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Research Article

Reduction of Antinutritional Factors of Three Varieties of Sesame (*Sesamum Indicum* L.) Seeds When Applying Heat-Alkaline Treatments

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Abstract

Diets rich in plant products have become popular in recent times due to the contribution of essential macronutrients, as well as micronutrients with beneficial characteristics for health and sesame (*Sesamum indicum*) is part of this group of foods for its protein content and its content of mono- and polyunsaturated fatty acids that contribute to the prevention of chronic non-communicable diseases. However, there are secondary metabolites synthesized by plants as protective mechanisms, called anti-nutritional factors, which affect the nutritional value of certain foods, in this case sesame seeds. We studied the effect on three different varieties of sesame seeds (DV-9; Guesa-4 and Guesa-150 whole and dehulled, the application of an alkaline treatment (KOH 0.7%) at 55°C for 5; 10 and 15 minutes, on the reduction of antinutritional factors (saponins, phytic acid and oxalates). The most effective treatment in reducing antinutritional factors was the alkaline treatment dehulled for 15 minutes because it reduced the content for the DV-9 variety, of saponins, phytic acid and oxalates by 27.76; 93.27 and 88.63% respectively, for the Guesa-4 variety by 23.79; 92.22 and 92.06% respectively and for the Guesa-150 variety by 23.79; 86.88 and 91.36% respectively. These results showed that when seeds were exposed to 0.7% KOH solution for 15 minutes, the phytic acid and oxalate content was reduced by a high percentage. The alkaline dehulled treatment during 15 minutes, produced changes in the proximal composition of the varieties of seeds studied, generating an increase in the content of moisture, crude protein and crude fat, and reduced the content of ash and carbohydrates.

Keywords: Sesame; Oxalate; Saponins; Phytic Acid; Nutritional Factors; Antinutritional Factors

Introduction

Diets rich in plant products have become popular in recent times due to both the supply of essential nutrients and chemical compounds with health-promoting characteristics, such as vitamins and antioxidants. A diet rich in whole grains and plant foods, low in total fat but high in soluble fibers and monounsaturated and polyunsaturated fatty acids, reduces the risk of chronic non-communicable diseases [1]. This food group includes sesame seeds, which have various nutritional properties [2]. Sesame, whose scientific name is *Sesamum indicum* L., belongs to the *Pedaliaceae* family, which is composed of 16 genera and 60 species [3]. Sesame is grown in tropical and subtropical regions on just over seven million hectares to produce six million tonnes per year [4]. The demand for sesame seed has increased every year due to commercial and industrial interest in the high oil content. Myanmar, India and China are now the world's leading producers, followed by Sudan, Nigeria, Ethiopia and Uganda. In America the largest producers are: Mexico, Guatemala, and Venezuela [4]. Sesame is used for the production of edible oil, margarines (it is appreciated in countries that consume it for its pleasant taste and being easily digestible), as an ingredient in the pharmaceutical industry, in the manufacture of soaps, cosmetics and paints. After the extraction of the oil, the residual part (cake) remains, useful for feeding livestock and poultry. It contains 40 to 50% protein. Sesame seed is used in the prepa-

ration of biscuits and confectionery [5,6]. The term antinutrients areis used to qualify those compounds that affect the nutritional value of some foods, especially seeds, because they hinder or inhibit the assimilation of nutrients that come from foods generally of plant origin (proteins and minerals), from the biochemical point of view these factors are of varied nature and can become toxic or cause undesirable physiological effects such as flatulence, Stomach distension, pancreatic affectations, agglutination of red blood cells, decrease in the assimilation of nutrients, among others, antinutritional factors are natural non-fibrous substances, generated by the secondary metabolism of plants as a defense mechanism to stressful situations or against the attack of moulds, bacteria, insects and birds [1,7]. Authors have [8] evaluated the effect of various treatments on the anti-nutritional factors of both whole and dehulled varieties of sesame seeds in Nigeria and observed that the use of water soaking, germination, autoclaving, roasting and cooking significantly reduced the levels of phytates and oxalates in whole and dehulled sesame seeds, with a maximum reduction in these levels after germination. Others [9] determined the content of anti-nutritional factors in sesame seeds during four days of fermentation, and it was observed that there was a 50% reduction in phytic acid content, while the oxalate content was reduced by 69%, after 96 hours of fermentation. In accordance with the above, it was proposed in the present work to evaluate the application of an alkaline treatment to reduce anti-nutritional factors in sesame seeds for use in the human diet, select the most effective treatments and perform a proximal analysis to evaluate the effect of the selected treatments on the nutritional composition of the seeds.

