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BIOLOGICAL EVALUATION AND APPLICATION OF CORIANDER FRUITS AND ITS ESSENTIAL OIL

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ABSTRACT

Our investigation is currently focusing on the impact of coriander fruits and their extracts (essential oil and aqueous extracts) as natural substances could be used as alternative food preservation as well as functional foods. So, the chemical constituents of coriander essential oil (CEO) and the *in vitro* antimicrobial as well as antioxidant activities were determined, also, the hypoglycemic effectiveness was applied on diabetic rats. Results indicated that Linalool, is found to be the major volatile component (62.2 %). The antimicrobial activity of three concentrations of CEO (1, 3 and 5%) and linalool (0.5,1.0 and 2.0%) against five bacterial and five fungal strains by using Disc –Diffusion technique was examined, compared with the results of Genatmicin and Amphotericin B. Results indicated that CEO showed more effective antimicrobial activity than linalool. Also, Gram-negative bacterial strains were susceptible towards tested materials than Gram- positive ones. CEO demonstrated antioxidant activity by DPPH assay. Also, it was found that supplementation of English rich cake with ground coriander fruits (GCF), succeeded in prolonging the shelf life of cake samples up to 12 weeks at 1 and 3 %, however, it reached 16 weeks in the cake supplemented with 5 % GCF, at room temperature (20± 2° C). The finding evinced the superior effect of GCF compared with CEO. On the other hand, our investigation proved the anti-diebetic activity of coriander fruits and their extracts (aqueous macerated and aqueous decocted) on Streptozotocin-induced diabetic rats *via* oral injection or feeding with pan bread incorporated with GCF or CEO.

1.Introduction

Coriander (*Coriandrum sativum* L.) being an annual herb, is most commonly used for seasoning purpose. The herbal material of corianderis the fruit not the seed. Fresh herb is also used as an aromatic spice (Nurzynska-Wierdak, 2013).Coriander is also well known for its antioxidant, anti-diabetic, anti-mutagenic, antianxiety and antimicrobial activities along with analgesic and hormone balancing effect that promotes its use in foods due to numerous health benefits. Furthermore, it is used to preserve the food for a long timefor its protective effect (Bhat, *et al.*, 2014). For the previous effectiveness, coriander is considered one of miraculous herb that functions as both, spice as well as herbal medicine.

Diabetes mellitus is a chronic, metabolic disease characterized by elevated levels of blood glucose (hyperglycemia), and disturbance of carbohydrate and glycogenolysis as well as gluconeogenesis fat and protein

metabolism, which leads over time to serious damage to the heart, blood vessels, eyes, kidneys and nerves. About 422 million peopleworldwide have diabetes, 1.6 million deaths are directly attributed to diabetes each year. Both the number of cases and the prevalence of diabetes have been steadily increasing over the past few decades (WHO, 2021). It was found that DM is associated with chronicle higher risk including heart attacks, blindness, kidney failure and neuropathy (Hameed, *et al.*, 2015).On this occasion, coriander fruit extract is used as a traditional medicine for diabetic patients. Incorporation of ground coriander fruit extract in diet led to marked decline in blood glucose and rise in levels of insulin in diabetic rats (Bhat, *et al.*, 2014). On this connection, Srinivasan, (2005) ascertained that the hypoglycaemic effect of spices may be used in conjunction with antidiabetic drugs to have better therapeutic potential and to minimize the oral hypoglycaemic drug dosage. Many investigations focused on the impact of herbs and spices, although they do not majorly contribute to nutrient supplementation of diet because of their use in lesser quantities and mostly utilized for the purpose of garnishing and flavoring. However, keeping in view the health-enhancing potential of these food components, they must be employed in designing and formulating functional foods (Eidi, *et al.*, 2009 and Helmy, *et al.*, 2017). It was also reported that activity of 200 mg/kg body weight dose of coriander extract is comparable to the commercially available synthetic drug. They also added that coriander had the ability to ameliorate oxidative stress and protect the liver and renal cell from damage (Sreelatha, *et al.*, 2009). Besides, peroxidative damage inhibition, addition of fruitsextract reactivated antioxidant enzymes and antioxidant levels in diabetic rats (Deepa & Anuradha, 2011). Keeping in view the importance of medicinal, aromatic plants as well as natural products, coriander fruits and their extracts (aqueous macerated, decocted and essential oil) were selected for the present study as biopreservative and anti-diabetic agents.

2.Materials and Methods

2.1.Materials

Coriander fruits (*Coriandrum sativum* L.) were purchased from local market, Giza, Egypt. Streptozotocin (STZ), DPPH (2, 2-diphenyl-1-picrylhydrazyl), BHT (Butylated Hydroxy Toluene) and Linalool ((3R)-3,7-dimethylocta-1,6-dien-3-ol) were purchased from Sigma Chemical Company, St Louis, Missouri, USA. Glucose kits were purchased from Bio-diagnostic (BD), Cairo, Egypt. Kits for determingAlanine amino transferase (ALT), Aspartate amino transferase (AST), triglycerides, total cholesterol, high density lipoprotein(HDL), low density lipoprotein(LDL)Creatinine and Urea were purchased from Bio -diagnostic Company, Cairo, Egypt. Methyl alcohol (99%) and ethyl alcohol (99.5%) were purchased from El-Nasr Pharmaceutical Chemical Co., Egypt. Anhydrous sodium sulphate (99%) was purchased from ElGomhoria Co. Chemicals trade, Cairo, Egypt. Ingredients of English rich cake and pan bread were purchased from local market, Giza, Egypt. All other chemicals and reagents used were of analytical grade.

2.2. Methods

2.2.1. Gross chemical composition of Coriander fruits

Coriander fruits were analyzed for their chemical constituents. All the proximate analysis including; moisture, crude protein, crude fat, crude fibers and total ash were determined according to the methods of AOAC, (2012). However, carbohydrates content of coriander fruits was determined to be a nitrogen free extract (NFE) by the following formula:

$$\text{NFE (\%)} = 100 - (\text{Moisture} + \text{crude fat} + \text{crude protein} + \text{crude fiber} + \text{total ash}). \quad (1)$$

2.2.2.Tested microorganisms

Four different bacterial strains, two Gram positive strains (*Bacillus subtilis* ATCC 33221

and *Staphylococcus aureus* ATCC 20231) and two strains of Gram negative bacterial strains (*Escherechia coli* ATCC 6933 and *Pseudomonas aeruginosa* ATCC 9027) were used in this study. Two strains of yeast including, *Saccharomyces cerevisiae* NRRLY 2034 and *Candida lypolitica* NRRLY 1095 and two strains of moulds were used which included *Aspergillus niger* NRRL 2322 and*Aspergillus flavus* EMCC 100. All previous strains were obtained from the Egyptian Microbial Culture Collection (EMCC), Faculty of Agriculture, Ain Shams University, Egypt, except *Aspergillus niger* NRRL 2322 which was obtained from Northern Regional Research Laboratories (NRRL), Peoria, Illinois, USA. The previous microorganisms were checked for their purities and they were reactivated monthly on the suitable media as reported by Conner and Beauchat (1984).

2.2.3. Tested animals

Forty male albino rats (Wister strain) weighing 200 -250g were supplied by the Animal House of National Research Center, Cairo-Egypt.

