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Nutrients and Constituents Relevant to Antioxidant, Antimicrobial and Anti-Breast Cancer Properties of *Salvia officinalis* L.

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMGD designed the study, managed the analyses of the study, performed the statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author GMH contributed in the antimicrobial analyses of the study. Author SAES contributed in the study design, interpretation of the results and revising process. All authors read and approved the final manuscript.

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ABSTRACT

Objective: Comprehensive assessment of the chemical composition of sage leaves (*Salvia officinalis* L.) in order to highlight constituents relevant to the antioxidant, antimicrobial and anticancer potentials, in addition to determining safe dose to facilitate its application in functional foods and dairy products.
Methods: High-Performance Liquid Chromatography (HPLC) was employed to determine constituents such as amino acids, fatty acids and phenolic compounds content. Antioxidant activity was characterized using, α- diphenyl-β-picrylhydrazyl (DPPH) and reducing power methods. The antimicrobial potentials were examined against nine pathogenic strains. MDA-MB-231 cell line was used to assess anticancer activity.
Results: Sage was found to be a good source of calcium, iron and zinc (894.3, 84 and 5.5 mg/ 100 g respectively) and vitamins B6 and B12 (1.5 and 0.3 mg/100 g respectively). Performed HPLC

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analysis indicated the rich content of essential amino acids, lysine, phenylalanine and leucine (10.4, 0.7 and 0.45 g/100 g), unsaturated fatty acids, Omega 3, 6 and 9 (6.46, 4.40 and 3.13 g/ 100 g) and phenolic compounds, quercetin and cinnamic (604.8 and 390.4 µg/mL), which interpreted its high antioxidant powers. Sage revealed antioxidant potentials with IC_{50} and EC_{50} reached (27.5 and 239.5 mg/mL respectively), and antimicrobial effect against the examined pathogenic strains with MICs reached 6.25 mm against *Staph. aureus, E. coli* and *Candida albicans*, not to mention its anticancer effect as an extra pharmacological feature, when sage performed an anti-proliferative activity with IC_{50} of 300 µg/mL, against MDA-MB-231 cell line.

Conclusion: Obtained results emphasis the sage leaves content of variable nutrients and active compounds that reflected on its vast nutritional and pharmacological potentials such as; antioxidant, antimicrobial and cytotoxic effect against breast MDA-MB-231 cell line, that could nominate it as applicable food bio-preservative in functional foods and dairy products.

Keywords: Sage (Salvia officinalis); HPLC; antioxidant potentials; antimicrobial properties; MDA-MB-231 cell line.

1. INTRODUCTION

Salvia officinalis "sage", which called Maramia in Levant, is initially derived from the Latin *salvere* (to save), pointing out to its healing powers [1]. *Salvia* recorded a long history of uses in nutritional, culinary, pharmacological and medicinal purposes. Abundant bioactive compounds content reported in sage seem to be responsible for its antimicrobial, antioxidant and pharmacological properties, including cytotoxicity against human cancer cells [2]. *S. officinalis* in food preparation was frequently reported as bio-preservative against Gram+ and Gram- bacteria [3,4]. Furthermore, studies highlighted the effect of *Salvia* in preventing and controlling various diseases naturally in a safe manner, and German Commission E (a governmental regulatory agency) has accepted the use of *S. officinalis* for a number of medical applications [5].

Exploring natural plants as anticancer agents are one of the fastest growing interest in research [6]. Phytochemicals such as polyphenols, alkaloids, triterpenes and saponins, are biologically active compounds that have shown promising anticancer properties in both *in vitro* and *in vivo* based on anti-proliferative activity on tumor cells and antioxidant scavenging activity [2,7]. In addition, they found to possess antimicrobial, anti-mutagenic, anti-inflammatory, and anti-cholinesterase properties. Currently, the demand has increased in the food and pharmaceutical industries for these compounds as alternative natural approaches seeking safety [8].

The objective of the present study was the assessment of nutritional and chemical compositions of sage leaves (*Salvia officinalis* L.) in order to highlight constituents relevant to antioxidant, antimicrobial and anticancer potentials against human breast cancer MDA-MB-231 cell line, and determine the safe dose to facilitate its application in functional foods and dairy products.

2. MATERIALS AND METHODS

2.1 Plant Material and Preparation

Common sage leaves (*Salvia officinalis* L.) was obtained from a reliable spice dealer, Alexandria, Egypt. To prepare sage aqueous extract (SAE), dried grounded leaves was extracted in Milli-Q water with the ratio (1:20 w/v), stirred for 3 h at a temperature (60^{o}C) and centrifuged (Pro-Centrifuge, Centurion Science Limited, UK) for 20 min at 5500 rpm. The aqueous extract was filtered, froze and then dried using vacuum freeze-dryer (Model FDF 0350, Korea) according to Garcia [9] with modifications.