Materials and Methods

Collection/preparation of sesame seed flour

The sesame seeds (*Sesamun indicum* L.) varieties Guesa-150, Guesa-4 and DV-9, were provided by the company Comercializadora Guesa C.A, located in Turen, Portuguesa state, in the Bolivarian Republic of Venezuela. Sesame seeds were washed with potable water, then alkaline treatment (KOH 0.7%) was applied at a temperature of 55°C for 5, 10 and 15 minutes. Whole and dehulled seeds were obtained. In the case of dehulled seeds, once the treatment in study was applied, the raw material was homogenized in a Metvisa® brand blender for 30 seconds. Then, the seeds were placed inside a 14 mesh sieve and successive washings (minimum 3) were performed, under water pressure in order to retain the bark of the seeds. To obtain whole seeds, after applying the treatment in study, successive washings with jet water were realized (minimum 3), trying to manipulate the seeds as less as possible. Once obtained the seeds (whole and dehulled) they were dried in a tray dehydrator (Mitchel Dryers 6451/59) to a temperature of 55 ºC during 5 hours. After drying the seeds, they were cold pressed, using a hydraulic press (Fisher Scientific Co. Carver Laboratory Press model B), under a pressure of approximately 24,000 psi, with which oil and cake (residue) were obtained. Once the oil was extracted, it was centrifuged and filtered and then stored in clean, dry glass containers. The cake was then reduced in size using a Corona® brand disc mill, and the material obtained was passed through a 60 mesh sieve to obtain sesame flour (partially defatted) which was then stored in plastic bags for later analysis.

Determination of proximate

The proximate composition of the samples was determined by A.O.A.C [10]. Moisture content (925.40) of the samples was carried out by oven drying at 105°C to constant weights.. Ash (950.49A) was determined by furnace incineration method. Crude protein (955.04) was determined using micro-kjeldahl method. This method consists of taking 2g of fresh sample, mixing it in a Kjeldahl flask with H_2SO_4. The flask is heated, and when it takes a dark color, it is neutralized with 45% NaOH. In a small flask 5 mL of saturated H_3BO_3 and 3 - 4 drops indicator added. Both flasks are placed in the micro Kjeldahl and it is waited until the coloration of the small flask changes from pink to yellow. Titrate with 0.02 N HCl and calculate % crude protein. Carbohydrate was obtained by difference.

Determination of crude fat

The determination of crude fat was performed through the Microwave Assisted Process (MAP) [11]. Under certain modifications, 1g of sample was weighed and placed in a test tube, 4 mL of petroleum ether was added and mixed in a vortex at a speed of 6, for 15 seconds then 4 mL of chloroform was added and homogenized in the same way. The tube was heated in microwaves for 4 seconds, three times continuous. It was centrifuged at 3000 rpm for 5 min, then the supernatant was recovered and the extraction repeated. The recovered supernatants were added to a preweighed heating plate and heated to evaporate. The residue was dried at 60°C in a stove and reweighed after cooling at room temperature.

Determination of anti-nutrients

Determination of saponins

The saponin content was determined according to the standard method of [12,13] and certain modifications, 1g of the defatted sample was mixed with 10 mL of a 20% ethanol solution in a test tube. The mixture was heated in a water bath for 90 minutes at 55 ºC. It was then filtered through a filter paper. The residue was extracted with 10 mL of 20% ethanol. The extract was reduced by approximately half in a water bath at 90°C and transferred to a centrifuge tube in which 5 mL of diethyl ether was added and agitated vigorously in vortex and centrifuged at 3000 rpm for 2 minutes. Extraction was performed twice until the aqueous layer became light coloured. The recovered aqueous layer was mixed with 5 mL propanol and 2 mL 5% NaCl solution, agitated vigorously in vortex and centrifuged at 3000 rpm for 2 minutes. The recovered aqueous layer evaporated to dryness on a previously weighed evaporation plate. The residue was dried at 60°C in a stove and reweighed after cooling in a desiccator. The content of saponins, expressed in %, was calculated by applying the following equation proposed by Obadoni and Ochuko [12].

$$\%\ \text{Saponin} = \frac{\text{weight of residue} \times 100}{\text{weight of sample}} \qquad \text{----------[12]}$$