2.2.4. Separation and phytochemical analysis of coriander essential oil using GC/MS technique

The dried coriander fruits sample was ground immediately prior to extraction in order to avoid losses of volatiles, and then subjected to hydro- distillation (Clevenger trap) for 4 hours according to the method described in the European Pharmacopoeia (1997). The extracted coriander essential oil (CEO) was collected and desiccated over anhydrous sodium sulphate. Extraction was carried out in triplicates and the mean values of essential oil yield was calculated as follows:

Yield (% v/w) = (volume of essential oil/mass of the dried fruits) x 100 (2)

The chemical constituents of CEOwere fractionated and identified by using Gas Chromatography/Mass Spectrometry (GC/MS) technique, using the GC/MS system (Agilent Technologies), which was equipped with Gas Chromatograph (7890B) and Mass Spectrometer detector (5977A). Oil sample was diluted with hexane (1:19, v/v).The GC was provided with HP-5MS column (30 m x 0.25 mm internal diameter and 0.25 µm film thickness). Helium was the carrier gas at a flow rate of 1.0 ml/min at a split ratio of 1:30, injection volume of 1 µl and the following temperature program: 40 °C for 1 min, rising at 3 °C /min to 160 °C and kept for 6 min, rising at 4 °C/min to 210 °C and kept for 1 min. The injector and detector were controlled at 280 °C and 220 °C, respectively. Mass spectra were obtained by electron ionization at 70 eV and using a spectral range of m/z 50-550. Identification was determined by comparing the spectrum fragmentation pattern with those stored in Wiley and National Institute of Standards and Technology Mass Spectral Library data.

2.2.5. Antimicrobial activity of coriander fruits essential oil

Precursorytrial ascertained that the CEO completely inhibited the tested microorganism, so, CEO was diluted to 1, 3 and 5 % by using ethanol 95 %. Also, Linalool was tested at different concentrations (0.5, 1.0 and 2.0%). Disc diffusion Assay was applied to assess the antimicrobial activity of coriander essential oil according to the method described by Hood *et al*. (2003). Twenty ml of either Mueller Hinton agar medium or Sabouraud agar medium, for antibacterial and antifungal activities assay, respectively, containing 1% Tween 80 as an emulsifier was poured in sterilized plates (90 mm diameter) according to Difco- Manual (1977). Ten µl of each concentration was placed on 6 mm blank antimicrobial susceptibility discs. The essential oil was impregnated the discs, then it was placed onto. The agar plates were incubated overnight at suitable temperature (30 and 37°C for fungal and bacterial strains, respectively). The microbial inhibition zones in millimeters (mm) were recorded.

2.2.6. Antioxidant activity of coriander essential oil

The antioxidant potency of coriander essential oil was determined by using DPPH Scavenging method as described by Choi (2010) and Viuda-Martos, *et al*. (2010). The DPPH analysis was measured as mentioned by Brand Williams, *et al.* (1995). Different concentrations from oil sample were added 10, 25, 50, 100, 150 and 200 µL in test tubes followed by addition 2.8 ml of 0.4 g /L DPPH solution (0.020 ± 0.0001 g DPPH in 50 mlmethanol as a solvent). Both BHT and ascorbic acid solutions at the same concentrations were considered reference antioxidants.

The IC_{50} (50% of inhibition) also was calculated from a graph plotting percentage inhibition against each essential oil concentration.

2.2.7. Preparation of cake

English rich cake samples were processed according to the method described in AACC (2002), by the Bakery Pilot Plant in Food Technology Research Institute (FTRI), Agriculture Research Center (ARC). The formula was (80% fat, 80% eggs, 80% sugars/ 100g flour). Preliminary sensory evaluation was applied to assess the acceptable addition % of ground coriander fruits and coriander essential oil in both cake and pan bread formulations. So cakes were incorporated with ground coriander fruits at 1, 3, 5, 7and 10% or its essential oil at 0.1, 0.3 and 0.5%, compared with BHT at 200 ppm to evaluate the efficiency of coriander fruits or their essential oils to preserve cake samples. Cakes were baked for 25 min at 180 °C, thenthe ten samples were cooled at the room temperature (21 ±3° C) and were packed in polypropylene bags at the room temperature (20± 2° C) for 24 weeks.

2.2.8. Determination of specific volume of cake

Specific volume of cake was determined to assess cake quality, according to the method of Chaiya &Pongsawatmanit (2011). After baking at 180 °C for 25 min, the final cake volume was obtained using the rapeseed displacement method. The cake was cut into 25 × 25 × 25 mm cubes. Then, one piece of cake was weighed (W), and placed in a container and the rest of the container volume was filled with rapeseed (V2). The volume of the empty container (V1) was calculated by filling with rapeseed. Both V1 and V2 were later determined by a graduated cylinder and the difference between V1 and V2 was defined as the cake volume (Vo). The specific volume was then calculated as the ratio of the volume to weight (Vo/W).

2.2.9. Determination of microbial load in cake during storage period

Microbial load was estimated by using pour plate method according to Vanderzant & Splittstoesser (1992). The counts of total bacteria (TBC), mold and yeasts (Fungal count, FC), respectively, were determined and expressed as $CFU.g^{-1}$, during storage period at (20± 2° C).Alsovisible microbial growth (MG) was recorded by visual observation.

2.2.10. Lipid oxidation

Two chemical parameters, Peroxide value (PV) andThiobarbituric acid (TBA) were determined as indications of lipid oxidation in the fat portion extracted from cake samples according to Habib & Brown (1956). PV was determined according to the methods of (AOAC, 2000) and expressed as (mequivalent peroxide/ Kg oil). However, TBA was determined colorimetrically at 538 nm as described by (Pearson & Cox, 1976). The results of (TBA) were expressed as mg malondialdehyde/kg oil sample.The samples of cake were analyzed for these parameters immediately after baking of cake samples (zero time) and 2 weeks interval for 24 weeks of storage at room temperature (20± 2° C).

2.2.11. Preparation of pan bread for biological assay

Pan bread was prepared according to the method described in (AACC, 2000) with some modifications. The coriander oil (0.2, 0.3 and 0.5 %) was added by replacing the oil of control sample, however, ground coriander fruits (3.0, 5.0, 7.5 and 10.0%) as appropriate

%were added by replacing the flour of control sample. The processing of pan bread was applied according to Abdulla & Abdel-Samie (2015). Bread loaves obtained were sensory evaluated to select the most accepted ratios for both coriander fruits and their essential oil to be utilized in the biological experiment.

2.2.12. Sensory evaluation of cake and pan bread

Cakes prepared by adding ground coriander fruits or their essential oil as well as BHT, compared with control sample (without additives), were sensorial evaluated. After cooling of cake samples at room temperature, sensory characteristics were judged by ten members from Experimental Kitchen Res. Unit, Food Tech. Research Institute. Giza, Egypt. Cake samples with a thickness of 1 cm, were evaluated on the basis of acceptance of their crust color (10), texture(10), odor(10), taste(10), appearance(10) and overall acceptability(10). The ten samples were coded differently and served to panelists. The panelists were asked to score the characteristics of cake samples crust color, odor, texture, taste and overall acceptability, according to Ibrahium, *et al.* (2013). Meanwhile, eight Pan Bread samples (prepared by adding ground coriander fruits or their essential oil compared with control sample) were coded and presented to evaluate sensory characteristics. Ten panelists, who are familiar with the product, from the Staff of the Cereal Technology Research Department, Food Technol. Research Institute, Agric. Res. Center, Giza, Egypt were asked to evaluate sensory characteristics of pan bread samples, which including crust color (15), crumb color (15), texture (15), odor (20), taste (20) and appearance (15). The scoring scheme was established according to the method described by AACC (2000). All samples were analyzed in the same session. Water was available for rinsing.

2.2.13. Antidiabetic effect of coriander fruitsand its extracts

2.2.13.1. Preparation of coriander fruit extracts for biological evaluation

Coriander fruits were ground by using an electrical blender and stored at – 18° C until utilized.

Decoction treatment: ground coriander fruits (25 gm) were suspended in distilled water (2.5 L) and heated to boil for 30 min., decoctedcoriander fruits (DC) was filtered after centrifugation.

Maceration treatment: ground coriander fruits (25 gm) were suspended in 2.5 Liters cold distilled water for 30 min, macerated coriander fruits (MC) obtained was filtered after centrifugation.