The plant leaves have been checked with http://www.theplantlist.org/tpl1.1/search?q=salvia+officinalis

2.2 Proximate Analysis

2.2.1 Nutrients content

Moisture, ash and protein content were determined as described by [10]. The protein content was determined by the Kjeldahl method, and calculated according to the equation; Protein= N x 6.25 to convert nitrogen content into protein content.

The crude fat content was determined using an Ankom^{XT10} fat extractor (Ankom Technology

Corp., Macedon, NY). Crude Fat contained within a food or feed sample can be calculated using the following formula:

$$\%\ \text{Crude fat} = \frac{100\ \text{x}\ (\text{W2} - \text{W3})}{\text{W1}}$$

Where: W1 = Original weight of the sample, W2 = Weight of pre-dried sample and filter bag, W3 = Weight of dried sample and filter bag after extraction.

Crude fibre content was determined using Crude Fiber Analysis in Feeds - Filter Bag Technique A2000 - AOCS Approved Procedure Ba 6a-05 (Ankom Technology Corp., Macedon, NY). Crude fibre percent according to the formula:

$$\%Crude\ fibre = \frac{\text{W3} - \text{W1}}{W2}\text{X}100$$

Where: W1 = Weight of pre-dried filter bag, W2 = Original weight of the sample, W3 = Weight of filter bag contains organic residue remaining after digesting https://www.ankom.com

The following formula calculated total carbohydrate by difference;

> 100 – (weight in g [protein + fat + water + ash] in 100 g of food) [11]

It should be clear that carbohydrate estimated in this fashion includes fibre.

2.2.2 Electrolytes and minerals concentrations

Concentrations of electrolytes; sodium and potassium and minerals; zinc, iron, magnesium and calcium were determined using Atomic Absorption Spectrometry analytical technique according to [12]. The concentration of phosphorus was determined using simplified colorimetric ammonium paramolybdate-vanadate method (yellow method), the colour intensity was measured at wavelength 420 nm (T80 UV/VIS Spectrophotometer, PG Instruments Ltd) according to [13]. Phosphorus concentrations were calculated using the formula;

$$\%P = \text{P}\ from\ st.curve\ X\frac{\text{V1}}{\text{W}\ sample}\text{X}\ \frac{1}{\text{V2}} \div 10\ 000$$

Where: V1: Volume of stock standard solution of sample (50 mL), V2: Volume of a stock standard solution of the sample used in measurements (5 mL), W *sample*: Weight of sample (≅0.5 gm).

2.2.3 B vitamins content

The concentrations of some B Vitamins; Niacin (Vitamin B3), Pyridoxine (Vitamin B6) and (Vitamin B12) were determined quantitatively via High Performance Liquid Chromatography (HPLC) at Food Safety and Quality Control Lab (FSQCLab), Faculty of Agriculture, Cairo University, Egypt, according to (Agilent Application Note, Publication number 5989-9313EN 2008) [14]. Agilent 1260 infinity HPLC Series (Agilent, USA), equipped with a Quaternary pump, a Kinetex XB-C18 column 100 mm X 4.6 mm (Phenomenex, USA), operated at 35°C. The separation was achieved using a binary linear elution gradient with (A) 25 mM NaH_2PO_4 pH 2.5 (v/v), (B) methanol. The injected volume was 20 µL. VWD detector was used for at 220 nm for vitamins B3, B6 and B12.

2.3 High-Performance Liquid Chromatography (HPLC) of Main Components

For determining amino acid content, acid hydrolysis was carried out according to Csomos [15]. Free amino acids extraction was carried out according to Emam [16]. The amino acid analysis was carried out using Automatic Amino Acid Analyzer (AAA 400 INGOS Ltd). Amino acids required pattern values are according to Food and Agriculture Organization (FAO) [17], while Amino Acid Score (AAS%) or Chemical Score (CS) was calculated as "Percentage of adequacy" as follows;

$$Amino\ Acid\ Score = \frac{\text{mg of amino acid in 1 g test protectin}}{\text{g of amino acid in requirement pattern}}\ \text{X}\ 100$$

Fatty acids were determined via saponified and unsaponified fat separation according to AOAC [18].

Phenolic compounds of sage leaves were identified according to Croci [19], using the following standards; gallic acid, caffeic acid, coumaric, syringic acid, vanillin, cinnamic acid, pyrogallol, catechin, quercetin and rutin.

