, the predominant glucosinolate in the mustard seed, is mainly degraded upon the enzymatic action of myrosinase under normal conditions to give allyl isothiocyanate [4, 8, 9]. Allyl isothiocyanate, has shown remarkable results in inhibiting the growth of food borne-pathogens and growth of cancer cells. Therefore, it has potential for use as an antimicrobial agent in a variety of foods because of its natural origin [6, 10-12]. Since time immemorial, mustard has been known for its antibacterial and antifungal properties, as an appetite stimulant and digestive aid by facilitating the secretion of gastric juices [13]. The objective of this work was to determine the physicochemical properties of yellow and brown mustard seeds with regards its contents of different nutrients (contents of protein and oil, indispensable amino acids, fatty acids and fiber) and as well to determine its contents of allyl isothiocyanate which is considered one of the most predominant breakdown components of glucosinolates which naturally occurrence phytochemicals in cruciferous vegetables. Also, the functional properties of prepared mustard meals prorein to evaluate.

MATERIALS AND METHODS

Materials: Yellow mustard (*Sinapis alba*) and brown mustard (*Brassica juncea*) seeds, about 1.0 kg were obtained from Harraz market (dealer in plant seeds), Cairo, Egypt.

Methods

Preparation of Mustard Seed Flours: The two varieties of mustard seeds were cleaned by passing through sieve to remove the stones and fine sand; afterwards, they were kept in a refrigerator at 4°C±2 until use. Immediately before used the mustard seeds were ground in small particles by using a laboratory disc mill (Braun AG Frankfurt Type: KM 32, Germany) for 2-3 min and the resulting flours were divided into two portions, one of them was ground in a laboratory mill to obtain the mustard seed flours to particles passing through 20 mesh sieve and kept in polyethylene bag until analysis to determine the physico-chemical properties, other portion was defatted in a Soxhlet apparatus using petroleum ether (B.p. 40-60°C) as the solvent. The obtained mustard meals were dried in an air- oven dryer at 60°C±2, the defatted meals were ground again in a laboratory disc mill to get that powder passed through 20 mesh sieve. The defatted mustard flours become already for different analyzed for determined the functional properties of mustard protein as described by Aluko and McIntosh[14] and Sadeghi *et al.* [15].

Gross Chemical Composition of Mustard Seed Flours: Moisture, protein (N × 6.25), ether extract, ash and fiber contents of yellow and brown mustard seeds flour were determined using the methods described of the A.O.A.C. [16]. Total carbohydrates content was calculated by subtraction in mustard seed samples as followed:

% carbohydrates = 100 - the sum of (% moisture + % protein + % fat + % ash + % fiber).

Determination of Allyl Isothiocyanate in Two Varieties of Mustard Seed Flours

Preparation of Samples: About 15g of yellow and brown mustard seeds were ground and sieved through No.20. Immediately, then 6.0 g of ground seeds was poured into 300 mL Erlenmeyer flask, 150 mL of 5% ethyl alcohol were added. After that, the flask was stopper tightly and stirred on magnetic stirrer for 90 ± 5 min. in water bath at 37°C.

Titration Method: Approximately 60 mL of the former extract was distillated into 100 mL volumetric flask containing 10 mL of NH_4OH in distillated water (at ratio 1:2), with taking care that end of condenser drips below surface of solution. 20 mL 0.1N $AgNO_3$ was added to distillate and let stand overnight at 30°C. Then, the mixture was heated to boiling in water bath (boil behind safety barrier) to agglomerate Ag_2S, cooled at room

temperature, diluted to 100 mL with distillated water and filtrated. After that, 50 mL of filtrate was acidified with 5 mL HNO_3, then the titration was performed with 0.1N NH_4SCN using 5 mL 10% $FeNH_4(SO_4)_2.12H_2O$ solution as indicator. 1 mL of 0.1N $AgNO_3$ = 0.004958 g allyl isothiocyanate according to A.O.A.C [16].

Determination of Amino Acids Composition for Mustard Seed Flours: The amino acids composition of the investigated samples (yellow and brown mustard seeds flour) were determined using HPLC-Pico-Tag method according to Millipore Cooperative as reported by Cohen *et al.* [17].