2.2.13.2. Induction of Diabetes

The experimental animals were kept in an environmentally controlled room (temperature 25 ± 2° C, humidity: > 60%) with regular light-dark cycle. The animals were housed individually in polypropylene aerated cages with screen bottoms and provided diet and water *ad libitum*through the experimental period (28 days).The rats were fed on a basal diet (pellet shaped) consisted of 21.70% casein, 53.30% corn starch, 15% sucrose, 5% corn oil, 4% mineral mixture and 1.00% vitamin mixture (Tebib *et al.*,1997) for 10 day as an adaptation period. After that, the rats were randomly divided into two groups, Group 1 (normal control group): Animals received a basal diet.The second group (35 rats) were kept fasting prior to streptozotocin injection. On the day of administration, Streptozotocin (STZ) dissolved in 0.1 M citrate buffer (pH7.4) was injected intravenously at the dosage of 60 mg/kg b.w. to induce hyperglycemia according to Ozsoy-Sacan *et al*. (2005). Blood glucose concentration was checked by the glucose oxidase method of Trinder, (1969). After 3 days of STZ injection, the animals with glucose concentration exceeding 200mg /dL were considered diabetic, so, they were divided into 7 groups, other than normal control rats group as follows:

G1: Normal control rats group fed on a basal diet according to Reeves et al., (1994).

G2: Diabetic control rats group, fed on a basal diet rats and injection with STZ (60mg/kg b.w).

G3: Diabetic rats group, fed on a basal diet and orally injection with (500mg/kg b.w/daily) of decoctedcoriander fruits (DC) by stomach tube.

G4: Diabetic rats group, fed on a basal diet and orally injection with (500mg/kg b.w/daily) macerated coriander fruits (MC) by stomach tube daily.

G5: Diabetic rats group, fed on a basal diet containing ground coriander fruits (GCF) at 500 mg/kg bw.

G6: Diabetic rats group, which fed on a basal diet and orally injection with coriander essential oil (40 mg/kg b.w/daily) by stomach tube (the dose of essential oil was chosen according to its LD_{50}, where the medium 50 lethal doses after acute toxicity as mentioned by Anon. (2021).

G7: Diabetic rats group, fed on pan bread containing 0.3 % coriander essential oil.

G8: Diabetic rats group, fed on pan bread containing 5 % ground coriander fruits.

The biological evaluation of the different tested was carried out by determination body weight gain percentage and hypoglycemic efficiency according to Chapman et al. (1959).

At the end of the experiment (after 28 days) from the beginning of the experiment, body weight gain (BWG)% was calculated as follows:

Body weight gain (%) = (Final weight – Initial weight / Initial weight) X 100. (3)

2.2.13.3. Blood samples collection and Biochemical analysis

At the end of biological experiment, rats were fasted for 12 hours then blood samples were collected retro-orbitally from the inner canthus of the eye under ether anesthesia using capillary tubes containing sodium EDTA (Schermer,1967).Plasma total lipids (TL) were determined by enzymatic method according to Zollener & Kirsch (1962). Triglycerides (TG) and total cholesterol (TC) were determined by enzymatic colorimetric method according toTrinder (1969). High density lipoprotein cholesterol (HDL) and low density lipoprotein cholesterol (LDL), were determined according to Assman, (1979), AST and ALTactivities were determined by colorimetric methods according to Reitman & Frankel (1957) as liver function enzymes. Serum glucose was determined by enzymatic colorimetric method, according to Barham &Trined, (1972). Regarding, kidney functions, Creatinineand Urea were determined according to Caraways, (1975). Glucose level was determined in blood serum of experimental rats using enzymatic method ascribed by Young *et al*. (1972).

2.2.14. Statistical Analysis

The collected data for various parameters were expressed as mean ± SD (standard deviation) of the mean of three replications, unless otherwise stated and compared using one way analysis of variance (ANOVA) test. All data were averaged.Values were considered statistically significant when P value was less than 0.05 were done using SPSS for windows version 10.

3. Results and discussions

3.1. Gross chemical composition of Coriander fruits

Results indicated that moisture constituted low content (8.86%) in coriander fruits, however, crude protein and total ash constituted 12.37 and 10.30 %, respectively. Regarding nitrogen free extract (NFE), it represented (8.80 %) and crude fibers (41.90 %). On the other hand, crude fat constituted 17.77%. These results are in accordance with those reported by Shahwar, *etal*. (2012). Also, our findings are highly matched with those found by Bhat, *et al.* (2014), who is reported that coriander fruits is considered a potential source of lipids (rich in petroselinic acid) and an essential oil (high in linalool) as well as high contents of dietary fibers and protein in the fruits make distillation residues suitable for animal feed.

3.2. Coriander essential oil yield and chemical composition of the essential oil

Results showed that the coriander fruits essential oil constituted 0.28 %(v/w, on dry basis), which is in agreement with that reported

by El Soud, *et al*. (2012), Freires *et al.* (2014) and Al-Sanafi (2016). Also, Nurzynska-Wierdak (2013) ascertained that the coriander fruits contained 0.17 – 0.29 %, essential oil, depending on the stage of plant development, which exhibited high variability.

Concerning chemical constituents of coriander essential oil, the GC/MS identified 26 components from total of 32 components which representing 98.5 % of total constituents of CEO (Table, 1). The oxygenated compounds constituted higher fraction. It could be noticed that the major constituent was Linalool with 62.2 %,which is considered as a cyclic monoterpene alcohol, followed by geranyl acetate (10.9%), γ -terpinene (10.2 %) and α-pinene (3.2 %). These results are in harmony with those reported by Abou El Soud, *etal*. (2012) and Sourmaghi, *et al.* (2014). The results also are in the same line with those presented in ES(2007).

3.3. Antimicrobial activity

The antimicrobial activity of CEO (1, 3 and 5%) as well as linalool (0.5, 1.0 and 2.0%), compared with two reference antibiotics (Gentamicin and Amphotericin B) at 10 µg, in similar conditions against pathogenic bacterial strains (*Escherichia coli* ATCC 6933, *Pesudomonasaeroginosa* ATCC 902, *Staphylococcus aureus* ATCC 20231 and *Bacillus subtilis* ATCC 33221) by disc-diffusion method was examined.On this connection, the concentrations of linalool were chosen depending on its percent in the selected concentration of the coriander fruits essential oil. The results illustrated in Table (2) showed that Gram-positive bacteria exhibited more sensitive to the CEO, especially *Bacillus subtilis* ATCC 33221 (inhibition zones being between 7.4 and 19.4 mm). Gram-negative bacteria were more resistant, especially, *Pesudomonas aeroginosa* ATCC 9027. It could be observed that the diameters of inhibition zones were directly proportional to oil and linalool concentrations. The sensitivity differencebetween the two groups of bacteria occurred because Gram-negative bacteria possess an outer membrane and a unique periplasmic space is not presented in gram-positive bacteria (Dorman & Deans, 2000).

It is noteworthy that the linalool exhibited lower antimicrobial activity against the tested strains compared with CEO, however, linalool, didn't show any inhibition at low concentration (0.5%), except on the two tested mold strains. On the other hand, the differences between the antimicrobial activities of oil were significant (Table 2). On the other hand, the results ascertained that CEO has demonstrated a remarkable antifungal effect against *Aspergillus niger* NRRL 2322 and *Aspergillus flavus* EMCC 100, compared to Gentamicin and Amphotericin B,at all concentrations used in this experiment. Similar findings were noticed for *Candida lypolitica* NRRLY 1095, where, the tested agents succeeded in inhibiting the growth of *Candida lypolitica* NRRLY 1095, with the remarked superiority of CEO ($p \geq 0.05$), followed by the rest tested agents.