2.4 Phytochemical, Phenolic and Flavonoid Content

Phytochemical screening analysis (Wagner's method, Fehling's test, foam test and Salkowki's test), were performed for SAE according to Wadood [20].

The total phenolic content assay was performed on SAE according to Singleton [21] using Folin-Ciocalteu reagent. The total phenolic content was expressed as gallic acid equivalents (GAE mg/g). All measurements were held in triplicates.

Total flavonoid contents of SAE was determined using the colorimetric method as described by Sakanaka [22]. Results expressed in term of a standard used for the quantification of flavonoids. All samples were performed in triplicates.

2.5 Pharmacological Potentials

2.5.1 Antioxidant activity

Antioxidant scavenging activity of SAE was determined using two different methods; DPPH (2,2-diphenyl-1-picrylhydrazyl) assay that was performed as described by Brand-Williams [23], and reducing power assay as described by Ferreira [24], then median inhibitory concentration values (IC_{50} and $EC_{50)}$ were calculated.

2.5.2 Antimicrobial screening

Antimicrobial potentials of SAE was screened against nine pathogenic strains using agar well diffusion assay as described by Hamad [25]. The nine tested pathogenic organisms were; five Gram-positive strains; *Staph. aureus* NCTC10788*, Staph. pyogenes* EMCC1772*, St. mutants* EMCC1815 *, B. subtilis* DB100 and *Clostridium botulinum* ATCC3584*,* three Gram-negative strains; *E. coli* BA12296*, E. coli* ATCC25922 and *K. pneumonia* ATCC12296 and one yeast strain; *Candida albicans* ATCCMYA2876. The pathogenic strains were obtained from Microbiological Recourses Center (Cairo MERCIN), Egypt Microbial Culture Collection (EMCC), Ain Shams University, Cairo, Egypt, and were maintained at Food Technology Dept., City of Scientific Research and Technological Applications. The minimum inhibitory concentration (MIC) values were assessed within the concentrations of 50, 25, 12.5 and 6.25 mg/ mL of sage extract.

2.5.3 Cytotoxicity and anticancer assay

This test was used to evaluate cytotoxicity. The membrane of viable cells capture the neutral red, therefore after subsequent lysis, absorbance can be used as a measure of cell viability [26]. The stock solution of NR (3.3 g/L) was diluted to 1/100 in the cell culture medium and the extracting solution consisted of 50% (v/v) ethanol in Milli-Q water with 1% (v/v) acetic acid. MDA-MB-231 Triple-negative breast cancer cells were grown for 48 h in presence of SAE, (50–600 µg) after incubation 150 µL of freshly prepared neutral red solution pre-warmed to 37°C was added to each well and all plates were incubated at 37°C for additional four hours. The cells were washed twice with PBS, 150 µL of destain solution were added to each well and plates were shaken for 15 min. The absorbance was determined at 540 nm using a Micro-plate Elisa Reader while light microscope (Olympus IX70-58F2 Multi-parameter Fluorescence Microscope) was used for monitoring the morphological changes in treated MDA-MB-231 cells after 48 h of incubation.

2.6 Statistical Analysis

Statistical analysis was performed using Analytical Software SPSS® 13.0 (Statistical Package for the Social Sciences) (2005).

3. RESULTS

3.1 Proximate Composition

Table 1 illustrated the proximate composition of sage leaves (*Salvia officinalis*) including, nutrients, minerals and B vitamins. The proximate nutrient composition of sage (*Salvia officinalis*), indicated that sage is a high-carbohydrate high-fibre nutrient source plant. Another advantage is the relatively high protein (17 g/100 g) with low-fat content (3.46 g/100g). High ash content indicated sage richness in minerals. The sage showed remarkable concentration of iron (84.037 mg/100 g), calcium (894.273 mg/100 g) and zinc (5.472 mg/100 g). On the other hand, sage showed a poor content of sodium and potassium (19.893, 34.605 mg/100 g). Vitamin B concentrations of sage were (3.258, 1.545, 0.329 mg/100 g) of vitamins B3, B6 and B12 respectively.

3.2 HPLC Analysis

3.2.1 Amino acids profile

The amino acid content of sage (*Salvia officinalis*) is represented in (Table 2). Obtained results showed that the main essential amino acid (EAA) in sage was lysine with content of (10.44 g/100 g). Sage also provided considerable content of phenylalanine and leucine (0.74 and 0.45 g/100 g respectively), and limiting content of

valine, threonine, histidine and isoleucine. On the other hand, sage exhibited generous content of non-essential amino acids, glycine, glutamic, alanine, and aspartic, (1.02, 0.83, 0.75 and 0.53 g/100 g respectively).

