New Valley Veterinary Journal

Original Research Article

ISSN (Print) 2786-0272 ISSN (Online) 2786-0280

Qualification of Bioactivity of Some Chemical Components of Ethanolic Peel *Citrullus colocynthis* Extract

Eman Ashraf [1], Mohamed Kandeil [2], Marwa El-Zeftawy [1]

[1]Biochemistry and Molecular Biology Department, Faculty of Veterinary Medicine, New Valley University, New Valley, Egypt.
[2]Biochemistry Department, Faculty of Veterinary Medicine, Beni-Suef University, Egypt.
*Corresponding author: marwa@vet.nvu.edu.eg

Received at: 2025-01-25 Accepted at: 2025-02-22

ABSTRACT: *Citrullus colocynthis* (CC) has its own nutritional and therapeutical values. Peels of CC (CCPs) are usually discarded as a waste product and are not utilized. The current study underscores the CCPs to explore their pharmacological worth by focusing on their component's biological activities. The CCPs were collected from CC in Eldakhla, New Valley governorate, and the ethanolic method was used, followed by an evaporation process and dry freezing to obtain crude extract. Then, gas chromatography-mass spectrometry (GC-MS) was operated to detect various components in CCPs and WILEY 09, and the NIST14 mass spectral database was employed as a reference. GC-MS depicts the presence of different flavonoids, phenolics, nitrogen, and organophosphorus compounds in CCPs that have a huge value in medicine against acute and chronic illnesses. The results conclude superior components as phenol (1,1-dimethyethyl)-4-methoxy (12.52%), ursodeoxycholic acid (7.02%), 2-methoxy-4-vinylphenol (6.42%), 13-heptadecyn-1-ol (5.51%), hexadecanoic acid (5.49%), desulphosinigrin (4.29%), phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy (3.99%), 16-octadecenoic acid, methyl ester (3.82%), 2,3-dihydro-benzofuran (3.65%), and trans-sinapyl alcohol (3.18%). These candidates have antioxidant, anti-inflammatory, anticancer, antidiabetic, antihypercholestermic, and antimicrobial bioactivities. Among the forty-five identified compounds in CCPs, the biological activities of only four weren't discovered. The results of this study would lead to pharmacological trials of the CCPs extract and its candidates on animal models.

KEYWORDS: *Citrullus colocynthis* peels, gas chromatography-mass spectrometry, antioxidant, anti-inflammatory, anti-cancer.

1. introduction

Plants fulfilled a multitude of basic animal and human requirements. The use of plants as an adjuvant remedy goes back thousands of years, and they are regarded as a valuable source for creating novel medication for reducing a number of conditions, encompassing neurodegenerative, cardiovascular, gastrointestinal, hepatic, renal, and muscular disorders [1]. *Citrullus colocynthis* (CC), known as bitter apple, Family *Cucurbitacea*, Genus *Citrullus Schard*, species *Citrullus colocynthis* (L.) Schard is a typical desert shrub originating on sandy and arid soils [2]. The CC whole fruit is round, has a smooth structure accompanied by an enormously bitter taste, and consists of peel, pulp, and seeds [3]. CC is engaged in many conventional sectors, such as animal nutritional crops [4], useful oil, and diesel biofuel [5]. It is also an excellent source for carbon compound creation needed for photocatalytic adsorption and oxidation of organic dyes [6]. CC peels (CCPs) are the outer protective layer of CC fruit, which shields it from hard environments and aids in the eradication of methylene blue dye from watery solutions as it is characterized as a well-adsorbent material [7]. Gas chromatography-mass spectrometry (GC-MS) is one of the analytical techniques that separate the components in the mixture among the stationary phase and carrier gas moving phase [8]. It is characterized by abundant replicability of retention time (RT) and mass spectra [9]. GC-MS has various applications, it is used to detect food contaminations and adulterations [10]. It identifies the unknown sample components in forensic medicine [11]. It also characterized the lipids components in green plants, cyanobacteria, macro and microalgae [12], and extracted oils [13]. The existing inquiry intends to identify the CCPs' chemical composition by GC-MS and investigate

NVVJ., Vol. 5, Issue (2), 2025

an overview of CCPs constituents' biological activity, which may involve the therapy of some ailments.

2. Materials and methods

2.1. Ethical statement

The inquiry was performed under the authorized ethical regulation of the Institutional Review Board, Faculty of Medicine, Assiut University, 04-2023-10066.

2.2. Extraction of CCPs

Dried peels of CC were obtained from a local herbs market, in Eldakhla, New Valley governorate and it was identified in the Faculty of Science, Alexandria University, Alexandria, Egypt. Further, CC had been checked via one of the international databases http://www.theplantlist.org. The method used to extract the CCPs' different components was in line with [14] with a few adjustments. An ethanolic extract was prepared by soaking 40 gm of the dry CCPs in 400 ml of 70% ethyl alcohol at 4ºC with daily shaking for 21 days. After that CCPs extract was sieved through double-layered gauze, and then the extract was stored at 4ºC. The ethanolic filtrate was evaporated via a rotary evaporator (HS 2005 V_N, Korea), and then the deposit was exposed to dry freezing by freeze dryer (FDF0350, Korea) and stored at -20ºC.

2.3. GC-MS evaluation of CCPs extract

Determination of the chemical composition in CCPs was performed predicated on the alternative approach to Abdelmonsef et al.[15]. GC-TSQ mass spectrometer (Thermo Scientific, Austin, TX, USA) with a direct capillary column TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness) was used. The column oven temperature was first stayed at 60ºC and then raised by 5ºC /min. to 250ºC withhold 2 min. later upwards to 280ºC with 25ºC/min. The injector temperature was preserved at 270ºC. Helium was utilized as a carrier gas at a constant 1 ml/min flow rate. The delay of the solvent was 4 min, and diluted specimens of 1 µl were injected immediately using autosampler AS3000 conjugated with GC in the split mode. Electron ionization mass spectra were assembled at 70 eV ionization voltages over the m/z 50-650 range in complete scan mode. The ion origin and the line of transfer were positioned at 200ºC and 280ºC, correspondingly. The components were realized by comparing their mass spectra with those of WILEY 09 and NIST14 mass spectral datasets.

3. Results

The outcomes of GC-MS inspection directed to the recognition of some chemical ingredients out of the GC fractions of CCPs ethanolic extract. Forty-five bioactive compounds were recognized and their RT, % of peak area, molecular formula, molecular weight, the match factor between system mass spectrum of the compound and data base mass spectrum and biological activities were portrayed in Table 1 and GC-MS chromatogram (Figure. 1). The predominant compounds were octadecanedioic acid (OCA) (0.91%), 9-oximino-2,7 diethoxy fluorene (9ODF) (0.66%), 10-methyl-8-tetradecen-1-ol acetate (10M8T) (1.3%), 4H-pyran-4-one,2,3-dihydro-3,5 dihydroxy-6-methyl (4HPDM) (1.80%), cis-10-nonadecenoic acid (C10N) (0.43%), 2,2,3,3,4,4 hexadeutero octadecanal (0.65%), 2,3-dihydro-benzofuran (2,3DB) (3.65%), 2-methoxy-4-vinylphenol (2M4V) (6.42%), 1,8-di(4-nitrophenylmethyl)-3,6-diazahomoadamantan-9-one (0.56%), phenol, 2,6-dimethoxy (P2,6D) (1.43%), D-tyrosine, 3-hydroxy (2.40%), 3-oxo-androsta-1,4-dien-17á-spiro-2'-3'-oxo-oxetane (0.34%), benzaldehyde, 3-hydroxy-4-methoxy (B3H4M) (1.58%), phenol, 2-methoxy-4-(2-propenyl) (P2M4P) (0.46%), 5-hydroxy-2,3,3-trimethyl-2-(3-methyl-buta-1,3-dienyl) cyclohexanone (5HTMBDC) (0.87%), 2-aminoethanethiol hydrogen sulfate (ester) (2AHS) (3.88%), phenol (1,1-dimethyethyl)-4-methoxy (PDM) (12.52%), tetra acetyl-d-xylonic nitrile (TADXN) (0.54%), mannose (0.56%), stevioside (STE) (1.05%),

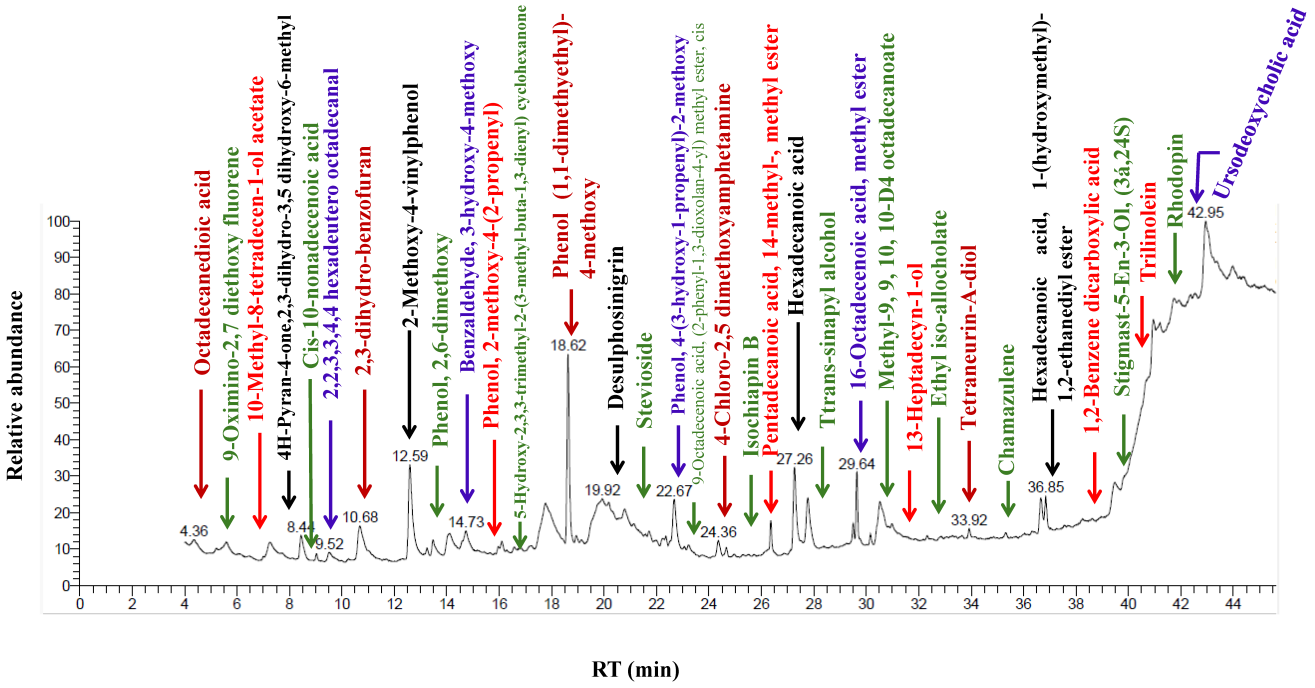


Figure 1: GC chromatogram of CCPs ethanolic extract.