Determination of phytic acid

The determinations were made under the methodology of [14,15], under certain modifications, where 2g of dry matter were soaked in 50 mL of 2% HCl for three hours and then filtered with Whatman N° 1 paper. 25 mL were recovered from the filtrate and 5 mL of potassium thiocyanate (KSCN) were added at 0.3% and 4 drops of ammonia (NH_3) were added as an indicator. 53.5 mL of distilled water was added to generate the appropriate acidity. The mixture was titrated with a solution of 0.01 M iron chloride ($FeCl_3$). The titration was stopped until a yellow color appeared that persisted for about 3 to 5 minutes. The phytic acid content, expressed in mg%, was calculated by applying the following equation proposed by Wheeler and Ferrel [14]

$$\text{Phytic acid (mg\%)} = \frac{\text{Tv} \times 1{,}19 \times 3{,}55 \times N \times DF \times 100}{\text{M}} \qquad \text{----------[14]}$$

Where (Tv) is the total volume of titration spent

1 mg of iron is equivalent to 1.19 mg of phytic phosphorus

To calculate the phytic acid content, multiply the value of phytic phosphorus by 3,55

3,55 is the ratio between the molecular weight of phytic acid (660g/mol) and the molecular weight of phytic phosphorus (186g/mol).

N is the Normality of $FeCl_3$

DF is the dilution factor (TV/A where TV: Total filtrate volume, 50 mL and A: aliquot, 25 mL)

M is the sample weight in mg.

Determination of oxalates

The standard method of Underwood [16] and certain modifications were used, 1g of dry matter was weighed in a beaker and mixed with 75 mL of H_2SO_4 3 M. It was agitated intermittently for 1 hour, with magnetic agitator. The mixture was filtered through Whatman Filter Paper No. 1. 25 mL of filtrate were used and 5 mL of H_2SO_4 6N and 50 mL of distilled water were added. It was titrated hot (80 - 90 ºC) against 0.1 N $KMnO_4$ solution till a faint pink color appeared and persisted for at least 30 seconds. The content of oxalates, expressed as mg%, was calculated by applying the following equation proposed by Underwood [16].

$$\text{Oxalate (mg\%)} = \frac{\text{Tv} \times 6{,}3 \times N \times DF \times 100}{\text{M}} \qquad \text{----------[16]}$$

Where:

Tv = Total volume of titration spent

1 mL of $KMnO_4$ 0,1 N is equivalent to 6,3 mg of oxalic acid

N is the Normality of $KMnO_4$

DF is the dilution factor (TV/A where TV: Total filtrate volume, 75 mL and A: aliquot, 25 mL)

M is the sample weight in mg

Selection of the best treatments

The most effective treatments to reduce antinutritional factors were selected and a proximal analysis was performed to determine their influence on the proximal composition of the seeds.

Statistical analysis

Significant differences between means were calculated using analysis of variance (ANOVA) and a multiple comparison test (Fisher's minimal significant difference) with a significance level of 5%. The statistical program Statgraphics Centurion was used.

Results and Discussion

Proximate composition of sesame seed

The results obtained for the chemical characterization of sesame seeds are observed in table 1, which shows that all the evaluated parameters presented statistically significant differences ($p < 0.05$). The moisture content of the seeds was between 4.17 to 5.17%, this being an acceptable value for these types of seeds, considering that it is mainly oilseed seed. Differences in moisture content can often be associated with the drying process in the field, highlighting that since these varieties are non-indehiscent, they must remain stacked once harvested to guarantee drying, which generally culminates when the plant is harvested. It is entirely yellow; this process is wholly heterogeneous and dependent on the climatic conditions of the production area. Some authors [8,17-23] have reported similar or different values for other sesame varieties. The crude protein content shows that the DV-9 has a higher contribution between 9.01 to 9.15% than the G-4 and G-150 varieties. These differences could be associated with the origin from which the types come. According to information from the seed's supplier, DV-9 is a seed generally used to commercialize in the Middle East due to its intensely bitter taste. Therefore, it was necessary to carry out various genetic crosses using seeds from different origins of the world. Sesame seeds are a significant source of vegetable protein, which can be consumed raw, representing great nutritional importance. According to other reports [18,19,22,24], the crude protein content of sesame shows fluctuations according to the variables analyzed.

