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Abstract:

Snacks are very popular among all age groups because they are delicious, crunchy, and easy to eat outside the home (work, schools, transport places …). Chia seeds have received great interest from consumers due to their health-promoting nutritional importance. Therefore, this study aims to produce healthy snacks fortified with chia seeds from (white flour, corn flour, and soaked chia seeds). The study also aims to identify the chemical, rheological properties, antioxidant and water activities and sensory evaluation of snacks fortified with soaked chia seeds. The results showed the chemical composition of chia seeds contain high levels of protein, fiber, fat, and ash. Protein contents increased and carbohydrate contents decreased in snacks fortified with soaked chia seeds compared to control snacks. Also, the results showed significant differences in antioxidant activity between control snacks and snacks fortified with soaked chia seeds. The rheological properties of the dough also showed increased water absorption, dough stability, and flexibility in all mixtures compared to control snacks. From here, it can be concluded that adding soaked chia seeds led to an increase in the nutritional value of the snacks. Moreover, the sensory evaluation showed that the fortified snacks were acceptable by the jury members, and the best product was the snacks (35% white flour + 35% corn flour + 30% chia seeds) that cooked in an oven. Therefore, it is recommended to use chia seeds to fortify snack products, as they increase the nutritional and functional value of many products.

Key words: Chia seeds, Chemical composition, Rheology.

دراسات كيميائيه وتكنولوجيه على بعض المنتجات الغذائيه المدعمه ببذور الشيا

مستخلص البحث:

اجريت الدراسة الحالية لإنتاج سناكس صحى مدعم ببذور الشيا وتقييم الخصائص الفيزيائية والكيميائيه ومضادات الأكسده والخصائص الحسيه. ونظرا للقيمه الغذائية العالية لبذور الشيا، فقد تم اضافته إلى أكثر المنتجات استهلاكا وشيوعا وهى الإسناكس (المقرمشات) وتوضيح تأثير إضافة نسب مختلفة من بذور الشيا المنقوعة فى الماء وإضافتها على الدقيق مباشرة دون أى إضافات أخرى. كما تم تقديرالخواص الريولوجية لعجينة الإسناكس وتقدير مضادات الأكسدة وإجراء تحليل النشاط المائي لعينات الإسناكس. أوضحت نتائج التركيب الكيميائي لبذور الشيا إحتوائها على نسبة عالية من البروتين والالياف الغذائية (١٨,٦ و ٤٠,٦ جم/١٠٠جم). كما أوضحت النتائج أنها تحتوى على نسبة عالية من العناصر المعدنية وبالأخص الكالسيوم حيث وجدت قيمته (١٠٤٣٠١مج/١٠٠جم). أيضا أظهرت النتائج إحتواء بذور الشيا على الفينولات والفلافونيدات بنسبة (٤٣.٥٧ و ٣٨.٧٥ مجم/جم). كما أظهرت نتائج التقييم الحسي أن عينة الإسناكس المكونة من الدقيق الأبيض ودقيق الذرة بنسبة متساوية والمدعمة بنسبة ٣٠% من بذور الشيا والمطهية في الفرن سجلت أعلى القيم لجميع صفات الجودة المختلفة مقارنة بعينات الإسناكس الأخرى. وأظهرت نتائج التركيب الكيميائي أن عينة الإسناكس المكونة من الدقيق الأبيض ودقيق الذرة بنسبة متساوية ومدعمة بنسبة ٣٠% من بذور الشيا والمطهية في الفرن أعلى نسبة في جميع العناصر الغذائية ماعدا الكربوهيدرات. أيضا أظهرت النتائج تحسن واضح في الخواص الريولوجية وزيادة في خواص الاكستنسوجراف والفارينوجراف بالنسبة لعينات الإسناكس المكونة من الدقيق الأبيض ودقيق الذرة بنسبة متساوية ومدعمة بنسبة ٣٠% من بذور الشيا والمطهية في الفرن. أيضا أظهرت النتائج إحتواء عينة الإسناكس المكونة من الدقيق الأبيض ودقيق الذرة ومدعمة بنسبة ٣٠% من بذور الشيا على نسبة من الفينولات والفلافونيدات (٢٥,٣٠ مجم/جم و ١٧,٥٢مجم/جم). وتعتبر هذه النسبة عالية ومفيدة لصحة الانسان. وأظهرت نتائج النشاط المائي لعينات الإسناكس انخفاض مستوي نشاط الماء في العينات المطهية في الزيت مقارنة بتلك التي تم طهيها في الفرن.

1. Introduction:

Snacks are one of the best favorite foods. They are the easiest and quickest meal to satisty hunger, crunchy, delicious snacks that come in many shapes and flavors are consumed all over the world. This demand affects public health particularly children. It is considered a cause of malnutrition. Snacks are broadly defined as consuming food or beverages between the three main meals**.** The snack is easy to use, so it is eating at home, while traveling, at work and at school. There are also other reasons for eating snacks, such as hungry and distraction. The term snack has been in use since 1757. It was defined as eating between main meals, and this indicates the existence of snacks from a long time ago **(Hess JM, *et. al.*, 2016).** Snacks remain an important source of energy in the diets of both children and adults in the United States (**Barnes T.L. *et al.*, 2015**). A correct definition of a snack is evidence of whether snacking is beneficial or harmful where a snack, is defined in some studies as foods that are poor in nutrients and rich in energy (**Hess, J.M. *et al.*, 2016**) which contains, a high percentage of nutrients to reduce (sodium, sugar, and/or saturated fat) like chips, cakes, cookies and other sugar-sweetened beverages and a salty snacks, "Dietary guidelines have spread in many places and United States snacks can also be defined to eating occasions outside of breakfast, lunch, or dinner at which any kind of food, nutrient poor or nutrient-dense, might be consumed. There are factors that determine the health effects of snacks, including: weight status of snackers, the food eaten as a snack and the motivation to consume snacks **(Robinson, E. *et al.*, 2013)**.