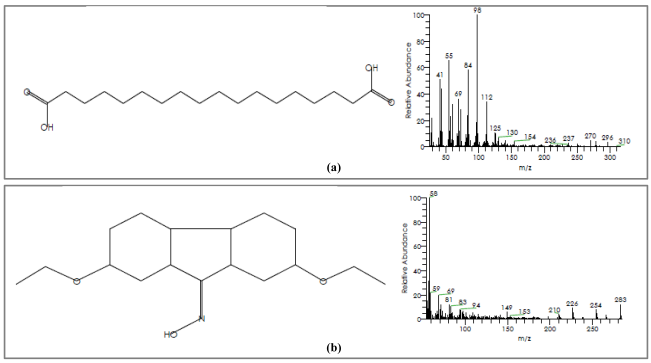
1-heptatriacotanol (1HE) (0.70%), phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy (PHM) (3.99%), 9-octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl) methyl ester, cis (9OA2PME) (0.47%), 4-chloro-2,5 dimethoxyamphetamine (4CD) (1.26%), isochiapin B (IB) (0.54%), pentadecanoic acid, 14-methyl-, methyl ester (PA, 14-ME) (1.65%), hexadecanoic acid (HA) (5.49%), trans-sinapyl alcohol (TSA) (3.18%), linoleic acid ethyl ester (LAME) (0.98%), 16-octadecenoic acid, methyl ester (16OAME) (3.82%), methyl-9, 9, 10, 10-D4 octadecanoate (MD4O) (0.63%), 13-heptadecyn-1-ol (13H-1-ol) (5.51%), ethyl iso-allocholate (EIA) (0.38%), tetraneurin-A-diol (TAD) (0.58%), hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester (HA1E) (2.29%), 1,2-benzenedicarboxylic acid, bis (2-ethylhexyl ester) (1,2BA) (1.68%), 5,16,20-pregnatriene-3 beta, 20-diol diacetate (5,16,20PD) (2.69%), rhodopin (RhO) (1.46%), flavone 4'-OH,5-OH,7-DI-O-glucoside (FOG) (0.44%), and ursodeoxycholic acid (UDA) (7.02%). Some candidates occupied various areas at different RT as desulphosinigrin (DES) appears at 19.74, 19.91, and 21.72. Also, chamazulene (CHZ) found at 22.36 and 35.31, and stigmast-5-En-3-Ol, (3á,24S) (STI) present at 39.46 and 43.99. Trilinolein (Tri) exists at 39.81 and 41.20, and 9-octadecenoic acid, 1,2,3-propanetriyl ester, (E,E,E) (9OAP) seems at 40.66 and 42.54.

The chemical structures and mass spectra of all recognized components are shown in Figure. 2, Figure. 3 and Figure. 4

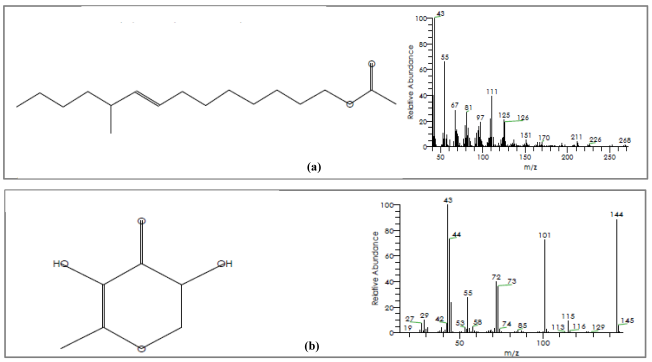
4. Discussion

Oxidative stress (OS) is a disproportion between oxidant manufacture and antioxidants. Antioxidants have a crucial role in reducing symptoms of most chronic diseases in two theories; the first is through hydrogen atom transfer that causes neutralization of the reactive oxygen species (ROS) [16]. The second theory is single electron transfer to the free radicals (FRs); hence, the oxidative process is diminished [17]. *Citrullus colocynthis* (CC) has a long history in therapeutical applications. Peels of

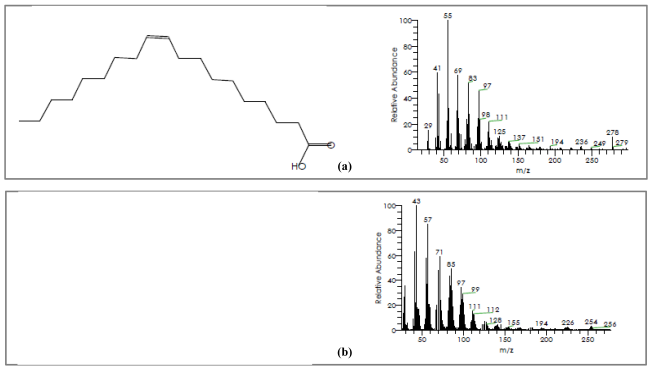
NVVJ., Vol. 5, Issue (2), 2025



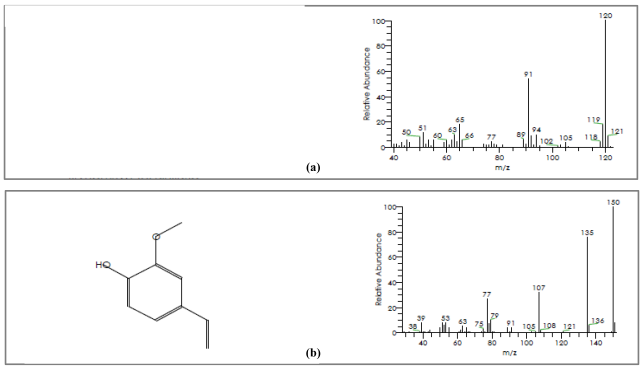
(a) Mass spectrum and structure of (a) Octadecanedioic acid (RT: 4.37 min.) and (b) 9-Oximino-2,7 diethoxy fluorene (RT: 5.60 min.)



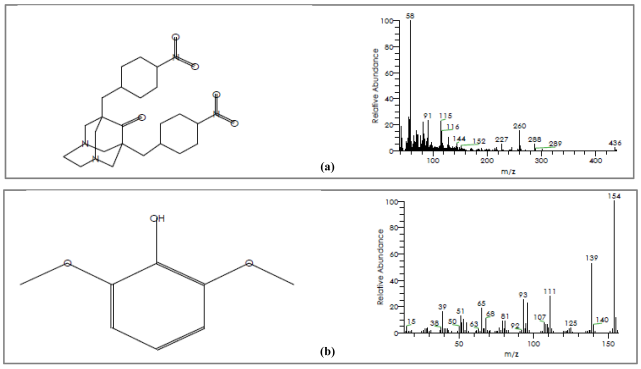
(b) Mass spectrum and structure of (a) 10-Methyl-8-tetradecen-1-ol acetate (RT: 7.25 min.) and (b) 4H-Pyran-4-one,2,3-dihydro-3,5 dihydroxy-6-methyl- (RT: 8.43 min.).



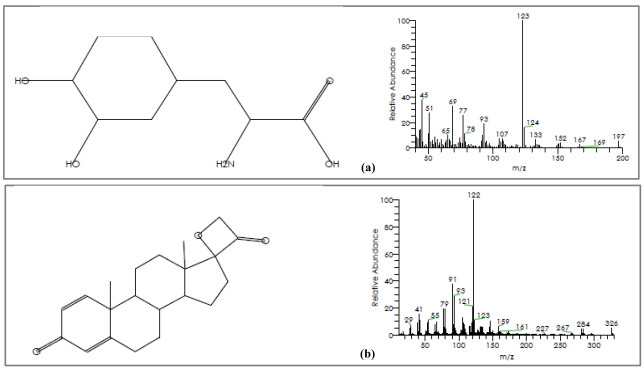
(c) Mass spectrum and structure of (a) Cis-10-nonadecenoic acid (RT: 9.03 min.) and (b) 2,2,3,3,4,4 hexadeutero octadecanal (RT: 9.51 min.).



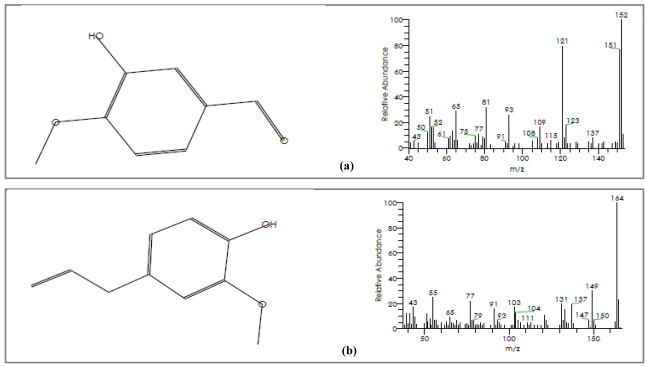
(d) Mass spectrum and structure of (a) 2,3-dihydro-benzofuran (RT: 10.68 min.) and (b) 2-Methoxy-4-vinylphenol (RT: 12.59 min.).



(e) Mass spectrum and structure of (a) 1,8-Di(4-nitrophenylmethyl)-3,6-diazahomoadamantan-9-one (RT: 13.24 min.) and (b) Phenol, 2,6-dimethoxy (RT: 13.47 min.).

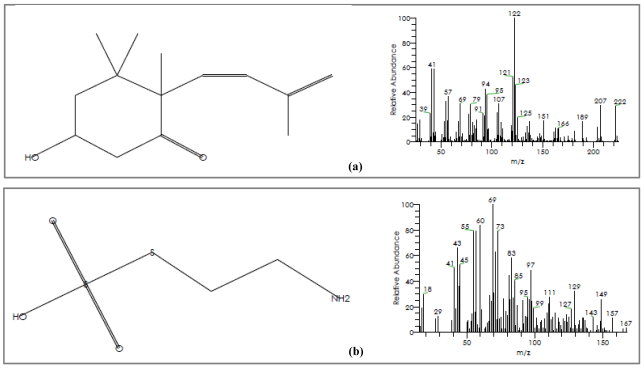


(f) . Mass spectrum and structure of (a) D-Tyrosine, 3-hydroxy (RT: 14.05 min.) and (b) 3-Oxo-androsta-1,4-dien-17á-spiro-2'-3'-oxo-oxetane (RT: 14.59 min.).

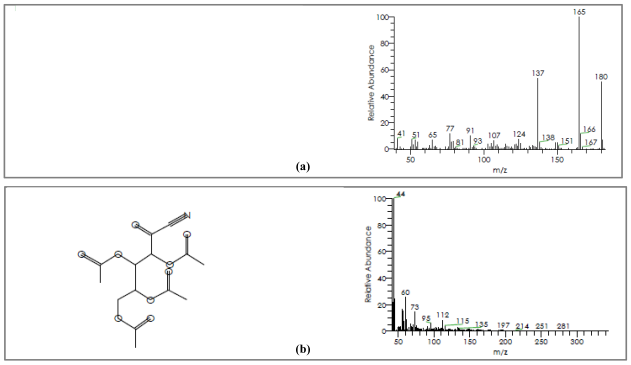


(g) Mass spectrum and structure of (a) Benzaldehyde, 3-hydroxy-4-methoxy (RT: 14.72 min.) and (b) Phenol, 2-methoxy-4-(2-propenyl) (RT: 15.96 min.).