Our finding means that the antimicrobial efficiency of such oil didn't refer to the main component only, but to the synergistic effect of all oil components as reported by Herman, *et al.* (2016), who ascertained the antimicrobial efficiency of linalool and also reported that a synergistic manner between linalool and some essential oil components enhanced their antimicrobial efficacy against *P. aeruginosa, S. aureus,E. coli* and *C. albicans*. Our results are highly in harmony with those found by Ultee, *et al.,* (2002) ascertained that the antifungal property of the oil was likely due to the eugenol. On the other hand, Nanasombat & Lohasupthawee (2005) proved that the antimicrobial effects of spices and herbs were due to their complex chemical composition, which included compounds such as thymol, carvacrol, methyl eugenol, linalool, α-pinene, 1, 8-cineole and camphor. Other component presented in CEO and has antimicrobial potency is geranyl acetate which has antifungal activity and anti-inflammatory effect (José Goncalvesa, *et al*., 2011). Furthermore, the antimicrobial activity of the essential oil could be contributed to the presence of active

compounds such as α-pinene and ß-pinene (Dorman & Deans 2000and Zardini, *et al*. (2012), ρ-cymene and γ-terpinene (Xianfei, *et al*. 2007). All the previous components were fractionated and identified in CEO (Table 1).Concerning Linalool, it was found to have antimicrobial activity against various microbes and it inhibits the spore germination and fungal growth by the mechanism of respiratory suppression of aerial mycelia (Koutsoudaki *et al.*, 2005).

Table 1. Chemical constituents of coriander EO by using GC/MS

Peak no.	**Compounds**	**RT***	**`Area (%)**
1	Nonane	4.13	0.2
2	Unknown	4.27	0.1
3	α-Pinene	4.38	3.2
4	Decane	4.74	0.2
5	Cis-Ocimene	5.01	0.3
6	β-Pinene	5.29	1.1
7	γ-Terpinene	5.79	10.2
8	Sabinene	6.32	0.4
9	Limonene	6.91	2.1
10	n-Ocatanal	8.12	0.6
11	Unknown	8.17	0.3
12	*p*-Cymene	9.02	0.2
13	Humulene	9.17	0.2
14	Nonnal	10.32	0.2
15	Linalool	13.71	62.2
16	Camphor	14.51	0.2
17	Citronellal	17.28	0.1
18	Decanal	18.79	3.8
19	Terpinen-4-ol	20.11	0.1
20	Borneol	23.27	0.2
21	Unknown	24.10	0.2
22	Unknown	25.37	0.3
23	Unknown	28.21	0.2
24	α-Terpineol	29.07	0.1
25	Bornyl acetate	30.21	0.2
26	Caryophyllene	31.32	0.3
27	Neryl acetate	33.74	0.1
28	Unknown	34.21	0.4
29	Geranyl acetate	37.52	10.9
30	Elemene	39.22	0.2
31	Eugenol	40.29	0.5
32	Octadecanol	42.39	0.7
Total identified (%)			**98.5**
Total non-oxygenated compounds (%)			**18.6**
Total oxygenated compounds (%)			**79.9**

Table 2. Antimicrobial activity of coriander essential oil and linalool using agar disc diffusion method (mm)*

Microbial Strains	Tested materials							
	Coriander essential oil (%)			Linalool (%)			Gentamicin*	Amphotericin B*
	1	3	5	0.5	1.0	2.0		
Gram positive bacteria								
Bacillus subtilis ATCC 33221	$7.4^{aD} \pm 0.13$	$12.3^{aBC} \pm 0.25$	$19.4^{aA} \pm 0.07$	$0.0^{bE} \pm 0.00$	$6.1^{bD} \pm 0.03$	$11.8^{abC} \pm 0.14$	$14.2^{aB} \pm 0.11$	$11.0^{bC} \pm 0.04$
Staphylococcus aureus ATCC 20231	$0.0^{bC**} \pm 0.00$	$7.1^{cB} \pm 0.03$	$14.0^{bA} \pm 0.21$	$0.0^{bC} \pm 0.00$	$0.0^{cC} \pm 0.00$	$8.2^{bB} \pm 0.28$	$13.3^{aA} \pm 0.2$	$0.0^{cC} \pm 0.00$
Gram negative bacteria								
Escherichia coli ATCC 6933	$7.2^{aC} \pm 0.05$	$10.0^{bB} \pm 0.14$	$13.7^{bA} \pm 0.14$	$0.0^{bD} \pm 0.00$	$7.1^{aC} \pm 0.07$	$10.3^{bB} \pm 0.11$	$11.5^{bAB} \pm 0.1$	$9.5^{bB} \pm 0.23$
*Pesudomonasaeroginosa*ATCC 9027	$0.0^{bC} \pm 0.00$	$7.4^{cBC} \pm 0.18$	$11.0^{bcA} \pm 0.00$	$0.0^{bD} \pm 0.00$	$6.8^{abBC} \pm 0.1$	$8.3^{bB} \pm 0.15$	$12.2^{abA} \pm 0.1$	$10.0^{bAB} \pm 0.1$
Molds								
*Aspergillus niger*NRRL 2322	$9.1^{aC} \pm 0.11$	$15.1^{aB} \pm 0.15$	$22.0^{aA} \pm 0.33$	$6.8^{aC} \pm 0.11$	$8.5^{aC} \pm 0.11$	$14.7^{aB} \pm 0.70$	$8.3^{cC} \pm 0.14$	$19.0^{aAB} \pm 0.1$
Aspergillus flavus EMCC 100	$8.8^{aD} \pm 0.71$	$15.9^{aB} \pm 0.22$	$19.8^{aA} \pm 0.13$	$7.1^{aD} \pm 0.16$	$9.3^{aD} \pm 0.33$	$12.3^{aC} \pm 0.28$	$9.0^{cD} \pm 0.21$	$17.3^{abA} \pm 0.2$
Yeasts								
Saccharomyces cerevisiae NRRLY 2034	$0.0^{bC} \pm 0.00$	$0.0^{dC} \pm 0.00$	$0.0^{cC} \pm 0.00$	$0.0^{bC} \pm 0.00$	$0.0^{cC} \pm 0.00$	$0.0^{cC} \pm 0.00$	$8.2^{cB} \pm 0.19$	$17.0^{abA} \pm 0.1$
Candida lypolitica NRRLY 1095	$7.2^{aC} \pm 0.05$	$10.0^{bB} \pm 0.14$	$13.7^{bA} \pm 0.14$	$0.0^{bD} \pm 0.00$	$7.1^{abC} \pm 0.1$	$10.3^{bB} \pm 0.11$	$11.5^{bAB} \pm 0.1$	$9.5^{bB} \pm 0.23$

Values are mean inhibition zones of three replicates ± standard deviation.
Means followed by different capital letters in the same row represents significant difference ($p \leq 0.05$) between tested materials or concentrations.
Means followed by different small letters in the same column represents significant difference ($p \leq 0.05$), for each microorganism.
* Reference antibiotics at concentration (10 μg). ** No observed inhibition zone.

On the contrary, neither CEO nor linalool affected the growth of *Saccharomyces cerevisiae* NRRLY 2034 strain, which was resistant, however, two tested antibiotics inhibited the growth of this strain. This means that CEO could be added to bakery products as a seasoner without negative effect on the growth of baker's yeast and consequently the fermentation process. The results of Freires *et al.* (2014) are matching with ourfindings.

Concerning the results of antimicrobial activity of reference antibiotics (Gentamicin and Amphotericin B), it was reported that Gentamicin is an aminoglycoside antibiotic and is considered as a bactericidal antibiotic that works by binding the 30S subunit of the bacterial ribosome, negatively impacting protein synthesis. However, Gentamicin was found to have antibacterial activity against *Escherichia coli*, *Pseudomonas aerogenosa* and *Staphylococcus aureus* (Anon., 2019).

