

Gamma-irradiation effect on the chemical composition and antibacterial activity of the Moroccan *Tanacetum Annuum* L. Essential Oil

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Abstract

The study aims to evaluate the Moroccan *Tanacetum annuum L.* essential oil by studying the effect of gamma irradiation on both the chemical composition and antibacterial activity, this is done by exposing the oil extracted from the dry aerial parts of the plant by hydrodistillation to irradiation dose of 5kGy and 10kGy.

The obtained results proved that irradiation technology can actually raise the percentage of chemical compounds that would increase the biological activity of the essential oil. This allows to increase the potential of the plant studied and its biological effectiveness, also the irradiation process has proven the ability to raise the quality of the chemical composition both in terms to reduce the risk of contamination it can be microbiological, physical, and chemical of one of the most abundant medicinal plants in northern Morocco.

1. Introduction

The wealth of Morocco in aromatic and medicinal plants (AMPs) means that the study of Moroccan flora presents a "fundamental" scientific interest for knowledge in the field of ethnobotany, and traditional pharmacopeia but also an "applied" scientific interest. in the field of the valorization of natural substances. The food, cosmetics, and pharmaceutical industries are also very interested in the properties of the active compounds of AMPs, especially since they are flavoring agents and natural preservatives. As a result, many researchers around the world are investigating their potential as a preservative (Burt, 2004). Most of these compounds are also very good natural antifungal and antibacterial agents used for food preservation due to their safety and the emergence of antibiotic-resistant pathogenic microorganisms. Many researchers have highlighted the effectiveness of these natural bioactive substances (Puškárová et al., 2017).

On the other hand, AMPs are susceptible to microbial contamination because of the infection-causing, microorganisms during the stage of collection, processing, transportation, drying, and storage which may cause changes, whether physical or chemical in their properties, or in their metabolites. There are many methods of decontamination but the most diverse treatment is treated with gamma irradiation.

Gamma rays as a phytosanitary remedy have been shown to be effective and safe in promoting the hygienic quality of different nutrients and herbs to extend their shelf life (World Health Organization, 1989).

Based on these findings, we were interested in studying the effect of radiation on the chemical profile and antibacterial activity of the *Tanacetum annuum L.* (*T.annuum L.*) essential oil (EO).

2. Materials And Methods

2.1. MATERIALS

2.1.1. Plant material

The aerial parts (leaves, stems and flowers) of *T.annuum L.* were collected from the natural population located in the region of Tanger-Tétouan-Al Hoceima, (northern Morocco) called Beni Aerousse in July 2021. The identification of the species was produced by the scientific institute in Rabat under the barcode: **RAB113321**.

The plant material, picked, was dried in the open air, at room temperature (25°C) in the shade until its weight stabilized. The parameters concerning the plant that we used during our experimentation are:

Table.1. Parameters concerning *Tanacetum annuum L.* plant

Species	Parts used	State	Mass in grams	Mass in EO	Harvest date	Drying time
<i>Tanacetum annuum L.</i>	Leaves stems and flowers	Dried	2164,48	5,06 g	13-07-2021	7 days

2.1.2. Microbiological material

Cultures of *Staphylococcus aureus* ATCC 29213 and *Escherichia coli* ATCC 25922 obtained from the Epidemiological Laboratory of Fez were used in the study. The slanted nutrient agar (Fluka, Seelze, Germany) cultures were activated by transfer to a nutrient agar medium (Fluka, Seelze, Germany) and then incubated at $35 \pm 2^\circ\text{C}$ for 24 h.

Table.2. Characteristics of the microbial strains tested.

A bacterial strain	n° ATCC	Gram	Family	Main infections caused	Backgrounds culture
Escherichia coli	25922	-	Enterobacteriaceae	- diarrhea -dysenteriformes. -Gastroentérites.	Mueller-Hinton
Staphylococcus aureus	29213	+	Micrococcaceae	- Gastroenteritis; - Urinary tract infections; - Osteomyelitis and arthritis.	Mueller-Hinton

2.2. METHODS

2.2.1. Essential oil extraction

The hydrodistillation process using a Clevenger type instrument based on the method previously described by the British Pharmacopoeia has been approved (British pharmacopoeia 1993. *Volume II*, 1993). Then, the process of drying the EOs samples over anhydrous sodium sulfate followed, and they were then placed in dark glass vials in a refrigerator at 4°C until they are used in the various analyses to be performed. Finally, the EO yield was estimated.

2.2.2. Treatment by irradiation of samples

For gamma irradiation, *T.annuum L.* EO was packaged in 5 ml glass vials for a total of 32 vials as shown in Fig. 1, and then exposed to 5 and 10 kGy gamma irradiation at room temperature (20°C) at the Boukhalef ionization station (SIBO) of Tangier-Morocco, by using the radioactive sources of cobalt-60.