Table 1. Proximate composition of sage (*Salvia officinalis*)

Component	Unit	Content (per 100 g)
Nutrients		
Protein	g	17.01±0.64
Crude fat	g	3.46±0.28
Carbohydrate, by difference	g	57.87
Crude fiber	g	35.96±0.46
Moisture	g	9.07±0.30
Ash	g	12.59±0.76
Electrolytes		
Sodium, Na	mg	19.893
Potassium, K	mg	34.605
Minerals		
Calcium, Ca	mg	894.273
Iron, Fe	mg	84.037
Magnesium, Mg	mg	19.601
Zinc, Zn	mg	5.472
Phosphorus, P	mg	Traces
B Vitamins		
Niacin, B3	mg	3.258
Pyridoxine, B6	mg	1.545
Cobalamin, B12	mg	0.329

Nutrients data represented are the mean ±standard deviation, n=3

3.2.2 Fatty acids content

Fatty acids (FA) profile of sage (*Salvia officinalis*) was exhibited in (Table 3). Sage showed USFAs/ SFAs ratio of 0.32 due to the superiority of SFAs. The highest content of SFAs belonged to tridecylic (C13:0) (11.33 g/100 g of total FA), followed by equal amounts of lauric (C12:0) and myristic (C14:0) (7.6 g/100 g of total FA). UFAs 18:3 ω-3, C18:2 ω-6 and C18:1 ω-9 was present with values of (6.46, 4.40 and 3.13 g/100 g of total FA respectively).

3.2.3 Phenolic compounds profile

Table 4 and Fig. 2 demonstrated phenolic compounds concentrations of sage aqueous extract. Within the ten used phenolic compound standards, three compounds were not detected in SAE; gallic acid, catechin and pyrogallol. Quercetin and cinnamic acid showed the highest concentrations (604.7575 and 390.3971 µg/mL respectively) representing (0.6756 and 0.4361%) of sage TPC (Table 5). The rest of tested phenolic compounds standards; caffeic acid, syringic acid, coumaric acid, vanillin and rutin existed in little concentrations (0.6132, 0.5134, 0.5134, 0.0856 and 0.0766 µg/mL respectively).

Table 2. Amino acids content of sage (*Salvia officinalis*)

Amino Acid	Symbol	Content (g/100 g)
Essential amino acids		
Histidine	His	0.17
Leucine	Leu	0.45
Isoleucine	Ile	0.13
Lysine	Lys	10.44
Methionine + cystine	Met+ Cys	0.03
Phenylalanine + tyrosin	Phe+ Tyr	0.74
Threonine	Thr	0.17
Valine	Val	0.28
CS	-	-
Limiting sequence		
Non-essential amino acids		
Alanine	Ala	0.75
Aspartic acid	Asp	0.53
Glutamic acid	Glu	0.83
Glycine	Gly	1.02
Proline	Pro	0.01
Serine	Ser	0.25
Tyrosine	Tyr	0.15

3.3 Phytochemical, Phenolic and Flavonoids Content

Qualitative screening of sage phytochemicals results showed the presence of a wide range of constituents include, carbohydrate (reducing sugars), volatile oil, phenolic compounds, flavonoids/ flavones, tannins, steroids, terpenoids and amino acids which are mostly responsible for antioxidant, antimicrobial and cytotoxic activities. Phenolic and flavonoid content of sage aqueous extract are exhibited in Table 5. Sage showed a total phenolic content of 88.57±3.14 mg GAE/ g, while total flavonoids were 37.13±1.83 mg catechol equivalent/ g.

3.4 Pharmacological Potentials

3.4.1 Antioxidant powers

Antioxidant and scavenging potentials of sage aqueous extract are illustrated in Table 5. DPPH results represented with inhibitory concentration at which 50% of DPPH radicals are scavenged

(IC_{50} mg/mL) and reducing power represented with effective concentration at which the absorbance is 0.5 (EC_{50} mg/mL). Sage leaves water extract showed IC_{50} and EC_{50} values (27.52 and 239.52 mg/ mL respectively).