Nutrients (%)	DV-9	Guesa-4	Guesa-150
Moisture	5.17 ± 0.03^{a}	4.33 ± 0.04^{b}	4.17 ± 0.06^{c}
Crude protein*	38.74 ± 0.39^{a}	29.59 ± 0.80^{c}	29.73 ± 0.22^{b}
Crude fat*	35.46 ± 0.26^{c}	36.89 ± 0.15^{b}	37.26 ± 0.26^{a}
Ash*	9.88 ± 0.07^{b}	10.11 ± 0.10^{a}	9.70 ± 0.10^{c}
Carbohydrate*	10.75 ± 0.25^{c}	19.08 ± 0.09^{b}	19.14 ± 0.36^{a}

Table 1: Proximal composition of sesame seeds.

Values are presented as mean ± standard deviation of three replicates. *base dry (bd).

The G-150 variety has a more significant contribution regarding the crude fat content. However, the yields of the DV-9 and G-4 varieties show that they can also be qualified for commercial oil extraction. Other researchers [18,24] have reported similar or higher values than those noted. Sesame oil is an excellent source of saturated and unsaturated fatty acids and other antioxidants. Therefore, its consumption is vital for any food system. The ash content allows us to observe that whole sesame seeds possibly have a high contribution of minerals, which is of great interest in food. Scientific reports [19,22,24] show similarity. The composition directly influences the total carbohydrates content that the varieties have in their other constituents. It is observed that the variety DV-9 reports a value 8% lower than G-4 and G-150, Coinciding with reports from others [19,22]. In general, the total carbohydrates content of sesame is constituent of dietary fiber. It represents a great nutritional contribution to sesame. In such a sense, it can be considered a superfood, which only requires effective cleaning treatments that guarantee its safety to be consumed as raw food.

Saponine

The content of saponins in sesame flour obtained from seed without applying any treatment was 16.34 ± 0.05, 15.42 ± 0.15 and 15.16 ± 0.01 % for varieties DV-9, Guesa-4 and Guesa-150 respectively (table 2). These values are higher than those reported by other authors for some varieties of *Sesamun indicum* such as: 4.91 - 5.03% [22]; 2.45 - 2.49% [20]; 9.20 - 10.14% [25]; 2.91 - 2.95% [26]; 3.14 - 4.46% [27] and 5.60% [23]. Table 2, it is shown, for the varieties of seeds in study, that the content of saponins was decreasing with the different treatments applied, observing statistically significant differences ($p < 0.05$) between them, however, no statistically significant differences were observed between the times applied for the same treatment, as well as it could be determined that the best treatment was: alkaline dehulled during 15 minutes, with a percentage of reduction of 27.76%; 23.79 and 23.79 for DV-9; Guesa-4 and Guesa-150 respectively. This study showed that the saponins are distributed throughout the seed since the dehulled by alkaline treatment eliminated part of the saponin content that was in the hull and pericarp [28,29]. Regarding the thermal stability of saponins, they are resistant to temperatures below 100 °C [29,30]. Therefore there was no significant difference between the times of 5, 10, and 15 minutes at 55 °C because from 60 °C the leaching rate increases [29]. The alkaline treatment, reduced the content of saponins, because they do not resist sudden changes in pH, very acid or alkaline values generate hydrolysis of *O*-glucosidic bonds (be-

tween the sugar chain and the aglycone) and interglucosidic bonds (between the sugar residues), resulting in the release of aglycones, prosapogenins, sugar residues or monosaccharides [31,32]. It is likely that the total saponin content has not been determined with the alkaline treatment because of the possible formation of soaps due to the fat content of the seed that could react with the KOH and the saponins acted as emulsifier.

Seed varieties			
Treatments	**DV-9 (mg%)**	**Guesa-4 (mg%)**	**Guesa-150 (mg%)**
Control	16.34 ± 0.05 a	15.42 ± 0.15 a	15.16 ± 0.01 a
Whole 05'.	14.19 ± 0.08 b	14.19 ± 0.04 b	13.46 ± 0.06 b
Whole 10´	14.00 ± 0.01 b	14.14 ± 0.20 b	13.45 ± 0.10 b
Whole 15´	13.92 ± 0.13 b	14.13 ± 0.01 b	13.43 ± 0.21 b
Dehulled 05´	11.93 ± 0.43 c	12.45 ± 0.06 c	11.58 ± 0.22 c
Dehulled 10´	11.89 ± 0.14 c	12.43 ± 0.08 c	11.56 ± 0.19 c
Dehulled 15´	11.80 ± 0.05 c	12.41 ± 0.06 c	11.55 ± 0.18 c

Table 2: Saponin content of treated seeds.