To ensure that the vials receive the desired doses, dosimetry work was performed in which similar vials (of the same composition, position, and packaging) were irradiated to determine dose rate and also dose uniformity. The EPR/alanine dosimetry system manufactured by ADANI was used. This system is considered as a reference system for the dose measurement in the interval (50Gy-100kGy), due to its advantageous metrological properties ("ISO/ASTM 51607:2013(en), Practice for using the alanine-EPR dosimetry system," n.d.). Because such systems allow for very reproducible and stable measurements (Aknouch et al., 2020b), the uncertainties in the experimental dose were rather low and amounted to 3.5% (Nasreddine et al., 2021). Alanine is an amino acid, and alanine dosimeters are in the granules form with a nominal diameter of 5.0 mm and a thickness of about 2.3 mm, their irradiation produces free radicals, the concentration of these is proportional to the absorbed dose, and measured by instrumentation is called electron paramagnetic resonance spectrometer (EPR) (Aknouch et al., 2020a).

Immediately after irradiation, the EOs were extracted and stored at (-18°C) for later use.

2.2.3. Analysis of irradiated and non-irradiated essential oils by GC-MS

For the species *T.annuum L.*, GC-MS analysis was carried out in (LIMOME) Laboratory. Below is the protocol applied for the analysis of the irradiated and un-irradiated samples of the specie *T.annuum L.*:

- **Gas Chromatography Type:** GCMS-TQ8040 NX (Shimadzu brand)
- **Type of detector:** TRIPLE quadrupole
- **Column:** Apolar capillary RTxi- 5 Sil MS – 30m x 0.25mm ID x 0.25 µm
- **Gas used:** Helium
- **injection volume:** 1 Microlitre (µl)

- **source temperature:** 200°C
- **Interface temp:** 280°C
- **Injection mode:** splitless
- **opening of the split at** 3.5 min
- **Injection temperature:** 250°C
- **Pressure:** 37.1 kPa
- **Temperature program:** Ti = 50°C for 2 min
- **Ramp 1:** 5°C/min up to 160°C for 2 min
- **Ramp 2:** 5°C/min up to 280°C for 2 min
- **Analysis time:** 50min
- **Diluting solvent:** Hexane

The GC/MS analyzes were carried out within the NIAR Institute in Tangier using a gas chromatograph coupled with a mass spectrophotometer (GC-MS) operating in electron impact mode (70 eV, m/z 40–450).

The capillary column used: 1MS (30m x 0.25mm x 0.25µm film thickness).

The analytical conditions were:

Injector and transfer line temperatures 250 and 300°C, respectively, oven temperature programmed 50 to 200°C at 10°C/min and 200 to 290°C at 35°C/min,

Helium carrier gas, at 1mL/min, injection of 1 µl (10% hexane solution),

The split ratio was 1h20.

2.2.4. Antimicrobial activity

Agar disk diffusion method

The antibacterial activity of EOs was carried out against bacterial strains by using the diffusion method on an agar disc (Ouedrhiri et al., 2016).

A fresh bacterial suspension prepared in sterile saline solution and adjusted to 0.5 McFarland was served for inoculation of Mueller Hinton Agar plates plates (Biokar diagnostics, Beauvais, France). Then, 10 µL of EO was impregnated in sterile Whatman paper discs (6 mm in diameter) and applied to the surface of

each plate. Incubation of the plates was at 37 °C for 18 to 24 h. Control test discs were soaked in 5 µL of sterile water. The measurement of the diameters of the zones of inhibition was in millimeters. However, all the experiments were performed in triplicate.

3. Results And Discussion

3.1. EO yield

The yield of EO obtained by of the aerial parts of *T.annuum* L. after 7 days of drying is 0.23%, which is lower than that of the EO of the same species with the same drying time which is 1.0% reported by Greche et al, (Greche et al., 2000). as well as that found by A. Zaim et al., and which corresponds to 1.2%.(Zaim et al., 2015)

By comparing our yield with those of other species of the same genus *Tanacetum*, so that it is relatively higher than that obtained for the two other species of this genus, namely *T.aucheranum* which was (0.15%) and for *T. chiliophyllum* was (0.22%) from Turkey (Salamci et al., 2007).

On the other hand, the scientific work of Rohloff et al., shows that the EO yield of harvested and cultivated tansy plants varied between 0.35 and 1.90% (v/w) with an average value of 0, 81% (Rohloff et al., 2004) . However, the study reported by Zeynep Ulukanli et al, showed that the EO yield was 0.4% for the same parts of *Tanacetum cilicicum* (v/w).(Ulukanli et al., 2017)

3.2. The chemical composition of the EO of *Tanacetum annuum* L.

In this study, the Moroccan Species *T. annuum* L., and the hydro-distilled essential oils of the aerial parts subjected to 5kGy and 10kGy irradiations are subsequently analyzed by GC-MS.

The composition of the EO of the Moroccan species *T.annuum* L. studied and those reported by the bibliography on the same species harvested in the same region are grouped in the table below:

Table.3.: The chemical constituents of the EOs of T. annuum obtained by hydrodistillation from the Tangier region (EO₁: studied, EO₂: Grech et al., EO₃: Zaim et al.