Chia is known (Salvia hispanica L.). It belongs to the Lamiaceae family. Chia is an annuals herbaceous plant it comes from northern Guatemala and southern Mexico. Chia seeds are grown mainly for its seeds. It produces hermaphrodite purple and white flowers, 3-4 mm size (**Baldevia 2018)**. Chia plant reaches a heigh of one meter and is sensitive to day light. Leaves are oppositely toothed and sinuous, 3-5 cm wide. Chia seeds are oval in shape, very small, 1-1.5 mm wide and 2mm long (**Grancieri, *et. al*., 2019).** Chia was considered as a part of human food for about 5500 years. The seeds were used in folk medicines, food and canvases **(Armstrong, 2004).** The word chia is derived from a spanish word chian which means oily. It is an oil seed, with a power house of omega-3 fatty acids, superior quality protein, higher extent of dietary fiber, vitamins, minerals and wide range of poly phenolic antioxidants which act as antioxidant and safeguard the seeds from chemical and microbial breakdown **(Cahill, 2003).** This is also admitted by the modern science. The massive nutritional and therapeutic potential of chia is little known, chia offers a great future perspective for food, medical and pharmaceutical sectors **(Hentry *et al.*, 1990)**. Many studies have confirmed that chia seeds consist of micronutrient component and vital macronutrient. Therefore, the idea of research came to provide a desirable product that is rich in nutritional elements

2. Materials and methods:

2.1. Materials

Wheat flour (WF) A soft wheat flour (72% extraction) was obtained from local market Zagazig, Egypt. Corn flour was obtained from local market Zagazig, Egypt, Chia Seeds was obtained from Haraz druggist (Cairo, Egypt). The other ingredients used in the production of nutritional products were salt and water

2.2. Methods

2.2.1. Preparation of materials:

Chia seeds are manually purified, cleaned of impurities, then depending on the addition rates after soaking in tap water to the flour.

2.2.2. Preparation of nutritional products:

Wheat flour (72 % extraction) is partially fortified with some healthy nutritional products to make nutritional products in different proportions**.** Corn flour was added to increase nutritional value and reducing carbohydrates. To make the dough, 70 *g* of mixture of wheat flour and corn flour were mixed by hand with 1.5 *g* salt and 30.0 *g* of soaked chia seeds in 50.0 *mL* water for 1/2 *h*, then place them on the flour mixture without raising material because chia seeds were used as a raising material After 15 *min* of rest the dough was separated in to pieces. Then, roll out of dough to a thickness of 2.0 *mm*, then cut it into different shapes and bake it for 15 min in the oven, Fig.1.

1a. Chia seeds

1b. Chia seeds after 5 min. in water

1c.Chia seeds after 15 min. in water

1d.Chia seeds after 30 min. in water

Fig.1. Stages of soaking of chia seeds

2.3. Chemical analysis:

The chemical composition of different materials was determined in the Central Laboratory for Soil, Foods, and Feedstuffs (International Accredited Lab, ISO 17025 since 2012), Faculty of Technology and Development, Zagazig University, Egypt.

Chemical analyses for materials were performed according to the International Standard Methods ISO.

Protein content:

The protein contents of samples under investigations were determined by using ISO 5465/ 2006 conditions (according to **ISO IEC**

17025, 2017). The environmental conditions of the experiments were 29 C°, moisture 36%.

Fat content:

Fat contents were determined by using ISO 26.2L54/37 volume 52/2009 (according to **ISO LEC 17025, 2017**). The environmental conditions of the experiments were 29 C°, moisture 36%.

Fiber content:

The fiber contents of samples were determined using ISO 26.2L 54/40 volume 52/2009 (according to **ISO LEC 17025, 2017**). The environmental conditions of the experiments were 29 C°, moisture 36%

Moisture content:

Moisture contents were determined using ISO5462/2006 (according to **ISO IEC17025, 2017**). The environmental conditions of the test was 29 C°, moisture 36%

***Crude ash content*:**

Ash contents were determined by using ISO 5464/2006 (according to **ISO IEC17025, 2017**). The environmental conditions of the test were 29 C°, moisture 36%

Total carbohydrate:

Total carbohydrate contents of samples were determined by the difference, according to the equation of **Chatffieled and Admas, (1940).**

Total carbohydrate =100−(moisture% + protein% + fiber% + fat% + ash%).

Determination of Minerals:

Phosphorus content:

Phosphorus (P) was determined by spectrophotometer (Manufacturer Iabomed, Inc, USA, Model spetro22, S,N 221101) using ISO 5491/2005 (according to **ISO IEC 17025, 2017).** The environmental condition of the test was 29 C°, moisture 36%.

Sodium and Potassium Contents:

Sodium (Na) and Potassium (k) elements contents were determined by Flame Photometer Spectroscopy Apparatus (CIBA corning model 410, USA, Serial No., 4887) using methods of **Westerman (1990).**

Mineral Contents:

Ca, Fe, Mn, Zn and Cu Minerals contents were determined and calculated . Elemental analyses were made on known weight (0.5 *g.*) for each dried sample. The elements were determined by the methods of **Nation and Robinson (1971).** Minerals were determined spectrophotometrically in the acid digested samples by using atomic absorption spectrophotometer model ICE 3000 SERIS.

2.4. Preparation of snacks with different proportions of chia seeds

Snacks with different proportions of chia seeds were prepared using wheat flour (72% extraction) and corn flour in equal ratios as control sample then, substituted with 30% and 40% of chia seeds (soaked).

Table 1. Mixture of wheat flour (72%) and corn flour supplemented with soaked chia seeds for snacks dough.

