

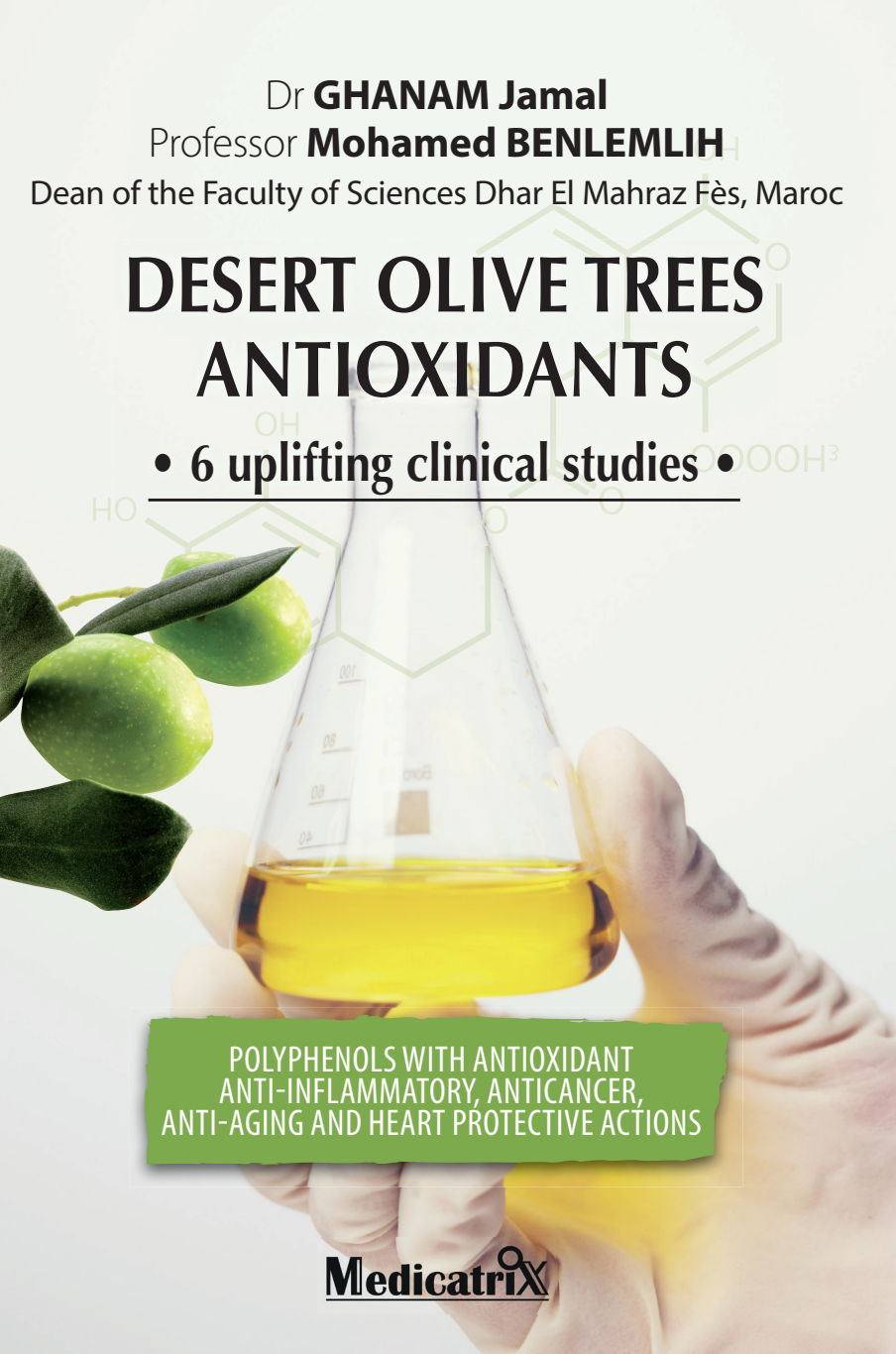
Dr **GHANAM Jamal**

Professor **Mohamed BENLEMLIH**

Dean of the Faculty of Sciences Dhar El Mahraz Fès, Maroc

DESERT OLIVE TREES ANTIOXIDANTS

• 6 uplifting clinical studies •



POLYPHENOLS WITH ANTIOXIDANT
ANTI-INFLAMMATORY, ANTICANCER,
ANTI-AGING AND HEART PROTECTIVE ACTIONS

MedicatriX

Dr GHANAM Jamal
Professor BENLEMLIH Mohamed
Foreword by Professor JOYEUX Henri

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Polyphenols with antioxidant,
anti-inflammatory, anticancer,
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DANGER



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TUE LE LIVRE**

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22, route des Fagnes - B-4190 Ferrières (Belgique)
Tél. : + 32 (0) 4 365 27 29 – Fax : + 32 (0) 4 341 29 21
E-mail : infos@mpéditions.be



INTRODUCTION



Olive oil rich in antioxidants

The natural antioxidants of olive oil are highly bioavailable and highly bioactive molecules, which give them many benefits to human health. They can fight against free radicals with deleterious effects: cell aggression, DNA modification, lipid oxidation.

Thus, recent studies have shown that the hydroxytyrosol of olive oil improves the mitochondrial function that prevents cellular aging and consequently the aging of the body. This leads us to conclude that this compound is a useful agent for preventing aging and age-related diseases.

Antioxidants in olive oil also help protect and treat cancer. In this context, it has been shown that hydroxytyrosol and oleuropein have an anti-cancer effect on colon cancer, blood cancer, breast cancer,... These famous compounds act against cancer by several anti-proliferative and pro-apoptotic mechanisms.

The benefits of phenolic compounds of olive oil on the heart system have been elucidated by several authors. In fact, the antioxidants in olive oil help to reduce the presence of cell adhesion molecules, increase the availability of nitric oxide, suppress platelet aggregation, protect LDL against oxidation to delay the formation of atherosclerosis and reduce inflammatory reactions.