Determination of Fatty Acids Composition for Mustard Seed Flours: The fatty acids composition of investigated samples (yellow and brown mustard seeds oil extracted) was determined as methyl ester by gas liquid chromatography. The methyl ester samples were prepared using BF3 in methanol (14%) as methylating agent according to the A.O.A.C. [16]. Instrumentation of chromatographic conditions: GC/MS system: Shimadzu GC/MS-QP 5050 A, Software: Class 5000, Searched library: Wiley Mass Spectral Database, Column: DBI, 25m, 0.53mm, 1.5um film (JFW Scientific), Carrier Gas: Helium, Ionization mode, Voltage: 70 ev, Temperature Program: 115°C to 200°C at 5°C/min, Detector temperatures 280°C, Injector temperatures 250°C.

Determination of Some Functional Properties of Defatted Mustard Seed Flours

Protein Solubility: Protein solubility (PS) was determined according to the method of Aluko and Yada [18] with some modifications. Each sample was mixed with 0.01M sodium phosphate buffer, pH 7.0 to give a dispersion of approximately 1% (w/v) protein content, followed by shaking on a vortex mixer for 5 min and centrifugation at 10 000 × g and 10°C for 30 min. The resultant supernatant (S1) was analyzed for protein content according to the method of Markwell *et al*. [19] and this was expressed as a percentage of the initial total protein content of the meal to obtain PS. An aliquot of S1 was heated in boiling water for 15 min, cooled to room temperature (23-25°C) and centrifuged at 10 000 × *g* for 30min and the amount of protein in the supernatant (S2) was determined according to the method of Markwell *et al*. [19] Heat coagulability (HC) was calculated as follows:

$$HC\ \% = \frac{\text{Protein content of S1 - Protein content of S2} \times 100}{\text{Protein content of S1}}$$

Emulsifying Capacity: Emulsifying capacity and emulsion stability determined according to the method of Ockerman [20] and Cserhalmi *et al.* [21] as follow: 1g of sample was dispersed in 1 M sodium chloride in a blender to give 1 % w/v solution and corn oil was added to the dispersion by using a burette at the rate of 0.8-1ml /second and the build up of viscosity was observed during mixing, when emulsion visually collapses (increasing the blender speed, decrease in emulsion viscosity and visual separation of emulsion was observed) the addition of oil was stopped and the total added amount determined and the emulsion capacity expressed as the amount of oil emulsified by 1 g of protein, the emulsion stability was determined by allowing the emulsions to stand at room temperature (23-25°C) for 30 min and the volume of emulsion after 30 min of standing divided by the initial emulsion volume and expressed as percentage.

Foam Expansion: Foam expansion (FE) was determined according to the procedure described by Poole *et al.* [22] and sadeghi and Bhagya [23]. Sample dispersions containing 1% (w/v) protein were prepared in 0.01M sodium phosphate buffer, pH 7.0 and homogenised for 30 s using a homogenizer (Braun AG Frank, 40-60 Hz /400W, Tipe MX 32, No. 4142, German) The volume of foam obtained was expressed as a percentage of the initial volume of the protein solution. To determine foam stability (FS), the volume of foam that remained after standing at room temperature (23-25°C) for 30 min was expressed as a percentage of the initial foam volume.

Statistical Analysis: Data were statistically analyzed by using SPSS (version 12.0 Inc. Chicago, USA) of Completely Randomized Design as described by Gomez and Gomez [24]. Treatment means were compared using the Least Significant Differences (LSD) at 0.05 levels of probability and Standard Error. Computations and statistical analysis of data were done using facilities of computer and statistical analysis system package SAS [25].

RESULTS AND DISCUSSION

Gross Chemical Composition of Investigated Mustard Seed Flours: The chemical composition of the two examined mustard varieties (yellow and brown mustard

Table 1: Chemical composition of yellow and brown mustard seed flours (Mean±SE)

	Mustard seed flours (MSF)*	
Components (%)	Yellow MSF	Brown MSF
Moisture	5.05±0.028	4.98±0.421
Protein	36.73±0.710	32.48±0.744
Oil	31.78±0.958	36.32±0.277
Ash	4.08±0.109	3.88±0.363
Dietary Fiber	5.87±0.513	6.34±0.132
Total Carbohydrates	16.49±0.779	16.60±0.802
Allyl isothiocyanate (mg/100g) *	148±2.309	479±4.618

*Allyl isothiocyanate (AIT): determined on wet weight basic

seeds) is summarized in Table 1, namely moisture, protein, oil, ash, dietary fiber and total carbohydrates, also the content of allyl isothiocyanate (mg/100g DM). It could be concluded that yellow and brown mustard seeds contained a higher amounts of both protein and oil contents. These high protein and oil contents in mustard seed varieties are similar to the results published by different authors [4, 21, 26, 27].