Samples No.	Mixture %			Cooking methods	
	Wheat flour	Corn flour	Chia seeds	In oil	In an oven
1	100	-	-	-	√
2	70	-	30	-	√
3	60	-	40	-	√
4	100	-	-	√	-
5	70	-	30	√	-
6	60	-	40	√	-
7	50	50	-	√	-
8	35	35	30	√	-
9	30	30	40	√	-
10	50	50	-	-	√
11	35	35	30	-	√
12	30	30	40	-	√

Control w. flourin the oven 30% chia in the oven 40% chia in the oven

Control w. flour in oil 30% chia in oil 40% in oil

Control (w+c) flour in oil 30% chia in oil 40% chia in oil

Control (w. + c.) flour in oven   30% chia in oil   40% chia in oil

Fig. 2. Photos of Snacks made from wheat flour, corn flour and different levels of chia seeds.

2.5. Sensory Evaluation:

Snacks samples were evaluated for their sensory characteristics by 20 panelists from the staff and non-staff members of the Department of Home Economics, Faculty of Specific Education, and Zagazig University. All samples were provided in plates having white color at ambient temperature. The panelists were asked to evaluate each sample of the snacks for general appearance, color, taste, odor, texture, and over all acceptability average. The samples were rated on (Excellent=10, very good=8, Good=6, Fair=4, and Poor=2) (**F. Sinesio, 2005**). Scores were collected and analyzed statistically. **ANOVA. (1991**)

2.6. Statistical Analysis

Statistical analyses were calculated using one way classification. Analysis of Variance was calculated with cost and least significant difference (LSD) (0.5). Data were statistically analyzed using one-way analysis of variance **. ANOVA (1991).**

2.7. HPLC Analysis of Chia Seeds and Snacks

HPLC analyses were performed using a Waters 2487 HPLC system consisting of a dual (ƛ) detector and a Waters 1525 binary pump and equipped with a Waters Symmetry C18 column (5.0 mm, 4.6×50.0 mm) with Waters sentry universal guard column (5.0 mm, 4.6×20.0 mm) (**Waters Corporation, Milford, MA, USA**). Phenolic compounds of chia seeds were studied using the reference HPLC method by (**Sakakibara *et al*., 2003),** comparing experimental retention times with reported reference values **(**total phenols of chia seeds were determined according to **(Singletion and Rossi (1965) and Akin *et al.* (2008),** respectively**).**

HPLC Conditions:

HPLC analyses were carried out using an Agilent 1260 series. The separation was carried out using Zorbax Eclipse Plus C8 column (4.6 mm × 250 mm i.d., 5.0 μm). The mobile phase consisted of water (A) and 0.05 % trifluoroacetic acid in acetonitrile (B) at a flow rate 0.9 mL/min. The mobile phase was programmed consecutively in a linear gradient as follows: 0.0 min (82% A); 0.0–1.0 min (82% A); 1.0–11.0 min (75% A);

11.0 – 18.0 min (60% A); 18.0–22.0 min (82% A); 22.0–24.0 min (82% A). The multi-wavelength detector was monitored at 280 nm. The injection volume was 5.0 µL for each of the sample solutions. The column temperature was maintained at 40 °C. **(Sakakibara *et al.*, 2003)**

2.8. Preparation of Extract:

Samples (2.0 g from sample 2 and 5.0 g from sample 1) were soaked with 200.0 mL of water and shaking at room temperature for 48 *h*. The extract was filtrated through Whatman number 1 and combined and this was followed by a concentration using rotary evaporator under pressure that was reduced at 45ºC. The obtained extract were dried using a rotary evaporator.

2.9. Rheological properties:

Beginning form and sides of the bowl were scraped down. When the mixing curve leveled off at a value larger than 500 BU, more water was added and the bowl was covered with a glass plate to prevent evaporation.

Subsequent farinograph test:

The test was carried out according to the constant flour weight method of **AACC method 54-21 (2000**) as follows. Three hundred grams of wheat flour extraction rate 72% (14% moisture base) were placed in the farinograph bowl. Water was then added immediately to the side of the bowl from the filled burette, nearly to the volume expected to be the right absorption of flour when the dough was titration was needed to adjust the absorption curve at 500 BU. For final titration, the total volume of water was then added within 25 seconds after opening burette's stopcock. Absorption values were corrected to the nearest 0.1 % and calculated on 14% moisture basis by the following equation:

$$Absorption\ \% = (X + Y - 300)/3$$

where X = mL of water required to produce the curve with a maximum consistency centered on 500 BU line. Y = grams of flour, equivalent to 300 grams 14% moisture basis.

The following parameters were obtained from the resulted farinogram.

Arrival time (min.): The time in minutes required for the curve to reach the 500 B.U. line after the mixer had been started and the water was added.

Dough development time (min.): It is the time in minutes from the first addition of water to the development of dough's maximum consistency.

Dough stability (min.): It is the time in minutes elapsing when the top of the curve interacts with the first 500 B.U. line and leaves that line.

Weakening of dough (B.U.): It is the difference in Brabender units from 500 B.U. line to the center of the curve measured after 12.0 minutes from reaching to the maximum consistency.

Extensograph test:

Extensograph test was carried out according to the method described in the **(AACC, 2000)** using an extensograph type: 4821384 (Brabender, Extensograph Germany HZ 50) as follows. A normal run of the farinograph was made in order to determine the water absorption capacity of the flour. The dough was prepared by using 300.0 g flour (14% moisture basis), 6.0 g sodium chloride and dissolved in the specific quantity of water (that previously determined by farinograph test). The ingredients were mixed and the produced dough was mixed for one minute, then rested for 5.0 minutes and resumed mixing until reached full development time of the farinograms. The dough was rounded in the extensograph rounder. The dough ball was then carefully centered on the shaping unit and rolled into a cylindrical test piece; that was then clamped in a lightly greased dough holder. The test piece was stored in humidified champers until required for testing. After a 45.0 minutes first period from the shaping operation, the investigated sample was placed on the balance arm of the extensograph and the recording pen was adjusted. At exactly 45.0 minutes from the end of the shaping operation, the stretching hook was started and stopped when the test piece was broken. The dough was removed after the first test, reshaped, then rested for 45.0 minutes and then stretched again. By repeating such procedure, the dough was tested at 45.0, 90.0 and 135.0 minutes. For evaluating the results of the extensograph test. The extensogram of the test period of 135.0 minutes was used to measure the following parameters:

Dough extensibility (E): The total length of base of the extensogram measured in millimeters or cm.