N°	Compound name	EO ₁	EO ₂	EO ₃
1	α-Thujene	-	-	0,25
2	α-Pinene	2.12	1,3	2,16
3	Camphene	0.94	0,5	1,01
4	Sabinene	14.39	8,1	9,49
5	β-pinene	5.27	2,7	7,70
6	β-Myrcene	2.49	3,1	13,67
7	α-phellandrene	5.10	2,0	6,95
8	δ-3-Carène	-	-	0,87
9	α-terpinene	0.76	0,5	0,79
10	p-Cymene	8.87	1,6	-
11	O-Cymene	-	-	0,42
12	D-Limonene	3.21	1,1	3,78
13	Camphenilone	-	-	0,70
14	1,8-cineole	1.07	0,8	-
15	γ-Terpinene	1.30	-	1,65
16	Terpinoline	-	-	0,28
17	Linalool	-	-	0,57
18	Hydrate de trans-Sabinene	-	-	0,34
19	Trans Pinan-2-ol	-	-	0,13
20	All-Ocimene	-	-	0,49
21	Cis-β-dihydro Terpeneol	-	-	0,16
22	Camphre	-	10,6	12,67
23	Camphor	14.21	-	-
24	β-Terpineol	-	-	0,17
25	Borneol	2.67	1,7	4,79
26	• 4-terpineol	2.06	2,1	2,89
27	• α-Terpineol	-	0,2	0,24
28	Polygone	-	-	0,19

N°	Compound name	EO ₁	EO ₂	EO ₃
29	γ-Terpinen-7-al	-	-	1,04
30	Iso-Longifollene	-	-	0,17
31	Thymol	1.43	1,0	-
32	β-Elemene	-	0,5	-
33	β-Caryophyllene	2.22	1,0	2,13
34	β-Farnesene	-	0,1	1,60
35	α-Humulene	-	-	0,23
36	Valencene	-	0,6	0,50
37	α-Farnesene	-	-	0,34
38	β-Sesquiphellandrene	1.79	-	-
39	Germacrene D	1.30	-	1,38
40	3,6-Dihydrochazulene	6.95	7,2	2,18
41	δ-Cadinene	-	-	0,23
42	Elemol	-	-	0,46
43	Oxyde de Caryophyllene	-	0,5	-
44	5,6-Dihydrochazulene	0,72	3,1	0,25
45	7,12-deshydro-5,6,7,8-tetrahydro Chamazulene	-	2,5	-
46	β-eudesmol	1.58	5,5	0,45
47	Chamazulene	17.74	24,2	5,87
48	9-(15,16-dihydro-15-méthylène)-α-Terpinene	-	0,3	-
49	9-(15,16-dihydro-15-methylene)-p-Cymene	-	1,5	-
50	Geranyl-α-terpinene	1.82	-	-
	Monoterpene Hydrocarbons	44,45	31,50	61,09
	Oxygenated monoterpenes	21,41	05,80	11,22
	Non-aromatic sesquiterpenes	06,89	09,90	07,49
	Aromatic sesquiterpenes	25,41	37,00	08,30
	Diterpene	01,82	-	-
	Total	99,98%	84,20%	88,10%

The GC-MS analysis of the EO showed that the oil studied resulted in the identification of 22 constituents, accounting for 99,98% of the total oil composition., consisting of 65.86% of monoterpenes, of which approximately 21.41% are oxygenated with the presence in particular of 14.39% of Sabinene, 14 .21% of Camphor, 8.87% of P-Cymene, 5.27% of β -Pinene and 5.10% of α -phellandrene, next to 31.58% of sesquiterpenes, the majority of which are aromatic hydrocarbons of the Chamazulene family responsible for the blue color of this EO and in particular chamazulene (17.74%) and its derivatives 3,6-Dihydrochazulene (6.95%) and 5,6-Dihydrochazulene (0.72%) which are found next to a diterpene geranyl- α -terpinene (1.82%).

Grech et al. (Greche et al., 2000), have identified more than 27 constituents, the majority of which are found in our EO with variable proportions and we note according to Table 3, the presence in the oil studied of the monoterpene Camphor with a proportion of 8.87% instead of Camphor and that this oil is much richer in Sabinene and p-Cymene and less rich in chamazulene.(Greche et al., 2000)

The study by Zaim et al (Zaim et al., 2015). made on the same species harvested in the same region, showed that the chemical composition of the EO they studied is much richer in monoterpene hydrocarbons and lower in particular in aromatic sesquiterpenes such as chamazulene and its derivatives. .As this oil is mainly made up of compounds such as myrcene with a percentage of (13.67%), camphor with (12.67%), sabinene (9.49%), β -pinene (7.70%), α - phellandrene (6.95%) as well than chamazulene (5.87%). The other compounds were identified with relatively large percentages, such as borneol (4.79%) and limonene (3.78%), Terpinene-4-ol (2.89%), 3,6-dihydrochamazulene (2.18%), α -pinene (2.16%), and β -caryophyllene (2.13%) have rate that vary between 2 and 3%. The remaining percentages of other constituents are less than 2%. Note that the EO of the same species harvested in the Larache area (Haddar et al., 2008), is much lower in myrcene (6%) and also in chamazulene (2.8%), but so richer in sabinene (22.3%), as well as the β -pinene (10.1%) and p-cymene (8.9%). These data also show that the chemical profile of the EO studied is relatively different from that of the EO extracted from the same species (Barrero et al., 1992) that is characterized by the following main components: the myrcene and the α -phellandrene (18%), also chamazulene (11%), camphor (10%), β -pinene (7.5%) and sabinene (5.5%), and contains only 1.1% limonene with the remarkable absence of borneol.