Comparing of both protein and oil contents of mustard seeds between yellow and brown varieties (Table 1) it could be noticed that the yellow mustard seed had a higher content of protein (36.73%) than this found in brown mustard seed (32.48%). In contrast, the oil content of brown mustardseed was higher (36.32%) than this found in yellow mustard seed (31.78%) of oil.

From the same table, it could be also observed that the tested mustard seeds of both yellow and brown varieties containing an adequate percentage of ash, dietary fiber and total carbohydrates which were found to be as 4.08, 5.87 and 16.60 % in yellow variety and 3.88, 6.34 and 16.49 % in brown variety; respectively.

The flavor of mustard seeds is derived from glucosinolates, which are thiocyanate glycosides. Sinalbin is responsible for the flavor of white mustard seed; sinigrin is responsible for the sharper taste associated with black and brown mustard seeds. The pungency is produced by glucosinolates, which are hydrolyzed by the enzyme myrosinase (a thioglucoside glucohydrolase) to flavor-active isothiocyanates (mustard oils). Sinalbin primarily yields the nonvolatile 4-hydroxybenzyl isothiocyanate, while sinigrin yields the volatile allyl isothiocyanate, which is responsible for the pungent aroma. Depending on the variety of mustard, the yield of allyl isothiocyanate is approximately 1% [28]. Allyl isothiocyanate (AITC), which has the potential to be used as flavoring, antibacterial, antifungal, antifermentative and antibrowning agent in food industry [27].

From the obtained results in the former table, it could be observed that the investigated mustard seeds flour had a considerable amount (ranged from 148 to 479 mg/ 100g, on wet weight basis) of allyl isothiocyanate, which is considered one of the most important phytochemicals having the antioxidant, antimicrobial and chemopreventive cancer properties [29]. On the other hand, the content of allyl isothiocyanate in brown mustard seeds flour was (148 mg/100g WT) higher as three times or more approximately than that found in yellow mustard seeds flour (479 mg/100g WT). The content of allyl isothiocyanate in different mustard seeds varieties was also investigated by [8, 15, 27, 30, 31]. Their results were relatively comparable with the present data.

Amino Acids Composition (mg/100g Protein) of Investigated Mustard Seed Flours: The protein quality of both yellow and brown mustard seeds flour was evaluated according to its content of indispensable amino acids (IAAs), in comparison to the reference protein pattern of FAO/WHO (1973), also the content of dispensable amino acids (DAAs) as shown in Table (2).

From the data obtained in Table 2, it could be observed that all indispensable amino acids were found in both yellow and brown mustard seeds flour in high amounts compared with that found in accordance with the FAO/WHO recommended value, which were contained a higher exceptionally contents of aromatic amino acids (Phenylalanine & tyrosine), amino acids-containing sulfur (Methionine & cystine), leucine, valine and lysine than the reference protein pattern. Thereby, the amino acids score (A.S) for these IAAs were higher than 100% of reference protein pattern and there was no deficient in any IAAs of both yellow and brown mustard seeds flour. These results are in accordance with the trend in the amino acids composition conducted on fractions obtained by other researchers [4, 21, 26, 32, 33] they reported that the amino acids composition of mustard protein is well balanced; it is rich in essential amino acids and the balance of amino acids found within the seed of mustard crops compares favorably with the required for human nutrition.

As shown in the obtained data (Table 2), it could be also observed that the yellow mustard seed flour had higher amounts of lysine and valine than those found in brown mustard seed flour, in contrary, it had lower amounts of aromatic amino acids (Phenylalanine & tyrosine), amino acids-containing sulfur (Methionine & cystine) and lysine.

Table 2: Amino acids composition (mg/100g protein) of yellow and brown mustard seed flours

Amino acids	Mustard seed flours (MSF)		FAO/WHO g/100g protein	Amino acid score%	
	Yellow MSF	Brown MSF		Yellow MSF	Brown MSF
I.A.As*					
Lysine	6.53	5.54	5.5	118.7	100.7
Meth+ Cyst	4.26	5.89	3.5	121.7	168.3
Isoleucine	4.28	4.54	4.0	107.0	113.5
Leucine	7.89	8.00	7.0	112.7	114.3
Phen + Tyro	7.57	8.41	6.0	126.2	140.2
Therionine	4.36	4.04	4.0	109.0	101.0
Valine	6.72	5.66	5.0	134.4	113.5
Total I.A.As	41.61	42.08			
D.A.As**					
Histidine	2.51	2.61			
Aspartic	8.99	8.69			
Glutamic	19.84	20.15			
Serine	5.55	4.94			
Glycine	4.47	5.04			
Arginine	4.70	7.76			
Alanine	4.03	4.54			
Proline	8.07	4.19			
Total D.A.As	58.16	57.92			