3.4. Free radical scavenging activity

In vitro antioxidant potential by means of free radical scavenging activity (RSA) of CEO was applied using the DPPH (1,1-diphenyl-2-picryl hydrazyl) radical method. Different concentrations of CEO and Linalool (10, 25, 50, 100, 150 and 200 µl) were tested, compared with BHT and ascorbic acid as control synthetic antioxidant agents at the same previous concentrations. Results in Table (3)indicated that no antioxidant activity was noted at low concentrations (10 and 25 µl) for CEO, linalool and ascorbic acid, however it exhibited RSAat 50 µl and above (except for linalool). Our findings ascertained that at 100 and 200 µl, both CEO and BHT exhibited the highest antiradical scavenging activity with no significant ($p \geq 0.05$)differences. On the other hand, no significant difference was recorded concerning RSAbetween linalool and CEO at 200 µl, where, significant differences were observed among ascorbic acid and the other tested materials ($p \geq 0.05$).

Table 3. The DPPH radical scavenging activity (%) of coriander fruits essential oil and linalool at different concentrations.

Tested materials	Concentrations (µl)					
	10	**25**	**50**	**100**	**150**	**200**
CEO*	$0.00^{a} \pm 0.00$	$0.00^{b} \pm 0.00$	$31.95^{c} \pm 2.12$	$51.28^{a} \pm 0.86$	$69.92^{b} \pm 0.77$	$88.63^{ab} \pm 1.64$
Linalool	$0.00^{a} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{d} \pm 0.00$	$46.22^{b} \pm 0.65$	$62.44^{c} \pm 2.81$	$83.18^{b} \pm 0.58$
BHT	$0.00^{a} \pm 0.00$	$50.80^{a} \pm 1.16$	$53.80^{a} \pm 1.95$	$58.22^{a} \pm 0.19$	$87.32^{a} \pm 1.01$	$99.16^{a} \pm 0.61$
Ascorbic acid	$0.00^{a} \pm 0.00$	$0.00^{b} \pm 0.00$	$40.03^{b} \pm 2.11$	$46.33^{b} \pm 2.83$	$63.12^{c} \pm 1.58$	$70.81^{c} \pm 1.03$
	IC_{50} (µg/ml)					
CEO*	$78.3^{b} \pm 1.91$					
Linalool	$82.1^{b} \pm 2.19$					
BHT	$76.5^{b} \pm 1.11$					
Ascorbic acid	$112.2^{a} \pm 2.87$					

* Coriander Essential oil.BHT and ascorbic acid were used as control antioxidant agents.
The mean values (n=3) with different letters in the same column are significantly different($p<0.05$).

Concerning the IC_{50} value (the concentration with scavenging activity of 50%), our findings illustrated in Table (3) indicated that the highest scavenging efficient was noticed for BHT (76.5µg/ml), however, no significant ($p \geq 0.05$) differences were found between BHT, CEO and linalool. On the contrary, ascorbic acid showed the lowest RSA, where IC_{50} value was significantly higher ($p \geq 0.05$)than those recorded by the other tested materials (112.2µg/ml).

The antioxidant potential of CEO could be referred to the presence of certain components such as thymol, eugenol and carvacrol

(phenolic compounds) which are indeed responsible for the antioxidant activity of many essential oils that contain the previous components (CEO contains 0.4 % eugenol) and a scant antioxidant activity is given to monoterpene and sesquiterpene hydrocarbons, three monocyclic components, γ-terpinene (10.2%), terpinen-4-ol (0.1%) and α-terpinene (0.1%), in addition to a lesser degree, a bicyclic sabinene (0.4%), which show considerable activity (Ruberto & Baratta, 2000). Zhang, *et al*. (2016), also ascertained the strong antioxidant activity of clove essential oil refers to the presence of eugenol, the main constituent of cloves.On the other hand, Jabir, *et al.* (2018) demonstrated the high antioxidant activity of linalool on in comparison with ascorbic acid as a standard reference. They also confirmed that linalool could donate hydrogen atoms and remove the electron from DPPH, and as a result, they suggested that linalool could be useful for the management of numerous deleterious diseases and cancer because of their scavenging activity. Also, Paarakh (2017) indicated that linalool has been traditionally used for medicinal purposes because of its potent antioxidative activity; hence, it could be used in the synthesis of several types of compounds with ability to act as antioxidant and could be used as a medicine drug.

3.5. Sensory evaluation of cake and pan bread samples

Sensory characteristics of cake samples supplemented with ground coriander fruits (1, 3, 5 and 7 and 10%) or coriander fruits essential oil (0.1, 0.3 and 0.5%) were evaluated and the results are illustrated in Table 4. It could be noticed that crust color, odor and taste parameters didn't affect with the substitution withGCF or their essential oil at the previous concentrations compared with a control cake sample. Meanwhile, texture, appearance and overall acceptability significantly ($p \geq 0.05$) decreased at 7 % GCF. However, no significant($p \geq 0.05$) differences were noted for cake samples supplemented with CEO at all tested concentrations, compared with control cake sample. On the contrary, supplementation with GCF at 10% reduced all sensory parameters, with significant ($p \geq 0.05$)differences except crust color. Also, adding BHT at 200ppm had no significant ($p \geq 0.05$) difference on evaluated sensory parameters. It is noteworthy that utilizing CEO at 0.1, 0.3 and 0.5% exhibited good sensorial properties. However, GCF at 3 and 5% gave approximately similar effect, besides increasing the nutritional value of cake due to its high contents of crude protein, crude fibers and ash.

Table 4. Sensory characteristics of cake supplemented with ground coriander fruits and their essential oil.

Sensory criteria	Control	Cake supplementedwith ground coriander fruits (%)					Cake supplemented with coriander essential oil (%)			BHT (200 ppm)
		1	3	5	7	10	0.1	0.3	0.5	
Crust Color (10)	9.60^{a} ±0.87	9.55^{a} ±0.17	9.50^{a} ±0.12	9.20^{a} ±0.11	9.15^{a} ±0.02	9.00^{a} ±0.07	9.50^{a} ±0.32	9.80^{a} ±0.72	9.08^{a} ±0.02	9.10^{a} ±0.04
Texture (10)	9.51^{a} ±0.56	9.37^{a} ±0.27	9.25^{a} ±0.01	9.50^{a} ±0.03	9.10^{b} ±0.01	7.30^{c} ±0.09	9.40^{a} ±0.01	9.50^{a} ±0.05	9.25^{a} ±0.13	9.23^{a} ±0.52
Odor (10)	9.52^{a} ±0.63	9.45^{a} ±0.38	9.15^{a} ±0.15	9.30^{a} ±0.04	9.00^{a} ±0.04	8.20^{b} ±0.06	9.50^{a} ±0.02	9.90^{a} ±0.80	9.12^{a} ±0.02	9.20^{a} ±0.13
Taste (10)	9.53^{a} ±0.73	9.51^{a} ±0.52	9.40^{a} ±0.12	9.50^{a} ±0.10	9.00^{a} ±0.12	6.10^{b} ±0.18	9.50^{a} ±0.11	9.65^{a} ±0.62	9.10^{a} ±0.01	9.12^{a} ±0.03
Appearance (10)	9.60^{a} ±0.81	9.58^{a} ±0.12	9.50^{a} ±0.02	9.55^{a} ±0.07	8.60^{b} ±0.23	6.00^{c} ±0.12	9.50^{a} ±0.02	9.55^{a} ±0.07	9.15^{a} ±0.23	9.33^{a} ±0.06
Overall acceptability (10)	9.38^{a} ±1.02	9.46^{a} ±0.33	9.36^{a} ±0.22	9.41^{a} ±0.50	8.85^{b} ±0.75	7.00^{c} ±0.10	9.48^{a} ±0.22	9.55^{a} ±0.50	8.83^{b} ±0.75	9.30^{a} ±1.43

Values are means (n= 10 ± SD).

Each value within the same row, followed by the same letter is not significantly different at 0.05 level.