Dough resistance to extension (R) (B.U.): The height of the extensograph curve measured in Barabender units.

Proportional number (R/E): R/E it was obtained through dividing the resistance to extension by the extensibility.

Dough energy (cm^2): It was represented by the area under the curve in cm^2.

Texture profile analysis of snacks:

A texture analyzer (Brookfield CT3 Texture Analyzer Operating Instructions Manual No. M08-372-C0113, Stable Micro Systems, USA) was used to measure the texture profile of sweet biscuits in terms of hardness (N) of the samples. Test Type: Compression, Target=1.0 mm, Hold Time=0.0 s, Trigger Load: 5.00 N (Newton), Test Speed= 2.00 mm/s, Return Speed= 2.0 mm/s, of Cycles: 1.0, Pretest Speed: 2.0 mm/s, Probe: TA-PFS-C, Fixture: TA-RT-KIT, Load Cell: 10000 g.The experiments were conducted under ambient conditions.

Pasting properties:

Pasting properties were determined using a starch cell (Physica Smart, Starch Analyzer-Anton Paar) attached to a CR/CS rheometer (RheoLab QC, Anton Paar, GmbH, Germany) and established methodology **(Jayakody et al., 2007).** A sample (4% w/w) was equilibrated at 50°C for 1.0 min, then heated from 50.0 to 95.0 °C at 6.0 °C/min, held at 95.0 °C for 5.0 min, cooled to 50.0 °C at 6.0 °C/min, and held at 50.0 °C for 2.0 min. The speed was 960 rpm for the first 10.0 s, then 160 rpm for the reminder of the experiment. The pasting properties of each sample were inferred from acquired diagrams including the peak time, peak viscosity, holding strength, setback, and final viscosity.

2.10. Water activity

Water activity of snacks samples were determined by recording data on water loss or gain per gram of samples and determined using a water activity measurement apparatus AW SPRINT TH-500; Axair Ltd., Pfäffikon, Switzerland **(Mnif *et al.*, 2012)**.

3. Results and discussion

Chemical composition of chia seeds:

The chemical composition of chia seeds is illustrated in Table 2 and Fig. 3. The result showed that, the content of moisture in chia seeds was 7.03g /100 g, protein content was 18.6 g/100g for chia seeds. Chia seeds had the highest dietary fiber content (40.6g/100g) but fat and ash content were 4.86 and 4.6g/100g, respectively. Also, the highest carbohydrates content was found in chia seeds as 24.31g/100g. These results are in agree with the data obtained by **Suri.*et al*., (2016), Nosha, A.S. Al-bayyar, A.H. (2017), Mohd Ali, *et al*., (2012)** and **(Rajaram, 2014) Carrillo *et al*., (2018).** They found that protein percent were (15 to 23%), ash (4 to 5%), fiber (36 to 40%), and total carbohydrate content (٤١%). Also, **Coelho and Salas-Mellado (2014)** found that, moisture, protein and ash contents of chia seeds on dry basis were (6.2, 19.6 and 4.6g/100g), respectively. Results varied with **Ixtaina *et al*., 2008**, and **Valdivia-Lopez and Tecante A., 2015). T**hey found that fat (30– 33 %), carbohydrate (41%). This may be due to the different strain of chia seeds.

Table 2. Chemical composition of chia seeds and snacks (*g*/100 *g*).

Compound	Chia seeds	Control sample of snacks	Snacks with 30% of chia seeds
	Conc.		
Protein	18.6	10.5	13.9
Fat	4.86	0.24	4.28
Fiber	40.6	1.14	6.71
Moisture	7.03	4.71	4.87
Ash	4.6	2.58	2.16
Carbohydrates	24.31	80.83	68.08

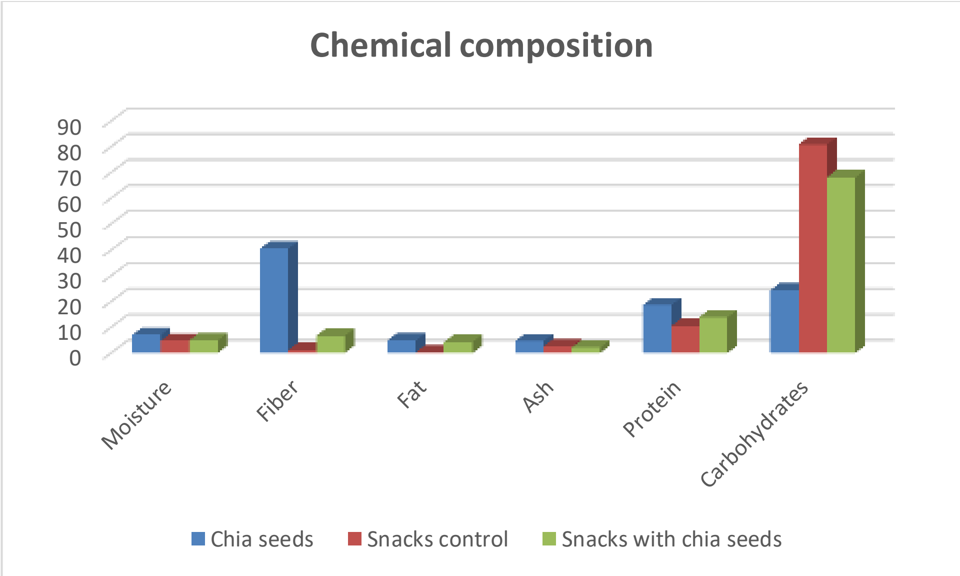


Fig. 3. Chemical composition of chia seeds under investigations

Chemical composition of control sample of snacks:

The chemical composition of control sample of snacks is illustrated in Table 2 and Fig. 4. The results showed that the moisture content in control sample of snacks was (4.71g /100 g) and protein content was (10.5 g/100 g). Control sample of snacks had the low dietary fiber content (1.14g/100g) as for fat and ash content was (0.24 and 2.58g/100g). Also the carbohydrates content was found to be the highest in control sample of snacks (80.83g/100g).