*I.A.As: indispensable amino acids **D.A.As: Dispensable amino acids
Meth+ Cyst: Methionine+Cystine (amino acids containing sulfur)
Phen + Tyro: Phenylalanine + Tyrosine (aromatic amino acids), Tryptophan was not determined

Table 3: Fatty acids composition (%) of yellow and brown mustard seed oils

Fatty acids (%)		Mustard seed flours (MSF)	
		Yellow MSF	brown MSF
Saturated fatty acids			
Myristic	14:0	ND	ND
Palmitic	16:0	2.58	3.64
Stearic	18:0	1.13	1.46
Arachidic	20:0	1.04	0.91
Behenic	22:0	2.23	2.34
Lignoceric	24:0	8.45	8.94
SFAs*			
Mono-unsaturated fatty acids			
Palmitoleic	16:1	0.32	0.34
Oleic	18:1	19.08	20.24
Gadoleic	20:1	6.89	12.10
Erucic	22:1	37.89	23.90
MSFAs*		64.18	56.58
Poly-unsaturated fatty acids			
Linoleic	18:2	12.37	21.36
Linolenic	18:3	12.00	11.56
Arachidonic	20:4	0.84	1.04
Eicosapentaenoic	20:5	0.19	ND
Docosapentaenoic	22:5	0.94	ND
PSFAs*		26.34	33.96

*SFAs: saturated fatty acids, MFAs: mono unsaturated fatty acids, ** PFAs: poly unsaturated fatty acids, DN: not detect

On the other hand, glutamic acid was the major amino acids in both yellow and brown mustard seeds flour; it was represented about 19.84 and 20.15%, respectively. These results are in agreement with the data previously obtained [15, 21].

It could seen also from the same table that no appreciable differences was found between yellow and brown mustard seeds flour regarding the dispensable amino acids; excepted in arginine which was found in higher amount (7.76%) in brown mustard seeds flour as compared to that found (4.70%) in yellow mustard seeds flour and proline which was also found in high amount (8.07%) in yellow mustard seeds flour when compared with those found (4.19%) in brown mustard seeds flour.

Fatty Acids Composition (%) of Investigated Mustard Seed Oils: The fatty acids composition for methylated samples of both yellow and brown mustard seeds oils were determined by gas chromatographic analysis, the obtained data are recorded in Table (3).

From these data, it could be concluded that erucic acid (C22:1) was predominant fatty acids in yellow and brown mustard seeds oils, which was represented about 37.89 and 23.90 %, respectively, The limiting factor of mustard seed oil for use in human food application or

animal feed formulation has been it's the high content of erucic acid, which is indigestible for human and animal organisms. The high erucic acid content of mustard seed could be reduced by breeding; some low erucic acid content genotypes are in cultivation in several countries [4]. Mustard oil rich in erucic acid is considered undesirable for human consumption. Conventional breeding has successfully produced low (zero) erucic acid containing canola. Efforts to develop low erucic acid Indian mustard (*B. juncea*) by back cross breeding [34].

Concerning the total saturated fatty acids as shown it Table (3), it could be remarked that both yellow and brown mustard seeds oils contained a little amounts (ranged between 8.45 to 8.94 %) of saturated fatty acids as compared to the other edible oils. These results are in agreement with previous studies [21, 34-36]. In this concern, it was reported that mustard oil is considered to be oil that has low saturated fat as compared to other cooking oils [37]. In contrary, the total unsaturated fatty acids in both yellow and brown mustard seeds oils were highly a considerable amount, which represented about more than 90%.