Values of crust color, crumb color, odor, texture, taste, appearance and overall acceptability of pan bread samples are shown in Fig. 1. Analysis of variance was done for all sensory parameters of pan breads and panelists accepted all pan bread samples with different acceptability ranks. Crust color and taste parameters didn't affect with any addition, where, no significant differences($p \geq 0.05$) were noticed. With respect to sensory criteria, no significant ($p \geq 0.05$) differences were noticed with addition of up to 7.5 % GCF and 0.3% coriander essential oil (CEO) compared with control sample of pan bread, where all organoleptic parameters were higher than 95.33% from the upper limit.

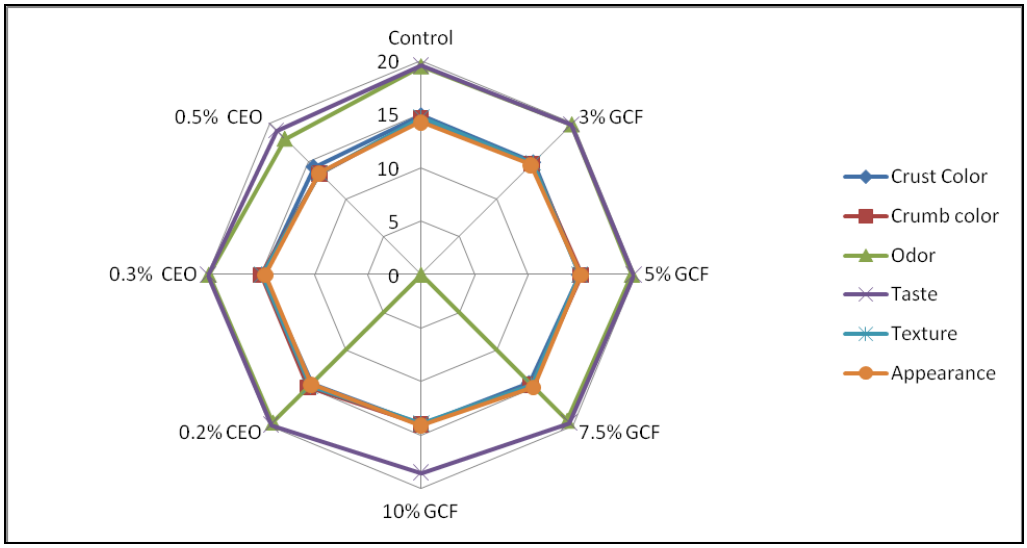

Figure 1. Sensory evaluation of pan bread incorporated with different % of coriander fruits and essential oils.

3.6. Microbial load in cake during storage period

To determine the efficiency of coriander fruits or its essential oil to prolong the shelf life of bakery products, cake was supplemented with coriander fruits (1, 3, 5, 7 and 10 %) and CEO (0.1, 0.3 and 0.5 %), compared with BHT at 200ppm and a control sample (without any additives).Storage was applied at room temperature (20± 2° C) for 24 weeks. Cake samples were prepared according to ES (2005). Data presented in Table (5) illustrated that no TBC or fungal counts were observed up to 6 weeks of storage in a control cake sample, this finding could be referred to the proper hygienic considerations applied during preparation. However, a slight growth (non visible growth) was detected 39 and 28 $CFU.g^{-1}$, respectively, and the numbers were approximately doubled, after 8 weeks, then clear microbial growth was noted (after 8 weeks). On the other hand, supplementation of cake with GCF succeeded in prolong the shelf life of cake samples up to 12 weeks in supplementation ratios of 1 and 3 %, however, it reached 16 weeks in the cake supplemented with 5 % coriander fruits.

Also, the perusal of data ascertained that supplementation with CEO could preserve the cake samples to 14, 16 and 22 weeks, at supplementation with 0.1, 0.3 and 0.5 % CEO, respectively. Furthermore, BHT (200ppm) led to prolong the shelf life of cake samples up to 14 weeks. These results are in harmony with those reported by Darughe, *et al.* (2012), who ascertained that CEO also showed better antifungal activity in cakesamplesat 0.15%. Such effect could be due to the presence of

terpenes and terpenoids compounds in the CEO. They also added that overall acceptability of cakes containing 0.05% CEO was almost equal to that of BHA.

3.7. Chemical quality evaluation during storage

The oxidation degradation of lipids is one of the main factors limiting the shelf life of food products. So, both peroxide value (PV) and thiobarbituric acid content (TBA) of the cake samples were determined during storage at room temperature (20± 2° C). Data presented in Table (6) indicated that the PV of control cake sample was higher than all supplemented cake samples at different storage periods and it increased gradually during storage time, which indicated that cakes were oxidized to lipid hydroperoxides, where, PV measures primary products of lipid oxidation. These unstable, primary oxidation products were consequently broken down by a free radical mechanism in which the O-O bond was cleaved on either side of the carbon atom bearing the oxygen atom to give the hydroxyl free radical and many types of secondary products such as alcohols, aldehydes, ketones and malonaldehydes which cause off-flavors (Lean & Mohamed, 1999). On the other hand, it was verified thatsupplementation with coriander on both forms (fruits or essential oil) gave slower increment rate of PV. It was noticed that the lowest PV was recorded for cakes prepared with 0.5 %CEO and BHT (200 ppm) compared with the respective initial mean value as well as control sample at zero time and during the storage period.

It is noteworthy that TBA measures the formation of secondary oxidation products, mainly malonadialdehyde, which may contribute off- flavors to Theoxidized oil (Rossel, 2005). Our findings indicated that TBA of control sample increased with storage time owing to the simultaneous increase in PV (Table, 6), wheresoever's, there were increments in the control sample that could be noticed during storage time at 20 ± 2°C up to 6 weeks, where the value reached 0.22 mg malondialdehyde/kg oil (initial TBA value was 0.11). This finding is highly in conformity with that reported by Darughe, *et al*. (2012), who mentioned that CEO exhibited good antioxidant activity in butter cake and its effect was comparable with BHA at 0.02%. These effects could be due to the presence of terpenes and terpenoids compounds in the CEO. Also, the finding of essential oil is due to its radical scavenging activity could be used as natural antioxidant to enhance the shelf stability of many foods (Ramadan *et al*., 2003). Moreover, addition of CEO at different levels also had TBA value almost equal to BHT at 0.02%. It indicates that CEO inhibited the formation rate of primary and secondary oxidation products in cake and their effects were almost equal to BHT at 0.02%. These findings could be due to Linalool, which has antioxidant activity as previously mentioned in Tables (3 and 4).

3.8.Specific volume of baked cake

It is noteworthy that the specific volume of baked cake indicated the amount of air that can remain in the final product, where a higher gas retention and higher expansion of the product leads to a higher specific volume. Furthermore, high voluminous cakes are desirable for the consumers. According to specific volume results (Table 7), the highest values were obtained by BHT (200 ppm) and 0.5% CEO (2.37 and 2.36 cm^3/g, respectively), compared to control cake, 2.34 cm^3/g (without additives) as shown in Table (7), which reflects the highest porosity and specific volume. On the contrary, cake supplemented with coriander fruits above 1%, led to decrement in specific volume. The explanation of this phenomenon is referred to nature and amount of dietary fiber are known to affect the specific volume of cakes (Aydogdu, *et al.,* 2018). Also, Jahanbakhshi & Ansari (2020) ascertained the reduction in specific volume after adding dietary fibers to cakes, which, probably happens because of a disruption in the gluten network which leads to the decrease in the gas retention capacity.