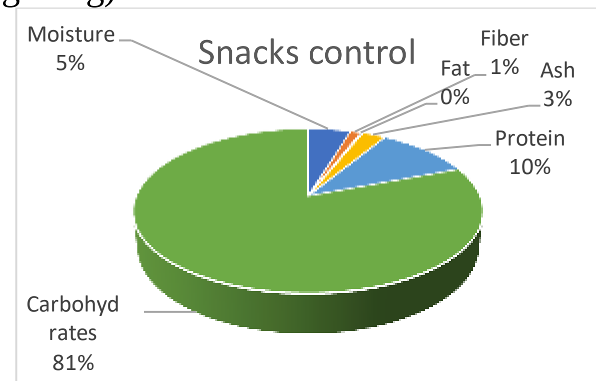


Fig.4. Chemical composition of control sample of snacks (g/100g)

Chemical Composition of Snacks with Chia Seeds:

The chemical composition of snacks with chia seeds is illustrated in Table 2 and Fig. 5. The results showed that the moisture content in snacks with chia seeds was (4.87g /100 g) and protein content was (13.9 g/100g). Snacks with chia seeds had dietary fiber content of 6.71g/100g. Also, fat and ash content was found to be (4.28 and 2.16g/100g). The highest carbohydrates content was found in control sample of snacks (68.08g/100g). The results showed that there were no significant differences in moisture content between control sample of snacks and snacks supplemented with 30% of soaked chia seeds. The fiber content of snacks supplemented with 30% soaked chia seeds were increased in comparison with control sample of snacks (6.71g/100g). While, the lowest fiber content was found to be 1.14% in control sample of snacks.

The protein content of snacks supplemented with chia seeds was increased in comparison with control sample of snacks without chia seeds. The highest protein content was (13.9%) in snacks supplemented with 30% of soaked chia seeds while, the lowest protein content was (10.5%) in control sample of snacks.

The results presented in Table 2 showed significant increases in the fat of snacks supplemented with 30% of soaked chia seeds. The highest fat content was (4.28%) in snacks supplemented with 30% of soaked chia seeds, while, the lowest fat content was found to be (0.24%) in control sample of snacks. The results showed that there were no significant differences in ash content between snacks supplemented with 30% of soaked chia seeds and controled snacks. The highest Ash content was 2.58% obtained in control sample of snacks. While, the lowest ash content was (2.16%) in the snacks supplemented with (30%) of soaked chia seeds.

Carbohydrates content was significantly decreased in snacks supplemented with 30% of soaked chia seeds as compared to the control snacks. The carbohydrates content was (80.83%) in control snacks. While, the lowest carbohydrates was (68.08%). The results are in agreement with the data obtained by **Mirand-Ramos and Haros (2020)** who confirmed that adding chia seeds to bakery products led to an increase in the levels of proteins, dietary fiber, ash and fats, while the starch content was significantly decreased.

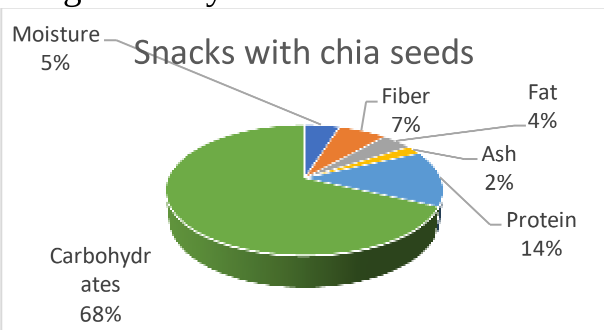


Fig. 5. Chemical composition of snacks with chia seeds (g/100g)

Minerals Content of Chia Seeds

The mineral contents of chia seeds were presented in Table 3 and Fig. 6. the result showed that chia seeds has the highest Mg , P , S , Cl, K , Ca , Mn , Fe , Cu , Zn , Se , and Sr as 0.1691, 0.3038, 0.0148, 0.0127, 0.8254, 1.4301, 0.0280, 0.0113,0.01332. 0.0169, 0.0106,and 0.0136, , respectively. The obtained results were compared to other common cereals and found that the content of Ca, P, K, and Mg of chia seeds were higher than that of wheat and corn **(Hrncic *et al.*, 2019-, Ullah *et al.*, 2016)**.

Table 3. Minerals content of chia seeds (mg/100g)

No.	Compound	Conc.
1	Mg	0.1691
2	P	0.3038
3	S	0.0148
4	Cl	0.0127
5	K	0.8254
6	Ca	1.4301
7	Mn	0.0280
8	Fe	0.0113
9	Cu	0.0133
10	Zn	0.0196
11	Se	0.0106
12	Sr	0.0136