Table 3. Fatty acid profile of sage (*Salvia officinalis*)

Fatty acid	Symbol	g/100 g
SFAs		
Capric	C10:0	1.28
Undecylic	C11:0	6.07
Lauric	C12:0	7.60
Tridecylic	C13:0	11.33
Myristic	C14:0	7.64
Pentadecylic	C15:0	6.95
Palmitic	C16:0	1.44
Stearic	C18:0	0.93
Arachidic	C20:0	0.54
%of total fat		43.78
USFAs		
MUSFAs		
Oleic	C18:1 ω-9	3.13
PUSFAs		
Linoleic	C18:2 ω-6	4.40
α-Linolenic	C18:3 ω-3	6.46
%of total fat		13.99
USFAs*/ *SFAs		0.32
ω6/ ω3 ratio		0.68

SFAs; Saturated fatty acids, USFAs; Unsaturated fatty acids, MUFAs; Monounsaturated fatty acids, PUFAs; Polyunsaturated fatty acids

Table 4. HPLC analysis of phenolic compounds concentrations of sage aqueous extract

Phenolic compound (µg/mL)	µg/mL
Caffeic acid	0.6132
Syringic acid	0.5134
Rutin	0.0766
Coumaric acid	0.4653
Vanillin	0.0856
Quercetin	604.7575
Cinnamic acid	390.3971

3.4.2 Antimicrobial activity

Table 6 presented inhibition zone diameter in mm of different concentrations of sage (*Salvia officinalis*) aqueous extract and Minimal Inhibitory Concentration (MIC) values for each strain. Results revealed that sage leaves extract owned antimicrobial activity against all tested pathogenic strains with varied MICs. According to MICs, the highest antimicrobial interaction of sage extract was against *Staph. aureus* NCTC10788 with inhibition zone diameter started from 20 mm with a concentration of 50 mg/mL and ended with 6 mm with a concentration of 6.25 mg/mL, which was the lowest MIC amongst the five Gram-positive strains. Whilst, sage showed MIC of 12.5 mg/mL against the other four Gram-positive strains with inhibition zone diameters started from 19 – 13.5 mm with extract concentration of 50 mg/mL. Antifungal activity of the sage aqueous extract was obvious against *Candida albicans* ATCCMYA2876 with MIC of 6.25 mg/mL and the inhibition zone diameter reached 22 mm with a concentration of 50 mg/mL.

Table 5. Phenolic, flavonoid content and antioxidant potentials of sage aqueous extract

Test	Unit	Values
Total phenolic	*mg /g	88.57±3.14
Total flavonoids	**mg /g	37.13±1.83
DPPH	[a]mg/mL	27.52±7.63
Reducing power	[b]mg/mL	239.52±0.41

*Data represented in means of duplicates ± standard deviation, *Total phenolic was expressed as gallic acid equivalents (GAE) mg/ g sample, **Total flavonoids was expressed as mg catechol/g sample*

[a] IC_{50} (mg/mL): Inhibitory concentration at which 50% of DPPH radicals are scavenged.

[b] EC_{50} (mg/mL): Effective concentration at which the absorbance is 0.5.

3.4.3 Cytotoxicity and anticancer potentials

Fig. 1 showed the anti-proliferative activity of sage (*Salvia officinalis*) aqueous extract (SAE) against MDA-MB-231 cell line via neutral red assay (IC_{50} of 300 µg/mL). Characteristics of dying cells appeared in sage extract-treated cells indicating its effect on cell viability with an IC_{50} of 300 µg. Fig. 2 (a and b), illustrated morphological changes in MDA-MB-231 Triple-negative breast cancer cell following treatment with sage aqueous extract (SAE) with a concentration of 300 µg/ mL for 48 h. Light microscopy observation of SAE-treated cells revealed morphological changes induced by the extract. As shown in Fig. 2b, MDA-MB-231 treated cells with a concentration of 300 µg/ mL SAE, underwent visible morphological changes after 48 h of incubation, where treated cells appeared smaller and rounded (characteristics of dying cells) (Fig. 2b, arrows), in addition to the decrease of neutral red uptake in a concentration-dependent manner.

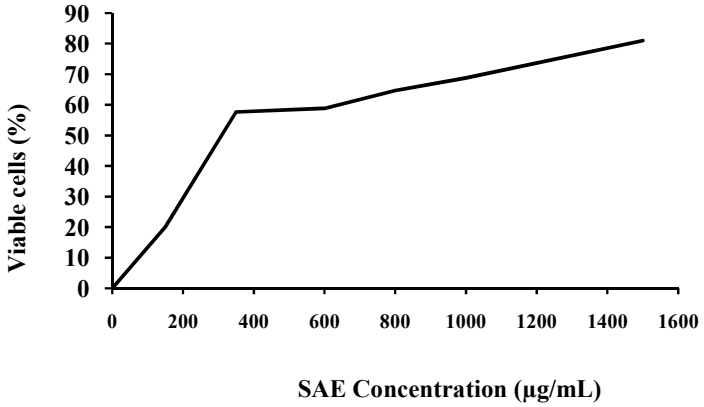

Fig. 1. Anti-proliferative activity of sage (*Salvia officinalis*) aqueous extract (SAE) against MDA-MB-231 cell line via neutral red assay (IC_{50} of 300 µg/mL)