This study showed that the EO of *Tanacetum annuum* L. compared to the oils of other species of the same genus *Tanacetum*, is characterized by the presence of chamazulene and its derivatives responsible for the blue coloring of its EO and in addition comparing the chemical profile of the oil studied with those of other oils of the same species, reported by the bibliography., it was found that the studied oil (table 3) is much richer in oxygenated monoterpenes and with a considerable percentage of Chamazulene which makes it likely to have important biological activities.

The results of the analysis by the technique of GC-MS of EOs irradiated by γ radiation at doses of 5kGy and 10kGy are grouped in the table below:

Table.4.: Variation in the chemical composition of irradiated and non-irradiated EOs of T. annuum L. as a function of irradiation doses

N°	RT	compound name	un-irradiated EO	EO irradiated at 5KGy	EO irradiated at 10KGy
1	7,936	α -Pinene	2.12	2.06	1.17
2	8,411	Camphene	0.94	0.93	0.54
3	9,067	Sabinene	14.39	13.12	9.20
4	9,221	β-pinene	5.27	4.91	3.43
5	9,529	β -Myrcene	2.49	2.10	1.95
6	10,055	α-phellandrene	5.10	4.33	2.75
7	10,378	α -terpinene	0.76	0.64	-
8	10,599	p-Cymene	8.87	8.44	9.75
9	10,752	D-Limonene	3.21	2.71	2.48
10	10,850	1,8-cineole	1.07	1.97	4.97
11	11,625	γ -Terpinene	1.30	1.21	1.20
12	14,295	Camphor	14.21	14.62	18.69
13	15,036	Borneol	2.67	2.77	3.70
14	15,285	α-4-terpineol	2.06	2.04	2.81
16	18,335	Thymol	1.43	1.48	1.93
17	21,930	Caryophyllene	2.22	2.21	2.99
18	22,395	β -Sesquiphellandrene	1.79	1.79	2.51
19	23,465	Germacrene D	1.30	1.43	1.64
21	24,156	3,6-Dihydrochazulene	6.95	6.59	4.19
22	24,467	β -Sesquiphellandrene	-	0,61	1,07
23	27,085	5,6-Dihydrochazulene	0,72	-	-
24	28,262	β-eudesmol	1.58	1,83	2.69
27	30,250	Chamazulene	17.74	17.67	15.08
28	36,520	geranyl- α -terpinene	1.82	1.94	2.33

N°	RT	compound name	un-irradiated EO	EO irradiated at 5KGy	EO irradiated at 10KGy
		Monoterpene Hydrocarbons	44,45	40,45	32,47
		Oxygenated monoterpenes	21,41	22,88	32,1
		Non-aromatic sesquiterpenes	6,89	7,87	10,09
		aromatic sesquiterpenes	25,41	24,26	19,27
		Diterpene	1,82	1,94	2,33
		Total	99,98%	97,40%	96,26%

The analysis showed that there is a variation in the percentages of the majority of these constituents accompanied by the appearance and disappearance of certain minor constituents. In particular, depending on the increasing dose of irradiation, there is a significant decrease in the percentages of non-aromatic monoterpene hydrocarbons, in particular; the α -Pinene, Camphene, Sabinene, β -Pinene, β -Myrcene, α -terpinene, D-Limonene and the γ -terpinene. Thus, an increase in p-Cymene and oxygenated monoterpen, as, 1,8-Cineole, Borneol, Camphor, 4-terpineol, and Thymol. As well as for the sesquiterpene hydrocarbons next to the oxygenated sesquiterpene β -eudesmol and the diterpene geranyl- α -terpinene. However, the percentage of aromatic sesquiterpenes of the Chamazulene family has undergone a significant decrease such as chamazulene and 3,6-Dihydrochazulene (6.95%) on the other hand note the disappearance of 5,6-Dihydrochazulene which was in the non-irradiated oil with a very low percentage (0.72%).

According to the above Fig. 2, so in particular the reduction in the percentages of monoterpene hydrocarbons and aromatic sesquiterpenes and the increase in oxygenated monoterpenes due to gamma irradiation which has significant energies which can cause the ionization of the material they contain. This converts atoms and molecules into ions and radicals which promote their oxygenation.

Referring to the studies carried out on this oil and taking into account the change which characterizes the chemical profile of the EO of this genus in general and in particular of the species *Tanacetum annuum* L., we can say that our oil is characterized by a high percentage of the chemical compounds it contains as shown in Fig. 3, also as we see, for example, for H. Greche et al, found that more than 130 compounds, representing about 90% of the oil, have been identified. Chamazulene was the major component of the oil (28%), while of the 16 monoterpene hydrocarbons identified (23.1%) the most important were sabinene (6.4%), β -pinene (3.1%) and myrcene (4.4%), and 3,6-dihydrochamazulene (3.7%) (Greche et al., 1999).