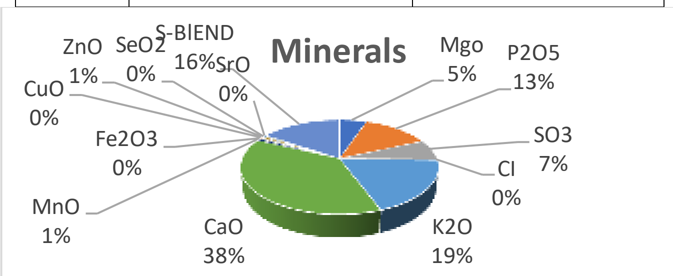
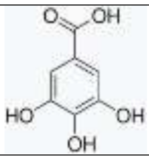
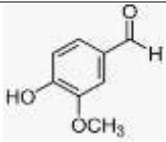
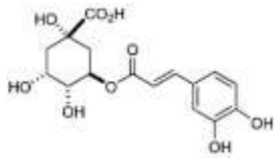
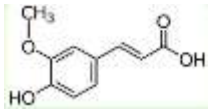
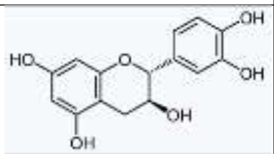
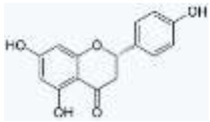
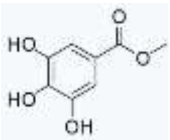
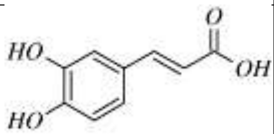
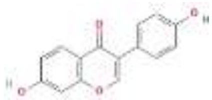
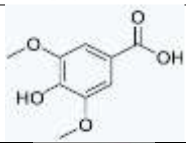
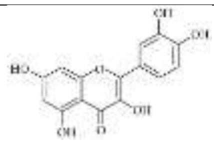
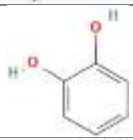
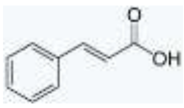
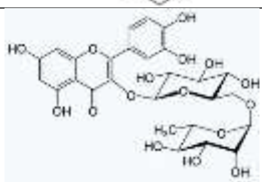
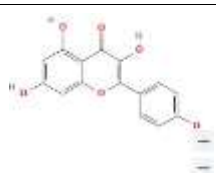
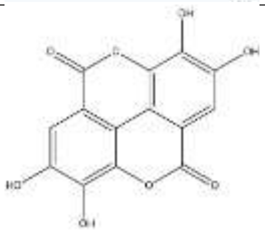


Fig. 6. Minerals content of chia seeds (mg/100g)

Identification of Phenolic and Flavonoids Compounds by HPLC in Chia Seeds and Snacks:

The phenolic and flavonoids compounds were presented in Tables 6a, b. The results showed that chia seeds has the highest phenols and flavonoids as gallic acid (3.46), chlorogenic acid (9.23), catechin (2.70), methylgallate (0.42), coffeic acid (0.17), syringic acid (0.13), pyrocatechol (1.21), rutin (0.00), ellagic acid (0.61), coumaric acid (0.25), vanillin (1.19), ferulic acid (0.17), naringenin (0.15), rosmarinic acid (2.12), Daidzein (0.00), querectin (0.00), cinnamic acid (0.07), kaempferol(0.00), hesperetin (0.00), respectively. While, snacks has the highest phenols and flavonoids as gallic acid(2.81), chlorogenic acid (7.83), catechin (3.40), methylgallate (1.06), coffeic acid (0.34), syringic acid (0.00), pyrocatechol (1.24), rutin(0.00), ellagic acid (0.92), coumaric acid (0.10), vanillin (1.05), ferulic acid (0.08), naringenin (0.00), rosmarinic acid (4.44), daidzein (0.05), querectin (0.00), cinnamic acid (0.09), kaempferol (0.00), hesperetin (3.04), respectively. The results showed that although the content of phenols and flavonoids in snacks fortified with chia seeds decreased due to the effect of heat during cooking, this percentage is considered as high and beneficial to human health (Figs.7a, b). These results were in accordance with those of **Sargi *et al.*, (2013), Marineli *et al*, (2015), de falco, B. *et al.*, (2017)**.

Table 6a. Identification of phenolic and flavonoid compounds by HPLC in chia seeds.

compound	Structure	Conce. mg/mL	compound	Structure	Conc. mg/mL
Gallic acid		3.46	vanillin		1.19
Chlorogenic acid		9.23	Ferulic acid		0.17
Catechin		2.70	Naringenin		0.15
Methyl gallate		0.42	Rosmarinic acid		2.12
Coffeic acid		**0.17**	**Daidzein**		**0.00**
Syringic acid		**o.13**	**Querectin**		**0.00**
Pyro catechol		**1.21**	**Cinnamic acid**		**0.07**
Rutin		**0.00**	**Kaempferol**		**0.00**
Ellagic acid		**0.61**	**Hesperetin**		**0.00**

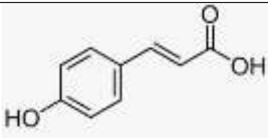
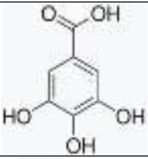
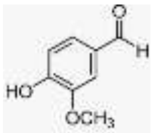
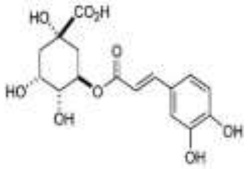
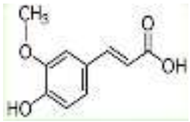
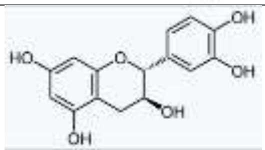
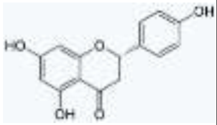
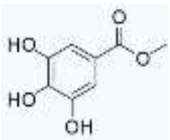
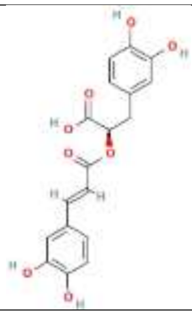
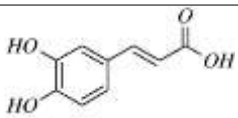
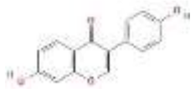
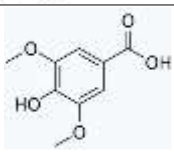
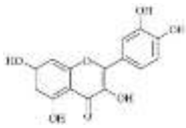
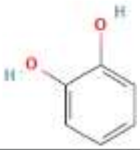
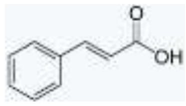
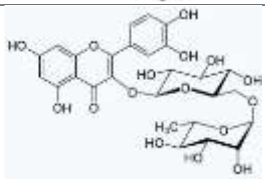
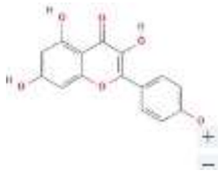
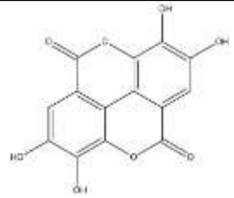
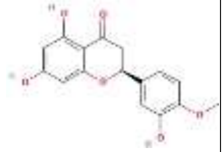
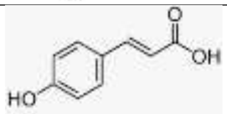
Coumaric acid		0.25			

Table 7b. Identification of phenolic and flavonoid compounds by HPLC in snacks with 3% chia seeds.