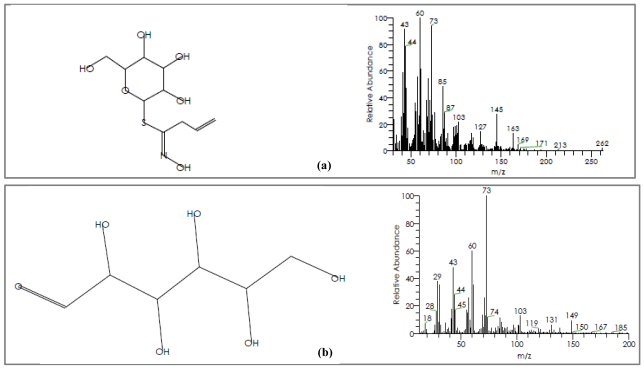
Figure 2



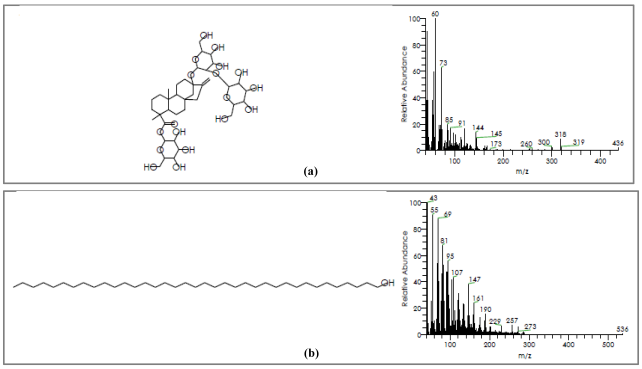
(a) Mass spectrum and structure of (a) 5-Hydroxy-2,3,3-trimethyl-2-(3-methyl-buta-1,3-dienyl) cyclohexanone (RT: 16.10 min.) and (b) 2-Aminoethanethiol hydrogen sulfate (ester) (RT: 17.75 min.)



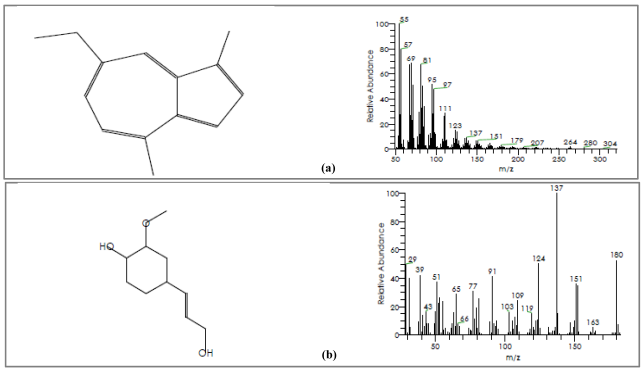
(b) Mass spectrum and structure of (a) Phenol (1,1-dimethyethyl)-4-methoxy (RT: 18.62 min.) and (b) Tetraacetyl-d-xylonic nitrile (RT: 18.93 min.)



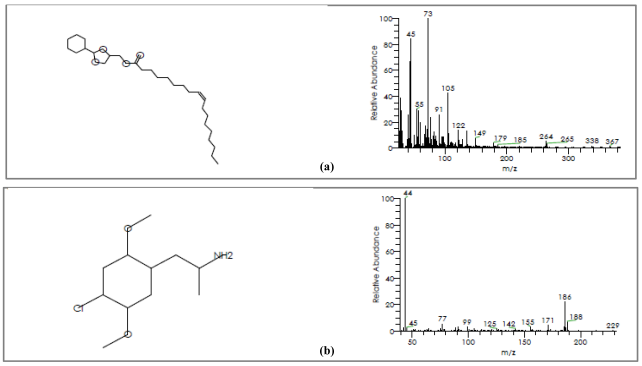
(c) .Mass spectrum and structure of (a) Desulphosinigrin (RT: 19.74, 19.91, and 21.72 mins.) and (b) Mannose (RT: 20.19 min.)



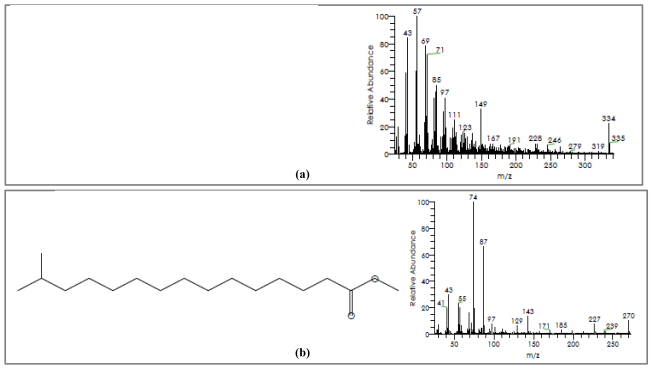
(d) Mass spectrum and structure of (a) Stevioside (RT: 20.79 min.) and (b) 1-Heptatriacotanol (RT: 22.22 min.)



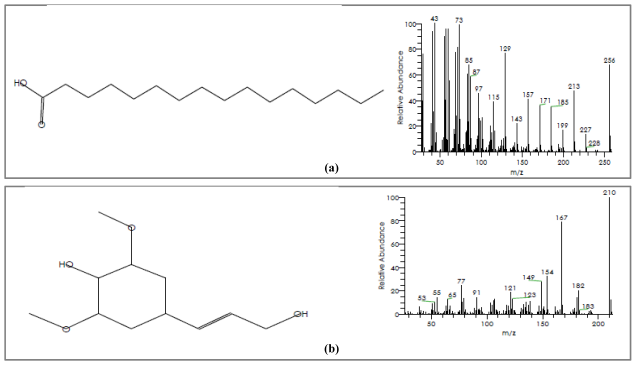
(e) Mass spectrum and structure of (a) Chamazulene (RT: 22.36, and 35.31 mins.) and (b) Phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy (RT: 22.67 min.)



(f) Mass spectrum and structure of (a) 9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl) methyl ester, cis (RT: 23.21 min.) and (b) 4-Chloro-2,5 dimethoxyamphetamine (RT: 24.35 min.)



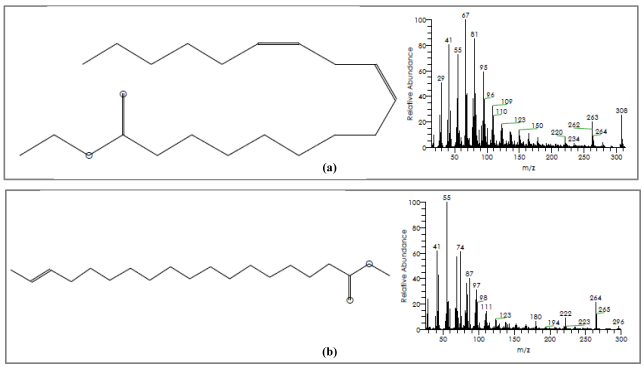
(g) Mass spectrum and structure of (a) Isochiapin B (RT: 24.67 min.) and (b) Pentadecanoic acid, 14-methyl-, methyl ester (RT: 26.36 min.)



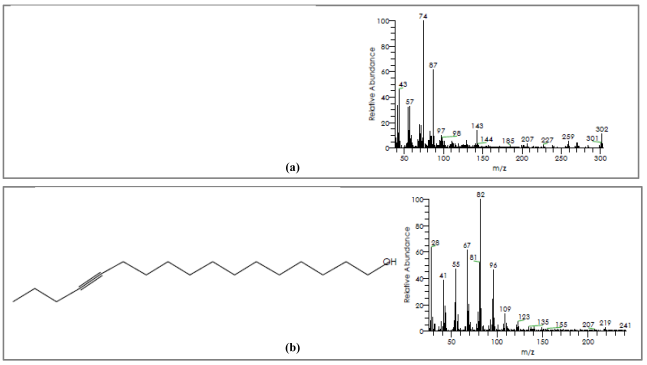
(h) Mass spectrum and structure of (a) Hexadecanoic acid (RT: 27.26 min.) and (b) Ttrans-Sinapyl alcohol (RT: 27.77 min.).

Figure 3

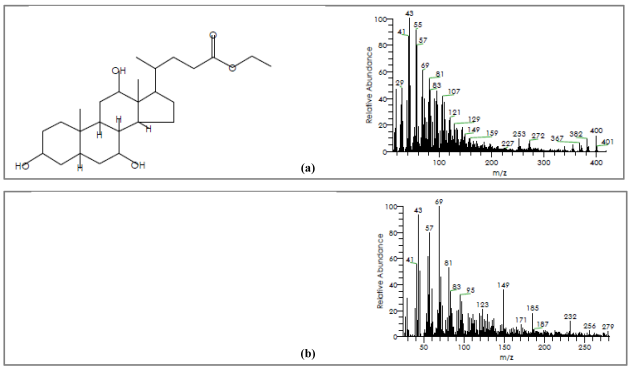
NVVJ., Vol. 5, Issue (2), 2025



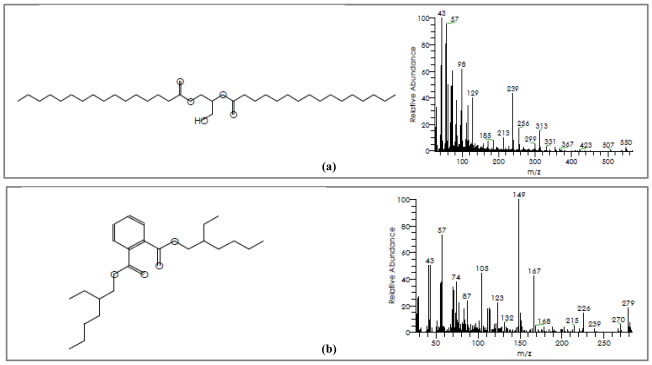
(a) Mass spectrum and structure of (a) Linoleic acid ethyl ester (RT: 29.50 min.) and (b) 16-Octadecenoic acid, methyl ester (RT: 29.64 min.)



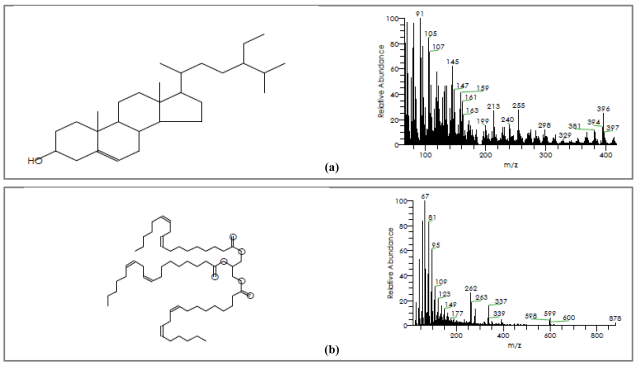
(b) Mass spectrum and structure of (a) Methyl-9, 9, 10, 10-D4 octadecanoate (RT: 30.16 min.) and (b) 13-Heptadecyn-1-ol (RT: 30.51 min.)