The same author granted in a study following the previous study that the chemical composition of the EO of *Tanacetum annuum* L. is characterized by sabinene (22.3%), camphor (13.2%) β -pinene (10.1%), P-cymene (8.9%) as major compounds (Greche et al., 2000).

S. El Haddar et al, in their study showed that the EO of the same species harvested in the region of Larache (north-west of Morocco) was very poor in myrcene (6%) and chamazulene (2.8%), but richer in sabinene (22.3%), β -pinene (10.1%) and p-cymene (8.9%) (Haddar et al., 2008)

A.Zaim et al, worked on the Moroccan species of *Tanacetum annuum* L. They had managed to the results whose main compounds were myrcene (13.67%), camphor (12.67%), sabinene (9.49%), β -pinene (7.70%), α -phellandrene (6.95%) and chamazulene (5.87%) (Zaim et al., 2015) .

For the oil which has undergone the dose of 5 kGy of irradiation, it was found that the chemical composition was similar to the non-irradiated oil with a slight difference in the proportions of certain compounds as shown in Fig. 4 such as chamazulene which has gone from (17.74%) to (17.67%), Sabinene decreases from (14.39%) to (13.12%), a remarkable increase in Camphor from (14.21%) to (14.62%), a decrease in p-cymene (8.87%) to (8.44%), also 3,6-Dihydrochazulene decreased from (6.95%) to (6.59%), as well as β -pinene from (5.27%) to (4.91%), α -phellandrene from (5.10%) to (4.33%), and d-limonene from (3.21%) to (2.71%), although borneol which saw an increase from (2.67%) to (2.77%).

Concerning the EO irradiated at 10 kGy, the change was very notable in terms of the chemical composition because a considerable modification is noted in the percentage of the chemical compounds of the EO as shown in Fig. 5. After chamazulene was the chemotype of non-irradiated EO and that irradiated at 5 kGy, Camphor became the major compound of irradiated oil at 10 kGy with a percentage of (18.69%), and chamazulene was ranked as the second major compound with a percentage of (15.08%), p-cymene also with (9.75%) became the third major compound characterizing the oil, Sabinene likewise saw an increase towards (9.20%), the 1,8-cineole went from (1.07%) in the case of the non-irradiated oil, to (1.97%) for the EO irradiated at 5kGy and to (4.97%) at 10kGy of irradiation, on the other hand 3,6-Dihydrochazulene is reduced from (6.95%) for non-irradiated EO to (6.59%) for that irradiated at 5kGy and to (4.19%) for the EO irradiated at 10kGy, borneol with a high percentage of (3.70%) compared to the non-irradiated state of the oil which had (2.67%) and (2.77%) for EO irradiated at 5kGy, a continuous decrease for β -pinene having (3.43%) as the percentage tag instead of (5.27%) before irradiation and (4.91%) at 5kGy of irradiation, caryophyllene experienced a successive increase of (2.22%), (2.21%), and of (2.99%), as well as 4-terpineol of (2.06%), (2.04%), and (2.81%), for the non-irradiated EO, irradiated at 5kGy and irradiated at 10kGy respectively, although the α -phellandrene percentage is successively decreased from (5.10%), to (4.33%), and to (2.75%) .

3.3. Antibacterial power of irradiated and non-irradiated essential oils of *Tanacetum annuum* L.

The results of the microbial activity inhibition tests are shown in Table.5. The values given are the average of three tests. The statistical analysis of the results is carried out with the "ANOVA" application using STATISTICA 5.5 software and the significance threshold is set at $P < 0.05$.

Table.5. Inhibition diameters

Inhibition Diameters in mm		
	Staphylococcus aureus ATCC	Escherichia coli ATCC
Un-irradiated EO	22.33 ± 0.44	42.00 ± 0.66
Irradiated EO at 5kGy	39.33 ± 1.55	40.00 ± 0.00
Irradiated EO at 10kGy	35.66 ± 2.22	40.66 ± 1.55

These results show that the EO of non-irradiated *T.annuum L.* showed an inhibitory effect against *Escherichia coli*. Zones of inhibition ranging from 06.00 mm to 42.00 mm are observed, which could indicate a very good bactericidal activity of this oil against this strain.

For oils of *T. annum L.* irradiated at 5kGy and 10kGy A slight decrease in the diameter of inhibition is noted, which can allow us to say that the antibacterial activity against *E. coli* remained constant between the oil non-irradiated with an inhibition diameter of 42.00 mm and the oil which underwent irradiation at 5kGy with a diameter of 40.00 mm and 40.66 mm for that irradiated at 10kGy.

Concerning the activity of EO of *T.annuum L.* on *Staphylococcus aureus*, it noted that the inhibition diameters of 06.00 to 22.33mm obtained for the crude oil of *T. annum L.* not irradiated on the one hand, on the other hand there is a significant increase in antibacterial activity when using the oil which has been subjected to irradiation at the dose of 5kGy, where the length of the inhibition diameter reaches 39.33mm after it was 22.33 mm before irradiation, then the length of the inhibition diameter was found to decrease to 35.66 mm at the 10kGy dose.