Compound	Structure	Con. mg/mL	compound	Structure	Conc. mg/mL
Gallic acid		2.81	Vanillin		1.05
Chlorogenic acid		7.83	Ferulic acid		0.08
Catechin		3.40	Naringenin		0.00
Methyl gallate		1.06	Rosmarinic acid		4.44
Coffeic acid		0.34	Daidzein		0.05
Syringic acid		0.00	Querectin		0.00
Pyro catechol		1.24	Cinnamic acid		0.09
Rutin		0.00	Kaempferol		0.00

Ellagic acid		**0.92**	**Hesperetin**		**3.04**
Coumaric acid		**0.10**			

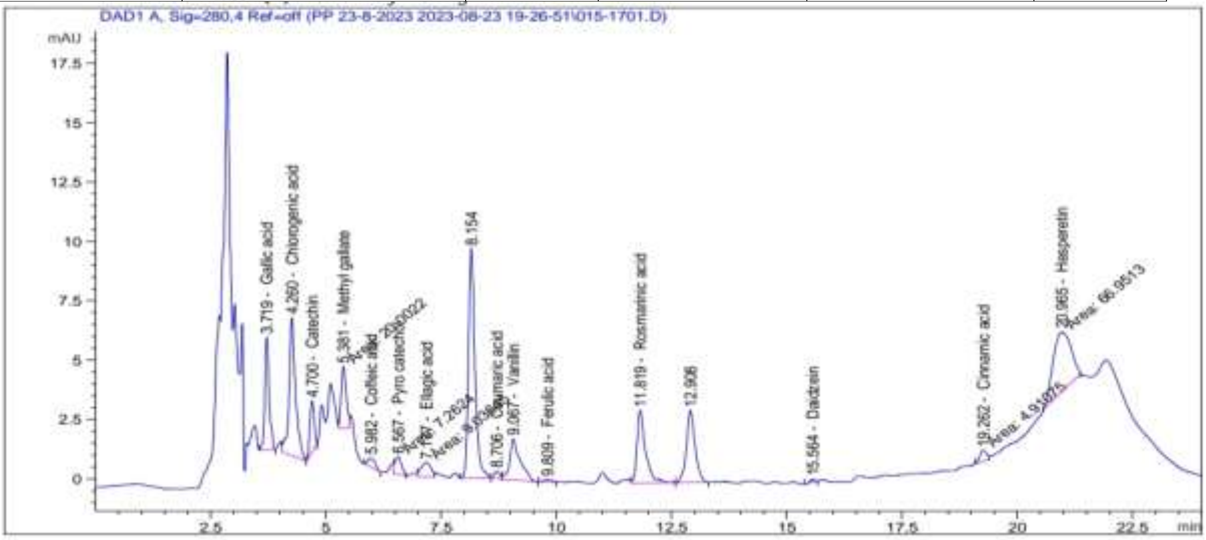


Fig. 7a. HPLC chromatogram of chia seeds.

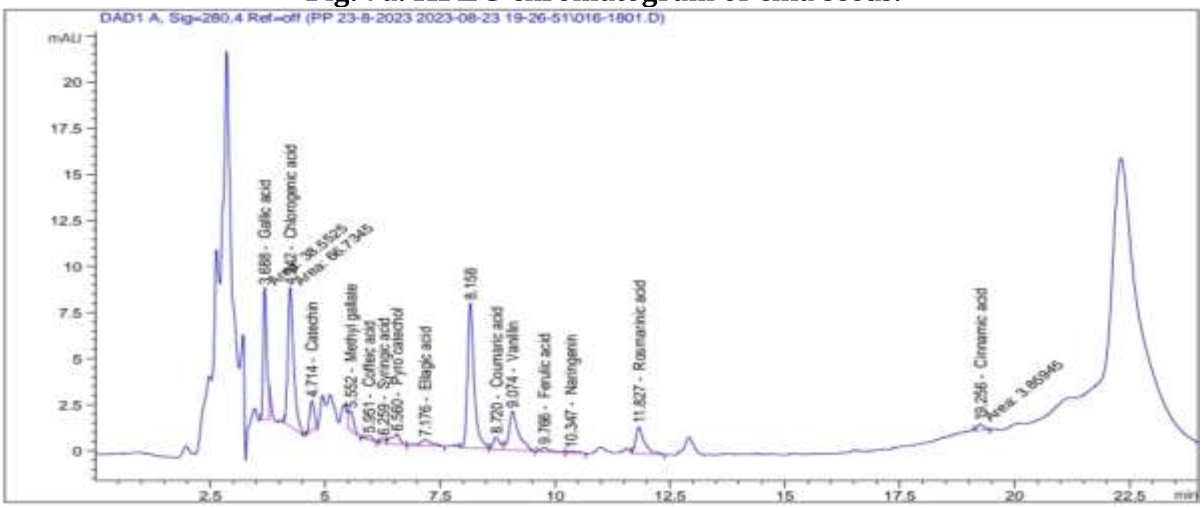


Fig. 7b. HPLC HPLC chromatogram of snacks with 30% chia seeds.

Effect of Chia Seeds on Sensory Evaluation of Snacks:

Samples of snacks that were made from wheat flour (72%) extraction and corn flour (control snacks) and snacks supplemented with different ratios of chia seeds were evaluated for shape, general appearance, color, taste, odor, texture, and over all acceptability average by (20) panelists. The obtained data were statistically analyzed and presented inTable 8 and Fig. 8. From Table 8, the results showed that the samples of snacks supplemented with 30% chia seeds and cooked in an oven scored the highest value in comparison with other snacks samples .