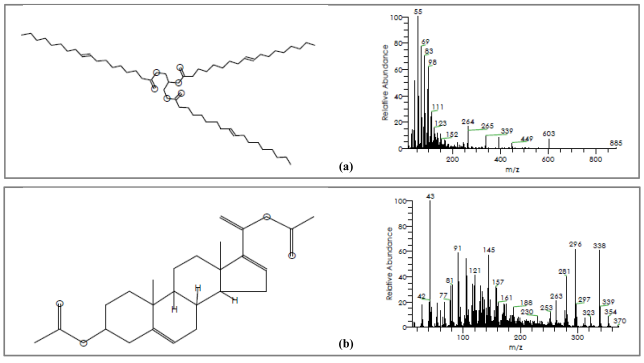
(c) Mass spectrum and structure of (a) Ethyl iso-allocholate (RT: 30.98 min.) and (b) Tetraneurin-A-diol (RT: 33.92 min.).



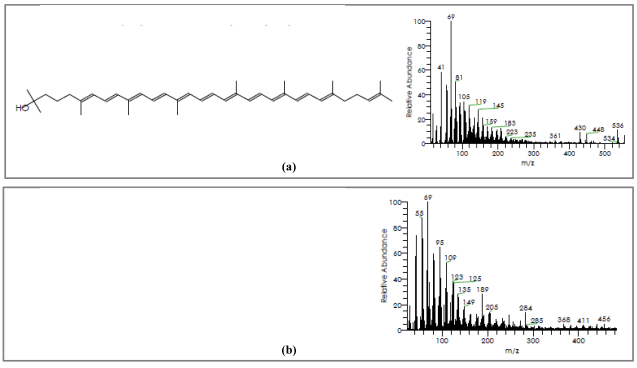
(d) Mass spectrum and structure of (a) Hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester (RT: 36.65 min.) and (b) 1,2-Benzenedicarboxylic acid, bis (2-ethylhexyl ester) (RT: 36.85 min.)



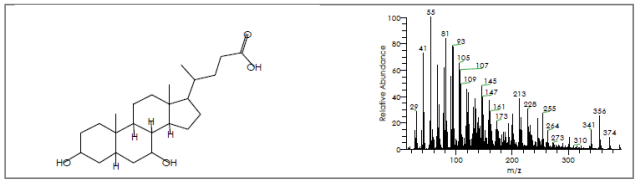
(e) Mass spectrum and structure of (a) Stigmast-5-En-3-Ol, (3á,24S) (RT: 39.46 and 43.99 mins.) and (b) Trilinolein (RT: 39.81 and 41.20 mins.).



(f) Mass spectrum and structure of (a) 9-Octadecenoic acid, 1,2,3-propanetriyl ester, (E,E,E) (RT: 40.66 and 42.54 mins.) and (b) 5,16,20-Pregnatriene-3 beta, 20-diol diacetate (RT: 40.93 min.).



(g) Mass spectrum and structure of (a) Rhodopin (RT: 41.71 min.) and (b) Flavone 4'-OH,5-OH,7-DI-O-glucoside (RT: 42.35 min.).



(h) Mass spectrum and structure of Ursodeoxycholic acid (RT: 42.95 min.)

Figure 4

	RT	Area %	Compound name	Molecular formula	Molecular weight	Match factor	Compound biological activity
1.	4.37	0.91	Octadecanedioic acid (OCA)	$C_{18}H_{34}O_4$	314	651	Anticancer activity
2.	5.60	0.66	9-Oximino-2,7 diethoxy fluorene (9ODF)	$C_{17}H_{17}NO_3$	283	649	Antidiabetic and antimicrobial activities
3.	7.25	1.31	10-Methyl-8-tetradecen-1-ol acetate (10M8T)	$C_{17}H_{32}O_2$	268	669	Antioxidant, anti-inflammatory, anticancer and antimicrobial activities
4.	8.43	1.80	4H-Pyran-4-one,2,3-dihydro-3,5 dihydroxy-6-methyl (4HPDM)	$C_6H_8O_4$	144	827	Antioxidant, and anticancer activities
5.	9.03	0.43	Cis-10-nonadecenoic acid (C10N)	$C_{19}H_{36}O_2$	296	685	Anticancer activity
6.	9.51	0.65	2,2,3,3,4,4 hexadeutero octadecanal	$C_{18}H_{30}D_{6O}$	274	722	Not detected
7.	10.68	3.65	2,3-dihydro-benzofuran (2,3DB)	C_8H_8O	120	845	Anticancer activity
8.	12.59	6.42	2-Methoxy-4-vinylphenol (2M4V)	$C_9H_{10}O_2$	150	933	Anti-inflammatory, and anticancer activities
9.	13.24	0.56	1,8-Di(4-nitrophenylmethyl)-3,6-diazahomoadamantan-9-one	$C_{23}H_{24}N_4O_5$	436	649	Not detected
10.	13.47	1.43	Phenol, 2,6-dimethoxy (P2,6D)	$C_8H_{10}O_3$	154	834	Antioxidant activity
11.	14.05	2.40	D-Tyrosine, 3-hydroxy	$C_9H_{11}NO_4$	197	702	Not detected
12.	14.59	0.34	3-Oxo-androsta-1,4-dien-17á-spiro-2'-3'-oxo-oxetane	$C_{12}H_{26}NO_3$	326	671	Not detected
13.	14.72	1.58	Benzaldehyde, 3-hydroxy-4-methoxy (B3H4M)	$C_8H_8O_3$	152	811	Antioxidant activity
14.	15.96	0.46	Phenol, 2-methoxy-4-(2-propenyl) (P2M4P)	$C_{10}H_{12}O_2$	164	807	Antimicrobial activity
15.	16.10	0.87	5-Hydroxy-2,3,3-trimethyl-2-(3-methyl-buta-1,3-dienyl) cyclohexanone (5HTMBDC)	$C_{14}H_{22}O_2$	222	633	Antioxidant activity
16.	17.75	3.88	2-Aminoethanethiol hydrogen sulfate (ester) (2AHS)	$C_2H_7NO_3S_2$	157	713	Antioxidant and anticancer activities
17.	18.62	12.52	Phenol (1,1-dimethyethyl)-4-methoxy (PDM)	$C_{11}H_{16}O_2$	180	837	Antimicrobial activity
18.	18.93	0.54	Tetra acetyl-d-xylonic nitrile (TADXN)	$C_{14}H_{17}NO_9$	343	767	Antioxidant, antihyperlipidemic, anti-inflammatory, anticancer, antidiabetic, antimicrobial, and anti-viral activities
19.	19.74	4.29	Desulphosinigrin (DES)	$C_{10}H_{17}NO_6S$	279	757	Anticancer, antibacterial and anti-asthmatic activities
20.	19.91	1.07	Desulphosinigrin (DES)	$C_{10}H_{17}NO_6S$	342	279	Anticancer, antibacterial and anti-asthmatic activities
21.	20.19	0.56	Mannose	$C_6H_{12}O_6$	180	767	Antiherpetic activity
22.	20.79	1.05	Stevioside (STE)	$C_{38}H_{60}O_{18}$	804	792	Antidiabetic and antihyperlipidemic activities
23.	21.72	0.52	Desulphosinigrin (DES)	$C_{10}H_{17}NO_6S$	279	724	Anticancer, antibacterial and anti-asthmatic activities
24.	22.22	0.70	1-Heptatriacotanol (1HE)	$C_{37}H_{76}O$	536	704	Antihyperlipidemic, antidiabetic and antimicrobial activities
25.	22.36	0.61	Chamazulene (CHZ)	$C_{14}H_{16}$	184	712	Antioxidant, and anti-inflammatory activities
26.	22.67	3.99	Phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy (PHM)	$C_{10}H_{12}O_3$	180	823	Antioxidant activity
27.	23.21	0.47	9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl) methyl ester, cis (9OA2PME)	$C_{28}H_{44}O_4$	444	719	Antioxidant, anti-inflammatory, and antimicrobial activities.
28.	24.35	1.26	4-Chloro-2,5 dimethoxyamphetamine (4CD)	$C_{11}H_{16}ClNO_2$	229	697	Serotonergic activity
29.	24.67	0.54	Isochiapin B (IB)	$C_{19}H_{26}O_6$	350	731	Antioxidant, anticancer and antimicrobial activities.
30.	26.36	1.65	Pentadecanoic acid, 14-methyl-, methyl ester (PA, 14-ME)	$C_{17}H_{34}O_2$	270	800	Antioxidant, anticancer, antimicrobial, and antifungal activities.
31.	27.26	5.49	Hexadecanoic acid (HA)	$C_{16}H_{32}O_2$	256	878	Antioxidant, anti-inflammatory, and anticancer
32.	27.77	3.18	Ttrans-sinapyl alcohol (TSA)	$C_{11}H_{14}O_4$	210	849	Anti-inflammatory activity
33.	29.50	0.98	Linoleic acid ethyl ester (LAME)	$C_{20}H_{36}O_2$	308	801	Infantile neuroaxonal dystrophy effect
34.	29.64	3.82	16-Octadecenoic acid, methyl ester (16OAME)	$C_{19}H_{36}O_2$	296	864	Anticancer activity
35.	30.16	0.63	Methyl-9, 9, 10, 10-D4 octadecanoate (MD4O)	$C_{19}H_{34}D_4O_2$	302	764	Antioxidant
36.	30.51	5.51	13-Heptadecyn-1-ol (13H-1-ol)	$C_{17}H_{32}O$	252	818	Antioxidant and antimicrobial activities.
37.	30.98	0.38	Ethyl iso-allocholate (EIA)	$C_{26}H_{44}O_5$	436	774	Anti-inflammatory, antiviral, and antimicrobial activities.
38.	33.92	0.58	Tetraneurin-A-diol (TAD)	$C_{15}H_{20}O_5$	280	794	Anti-inflammatory, anticancer and hepatoprotective activities.
39.	35.31	0.48	Chamazulene (CHZ)	$C_{14}H_{16}$	184	726	Antioxidant, and anti-inflammatory activities
40.	36.65	2.29	Hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester (HA1E)	$C_{35}H_{68}O_5$	568	789	Antimicrobial activity
41.	36.85	1.68	1,2-Benzenedicarboxylic acid, bis (2-ethylhexyl ester) (1,2BA)	$C_{24}H_{38}O_4$	390	772	Antidiabetic and antimicrobial activities
42.	39.46	2.25	Stigmast-5-En-3-Ol, (3á,24S) (STI)	$C_{29}H_{50}O$	414	749	Antioxidant, anti-inflammatory, antidiabetic, anticancer, antihypercholestermic, and hepatoprotective activities
43.	39.81	0.48	Trilinolein (Tri)	$C_{57}H_{98}O_6$	878	766	Antioxidant, anti-inflammatory activities.
44.	40.66	1.00	9-Octadecenoic acid, 1,2,3-propanetriyl ester, (E,E,E) (9OAP)	$C_{57}H_{104}O_6$	884	754	Antioxidant, and anti-inflammatory activities
45.	40.93	2.69	5,16,20-Pregnatriene-3 beta, 20-diol diacetate (5,16,20PD)	$C_{25}H_{34}O_4$	398	706	Treatment of jaundice and pain
46.	41.20	0.80	Trilinolein (Tri)	$C_{57}H_{98}O_6$	878	796	Antioxidant, anti-inflammatory activities.
47.	41.71	1.46	Rhodopin (RhO)	$C_{40}H_{58}O$	554	713	Antioxidant activity.
48.	42.35	0.44	Flavone 4'-OH,5-OH,7-DI-O-glucoside (FOG)	$C_{27}H_{30}O_{15}$	594	748	Antioxidant activity
49.	42.54	0.53	9-Octadecenoic acid, 1,2,3-propanetriyl ester, (E,E,E) (9OAP)	$C_{57}H_{104}O_6$	884	758	Antioxidant, and anti-inflammatory activities
50.	42.95	7.02	Ursodeoxycholic acid (UDA)	$C_{24}H_{40}O_4$	392	700	Anti-inflammatory, anti-apoptotic, hypocholesterolemic, and hepatoprotective activities
51.	43.99	1.37	Stigmast-5-En-3-Ol, (3á,24S) (STI)	$C_{29}H_{50}O$	414	748	Antioxidant, anti-inflammatory, antidiabetic, anticancer, antihypercholestermic, and hepatoprotective activities

Table 1: Compounds detected in GC-MS analysis of CCPs.