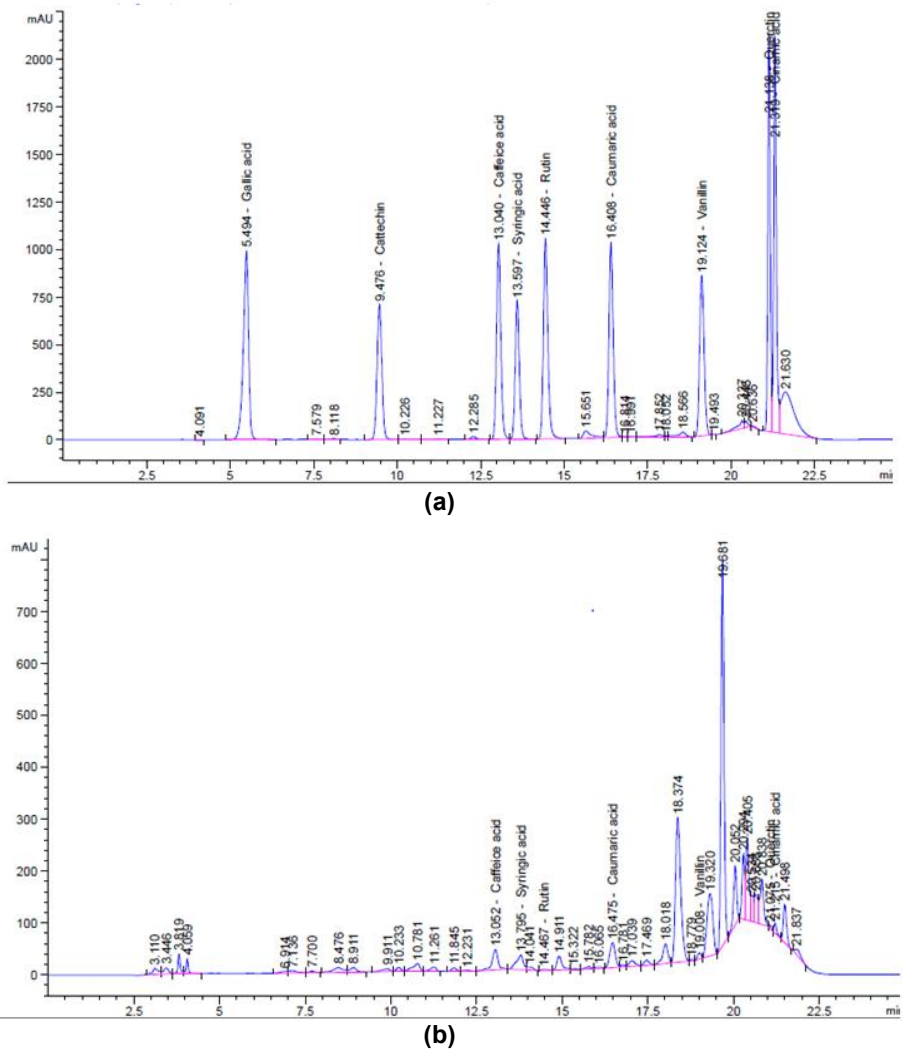

Fig. 2. HPLC graph of phenolic compounds concentrations of sage aqueous extract (b) comparing to control (a)

Table 6. Inhibition zone diameter in mm of different concentrations of sage (*Salvia officinalis*) aqueous extract and MIC for each strain

Pathogenic strain	Inhibition zone diameter (mm)**					
	75*	50*	25*	12.50*	6.25*	MIC
Gram-positive bacteria						
Staphylococcus aureus NCTC10788	23.0	20.0	18.0	12.0	6.0	6.25
Staphylococcus pyogenes EMCC1772	18.5	13.5	10.0	5.5	ND	12.50
Streptococcus mutants EMCC1815	21.0	18.0	11.0	7.0	ND	12.50
Bacillus subtilis DB100	22.5	19.0	14.5	5.5	ND	12.50
Clostridium botulinum ATCC3584	21.0	15.5	11.0	7.5	ND	12.50
Gram-negative bacteria						
Escherichia coli BA12296	21.0	18.0	17.0	10.0	5.0	6.25
Escherichia coli ATCC25922	25.0	19.0	13.0	5.0	ND	12.50
Klebseilla pneumonia ATCC12296	22.0	18.0	13.0	5.0	ND	12.50
Yeast						
Candida albicans ATCCMYA2876	25.0	22.0	18.5	8.0	5.0	6.25