Table (5): Bacterial and fungal counts (CFU.g^{-1}) of English rich cake supplemented with coriander fruits and its essential oil during storage at room temperature (20 ± 2° C)

Microbial count	Control	Ground coriander fruits (%)					Coriander ess. oil (%)			BHT
		1	3	5	7	10	0.1	0.3	0.5	
At zero time										
TBC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fungal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
After 2 weeks										
TBC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fungal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
After 4 weeks										
TBC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fungal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
After 6 weeks										
TBC	3.9 X 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fungal	2.8 X 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
After 8 weeks										
TBC	3.7 X 10^2	ND	ND	ND	3.1 X 10	ND	ND	ND	ND	ND
Fungal	2.4 X 10^2	ND	ND	ND	3.0 X 10	ND	ND	ND	ND	ND
After 10 weeks										
TBC	6.7 X 10^4	ND	ND	ND	3.9 X 10	3.7 X 10	ND	ND	ND	ND
Fungal	4.1 X 10^3	ND	ND	ND	3.1 X 10	3.0 X 10	ND	ND	ND	ND
After 12 weeks										
TBC	**MG	ND	ND	ND	7.7 X 10	4.9 X 10	ND	ND	ND	ND
Fungal	MG	ND	ND	ND	5.1 X 10	3.7 X 10	ND	ND	ND	ND
After 14 weeks										
TBC	MG	3.4 X 10	3.7 X 10	ND	ND	ND	1.3 X 10	ND	ND	3.1 X 10
Fungal	MG	3.1 X 10	3.7 X 10	ND	ND	ND	0.7 X 10	ND	ND	2.1 X 10
After 16 weeks										
TBC	MG	7.9 X 10	5.9 X 10	4.1 X 10	MG	1.7 X 10^2	3.0 X 10	1.2 X 10	ND	1.1 X 10^2
Fungal	MG	5.9 X 10	4.2 X 10	3.1 X 10	MG	1.1 X 10^2	1.2 X 10	0.5 X 10	ND	0.9 X 10^2
After 18 weeks										
TBC	MG	2.3 X 10^2	2.1 X 10^2	9.1 X 10	MG	MG	2.4 X 10^2	2.7 X 10	ND	MG

Fungal	MG	1.7×10^2	1.1×10^2	4.1 X 10	MG	MG	2.7 X 10	1.3 X 10	ND	MG
After 20 weeks										
TBC	MG	MG	MG	MG	MG	MG	MG	6.3 X 10	ND	MG
Fungal	MG	MG	MG	MG	MG	MG	MG	5.3 X 10	ND	MG
After 22 weeks										
TBC	MG	MG	MG	MG	MG	MG	MG	1.3×10^2	2.0 X 10	MG
Fungal	MG	MG	MG	MG	MG	MG	MG	0.6×10^2	1.3 X 10	MG
After 24 weeks										
TBC	MG	MG	MG	MG	MG	MG	MG	MG	1.7×10^2	MG
Fungal	MG	MG	MG	MG	MG	MG	MG	MG	0.8×10^2	MG

* TBC: Total Bacterial Count Values are means of three replicates. ** ND: No observed microbial growth.
[a] MG: Visible microbial growth. BHT was added at 200 ppm

Table (6): Effect of supplemented with GCF and CEO on lipid profile of cake during storage (20 ± 2° C).

Oxidative stability	Control	GCF (%)					CEO (%)			BHT (200ppm)
		1	3	5	7	10	0.1	0.3	0.5	
At zero time										
PV*	1.74	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
TBA**	0.11	0.11	0.11	0.10	0.10	0.12	0.08	0.08	0.09	0.08
After 2 weeks										
PV	2.84	1.57	1.59	1.56	1.59	1.59	1.54	1.52	1.52	1.48
TBA	0.13	0.11	0.11	0.11	0.11	0.10	0.08	0.08	0.09	0.12
After 4 weeks										
PV	3.12	1.55	1.59	1.59	1.59	1.59	1.54	1.53	1.55	1.41
TBA	0.17	0.13	0.12	0.11	0.11	0.11	0.08	0.09	0.09	0.11
After 6 weeks										
PV	3.37	1.40	1.54	1.61	1.60	1.61	1.53	1.53	1.49	1.40
TBA	0. 22	0.14	0.12	0.13	0.12	0.13	0.09	0.10	0.09	0.09
After 8 weeks										
PV	4.11	1.42	1.54	1.61	1.60	1.61	1.53	1.50	1.42	1.42
TBA	0.34	0.15	0.12	0.13	0.12	0.16	0.09	0.10	0.10	0.08

After 10 weeks										
PV	4.17	1.44	1.52	1.64	1.55	1.59	1.52	1.49	1.40	1.44
TBA	0.44	1.15	0.13	0.14	0.12	0.19	0.09	0.11	0.10	0.07
After 12 weeks										
PV	**MG	1.48	1.50	1.62	1.52	1.56	1.51	1.48	1.40	1.41
TBA	MG	1.14	0.15	0.14	0.13	0.22	0.12	0.11	0.10	0.07
After 14 weeks										
PV	MG	1.49	1.50	1.63	1.50	1.53	1.48	1.47	1.32	1.45
TBA	MG	0.16	0.17	0.14	0.13	0.28	0.12	0.11	0.10	0.07
After 16 weeks										
PV	MG	1.52	1.50	1.63	MG	1.52	1.46	1.40	1.29	1.49
TBA	MG	1.18	0.18	0.17	MG	0.33	0.13	0.11	0.09	0.09
After 18 weeks										
TBC	MG	1.55	1.49	1.60	MG	MG	1.43	1.40	1.29	MG
TBA	MG	0.18	0.18	0.18	MG	MG	0.13	0.11	0.11	MG
After 20 weeks										
PV	MG	MG	MG	MG	MG	MG	MG	1.39	1.29	MG
TBA	MG	MG	MG	MG	MG	MG	MG	0.14	0.12	MG
After 22 weeks										
PV	MG	MG	MG	MG	MG	MG	MG	1.38	1.31	MG
TBA	MG	MG	MG	MG	MG	MG	MG	0.15	0.13	MG
After 24 weeks										
PV	MG	MG	MG	MG	MG	MG	MG	MG	1.37	MG
TBA	MG	MG	MG	MG	MG	MG	MG	MG	0.15	MG

Values are means of three replicates. Samples spoiled by microbial growth didn't subject to the tests.

* PV is expressed as mequivalent peroxide / Kg oil. ** TBA is expressed as mg malondialdehyde/kg oil

3.9. Anti-diebetic activity

The produced bread loaves with 0.3 and 5%, CEO and GCF, respectively, were selected to be utilized *in vivo* anti-diebetic activity on experimental rats, (according to sensory evaluated), beside aqueous macerated as well as aqueous decocted coriander extracts.

Table (7). Specific volume of cake supplemented with ground coriander fruits and their essential oil at different concentrations.

Cake sample formulation	Weight (g)	Volume (cm^3)	Specific volume(cm^3/g)
Control	110.88	260	2.34
BHT (200 ppm)	100.9	240	2.37
Coriander essential oil (0.1 %)	97.82	230	2.35
Coriander essential oil (0.3 %)	101.53	236	2.32
Coriander essential oil (0.5 %)	98.85	235	2.36
Ground coriander fruits (1%)	126.22	290	2.35
Ground coriander fruits (3%)	154.6	350	2.26
Ground coriander fruits (5%)	145.81	305	2.04
Ground coriander fruits (7%)	145.14	290	1.99
Ground coriander fruits (10%)	130.89	256	1.95

Table 8. Body weight gain and serum glucose level of rats given with coriander fruits and their extracts.

Groups	Body weight				Serum Glucose (mg/dl)
	Initial	final	WG	BWG (%)	
G1 (Normal Control)	220.0	250.8	30.8	14.00	84.27^{e}±2.02
G2 (Diabetic Control)	220.0	240.3	20.3	9.23	256.47^{a} ±4.57
G3	220.0	280.5	60.5	27.50	109.74^{d}±2.60
G4	221.0	288.0	67.0	30.32	104.40^{d}±1.52
G5	220.0	277.0	57.0	25.91	115.31^{c}±2.09
G6	220.0	277.0	57.0	25.91	119.00^{c}±1.83
G7	220.0	275.0	55.0	25.00	205.32^{b}±2.17
G8	219.0	273.0	54.0	24.66	209.10^{b}±5.18

The mean values (n=5)± SD with different letters in the same column are significantly ($p \geq 0.05$) different. * WG: Weight gain BWG: Body weight gain

G3: Diabetic rats group orally injection decoction coriander extract.