NVVJ., Vol. 5, Issue (2), 2025

CC are considered ordinary wastes of CC. Despite this, several components have been identified in CCPs, and exciting pharmaceutical activities have made CCPs valuable parts of CC. Phytonutrients are categorized into multiple clusters, including flavonoids, phenolics, alkaloids, organosulfur compounds (OSCs), nitrogen-containing compounds, carotenoids, and phytosterols [18]. GC-MS of CCPs exhibited the presence of 4HPDM, and its antioxidant property is attributed to its classification as a one of flavonoid fraction[19] characterized by its steady enediol framework integrated into the matching heterocycles [20]. It can scavenge 1,1-Diphenyl-2-picryl-hydrazyl (DPPH) and 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) radicals and diminish the ferric ions [21]. It also stimulates the activities of reduced glutathione and sodium/potassium adenosine triphosphatase [22]. 4HPDM sweeps the active oxygen by attaching to the triterpene aglycone [20] and binding to macromolecules that impede oxygen access [23]. Our results were similar to El-Zeftawy and Ghareeb [13], who detected the presence of 4HPDM in the *Ceratonia siliqua* pulp aqueous extract. Additionally, in GC-MS of CCPs, FOG is recognized and considered one of the isoflavonoids with potent antioxidant capacity because of the hydroxyl (OH) group existence in its chemical construction [24]. Phenolic compounds represent the main types of antioxidant molecules owing to the fact of the existence of OH and allyl groups [25]. Several prominent phenolics are recorded in CCPs by GC-MS. The P2,6D and PHM are phenolic compounds that employ their antioxidant influence due to the presence of two methoxy groups attached to the phenolic benzene ring that enhances higher antiradical power [26, 27]. A preceding inquiry by [28] explored that P2,6D performed meaningful joining in the caspase-3 receptor of a hydrogenic type, ascribed to its robust antioxidant capability. Furthermore, 5HTMBDC, another phenolic [29], revealed antioxidant potentiality as a result of the presence of five OH groups bound to three methyl (CH_3) groups in different positions, and that was in harmony with [30]. The present data demonstrated the existence of 2M4V in CCPs, one phenolic compound member, that has an anti-inflammatory impact by hindering the initiation of mitogen-activated protein kinase that is accountable for the creation of inflammatory representatives as cyclooxygenase-2 (COX II) and tumor necrosis factor-alpha [31]. Additionally, 2M4V suppresses nitric oxide (NO) formation by preventing the activities of prostaglandin E2 and inducible NO synthase enzyme [32]. It also blocks nuclear factor kappa B (NF-kB) through the degradation of beta-catenine kinase [33]. Alkaloid composites have vigorous biological actions and contain at least one nitrogen atom [34]. B3H4M is one of the alkaloids [35] distinguished by the presence of three OH groups that augment its antioxidant features [36]. Further, the 4-methoxy group is more active than the CH_3 group and can donate a pair of electrons to the carbon bearing the carboxyl group through the polarity influence [37]. The OSCs maintain redox homeostasis and diminish the adverse effects of ROS mainly by hydrogen atom transfer mechanism [38]. They are scavengers for most radicals, reduce cupric to cuprous, and hinder NO and lipid peroxidation [39]. Further, they activate the nuclear factor erythroid 2-related factor 2 signaling pathway, which governs the cellular response against OS [40]. GC-MS of CCPs has investigated the existence of 2AHS, one of the OSCs [41], characterized by attaching the sulfur with hydrogen that helps it to scavenge the FRs and adjust the gene expression [42]. It also triggers the cytochrome and detoxifies the glutathione S-transferases [43]. Moreover, TADXN in CCPs displays antioxidant traits via its nature as a nitrogen organic molecule that prohibits oxidation [44]. Further, CHZ in CCPs is affirmed as a bicyclic unsaturated hydrocarbon [45]. It is a natural proazulene with anti-oxidative and anti-inflammatory impresses [46], and it is one of the secondary metabolites of chamomile [47]. CHZ antioxidant hallmarks are ascribed to its ability

to clear FRs such as OH and ABTS radical cation and raise the antioxidant enzyme activities [48]. On the same hand, CHZ possesses an anti-inflammatory potential due to its inhibitory effect versus 5-lipooxygenase and COX II enzymes, which participate in prostaglandin biosynthesis [49]. Also, CHZ hinders arachidonic acid (ARA) peroxidation [50]. Another theory of CHZ's anti-inflammatory effect is attributed to its ability to down-regulate the matrix metalloproteinase-3 (MMP-3) and MMP-9 and the NF-kB signaling pathway [51]. Fatty acid methyl ester (FAME) in CCPs such as 9OA2PME, PA, and 14-ME occupied a vital antioxidant influence [52]. They can capture the DPPH radicals by giving hydrogen to the FRs and reducing them to non-reactive species [53]. Previous research by [54] exposed that the presence of the FAME form improves the antioxidant effect than the non-methyl ester form. Another notable fatty acid (FA) in CCPs contributing to its antioxidant vitality is HA due to carboxylic groups in its chemical structure that boost its antioxidant efficiency [55] . HA quenches DPPH, OH, NO, and superoxide dismutase (SOD) radicals [56]. It also captures ABTS radicals via its hydrogen-donating ability [55]. Further, HA hinders the inflammatory pathway via the prevention of the phospholipase A2 enzyme [57] that hydrolyzes the glycerophospholipid and produces ARA that is responsible for prostaglandins and leukotrienes creation. The GC-MS of PPs likewise investigates the presence of 9OAP, FA ester [58] holds antioxidant and anti-inflammatory features [59]. Moreover, the anti-inflammatory and antioxidant impress of STI is stated by [60, 61]. respectively. Therefore, STI has proven hepatoprotective validity against some hepatic complaints [62]. Besides, HA is one of the chief candidates conferring anticancer potentiality by augmenting lactate dehydrogenase enzyme flow, which converts lactic acid into pyruvic acid and causes tumor cell necrosis. HA also modulates the cells in the G0/G1 stage of the cell cycle [63]. Additionally, MD4O is another FA in CCPs that revealed higher power against ROS as a result of their being four CH_3 groups within its chemical structure, which enhance its physical, chemical, and biological properties [64] and persevere the stability of cell membrane [65]. CCPs GC-MS exposed the presence of Tri, a triacylglycerol with double unsaturated bonds at the three esterified sites of glycerol [66]. It performs its action as opposed to the FRs by alleviating SOD enzyme activity [67] and protecting the mitochondrial function [68]. It also inhibits the triggering of nicotinamide adenine dinucleotide phosphate oxidase-2, a vital ROS source [69]. Tri also promotes cellular autophagy and apoptosis by lowering the mammalian target of rapamycin phosphorylation and enriching adenosine monophosphate protein kinase phosphorylation [47]. The carotenoids are characterized by higher antioxidant authority attributed to conjugated double bonds, ketone groups, and cyclopentane rings in their chemical construction [70]. Moreover, carotenoids exert impacts against OSCs via scavenging singlet oxygen and FRs as peroxyl and hydrogen peroxide radicals [9]. RhO is a carotenoid candidate recognized in CCPs, and it is known that RhO is synthesized from phototropic bacteria such as *Rodosiprillum rubrum* [71] . RhO is emitted from methylerythritol phosphate and carotenoid synthetic pathways [72]. A previous investigate by Ashour et al.[73]. stated the antioxidant activity of RhO in marine seaweed. Likewise, a prior study by Abdelaziz et al.[74] explored the antioxidant properties of 13H-1-ol, another compound identified in CCPs GC-MS. In addition to the presence of TSA, an aromatic acid, evokes anti-inflammatory properties by hindering cyclooxygenase action [75]. Adding to the previous anti-inflammatory compound, it is noted presence of EIA by GC-MS of CCPs. It is a steroid in nature [76] and possesses an anti-inflammatory imposed through the activation of the caspase-1 pathway that is responsible for organizing proteins required for tissue repair [77]. In addition, some