By this, which allows to make a deduction that irradiation can increase the antibacterial effect of EO against *Staphylococcus aureus* at doses below 10kGy.

This is what reminds of the central objective of this research and its prospects, which is to determine the optimal dose which makes it possible to obtain a concentrated chemical composition with compounds of great effectiveness and thus to increase the biological activity. oil and why not the anticorrosion activity too. By comparing the susceptibility of the two strains to the oils tested, so that the effectiveness of the oil differs from one bacterium to another as well as to the type of oil, whether it is irradiated or not. *Escherichia coli* is the most resistant of the non-irradiated oil, however, *Staphylococcus aureus* is the most sensitive to the non-irradiated oil tested while the antibacterial efficacy of the irradiated oils is highly convergent against both bacteria.

This important bioactivity of the essential oils of *T.annum L.*, studied is related to its chemical composition. Indeed (Faleiro, 2011). On the other hand, the *T.annum L.* oil exhibits remarkable efficacy. This can be attributed to its content of Chamazulene, sabinene and comphor.

It is also likely that this antibacterial effect is not due to the sole presence of specific substances but, as a result of the interaction between various aromatic structures, these molecules would most often act

through a synergistic action, either alone within the essential oil. In addition to these major compounds, minor compounds can contribute significantly to the activity of essential oils (Ashby et al., 2011).

4. Conclusion

These results constitute a scientific basis that justifies the traditional use of *T.annuum L.* in Morocco. The work presented in this article represents our humble contribution to the study pharmacology of this plant. This is why more research is needed to identify these constituents by widening the range of irradiation doses. This will isolate and determine the active principles of *T.annuum L.* and finally to select highly valuable varieties and define/determine their action mechanism aims to promote one of the plants that grow widely in Morocco country.

Declarations

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Competing interests The authors declare they have no conflict of interest.

Authors' contributions

Hasna BELCADI: the author and lead editor of the article and processor for research findings and analysis.

Adil AKNOUCH: presented various experimental proposals related to irradiation and also processed the results of research and analysis of irradiation.

Soukayna EL AMRANI: contributed to the completion of experiments related to antibacterial activity.

Anas CHRAKA: helped with the technical aspect of drafting the article.

Mohammed LACHKAR: supervised the chromatographic analysis of essential oil samples

Mohamed MOUHIB and Said ZANTAR: supervised the irradiation of samples in the laboratory

Ahmed IBNMANSOUR: the owner of the idea of the article and its general supervisor and analysis were performed by him.

All authors read and approved the final manuscript.