From the obtained data Table (3), it could be also showed that the unsaturated fatty acids of both yellow and brown mustard seeds oils was characterized by the presence of four major unsaturated fatty acids; namely, oleic (18:1), linoleic (18:2), linolenic (18:3) and gadoleic acids (20:1). Whereas, oleic acid (18:1) was the prevalent unsaturated fatty acids, which was ranged between 19.08 to 20.24% of total fatty acid profiles in both yellow and brown mustard seeds oils, respectively. Moreover, linoleic acid is the second dominant unsaturated fatty acids, which one of the most important of the essential fatty acids (ω-6), which recorded about from 12.37 to 21.36% in both yellow and brown mustard seeds oils, respectively. In this concern, brown mustard seed oils acid had higher amount of linoleic acid than those found in yellow mustard seeds oil. In addition, mustard seed oils also containing a considerable amount of linolenic acid (ω-3), which is considered of the most important essential fatty acids. Linolenic acid was represented about 12.0 and 11.56% in both yellow and brown mustard seeds oils, respectively. Furthermore, gadoleic acid (20:1, cis-icos-9-enoic acid) was found in adequate amount in investigated mustard oils, which was a higher amount (12.10%) in brown mustard seeds oil than that found in yellow mustard seeds oil (6.89%). These results are in accordance with the data previously obtained [21, 34-39]. Also, the mustard oil has a special fatty acid composition [4]. The oil of different mustard genotypes contains about 20- 28% oleic acid, 10-12% linoleic and 9.0-9.5% linolenic acid.

Table 4: Functional properties of defatted yellow and brown mustard seed flours (Mean±SE)

	Mustard seed flours (MSF)*	
Parameter	Yellow MSF	Brown MSF
Protein solubility (PS) %	20.63 ± 0.05	22.41 ±0.17
Heat coagulability (HC) %	35.38 ± 0.04	42.13 ±0.19
Emulsion Capacity (EC) **	48.64 ± 0.03	56.11 ± 0.24
Emulsion stability (ES) %	78 ± 0.29	81.5 ± 0.35
Foam expansion (FE) %	232.86 ± 0.76	246.3 ± 0.99
Foam stability (FE) %	70.38 ± 0.57	68.46 ± 0.47

*each value is mean of three determinations.

** ml oil/1g protein

From the same table it could bee observed that the investigated mustard seed oils contained little amounts of poly unsaturated fatty acids, especially arachidonic acid (20:4) which one of the important essential fatty acids, it was ranged between 0.84 to 1.04%.

Functional Properties of Defatted Mustard Seed Flours:

Data in Table (4) show that defatted brown MSF had higher soluble protein content than that found in yellow MSF, since Surface hydrophobicity and surface hydrophilicity characteristics of a protein have been suggested to be the most important factors that determine solubility properties [40]. Therefore, the results suggested that the brown MSF proteins have a structure or conformation that exposes more hydrophilic groups, which facilitate increased interaction with the aqueous environment and hence higher protein solubility (PS) when compared to yellow MSF proteins, these results are in agreement with the foundation of a previous study [14], since they found that defatted brown MSF had significantly higher soluble protein than defatted yellow MSF.

In regarding to heat coagulability, the data in Table (4) exhibit that brown MSF had higher heat coagulability than those found in yellow MSF, since proteins brown MSF were significantly more susceptible to heat-induced coagulation than proteins present in the Yellow MSF, similar results were previously obtained [3], they reported that increased resistance of the yellow MSF proteins to heat-induced precipitation may be due to the presence of a protein (with MW=135 kDa), which probably has a rigid structure as a result of disulfide bonds [41, 42], while this protein is absent in brown MSF.

From the obtained results in Table (4), it could be observed that both emulsion capacity (EC) and emulsion stability (ES) were high percentage obviously in defatted brown MSF as compared to that found in defatted yellow MSF. These results are in accordance with the previous obtained data [3], they reported that brown MSF flour had better emulsion-forming ability than those obtained for the yellow MSF flour, also, the increased emulsifying capacity has been associated with proteins that possess lower molecular weights and better interfacial properties at the oil–water interface [43], thus the lower emulsion capacity of the yellow MSF protein products could have been due to the higher levels of high-molecular-mass polypeptides when compared with the polypeptides of the brown MSF proteins [3, 14].

From the same table, it could be also exhibited that foam expansion (FE) of defatted brown MSF was high percent more than that obtained by defatted yellow MSF, on the other hand, the foam stability (FS) of both defatted brown and yellow MSFs was the same values approximately. These results are in agreement with the results of a previous study [14].

CONCLUSION

From the present results, it is recommended that it should be directed toward the utilization of mustard seed flour especially after defatted in production of meat products and food fortification as a good and available inexpensive source of fiber, allyl isothiocyanate (phytochemical), ash and protein characterized with both an exceptionally high content of indispensable amino acids and good functional properties.

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