G4: Diabetic rats group orally injection macerated coriander extract.

G5: Diabetic rats group, fed on coriander powder (2gm /100gm diet).

G6: Diabetic rats group orally injection coriander essential oil (40 mg/kg bw daily).

G7: Diabetic rats group, fed on a basal diet with pan bread containing 0.3% oil.

G8: Diabetic rats group, fed on a basal diet with pan bread (5 % coriander fruits).

By referring to the findings in Table (8), it could be noticed that all groups received GCFor their extracts recorded higher body weight gain % (24.66 – 30.32%), compared with that of normal control group (G1, 14.00%) and diabetic control group (G2, 9.23%). The highest values pertained to those groups given aqueous extracts of coriander fruits (G4 & G3, decocted and macerated extracts, respectively). Our findings are supported by Khubeiz&Shirif (2020), who found that final body weight was ($p<0.01$) higher in 2% coriander fruits and feed conversion ratio was significantly ($p<0.05$) better for birds compared with other groups.

The results presented in Table (8) also illustrated that there are significant ($p \geq 0.05$) differences in serum glucose level among all tested groups of rats, however, the normal control group recorded the lowest glucose level (84.27mg/dl), followed by rats received aqueous macerated coriander and aqueous decocted coriander extracts, with non significancy ($p \geq 0.05$) between the last two groups. Similar findings were observed in rat groups received ground coriander fruits (115.31mg/dl) and coriander essential oil (119.00mg/dl). Although, high serum glucose levels noticed in groups received pan bread incorporated with either ground coriander fruits or their essential oil (209.10 and 205.32mg/dl, respectively), they are still significantly lower than that of diabetic control group (256.47mg/dl).

Our findings are in harmony with those found by Gray & Flatt (1999), who ascertained the antidiabetic potential of coriander fruits in streptozotocin-induced diabetic mice. They also observed that consumption of coriander fruits aqueous extract evoked 1.3-5.7 fold stimulation of insulin secretion from colon β-cell line and increased the 2-deoxyglucose transport by 1.6 folds, glucose oxidation by 1.4 folds and incorporation of glucose into glycogen of isolated abdominal muscle by 1.7 folds. They purported also ascertained that insulin releasing and insulin like activity of coriander. Similar findings were also reported by Waheed, et al. (2006), for an aqueous extract of coriander.

Concerning lipid profile of rats as affecting by incorporated with coriander fruits and their extracts, results presented in Table (9) showed that triglycerides (TG), total cholesterol (TC), low density lipoprotein cholesterol (LDL) reduced in all tested groups, with different rates compared to diabetic rats group, however, the parameters of a group incorporated with aqueous extract (decoction one) is close to normal control group in most parameters; no significant ($p \geq 0.05$) differences (TG& LDL), followed by a group orally injected with aqueous extract (maceration one). Also, both coriander fruits and its essential oil could reduce the lipid profile parameters.

Table 9. Blood Lipid profile of rats incorporated with coriander fruits and their extracts

Groups	Lipid profile of rats			
	TG (mg/dL)	TC (mg/dL)	LDL (mg/dL)	HDL (mg/dL)
G1 (Normal Control)	$118.15^{d}\pm5.03$	$120.53^{g}\pm7.21$	$41.90^{e}\pm4.37$	$38.60^{e}\pm1.83$
G2 (Diabetic Control)	$260.80^{a}\pm9.51$	$276.34^{a}\pm4.49$	$226.40^{a}\pm6.79$	$24.56^{f}\pm4.90$
G3	$128.90^{c}\pm0.10$	$158.90^{e}\pm5.63$	$105.64^{d}\pm2.40$	$41.92^{de}\pm4.72$
G4	$114.70^{d}\pm6.95$	$150.33^{f}\pm5.55$	$100.00^{de}\pm4.30$	$37.27^{e}\pm3.90$
G5	$129.00^{c}\pm5.01$	$185.00^{c}\pm7.50$	$111.60^{c}\pm2.55$	$44.82^{d}\pm2.79$
G6	$140.00^{b}\pm4.23$	$180.50^{cd}\pm3.76$	$109.50^{c}\pm4.90$	$60.52^{b}\pm7.55$
G7	$133.00^{bc}\pm3.76$	$176.64^{d}\pm6.79$	$121.71^{bc}\pm3.45$	$55.53^{c}\pm4.87$
G8	$122.00^{cd}\pm2.93$	$196.40^{b}\pm4.01$	$124.20^{b}\pm2.66$	$63.50^{a}\pm2.66$

The mean values (n=5) ± SD with different letters in the same column are significantly different($p<0.05$).

On the other hand, high density lipoprotein cholesterol (HDL) increased as a result of incorporation with coriander fruits and their extracts in a similar pattern. Our findings are supported with the results of Naquvi, et al. (2012), where they showed that aqueous extract of fruits of coriander (obtained by maceration) at two doses 250 and 500 mg/kg, decreased significantly blood glucose level, with the superiority to higher dose. Also, it also significantly decreased total cholesterol level and increased high density lipid cholesterol.They also ascertained that the aqueous extract of coriander had antidiabetic activity. Numerous investigations proved the hypoglycemic efficiency of coriander essential

oil, Paarakh, (2017) showed that 75 % methanol extract showed significant decrease in blood glucose level at a dose of 100 mg/kg and 200 mg/kg. It also decreased the lipid parameters such as total cholesterol, total triglycerides ASTand ALT when compared with diabetic control. However, Al-Jaff(2011) reported that 2% coriander fruits lower serum glucose ($p<0.05$), serum total cholesterol and LDL, while HDL increased when compared with the control. On this connection, Khubeiz & Shirif (2020) ascertained that the serum TG of broiler chickens was significantly reduced at 1.5%, while the HDL was significantly increased at level 1.5% when compared with the control.

Table 10. Liver and kidney functions of rats incorporated with coriander fruits and their extracts

Groups	Liver function enzymes		Kidney functions	
	AST(U/L)	ALT (U/L)	Creatinine(mg/dl)	Urea (mg/dl)
G1 (Normal Control)	29.55±0.11	24.55±0.56	36.80±0.83	36.82±0.32
G2 (Diabetic Control)	80.56±0.45	73.56±0.44	60.00±0.23	59.53±0.53
G3	44.65±0.67	33.52±0.51	48.50±0.31	47.96±0.66
G4	40.54±0.73	30.75±0.67	40.84±0.23	43.57±0.72
G5	55.38±0.45	40.75±0.53	52.92±0.34	50.80±0.79
G6	51.92±0.11	44.06±0.32	50.00±0.44	52.58±0.33
G7	49.59±0.22	42.56±0-87	53.94±0.32	55.82±0.67
G8	48.51±0.36	43.72±0.34	49.30±0.45	51.59±0.48

The mean values (n=5) ± SD with different letters in the same column are significantly different($p<0.05$).

Regarding liver and kidney functions, results in Table (10), ascertained that all tested groups incorporated with coriander fruits and their extracts recorded the lowest liver function enzymes (AST&ALT), compared with diabetic group. On the other hand, groups of rats orally injected with aqueous extracts by decoction and maceration are closed to those of normal control group. Similar findings were observed for creatinine and urea as kidney functions. Concerning liver function enzymes, our findings are in the same line with those found by Moustafa, *et al.*(2012). Their conclusion depends on the histological observations basically and supported the results obtained from serum enzyme assays. Also, these results are in harmony with those found by Sreelatha, *et al.* (2009) and El- Masry, *et al*. (2016). They added that active components which present in coriander fruits extracts, including flavonoids, polyphenols and carotenoids had antioxidant, anti-inflammatory and free radicals scavenging activities.

4.Conclusions

The obtained results ascertained the potency of coriander fruits and their essential oils as biopreservative agent, for bakery products. Also, on the basis of aforementioned facts, the antidiabetic ability of coriander fruits and their extracts.

5.References

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