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Figures



Figure 1

Distribution of samples exposed to gamma rays

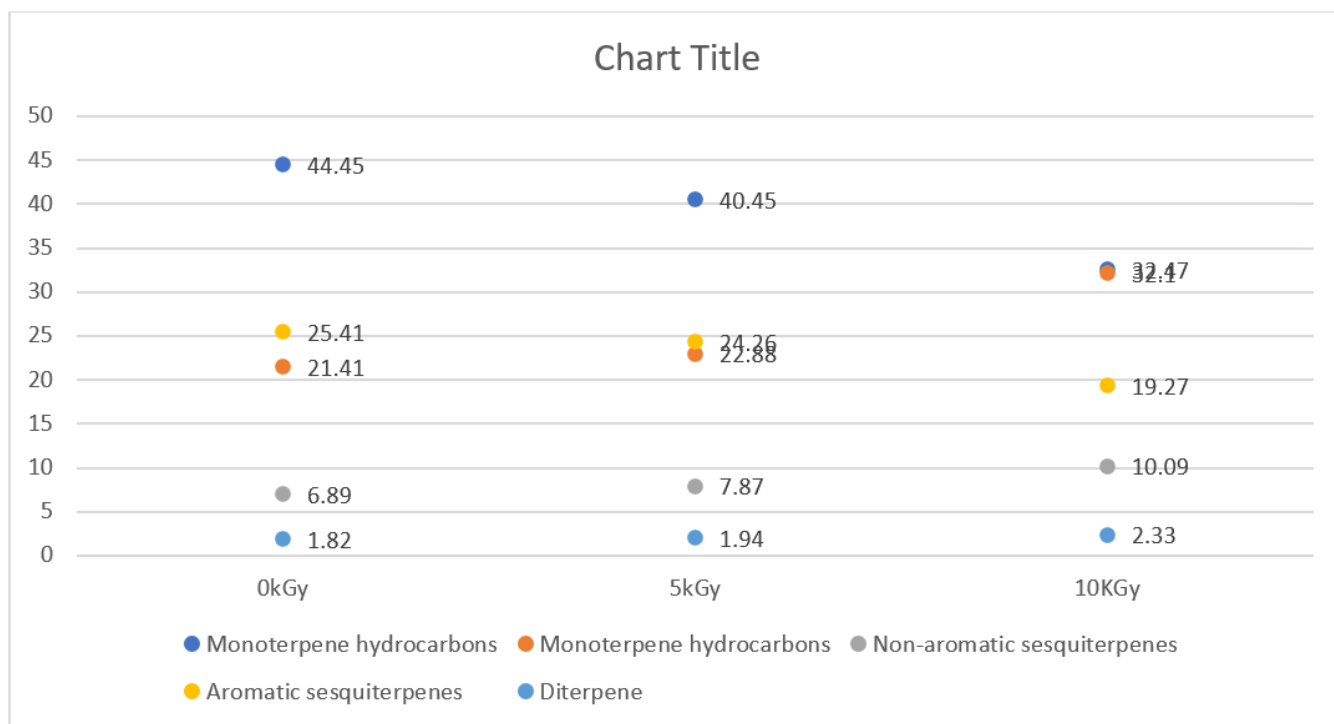


Figure 2

Variation of the percentages of the classes of organic substances of the EO of *T. anuum* according to the dose of irradiation