NVVJ., Vol. 5, Issue (2), 2025

members of CCPs are recognized for their antitumor effects. From those compounds, IB, sesquiterpene lactone, which is a class of sesquiterpenoids and contains a lactone ring that elicits an anticancer effect through a change in the redox cell equilibrium and its consequence on NF-kB and signal transducer and activator of transcription-3 pathway. These activities reduce the manifestation of cell cycle-related components, raise apoptotic variables, and discount anti-apoptotic, metastasis, and cellular intrusion issues [78]. Further, the anticancer consequence of phenolic components is endorsed to initiating phase II detoxifying and improving the nuclear factor erythroid-2-related factor-2/ kelch-like ECH-associated protein-1 signaling pathway [79]. 4HPDM is another cRhodompound in CCPs, and its ability to restrain colon cancer cell development by provoking apoptotic cell death via the suppression of NF-kB was recorded in the previous study [20]. At the same time, C10N in CCPs performs an antitumor effect via induction of apoptosis and prevents cancer cell proliferation [80]. Moreover, it is noted the biological activity of 2M4V against carcinogenic cells through downregulation of the phosphorylation of retinoblastoma protein so that the cellular cycle will be arrested and cell proliferation controlled [81]. Also, DES occupies a high percentage in CCPs and affords an inhibitory effect versus cyclin-dependent kinases; hence, phosphorylated carcinogenic target genes will be blocked [82]. Further, the current GC-MS information exposed the presence of OCA, one of the organic acids, and it is the result of FA hydroperoxide [83], recognized by its anticancer impact. A previous study [84] revealed the role of OCA against BRAF, one of the protein kinases that enhances tumor incidence. In addition, it is reported the antiproliferative efficacy of STI through the activation of B-cell leukemia/lymphoma-2 protein and phosphatidyl-insitol-3-kinase/protein kinase-B (PI3k/Akt) signals [85]. Further, 2,3DB belongs to benzofurans [86] and possesses an antitumor effect against several cancer types [87] due to its heterocyclic ring structure contains oxygen that improves its action versus tumor by preventing cell proliferation and metastasis [88]. The activity of 16OAME, FAME identified in CCPs compounds, against tumor incidence is attributable to its ability to block the action of eukaryotic deoxy ribonucleic acid polymerase enzyme during cancer which leads to the replication is disrupted so tumor growth and cellular hyperproliferation have deteriorated and cell death happened [89].CCPs contain some antidiabetic candidates such as STE, one of the glucosides, which potentiates insulin secretion in non-insulin-dependent diabetes mellitus and inhibits the glucagon secretion from α-cell of the pancreas [90] by improving the translocation of glucose transporter-4 to the plasma membrane [91]. Further, STE alleviates the ß-oxidation of fatty acids [92] and lessens phosphenol pyruvate carboxykinase activity during gluconeogenesis [93]. The results documented the presence of one of the phytosterols, STI, in CCPs [94] that has an antidiabetic potential to multiple theories [95]. The first one is via its capability to inhibit alpha-amylase enzyme activity that hydrolyzes α-1,4 glucoside linkage of polysaccharides and produces oligosaccharides and glucose [96]. The second theory is STI hinders the action of glucoamylase enzyme that breakdowns both α-1,4 and α-1,6 glycosidic binding and yields glucose [97]. Furthermore, STI regulates glucose transport and overcomes insulin resistance in non-insulin-dependent diabetes mellitus by activation of glucose transporter-4 and PI3k/Akt pathway [98]. The current results of GC-MS of CCPs evoked some antihyperlipidemic molecules, such as TADXN, that obstruct the proprotein convertase subtilisin kexin type 9, which regulates the low-density lipoprotein metabolism via binding to hydrogen bond number 6 [99]. Moreover, CCPs contain 1HE, a long-chain unsaturated FA alcohol, that elicits hypoglycemic action by curbing lipid accumulation [100]. It lowers total cholesterol, triacylglycerol, low-density lipoprotein cholesterol, and very

low-density lipoprotein cholesterol and increases high-density lipoprotein cholesterol [101]. Besides, STI is one of the hypocholesterolemic candidates in CCPs [102]. In addition, GC-MS of CCPs discovered UDA, one of the bile acid derivatives [103]. It is one of the vital antihyperchlostermic candidates through improving i: the bile acid transport that is required for cholesterol catabolism [104] and ii: farnesoid X receptor that regulates the lipid metabolism [105]. It also has hepatoprotective effects particularly in cholestatic hepatitis [106], and anti-apoptotic actions [107]. It is reported to have an anti-inflammatory role [108] through the curbing of COX II and mast cells [109]. Furthermore, some candidates in CCPs exposed effect on the central nervous system as 4CD has an agonistic effect on serotonin receptors by binding to its receptor and elevating its amount in the brain [110], so various physiological and neurological processes as thermoregulation, anxiety, sexual behavior, and cardiovascular hemostasis will be mediated [111]. Further, it is reported presence of LAME in CCPs is an esterified form of linoleic acid and may have a role in treatment the of infantile neuroaxonal dystrophy [112] which is a childhood fatal genetic disorder accompanied by cognitive disorders, lipid peroxidation, and breathing difficulties [113]. The antiviral influence of some components in CCPs is documented by GC-MS. EIA has a repressing potency against severe acute respiratory syndrome-coronaviruses (SARS-CoV) by prevention of i: binding the genome virus by angiotensin-converting enzyme-2 receptor on the cell [114] and ii: SARS-CoV-main-protease that responsible for the virus eradication [115]. Also, the presence of mannose in CPPs has an antiherpetic impact which reduces the risk of dementia in case of infection with herpes simplex virus [116]. Antimicrobial roles of CCPs were recorded as a consequence of the presence of some long-chain fatty alcohol compounds, such as 13H-1-ol, that imply a significant antimicrobial effect due to their potential to denature the proteins and block the cell fermentation [117]. Also, P2M4P and PDM, are alkylphenolic compounds and sub-categorized as terpenes that create antimicrobial actions [118]. Other components in CCPs were identified, but their full real mechanistic action is still unknown and required further studies such as 1,2BA and 9ODF have antidiabetic and antimicrobial features [119, 120]. Also, Sunitha et al.[121] found that 10M8T owed antioxidant, anti-inflammatory, antitumor, and antimicrobial initiatives. A study by Sadeghi et al. [122] showed DES, one of the CCPs candidates, revealed antibacterial and anti-asthmatic effects. Also, 1HE, EIA, and HA1E were demonstrated for their antimicrobial effect [123, 124, 125]. In addition, PA, 14-ME, IB, 9OA2PME, and TADXN have antimicrobial roles [126, 127, 128, 44]. Further, the anti-inflammatory characteristics of Tri [129], TADXN [130], and 9OA2PME [131] were reported. Both PA, 14-ME, and IB presented antioxidant functions [132, 133]. In the same way, TADXN, 2AHS, and PA, 14-ME exposed anticancer influence [134, 135, 136]. Other biological activities for some candidates in CPPs are demonstrated as TADXN has antidiabetic [134] and antiviral impacts [137] and PA, 14-ME owns antifungal impress [138]. Moreover, TAD is a sesquiterpene lactone in nature [139] and its activity was reported by [140] who exhibited the protective impact of TAD in liver disorders and its suppressive effect against tumors and inflammation. Extra, 5,16,20PD is a steroid that diminishes jaundice and it is considered one of the painkillers [141]. On the other hand, PPC is one of the oxygenated hydrocarbons found in CCPs but its action has not been detected till now [142].

Conclusion

In light of the results of the study employing gas chromatography-mass spectrometry (GC-MS), it was found that *Citrullus colocynthis* peels (CCPs) contain forty-five principal components. These compounds in

NVVJ., Vol. 5, Issue (2), 2025

CCPs possess the capacity to be developed as conventional medicines for advanced illness. Nevertheless, more exact study is required to figure-out the therapeutic effects of using compounds on CCPs. Most of those components have antioxidants, anticancer, anti-inflammatory, and antimicrobial. In the future, additional research is necessary to comprehensively evaluate the compound content of CCPs for their potential as candidates for therapeutic medicine.

Acknowledgments

The authors thank all participants for their support during this work.

Conflict of interest statement

There are no disclosed conflicts of interest for the authors.

References

[1] R. Chaughule and R. Barve, *Role of herbal medicines in the treatment of infectious diseases*, 2023.

[2] G. Doumane, J. Bensalah, M. Ouakki, Z. Aribou, O. Boussalem, K. Mzioud, Z. Safi, A. Berisha, M. Bourhia, Z. AR, S. Ibenmoussa, G. Wondmie, A. Zarrouk, M. Touhami and A. Habsaoui, *Sci Rep*, 2024, **14**, 16857–16878.

[3] V. Rao and A. Poonia, *Food Production, Processing and Nutrition*, 2023, **5**, 1–12.

[4] C. Stein, J. Voigts, L. Niederreiter, S. Kowarschik, R. Huber and V. Luth, *J Ethnopharmacol*, 2024, **328**, 118053–118068.

[5] A. Elnaggar, F. Tsombou, M. Hussain, A. Almehdi, Z. Abideen, J. Yong and A. El-Keblawy, *Plant Stress*, 2024, **12**, 100502–100516.

[6] M. Bhatti, E. Dawi, A. Tahira, A. Hulio, I. Halepoto, S. Chang, A. Solangi, A. Nafady, M. Tonezzer, A.-K. Haj Ismail and Z. Ibupoto, *Frontiers in Materials*, 2024, **11**, 1–12.

[7] W. Alghamdi and I. El Mannoubi, *Processes*, 2021, **9**, 1–19.

[8] H. Parastar and P. Weller, *TrAC Trends in Analytical Chemistry*, 2024, **170**, 117438–117449.

[9] A. Guo, H. McKenzie, J. Okoroma, P. Amini, M. Fair, K. Green, A. Saini, L. Jantunen and J. Okeme, *Chemosphere*, 2024, **366**, 143544–143553.

[10] S. Putri, M. Ikram, A. Sato, H. Dahlan, D. Rahmawati, Y. Ohto and E. Fukusaki, *J Biosci Bioeng*, 2022, **133**, 425–435.

[11] O. Gould, N. Nguyen and K. Honeychurch, *Chemosensors*, 2023, **11**, 527–561.

[12] J.-F. Rontani, *Molecules*, 2022, **27**, 1629–1655.

[13] M. El-Zeftawy and D. Ghareeb, *Sci Rep*, 2023, **13**, 12209–12226.

[14] T. Tadi, F. A., N. M., M. S., B. Goliaei and A. Nowrouzi, *Heliyon*, 2024, **10**, 35825– 35843.

[15] M. Abdelmonsef, E. Shawky, D. Ghareeb, E. El Naggar and N. El Newehy, *Food Res Int*, 2024, **192**, 114771–114787.

[16] A. Blagov, V. Summerhill, V. Sukhorukov, E. Zhigmitova, A. Postnov and A. Orekhov, *Front Pharmacol*, 2024, **15**, 1378335–1378357.

[17] A. Bakheit, T. Wani, A. Al-Majed, H. Alkahtani, M. Alanazi, F. Alqahtani and S. Zargar, *Frontiers in Chemistry*, 2024, **12**, 1–16.

[18] M. Mahmoudieh, M. Naghavi, Z. Sobri, A. Azzeme, N. Abd-Aziz, N. Nik Abd Rahman, N. Alitheen, Y. Hussin, G. Bahmanrokh and N. Baharum, *Biocatalysis and Agricultural Biotechnology*, 2024, **59**, 103249–103267.

[19] A. Alfalahi, M. Alrawi, R. Theer, K. Dawood, S. Charfi and A. Almehemdi, *J Ethnopharmacol*, 2024, **318**, 116965–116977.

[20] Y. Qiao, J. Bi, Q. Chen, X. Wu, X. Jin, M. Gou, X. Yang and G. Purcaro, *Food Control*, 2022, **135**, 108820–108830.

[21] X. Yu, M. Zhao, F. Liu, S. Zeng and J. Hu, *Food Research International*, 2013, **51**, 397–403.

[22] O. Olaniyan, O. Kunle-Alabi and Y. Raji, *JBRA Assist Reprod*, 2018, **22**, 289–300.

[23] L. Čechovská, K. Cejpek, M. Konečný and J. Velíšek, *European Food Research and Technology*, 2011, **233**, 367–376.

[24] P. Semwal, S. Painuli, H. Badoni and R. Bacheti, *Clinical Phytoscience*, 2018, **4**, 1–6.

[25] D. Lazaridis, A.-P. Kitsios, A. Koutoulis, O. Malisova and I. Karabagias, *Methods of Extraction and Beneficial Health Properties. Antioxidants*, 2024, **13**, 1335–1366.