Values are mean ± SD from triplicate determinations; different letters in the same column are significantly different $p \leq 0.05$.

Phytic acid

The phytic acid content in sesame flour obtained from seed without applying any treatment was 30.86 ± 0.61, 27.01 ± 0.35 and 25.36 ± 0.40 mg% for varieties DV-9, Guesa-4 and Guesa-150 respectively, (table 2), these values are within the range reported by other authors for some varieties of *Sesamun indicum* such as: 30.64 - 32.54 mg% [9] and 29.00 - 31.00 mg% [33], in the case of DV-9 varieties; 27.00 - 27.86 mg% [25], for the case of varieties Guesa-4; 23.75 - 25.96 mg% [19], for the case of varieties Guesa-150, and both for varieties Guesa-4 and Guesa-150 with a range of 20.45 - 29.65 mg% [22]. In addition, they are higher than the value observed in sesame seeds from Nigeria, which was 1.42 mg% [20], as well as for white dehulled sesame seeds, with a range of 0.83 - 0.85 mg% [34] and lower than observed in NCRI - 98 - 60 (white) seed varieties of 60.15 - 65.19 mg% and for NCRI - 97 - 28 (black) varieties of 51.07-54.13 mg% [8]. The phytic acid content can vary depending on the variety of crop, climatic conditions, location, irrigation conditions, type of soil, and the year during which they are grown [35]. Table 3, it is shown, for the varieties of seeds in study, that the phytic acid content was decreasing with the different treatments applied, observing statistically significant differences ($p < 0.05$) between them, and it could be determined that the best treatment was: alkaline dehulled during 15 minutes, with a percentage of reduction of 93.27%; 92.22% and 86.88% for DV-9; Guesa-4 and Guesa-150 respectively. Different treatments such as: dehulled, autoclave, soaking, extrusion, microwave, cooking, germination and fermentation, are the main ones to reduce the amounts of phytic acid and other anti-nutritional factors in food [36]. Phytic acid is synthesized during the development of the seed and is deposited in structures called globoids in the form of magnesium and potassium salts [37]. These structures are located inside the protein corpuscles of the cells of the cotyledon, in the hull and pericarp of the oilseeds [38]. In sesame seeds, specifically in the hull, a significant amount of anti-nutritional factors such as phytic acid are found and the removal of this hull implies a reduction in the phytic acid content [8]. The alkaline treatment applied in this study reduced the phytic acid content of sesame seeds, probably for several reasons, one of which was enzymatic hydrolysis due to temperature (55 °C) and alkaline pH conditions [39]. The activation of the intrinsic alkaline phytase, whose optimal temperature is 50 - 60 °C, catalysed the enzymatic hydrolysis of the phytic acid and thus the reduction of the seed content [39,40,41]. Intrinsic phytases are located in the hull and in the cotyledons, however, the enzymatic activity of phytases increases after dehulling and temperature increase above 50 °C, due to altered cell membrane properties, so that it is possible for phytase and phytic acid contained in cotyledons to come into contact [42,43]. Another probable reason for the reduction of phytic acid content under alkaline conditions is the formation of a ternary complex between proteins, a multivalent cation and phytic acid, because under alkaline conditions, both proteins and phytic acid are negatively charged and the presence of cations such as calcium, magnesium or zinc, bind through a cationic bridge forming the protein-cation-phytic acid complex [38,44,45].

Values are mean ± SD from triplicate determinations; different letters in the same column are significantly different $p \leq 0.05$

Oxalates

The oxalate content of sesame flour obtained from seed without applying any treatment was 2.11 ± 0.02, 2.15 ± 0.03 and 1.85 ± 0.03 mg% for varieties DV-9, Guesa-4 and Guesa-150 respectively, (table

Seed varieties			
Treatments	**DV-9 (mg%)**	**Guesa-4 (mg%)**	**Guesa-150 (mg%)**
Control	30.86 ± 0.61 a	27.01 ± 0.35 a	25.36 ± 0.40 a
Whole 05'.	13.05 ± 0.19 b	11.51 ± 0.26 b	8.38 ± 0.27 b
Whole 10´	10.15 ± 0.28 c	9.81 ± 0.32 c	7.61 ± 0.27 c
Whole 15´	8.03 ± 0.22 d	7.64 ± 0.23 d	6.39 ± 0.25 d
Dehulled 05´	6.04 ± 0.20 e	4.12 ± 0.00 e	5.97 ± 0.23 e
Dehulled 10´	4.27 ± 0.22 f	3.33 ± 0.02 f	4.56 ± 0.03 f
Dehulled 15´	2.08 ± 0.01 g	2.10 ± 0.00 g	3.33 ± 0.02 g

Table 3: Phytic acid content in treated seeds.