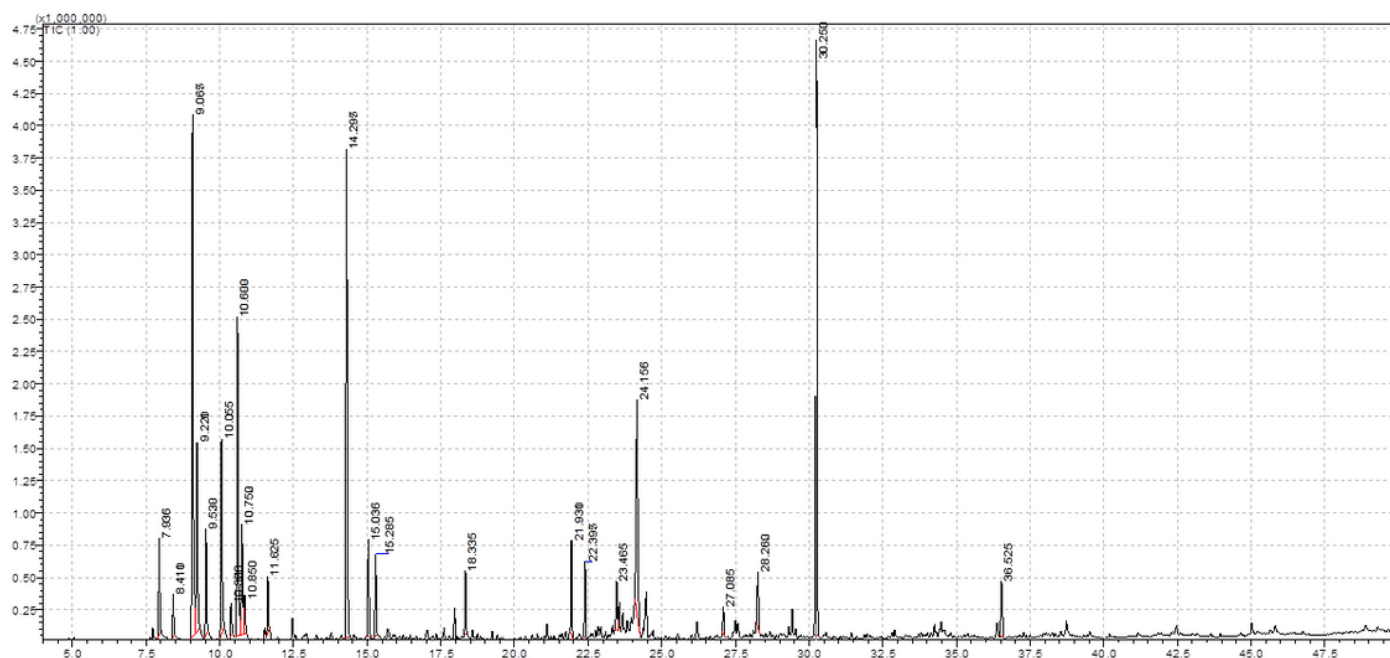


Figure 3

chromatogram of un- irradiated EO

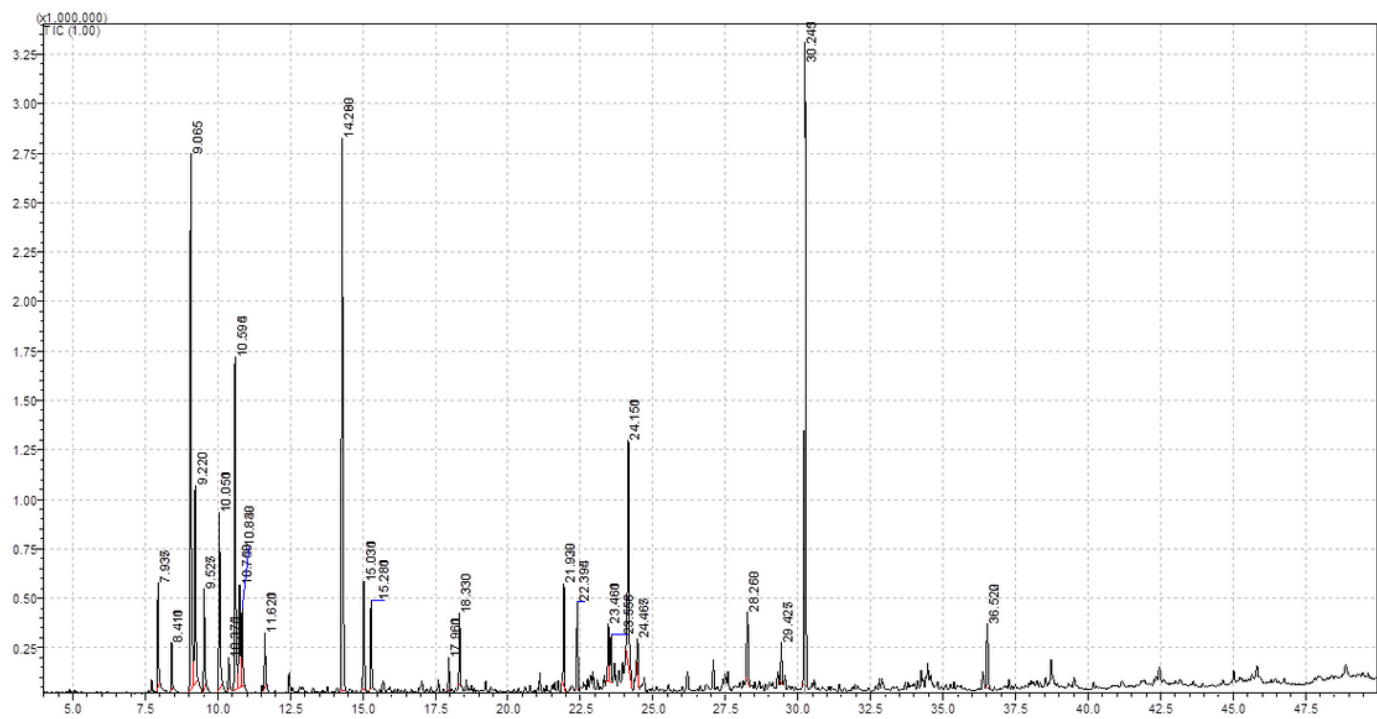


Figure 4

Chromatogram irradiated EO at 5 kGY

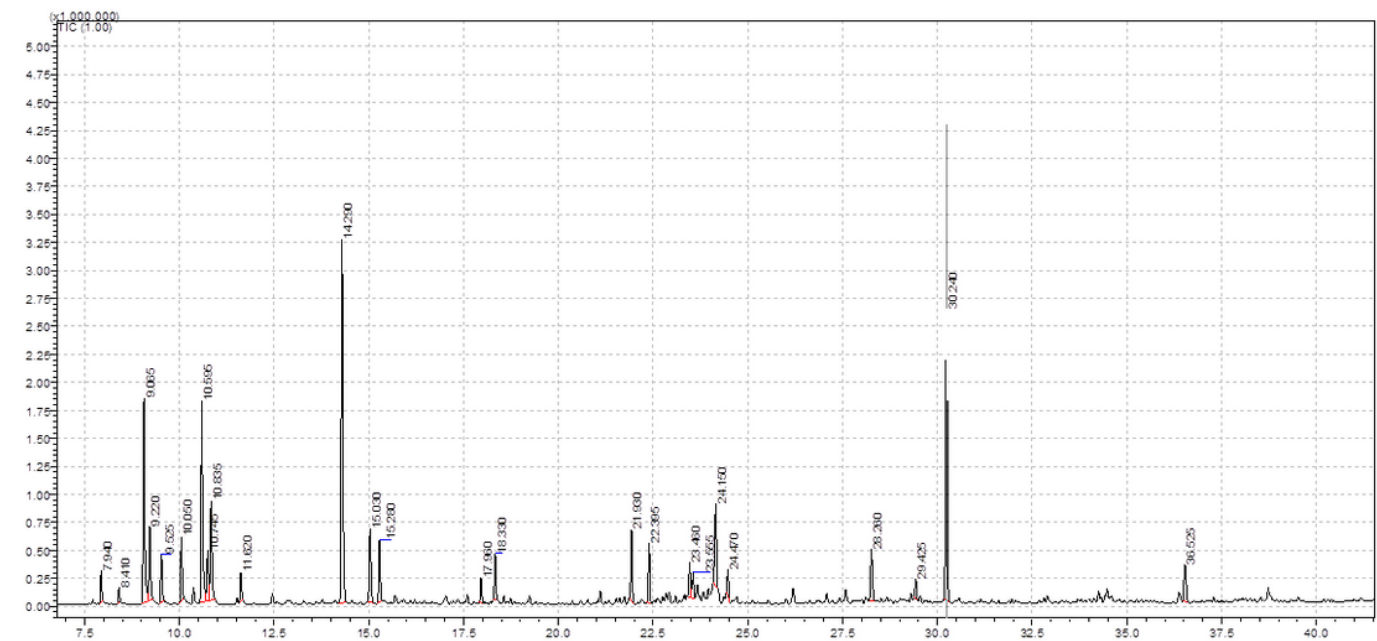


Figure 5

Chromatogram irradiated EO at 10 kGY