[26] M. Azadfar, A. Gao, M. Bule and S. Chen, *Int J Biol Macromol*, 2015, **75**, 58–66.

[27] K. Soongprasit, V. Sricharoenchaikul and D. Atong, *Energy Reports*, 2020, **6**, 151–167.

[28] M. Aboul-Soud, H. Ennaji, A. Kumar, M. Alfhili, A. Bari, M. Ahamed, M. Chebaibi, M. Bourhia, F. Khallouki, K. Alghamdi and J. Giesy, *Antioxidants (Basel*, 2022, **11**, 1514–1531.

[29] S. Mahadkar, S. Valvi and V. Jadhav, *Asian J Pharm Clin Res*, 2013, **6**, 136–139.

[30] H. Manya Mboni, M. Faes, S. Fraselle, M. Compaore, B. Salvius, K. Joseph, P. Duez, L. Jean-Baptiste and C. Stevigny, *Heliyon*, 2023, **9**, 20103– 20117.

[31] D. Kim, S. Han, B. Go, U. Oh, C. Kim, Y. Jung, J. Lee and J. Kim, *Anticancer Res*, 2019, **39**, 6685–6691.

[32] K. Ramarao, Z. Razali, C. Somasundram, W. Kunasekaran and T. Jin, *Molecules*, 2024, **29**, 1762–1776.

[33] J. Jeong, S. Hong, H. Jeong and J. Koo, *Arch Pharm Res*, 2011, **34**, 2109–2116.

[34] E. Álvarez, E. Romano and A. Ledesma, *Journal of Molecular Structure*, 2024, **1317**, 139036–139045.

[35] S. Nandy, A. Hazra, D. Pandey, P. Ray and A. Dey, *Industrial Crops and Products*, 2021, **164**, 113375–113388.

[36] N. Yayli, G. Kilic, N. Kahriman, S. Kanbolat, A. Bozdeveci, S. Alpay Karaoglu, R. Aliyazicioglu, H. Erdinc Sellitepe, I. Selin Dogan, A. Aydin and G. Tatar, *Bioorg Chem*, 2021, **115**, 105183–105201.

[37] J. Chen, J. Yang, L. Ma, J. Li, N. Shahzad and C. Kim, *Sci Rep*, 2020, **10**, 2611–2620.

[38] V. Osipova, M. Polovinkina, Y. Gracheva, D. Shpakovsky, A. Osipova and N. Berberova, *Arabian Journal of Chemistry*, 2021, **14**, 103068–103079.

[39] R. Ruhee, L. Roberts, S. Ma and K. Suzuki, *Front Nutr*, 2020, **7**, 1–11.

[40] E. Mirhadi, M. Mirhadi, P. Kesharwani and A. Sahebkar, *PharmaNutrition*, 2024, **27**, 100382–100389.

[41] K. Barakat, Y. Gohar, H.-B. Ghonam and G. Bashir, *IRAN. J. MICROBIOL*, 2024, **16**, 666–675.

[42] A. Francioso, S. Dupré and M. Fontana, *Separations*, 2022, **9**, 45–64.

[43] H. Yousif, E.-M. M., M. Hassan and M. Mansour, *Kafkas Univ Vet Fak Derg*, 2024, **30**, 73–80.

[44] D. Rodríguez, L. García-Hernández, N. Rocha-Guzmán, M. Moreno-Jiménez, R. Rodríguez-García, M. Díaz-Jiménez, A. Sáenz-Galindo, J. Villarreal-Quintanilla, F. Peña-Ramos, M. Flores-López and D. Carrillo-Lomelí, *Industrial Crops and Products*, 2017, **107**, 489–498.

[45] A. Russo, M. Bruno, R. Avola, V. Cardile and D. Rigano, *Plants (Basel*, 2020, **9**, 1–19.

[46] L. Pastare, M. Berga, L. Kienkas, M. Boroduskis, A. Ramata-Stunda, D. Reihmane, M. Senkovs, G. Skudrins and I. Nakurte, *Antioxidants (Basel*, 2023, **12**, 1092–1117.

[47] J. Lu, Z. Jiang, J. Dang, D. Li, D. Yu, C. Qu and Q. Wu, *Foods*, 2024, **13**, 1865–1881.

[48] X. Wang, K. Dong, Y. Ma, Q. Jin, S. Yin and S. Wang, *Open Life Sci*, 2020, **15**, 251–258.

[49] S. Mosaddad, A. Hussain and H. Tebyaniyan, *Microorganisms*, 2023, **11**, 1269–1338.

[50] M. Flemming, B. Kraus, A. Rascle, G. Jurgenliemk, S. Fuchs, R. Furst and J. Heilmann, *Fitoterapia*, 2015, **106**, 122–128.

[51] D. Ma, J. He and D. He, *Biosci Biotechnol Biochem*, 2020, **84**, 402–410.

[52] R. Makhuvele, S. Gbashi and P. Njobeh, *Journal of King Saud University - Science*, 2022, **34**, 102278–102288.

[53] M. Davoodbasha, B. Edachery, T. Nooruddin, S. Lee and J. Kim, *Microb Pathog*, 2018, **115**, 233–238.

[54] M. Toorani, R. Farhoosh, M. Golmakani and A. Sharif, *Lwt*, 2019, **103**, 271–278.

[55] T. Ganesan, M. Subban, C. B., S. Kuppannan and P. Seedevi, *Biomass Conversion and Biorefinery*, 2022, **14**, 14547–14558.

[56] S. Chakraborty, S. Majumder, A. Ghosh, S. Saha and M. Bhattacharya, *Bulletin of the National Research Centre*, 2021, **45**, 1–12.

[57] V. Aparna, K. Dileep, P. Mandal, P. Karthe, C. Sadasivan and M. Haridas, *Chem Biol Drug Des*, 2012, **80**, 434–439.

[58] V. Salau, O. Erukainure, K. Olofinsan, B. Omotoso and M. Islam, *Medicine in Omics*, 2023, **8**, 100021–100034.

[59] A. Youssef, D. Maaty and Y. Al-Saraireh, *Molecules*, 2023, **28**, 3939–3963.

[60] M. El-Sheekh, N. Kasem, H. Alsoghier, A. Jillany, H. Galal and E. Alwaleed, *Bioactive Carbohydrates and Dietary Fibre*, 2024, **31**, 100403–100414.

[61] P. Patial, A. Sharma, I. Kaur and D. Cannoo, *Biocatalysis and Agricultural Biotechnology*, 2019, **20**, 101275–101289.

[62] N. Dolma, B. Shahar and N. Chongtham, *Measurement: Food*, 2024, **13**, 100144–100153.

[63] B. Bharath, K. Perinbam, S. Devanesan, M. AlSalhi and M. Saravanan, *Journal of Molecular Structure*, 2021, **1235**, 130229–130240.

[64] H. Schonherr and T. Cernak, *Angew Chem Int Ed Engl*, 2013, **52**, 12256–12267.

[65] R. Kavitha, G.-M. LEAF and F. TRICHOSANTHESIS, *International Journal of Pharmaceutical Sciences and Research*, 2021, **12**, 2755–2764.

[66] A. Borchers and T. Pieler, *Genes (Basel*, 2010, **1**, 413–426.

[67] X. Lin, N. Deng, H. Li, J. Duan, W. Chen, T. Liu, S. Sun and J. Chu, *Toxicol Appl Pharmacol*, 2024, **483**, 116836–116847.

[68] Y. Wang, H. Lu, L. Cheng, W. Guo, Y. Hu, X. Du, X. Liu, M. Xu, Y. Liu, Y. Zhang, R. Xi, P. Wang, X. Liu, Y. Duan, J. Zhu and F. Li, *Phytomedicine*, 2024, **132**, 155856–155873.

[69] H. Yang, J. Liu, Y. Chen, C. Chen, H. Lin, J. Lin, W. Chiu, J. Chen and T. Cheng, *Naunyn Schmiedebergs Arch Pharmacol*, 2005, **372**, 160–167.

[70] J. Queiroz, I. Medeiros, A. Trajano, G. Piuvezam, A. F. Nunes, T. Passos and A. A. Morais, *Food Chem*, 2022, **385**, 132593–132603.

[71] M. Ridho, A. Setiawan, A. Sarno, E. Patriono and Sulistiono, *Journal of Ecological Engineering*, 2020, **21**, 70–80.

NVVJ., Vol. 5, Issue (2), 2025

[72] M. Li, T. Zhu, R. Yang, Z. Wang, M. Liu and J. Yang, *Front Microbiol*, 2023, **14**, 1292937–1292951.

[73] M. Ashour, M. Mabrouk, H. Ayoub, M. El-Feky, S. Zaki, S. Hoseinifar, W. Rossi, H. Doan, E. El-Haroun and A. Goda, *Journal of Applied Phycology*, 2020, **32**, 3467–3479.

[74] A. Abdelaziz, A. Abdel-Maksoud, F. M., A. S., K. S., B. H. and A. Hashem, *PLoS One*, 2024, **19**, 0310298–0310318.

[75] S. Kumar, M. Arif, T. Jawaid, O. Al-Khamees, A. Anjum, S. Shafi, V. Thirunavukkarasu, S. Josephine, G. Muteeb, K. Singh and A. Qadir, *Intelligent Pharmacy*, 2023, **1**, 224–231.

[76] A. Muthulakshmi, R. Jothibai Margret and V. Mohan, *Journal of Applied Pharmaceutical Science*, 2012, **02**, 69–74.

[77] T. Johnson, K. Odoh, C. Nwonuma, A. Akinsanmi and A. Adegboyega, *Heliyon*, 2020, **6**, 03893– 03903.

[78] G. Babaei, A. Aliarab, S. Abroon, Y. Rasmi and S. Aziz, *Biomed Pharmacother*, 2018, **106**, 239–246.

[79] B. Hilal, M. Khan and Q. Fariduddin, *Plant Physiol Biochem*, 2024, **211**, 108674–108690.

[80] P. Gao, T. Hirano, Z. Chen, T. Yasuhara, Y. Nakata and A. Sugimoto, *Fitoterapia*, 2012, **83**, 490–499.

[81] J. Jeong and H. Jeong, *Biochem Biophys Res Commun*, 2010, **400**, 752–757.

[82] Y. Al-Saraireh, A. Youssef, A. Alsarayreh, T. Al Hujran, S. Al-Sarayreh, J. Al-Shuneigat and H. Alrawashdeh, *crude extracts. J. Pharm. Pharmacogn. Res*, 2021, **9**, 13–23.

[83] X. Jia, X. Yang, M. Xu, W. Tan, M. Yin, P. Liu and H. Tong, *Postharvest Biology and Technology*, 2023, **199**, 112297–112308.

[84] C. Bhuvaneshwari and S. Ambiga, *Journal of Current Opinion in Crop Science*, 2022, **3**, 79–89.

[85] M. Govindaraj, M. Suresh, T. Palaniyandi, S. Viswanathan, M. Wahab, G. Baskar, H. Surendran, M. Ravi and A. Sivaji, *Journal of Molecular Structure*, 2023, **1281**, 135178–135192.