4), these values are similar compared with those reported by other authors for varieties DV-9 such as: 2.10 mg% [20]; while the values of 2.03 - 2.37 mg% [46] were similar for both DV-9 and Guesa-4 varieties. They are also higher than the values reported by several authors such as: 0.0049 - 0.0057 mg% [25]; 0.95 - 1.15 mg% [9]; 0.41 - 0.44 mg% [26]; 1.28 - 1.30 mg% [34]; and 1.28 - 1.30 mg% [34]; and are lower than the value observed for Nigerian sesame seeds which was 85.44 - 85.90 mg% [33]; 15.21 - 16.11 mg% [22], as well as for NCRI - 98 - 60 (white) seed varieties which was 181.74-185.10 mg% and for NCRI - 97 - 28 (black) varieties which was 150.40 - 157.60 mg% [8]. The amount of these antinutrients in the seeds depends not only on the plant, but also on the season, soil nutrients and local water conditions of the soil where they are grown [47]. Table 4, it is shown, for the seed varieties under study, that the oxalate content was decreasing with the different treatments applied, observing statistically significant differences ($p < 0.05$) among them, and it could be determined that the best treatment was: alcaline dehulled for 15 minutes, with a percentage reduction of 88.63%; 92.06% and 91.36% for DV-9; Guesa-4 and Guesa-150 respectively. Different treatments such as: dehulled, autoclaving, soaking, extrusion, microwave, cooking, germination and fermentation, are the main ones to reduce the amounts of oxalates and other anti-nutritional factors in food [36]. Oxalate is synthesized in the form of crystals, in structures called idioblasts, located in the cotyledons and hull of oilseeds [48,49]. In sesame seeds, specifically in the hull, a significant amount of anti-nutritional factors such as oxalate are found and the removal of this bark implies a reduction in the oxalate content [8]. The alkaline treatment applied in this study increased the loss of oxalate content from sesame seeds, due to the formation of potassium oxalate, by reacting calcium oxalate with the potassium hydroxide used in the alkaline treatment. Potassium oxalate is a water-soluble salt whose solubility increases at temperatures above 50 °C [50]. The drastic decrease in oxalates after 15 minutes may be associated in the first place with the fact that this time helps to completely solubilize the oxalate crystals and also because part of the content is located in the rind of the sesame and this is removed with this process.

Seed varieties			
Treatments	**DV-9 (mg%)**	**Guesa-4 (mg%)**	**Guesa-150 (mg%)**
Control	2.11 ± 0.02^{a}	2.15 ± 0.03^{a}	1.85 ± 0.03^{a}
Whole 05'.	0.82 ± 0.02^{b}	0.84 ± 0.02^{b}	0.41 ± 0.01^{b}
Whole 10´	0.66 ± 0.02^{c}	0.69 ± 0.03^{c}	0.39 ± 0.02^{b}
Whole 15´	0.52 ± 0.02^{d}	0.54 ± 0.01^{d}	0.32 ± 0.01^{c}
Dehulled 05´	0.44 ± 0.02^{e}	0.36 ± 0.01^{e}	0.24 ± 0.01^{d}
Dehulled 10´	0.40 ± 0.01^{f}	0.33 ± 0.01^{f}	0.19 ± 0.01^{e}
Dehulled 15´	0.24 ± 0.01^{g}	0.17 ± 0.01^{g}	0.16 ± 0.00^{f}

Table 4: Oxalate content in treated seeds.

Values are mean ± SD from triplicate determinations; different letters in the same column are significantly different $p \leq 0.05$

Proximal composition of sesame varieties subjected to thermal-alkaline treatments

The compositional evaluation of the three varieties of sesame is shown in table 5. Again, there were statistically significant differences ($p \leq 0.05$) for each type depending on the three treatments used. The proximal composition is a percentage; for this reason, the changes are directly proportional. On the other hand, the moisture content presented variations concerning the control; perhaps this result could be associated with the size of the sesame seeds and their dehydration capacity, considering that they were all subjected to the same temperature and time conditions after the alkaline thermal treatments.