*Data represented are average of duplicates, *Concentrations of extract and MIC are in mg/mL*
***Diameter included 5 mm well diameter, MIC; Minimum Inhibition Concentration*

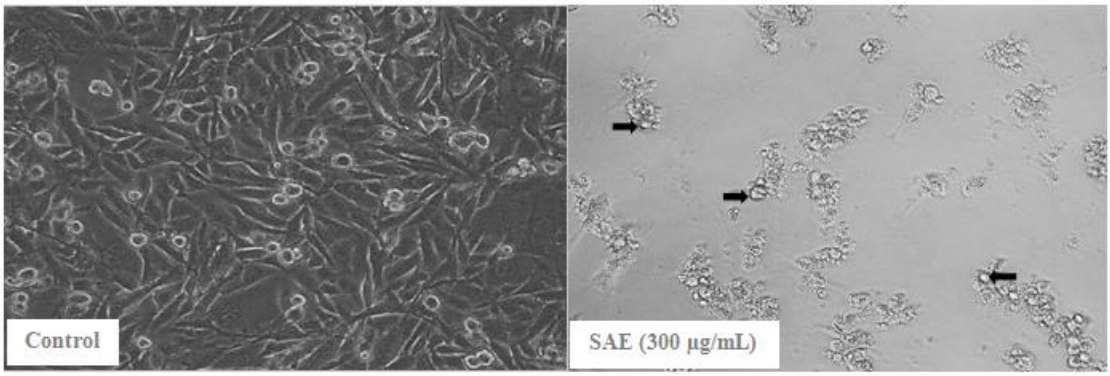

Fig. 3. Morphological changes in MDA-MB-231 Triple negative breast cancer cell following treatment with sage aqueous extract (SAE) with concentration of 300 µg/ mL for 48 h

Mentions: Light microscopy observation of SAE-treated MDA-MB-231 Triple negative breast cancer cells revealed morphological changes induced by the extract. As shown on Fig. 2b, MDA-MB-231 treated cells with concentration of 300 µg/ mL SAE, underwent visible morphological changes after 48 h of treatment, where treated cells appeared smaller and rounded, characteristics of dying cells (Fig. 2b, arrows) in addition to decrease of neutral red uptake in a concentration-dependent manner

4. DISCUSSION

Plant-fibre-enriched foods are reported to improve glucose and lipid metabolism, they lower serum cholesterol concentrations in patients with diabetes, in addition to multiple effects on different cardiovascular risk factors [27]. The electrolytes results emphasized that sage contains 3 times more calcium and 5.5 times more zinc than milk. USDA [28] reported different values for sage mineral except for zinc and sodium content. Alterations in essential trace elements like Fe, Zn and Ca play an important role in the pathogenesis of complex diseases including cancers. Dietary calcium intake found to be associated with a reduced incidence of cancer, while iron, is involved in many processes including DNA, RNA and protein synthesis, and Zn may represent an independent risk factor for cancer and therefore a possible target for prevention [29,30]. Obtained vitamin results indicated that sage could be considered a good source of vitamins B6 and B12 and encourage suggestions of using a food supplement especially for vegetarians and elderly. What is most important that Vitamin B6 and B12 was reported to sensitize a large panel of cancer cell lines to apoptosis [31,32]. Obtained values of B vitamins fluctuated between agreement and disagreement with [28,33]. The nutritional profile

may aid to explain the current increased demand for *Salvia* species for nutritional and pharmacological industries [8].

Many biological functions requiring lysine; include synthesis of connective tissues and carnitine, conversion of fatty acids to energy that support healthy growth in children and maintenance of healthy immune function especially in the management of Herpes simplex virus (HSV) infections [34]. Lysine also found to enhance calcium absorption preventing Osteoporosis. On food technology wise; lysine is involved in the browning reaction applied to foods such as pastries and desserts [35]. Through obtained results, it is recommended to mix sage with foods rich in limited EAA. Apart from an amino acid, starvation diets theories - that stimulates autophagy in cancer- which is complex and likely context-dependent, the maintenance of the intracellular level of amino acids is crucial for cellular homeostasis. Deficiency or imbalance of essential amino acids in the diet was reported to produce profound depression in the immune resistance of the host animal to tumors [36,37].