[86] A. Nath, A. Kumer and M.-W. Khan, *Journal of Molecular Structure*, 2021, **1224**, 129225 –129233.

[87] A. Gonzalez, M. Valencia, R. Cervantes-Villagrana, A. Zapata and A. Cervantes-Villagrana, *Molecules*, 2023, **28**, 1–30.

[88] A. Nousheen, M. Chandrakanth, B. Sagar and V. Somarapu, *Journal of Molecular Structure*, 2022, **1261**, 132899 – 132914.

[89] A. Elaiyaraja and G. Chandramohan, *J Pharmacogn Phytochem*, 2016, **5**, 383–389.

[90] X. Chen, K. Hermansen, J. Xiao, S. Bystrup, L. O'Driscoll and P. Jeppesen, *PLoS One*, 2012, **7**, 34361– 34371.

[91] A. Deenadayalan, V. Subramanian, V. Paramasivan, V. Veeraraghavan, G. Rengasamy, S. Coiambatore, P. Rajagopal and S. Jayaraman, *Molecules*, 2021, **26**, 7689–7711.

[92] L. An, X. Fu, J. Chen and J. Ma, *International journal of molecular sciences*, 2023, **24**, 1173–1208.

[93] A. Jugran, S. Rawat, H. Devkota, I. Bhatt and R. Rawal, *Phytother Res*, 2021, **35**, 223–245.

[94] J. Hu, W. Huang, F. Zhang, X. Luo, Y. Chen and J. Xie, *Molecules*, 2020, **25**, 5046–5056.

[95] M. Abdelhamid, E. Kondratenko and N. Lomteva, *Journal of Applied Pharmaceutical Science*, 2015, **5**, 115–118.

[96] R. Settu, D. Selvaraj and I. Padikasan, *Food Bioscience*, 2021, **42**, 101154–101165.

[97] B. Bolar, J. George and G. Meshram, *World Journal of Pharmaceutical Research*, 2016, **6**, 696–704.

[98] K. Sangeetha, S. Sujatha, V. Muthusamy, S. Anand, K. Shilpa, B. Sarathkumar, G. Thiyagarajan and B. Lakshmi, *Bioinformation*, 2017, **13**, 394–399.

[99] T. Ongtanasup, N. Prommee, O. Jampa, T. Limcharoen, S. Wanmasae, V. Nissapatorn, A. Paul, M. Pereira, P. Wilairatana, N. Nasongkla and K. Eawsakul, *The Cholesterol-Modulating Effect of the New Herbal Medicinal Recipe from Yellow Vine*, 2022, Carthamus tinctorius L.) on Suppressing PCSK9 Expression to Upregulate LDLR Expression in HepG2 Cells. Plants (Basel),.

[100] A. Reshma, T. Tamilanban, V. Chitra, V. Subramaniyan, G. Gupta, N. Fuloria, M. Sekar, S. Fuloria, R. Sahu, J. Narayanan, S. Chakravarthy and S. Selvaraj, *Sci Rep*, 2023, **13**, 18449–18470.

[101] A. Balkrishna, M. Joshi, Y. Varshney, S. Verma, P. M, P. Nain and A. Varshney, *J Pharm Biomed Anal*, 2024, **251**, 116444–116453.

[102] B. Huwaimel, K. Younes, A. Abouzied, A. Elkashlan, F. Alheibshy, A. Alobaida, A. Turki, S. Alquwaiay, N. Alqahatani and S. Alsuwayagh, *Sci Rep*, 2024, **14**, 25462–25476.

[103] H. Zeng, S. He, Z. Xiong, J. Su, Y. Wang, B. Zheng and Y. Zhang, *Carbohydr Polym*, 2023, **314**, 120939–120954.

[104] T. Nehere, P. Kolhe, R. Khawale and S. Chakorkar, *Indo American Journal of Pharmaceutical Research*, 2023, **13**, 1206–1218.

[105] A. Zhu, D. Xu, Q. Li, W. Li, X. Zhang and X. Yan, *Aquaculture*, 2024, **592**, 741166–741178.

[106] K. Zhang, Y. Yao, M. Wang, F. Liu, Q. Wang, H. Ma, Y. Xie, Y. Ma, P. Dai, C. Zhu and C. Lin, *Phytomedicine*, 2021, **91**, 153683–153698.

[107] T. Ikegami and Y. Matsuzaki, *Hepatol Res*, 2008, **38**, 123–131.

[108] M. Khosravi, *Front Psychiatry*, 2021, **12**, year.

[109] S. Carotti, M. Guarino, M. Cicala, G. Perrone, R. Alloni, F. Segreto, C. Rabitti and S. Morini, *Neurogastroenterol Motil*, 2010, **22**, 866–874.

[110] H. Cha, S. Jeon, H. Jang, J. Shin, Y. Kim and S. Suh, *Neurosci Lett*, 2018, **676**, 66–70.

[111] R. Gračan, S. Blažević, M. Brižić and D. Hranilovic, *Biomedicines*, 2024, **12**, 357–374.

[112] H. Ibrahim, A. Uttu, M. Sallau and O. Lyun, *Beni-Suef University Journal of Basic and Applied Sciences*, 2021, **10**, 1–8.

[113] D. Adams, M. Midei, J. Dastgir, C. Flora, R. Molinari, F. Heerinckx, S. Endemann, P. Atwal, P. Milner and M. Shchepinov, *JIMD Rep*, 2020, **54**, 54–60.

[114] S. Poochi, M. Easwaran, B. Balasubramanian, M. Anbuselvam, A. Meyyazhagan, S. Park, H. Bhotla, J. Anbuselvam, V. Arumugam, S. Keshavarao, G. Kanniyappan, M. Pappusamy and T. Kaul, *Food Front*, 2020, **1**, 168–179.

[115] I. Arsana, N. Juliasih, A. Widyantari, N. Suriani and A. Manto, *Cellular, Molecular and Biomedical Reports*, 2022, **2**, 151–161.

[116] d.-S. Bruno, K. Gangadhar, J. Macridachis, M. Pavão, T. Morais, L. Campino, J. Varela and J. Lago, *Tetrahedron: Asymmetry*, 2017, **28**, 1486–1505.

[117] T. Tran, P. Ha, R. Henry, D. Nguyen, P. Tuyen and N. Liem, *J Microbiol Biotechnol*, 2024, **34**, 94–102.

[118] D. Dubey, R. Patnaik, G. Ghosh and R. Padhy, *Osong Public Health Res Perspect*, 2014, **5**, 298–312.

[119] H. Abdel-Hady, M. Abdel-Wareth, E. El-Wakil and E. Helmy, *pharmaceuticals*, 2016, **5**, 2021–2039.

[120] T. Benoite and N. Vigasini, *Asian Journal of Biological and Life Sciences*, 2021, **10**, 217–224.

[121] R. Sunitha, G. Gayathry, P. Maheshwari, K. Ganesan, M. Suganthy, S. Padmapriya, S. Shenbagavalli and A. Bharani, *Indian Journal of Animal Research*, 2023, **B-5204**, 1–7.

[122] M. Sadeghi, M. Khomartash, S. Gorgani-Firuzjaee, M. Vahidi, F. Khiavi and P. Taslimi, *Arabian Journal of Chemistry*, 2022, **15**, 104055–104070.

[123] H. Gazwi, M. Omar and M. Mahmoud, *BMC Chem*, 2023, **17**, 1–14.

[124] K. Malathi, A. Anbarasu and S. Ramaiah, *Indian journal of pharmaceutical sciences*, 2016, **78**, 780–788.

[125] K. Sharath and R. Naika, *Indian J. Applied and Pure Bio*, 2022, **37**, 524–530.

[126] I. Ahmad, S. Ahmed, E. Akkol, H. Rao, M. Shahzad, U. Shaukat, A. Basit and M. Fatima, *Johnst. (Cenizo). South African Journal of Botany*, 2022, **148**, 200–209.

[127] A. Al-Rajhi, H. Qanash, M. Almuhayawi, S. Al Jaouni, M. Bakri, M. Ganash, H. Salama, S. Selim and T. Abdelghany, *Molecules*, 2022, **27**, 4824–4850.

[128] N. El-Desoky, N. Hashem, A. Elkomy and Z. Abo-Elezz, *Animal*, 2017, **11**, 1549–1557.

[129] T. Luo, Z. Deng, X. Li, H. Rao and Y. Fan, *Lipids*, 2014, **49**, 495–504.

[130] S. Kandasamy, S. Chinnappan, S. Thangaswamy, S. Balakrishnan and A. Khalifa, *International Journal of Peptide Research and Therapeutics*, 2019, **26**, 1575–1581.

[131] D. Kamel, A. Mansour, M. El-Diin, A. Hammam, D. Mehta and A. Abdel-Rahman, *Foods*, 2022, **11**, 1–22.

[132] M. Imran, A. Iqbal, A. Al-Huqail, S. Alghanem, S. Badshah, S. Alghamdi, M. Almehmadi, U. Algopishi, B. Ali, S. Sohni, M. Javed and D. Darwish, *South African Journal of Botany*, 2024, **171**, 695–709.

[133] S. Orabi, E. Al-Sabbagh, H. Khalifa, M. Mohamed, M. Elhamouly, S. Gad-Allah, M. Abdel-Daim and M. Eldaim, *Nutrients*, 2020, **12**, 1–19.

[134] D. Das, G. Dutta, J. Jahnavi, P. Patra, O. Bhuniya, A. Ramlal and A. Samanta, *Nutrire*, 2024, **49**, 1–6.

[135] H. Hussein, H. Mohamad, M. Ghazaly, A. Laith and M. Abdullah, *Journal of King Saud University - Science*, 2020, **32**, 3486–3494.

[136] A. Salman, S. Alkhatib, F. Ahmed and R. Hamouda, *Pharmaceutics*, 2023, **15**, 2551–2570.

[137] D. Rodríguez, L. García-Hernández, N. Rocha-Guzmán, M. Moreno-Jiménez, R. Rodríguez-García, M. Díaz-Jiménez, A. Sáenz-Galindo, J. Villarreal-Quintanilla, F. Peña-Ramos, M. Flores-López and D. Carrillo-Lomelí, *Industrial Crops and Products*, 2017, **107**, 489–498.

[138] Y. Rehman, A. Iqbal, G. Ali, G. Alotaibi, A. Ahmed and M. Ayaz, *BMC Complementary Medicine and Therapies*, 2024, **24**, 1–14.

[139] S. Bashir, S. Behiry, A. Al-Askar, P. Kowalczewski, H. Emaish and A. Abdelkhalek, *Open Life Sci*, 2024, **19**, 20220962–20220976.

[140] M. Duraisamy and R. Selvaraju, *Aegaeum J*, 2020, **8**, 1437–1457.

[141] G. Hase, K. Deshmukh, R. Pokharkar, T. Gaje and N. Phatanagre, *International Journal of Pharmacognosy and Phytochemical Research*, 2017, **9**, 885–891.

[142] Y. El-Amier, H. ElHalawany and B. El-Nabawy, *Egyptian Journal of Chemistry*, 2022, **65**, 933 – 940.