The sensory characteristics of snacks were scored differently in each sample. These differences are caused by the amount of chia seeds used and cooking methods in the same table. Snacks supplemented with 30% chia seeds and cooked in an oven recorded a higher acceptability than other samples.

Table 8. Sensory evaluation of snacks made from wheat flour, corn flour and chia seeds.

	1 (Mean±S.D)	2 (Mean±S.D)	3 (Mean±S.D)	4 (Mean±S.D)	5 (Mean±S.D)	6 (Mean±S.D)	7 (Mean±S.D)	8 (Mean±S.D)	9 (Mean±S.D)	10 (Mean±S.D)	11 (Mean±S.D)	12 (Mean±S.D)	LSD
General appearance	$8.45^{b} \pm 1.10$	$8.45^{b} \pm 1.10$	$7.45^{bc} \pm 1.50$	$7.55^{bc} \pm 1.82$	$7.65^{bc} \pm 1.63$	$6.8^{cd} \pm 1.82$	$8.25^{b} \pm 1.16$	$7.75^{bc} \pm 1.68$	$8.15^{b} \pm 1.42$	$8.65^{b} \pm 1.18$	$9.65^{a} \pm 0.59$	$5.95^{d} \pm 0.69$	0.85
Color	$8.15^{bc} \pm 1.39$	$7.8^{bcd} \pm 1.20$	$7.05^{cd} \pm 1.39$	$7.3^{cd} \pm 1.78$	$7.55^{bcd} \pm 1.43$	$6.85^{d} \pm 1.46$	$8.25^{bc} \pm 0.91$	$7.95^{bcd} \pm 1.43$	$7.8^{bcd} \pm 1.67$	$8.65^{b} \pm 1.23$	$9.65^{a} \pm 0.59$	$5.9^{e} \pm 0.79$	0.82
Taste	$8.4^{bc} \pm 1.43$	$8.2^{bc} \pm 1.54$	$7.35^{bc} \pm 1.95$	$7.4^{bc} \pm 2.11$	$7.55^{bc} \pm 1.88$	$6.95^{c} \pm 1.64$	$8.55^{b} \pm 1.15$	$7.55^{bc} \pm 1.79$	$8.05^{bc} \pm 2.04$	$8.7^{b} \pm 1.34$	$9.9^{a} \pm 0.31$	$5.85^{d} \pm 0.93$	0.99
Odor	$7.95^{bcd} \pm 1.43$	$7.95^{bcd} \pm 1.43$	$7.35^{bcd} \pm 1.76$	$7.00^{cd} \pm 2.08$	$7.15^{bcd} \pm 1.81$	$6.65^{de} \pm 1.63$	$8.2^{bc} \pm 1.20$	$7.5^{bcd} \pm 1.76$	$7.75^{bcd} \pm 1.86$	$8.55^{b} \pm 1.50$	$9.8^{a} \pm 0.52$	$5.8^{e} \pm 0.77$	0.96
Texture	$8.6^{b} \pm 1.05$	$8.15^{b} \pm 1.53$	$7.46^{b} \pm 1.76$	$7.5^{b} \pm 1.70$	$7.65^{b} \pm 1.60$	$7.25^{b} \pm 1.52$	$8.2^{b} \pm 1.24$	$7.95^{b} \pm 1.51$	$7.7^{b} \pm 2.03$	$8.7^{b} \pm 1.49$	$9.9^{a} \pm 0.31$	$5.7^{c} \pm 0.57$	0.90
Product acceptability	$8.45^{b} \pm 1.10$	$8.15^{bc} \pm 1.46$	$7.65^{bc} \pm 1.60$	$7.9^{bc} \pm 1.77$	$7.85^{bc} \pm 1.57$	$6.9^{c} \pm 1.77$	$8.65^{b} \pm 1.09$	$7.9^{bc} \pm 1.52$	$7.95^{bc} \pm 1.73$	$8.9^{b} \pm 1.45$	$9.85^{a} \pm 0.37$	$5.65^{d} \pm 0.59$	0.88

Water Activity:

Most common and easy method of controlling water activity is draying or dehydration. It removes water and thus reduces water activity resulting in increased shelf life. Beef jerky, dried fruits, are great examples. Also, dried spices like red chillies have a lower water activity and can be stored for longer time. Drying can be done by various methods like freeze-draying, sun draying, mechanical draying, *etc*. Water activity also affects the physical properties of a food product. The foods of low water activity are dry and hard whereas, foods with high water activity can be juicy, soft in texture. Increasing and decreasing the water activity of these products can affect their textural properties.

Water activity of different samples of snacks were determined by recording data on water loss or gain per gram of samples and determined using a water activity measurement apparatus, AW SPRINT TH-500; Axair Ltd., Pfäffikon, Switzerland **(Mnif *et al.*, 2012)**.Table 9 showed that both moisture and water activity decreased with the higher percentages of snacks chia. After baking, chia snacks experimented with lower weight loss compared with wheat control sample, more markedly with a greater addition of seeds in the formulation and cooking. These results agreed with those obtained by **Coelho *et al*., (2015).**In snacks supplemented with with chia seeds and corn flour, the results demonstrated a minor loss of mass upon baking in formulated with a greater percentage of chia compared to the control sample due to the fiber of chia absorbing a loge quantity of water avoiding its evaporation during the baking process. The results also demonstrated a lower level of water activity in samples that ware cooked in oil than in those that were cooked in an oven without using a fatty substance.

Table 9. Water activity of Snacks.

No.	Samples	Water activity
1	Control of 100 % flour in oven	0.554
2	Control 00% flour in oil	0.431
3	Control (w+c) flour in oven	0.503
4	Control (w+c) flour in oil	0.417
5	w+c) +30% chia in oven	0.456
6	(w+c) +30% chia in oil	0.411

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