Increased intake of lauric, myristic or palmitic acid was reported to raise serum total, LDL and HDL cholesterol levels, and lowered triglyceride levels, while lauric acid alone reduced the total cholesterol to HDL cholesterol and LDL cholesterol to HDL cholesterol ratios [38]. Unsaturated fatty acids (UFAs) was reported to exert antineoplastic activity by inducing apoptotic cell death in human cancer cells by increasing the sensitivity of tumor cells to conventional therapies [39]. In this context, USDA [28] reported vitiated values about sage. Reported laboratory studies indicated a clear role for omega-3 PUFAs in preventing cancer development at various stages [40,41]. Generally, it is difficult to match results of nutrients and constituents with earlier researchers since *Salvia* species have various compositions depending on the genetic, climatic, seasonal, and environmental factors [1].

Caffeic acid and its derivatives including rosmarinic acid was reported to be the most representative phenolic compounds in *Lamiaceae*, *S. officinalis* extracts [42]. Anticancer activities of cinnamic acid derivatives include induction of apoptosis by irreversible DNA damage leading to cell death was reported [43]. Since phenolic compounds are the key for several therapeutic properties, quantitative identification of sage leaves phenolic compounds indicated pharmacological potentials to be useful as a source for novel applications in functional food and pharmaceutical industries [44].

Earlier studies on sage reported the presence of obtained phytochemicals classes of active compounds [1,5]. Obtained results of phenolic and flavonoid content were in context with Özcan [45], while it disagreed with Gîrd and Pop [46, 47]. Sage was reported to possess the greatest antioxidant capacity amongst fresh herbs, due to its phenolic and flavonoids content which related for multiple health benefits, including a reduction in cancer risk and modification of tumor behavior [48,49].

The activity of sage against filamentous fungi and yeasts such as *Candida albicans* was previously reported by Sirirat and Jelena [50], and thus may be useful in the treatment of different kinds of fungi in human. Antimicrobial results can nominate sage as a promising natural antimicrobial agent which is in accordance to the results of Zomorodian [51]. Reasonable antimicrobial and antioxidant activities encouraged further investigation of anti-breast cancer activities of sage extract.

Alterations of the MDA-MB-231 cell surface or of the sensitive lysosomal membrane lead to lysosomal fragility and other changes that gradually become irreversible. The main advantage of the neutral red assay is that it detects only viable cells [52]. Previous researches reported the antitumor properties of sage extract which probably in correlation to its announced antioxidant activity as in other plant extracts [9,53]. Sage bioactive compounds, linalyl acetate (Ly), terpeniol (Te) and camphor (Ca), has been reported to have a synergistic effect on two human colon cancer cell lines HCT-116 (p53 (+/+) and p53 (-/-)). Apoptosis by Ly + Te + Ca, in p53 (+/+) cells [54]. Despite progress in cancer research, the biologically active components and antitumor mechanisms have not yet been exactly determined, but mitochondrial membrane potential decay is one of the accompanying processes of the intrinsic apoptotic pathway activation [55]. On the other hand, concerns and limitations for the amount and quantity used of sage attributed to the predominant volatile neurotoxic components; camphor, α- and β-thujone, which are most present phytochemicals in *Salvia officinalis* leaves. A daily intake of 5.0 mg/person is

acceptable for a maximum duration of use of 2 weeks, and the overdose is more than 15 g of sage leaves per day [56]. It is noteworthy that sage use during pregnancy and lactation is not recommended [57]. Our findings encourage further studies of sage components as promising antitumor therapy against breast cancer.

5. CONCLUSION

In conclusion, *Salvia officinalis* possessed abundant antioxidant, antimicrobial and anti-breast cancer activities due to its rich combination of nutrients and constituents. Sage considered a good source of calcium, iron, zinc, vitamins B6 and B12, essential amino acids, lysine, phenylalanine and leucine and unsaturated fatty acids (UFAs) ω-3, ω-6 and ω-9, which all reported to have a role as anti-cancer in different mechanisms. Presence of a wide range of constituents includes volatile oil, flavonoids/ flavones, tannins, steroids, terpenoids combined with significant amounts of phenolic compounds, especially quercetin and cinnamic, interpreted its high antioxidant powers. In addition, to marked antimicrobial potentials that showed against all nine tested pathogens, that could be beneficially used in food fortification for preservation and pharmacologically as an anti-tumour alternative natural supplement. SAE performed anti-proliferative activity against MDA-MB-231 cell line with IC_{50} of 300 µg/mL. These results encourage further research on sage components as a promising antitumor agent. Sage leaves possessed variable nutrients and active compounds that reflected on its vast nutritional and pharmacological potentials and support it as a functional nutritional additive and a natural bio-preservative in food and dairy preparations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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