The results are expressed as the average of three replicates (n = 3) ± followed by the standard deviation. Different lower case letters in different columns represent statistically significant differences ($p \leq 0.05$) in the evaluated parameter and the control. *bd C. protein: crude protein, T. Carbohyd: Total Carbohydrates, determing by difference.

Treatments	Variety	Moisture	C. protein*	Crude fat*	Ash*	T. Carbohyd*
Control	DV-9	5.17 ± 0.03^{b}	38.74 ± 1.39^{c}	35.46 ± 0.26^{g}	9.88 ± 0.07^{c}	10.75 ± 0.25^{h}
	G-4	4.33 ± 0.04^{f}	29.59 ± 0.80^{h}	36.89 ± 0.15^{e}	10.11 ± 0.10^{a}	19.08 ± 0.09^{d}
	G-150	4.17 ± 0.06^{h}	29.73 ± 1.22^{f}	37.26 ± 0.26^{d}	9.70 ± 0.10^{e}	19.14 ± 0.36^{c}
Whole 15´	DV-9	4.89 ± 0.30^{d}	39.06 ± 0.12^{b}	34.21 ± 0.04^{i}	9.74 ± 0.04^{d}	12.10 ± 0.50^{g}
	G-4	4.26 ± 0.12^{g}	29.30 ± 1.48^{i}	35.31 ± 0.66^{h}	9.91 ± 0.03^{b}	21.22 ± 0.29^{a}
	G-150	4.44 ± 0.18^{e}	29.62 ± 0.59^{g}	36.10 ± 0.28^{f}	9.55 ± 0.04^{f}	20.29 ± 0.09^{b}
Dehulled 15´	DV-9	5.56 ± 0.05^{b}	41.11 ± 0.37^{a}	39.65 ± 0.21^{c}	5.81 ± 0.02^{i}	7.87 ± 0.35^{i}
	G-4	4.97 ± 0.17^{c}	32.84 ± 0.99^{d}	40.79 ± 0.04^{b}	6.48 ± 0.13^{g}	14.92 ± 0.33^{e}
	G-150	5.31 ± 0.31^{a}	32.46 ± 0.82^{e}	42.05 ± 0.35^{a}	5.94 ± 0.01^{h}	14.28 ± 0.49^{f}

Table 5: Proximal analysis of selected treatments for sesame seeds variety DV-9, G-4 and G-150.

The crude protein content varied, and it was observed that the hulling treatment influenced the increase in the protein fraction. Likewise, the crude fat content increased up to 4% for the hulled seeds based on the control results. However, when comparing the crude fat values of the control versus whole seeds for 15 minutes, the content of the latter decreased slightly; may be associated with saponification processes that could occur during the thermal-alkaline treatment. Remarkably, a decrease of up to 4% in the ash content was observed. This result shows that the applied treatments affect the hulling and, therefore on the mineral content of the sesame. The carbohydrate content presented variability for all the sesame seeds and used treatments.

The results obtained from the composition of the sesame seeds allow us to observe that after applying different thermal-alkaline treatments, it is possible to get sesame seeds with a more significant contribution of protein and crude fat. This aspect becomes interesting when allocating these raw materials as alternative food sources. or for oil extraction. However, the increase in these components reduces minerals that sesame usually provides, including calcium, which represents one of the main advantages of raw sesame consumption. Changes in the carbohydrate content are related to the decrease in dietary fiber content, a component of great importance in human nutrition that we can obtain naturally in sesame. In addition, the treatments applied could reduce other antinutritional agents such as lectins, tannins, amylase inhibitors, oligosaccharides, glucosinates, antivitamins. In this sense, applying any treatment thermal-alkaline would cause changes, which can be positive or negative depending on the feeding conditions that each individual establishes.

Conclusion

The application of the alkaline treatment, showed statistically significant differences in terms of time applied, demonstrating that when the seeds were exposed for 15 minutes with 0.7% KOH solution, the phytic acid and oxalate content was reduced by a high percentage.The alkaline dehulled treatment during 15 minutes, produced changes in the proximal composition of the varieties of seeds studied, generating an increase in the content of moisture, crude protein and crude fat, and reduced the content of ash and carbohydrates.

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