Currently, other virtues of olive oil antioxidants are recognized, including their antibacterial effect, the treatment and prevention of diabetes and Alzheimer's disease.

*"The olive tree, rustic tree
and centuries-old, is a symbol
wisdom, power, peace and health."*

Pr Henri Joyeux

A series of overlapping light gray squares of various sizes in the top left corner.

INTRODUCTION BY PROFESSOR HENRI JOYEUX

A series of overlapping light gray squares of various sizes in the top right corner.

This is the book that was lacking to demonstrate scientifically and understandably by all the interest of Olive Oil, and not just any, the interest for our HEALTH.

Understand its production process, select the best and consume it regularly knowing all the assets it brings to our body.

To prevent Alzheimer's, which is so scary, to prevent the premature aging of our tissues and organs, to prevent cancer, overload heart disease, excess cholesterol, strokes... in short, to remain in good health for the century we are given, it is our dearest wish.

The Olive Oil of this harsh rocky desert of the Moroccan Atlas is a treasure of health. Compared with all other oils around the Mediterranean and beyond, it concentrates little-known polyphenols (antioxidants): Tyrosol and Hydroxytyrosol at levels never measured in a food, 30 times more (223 mg / kg) than in oils generally consumed (8 mg / kg). Its antioxidants content is maximum at a particular period of the olives life, exactly when the olive fruits take their green-red-purplish color at the sunset of the Atlas.

Why is this extra virgin olive oil "OLIVIE Plus 30X" so rich?

Simply because this oil comes from organic olive trees planted in a rocky desert. Just like the wine, it is well known that the olive tree needs to suffer to produce the best of itself. Considering the very hot environment (up to 127°F in summer), the rocky soil where roots cannot develop easily, the lack of water, olive trees stress. A panic phenomenon occurs in the trees (instinct of survival), which results in a raised production of polyphenols (antioxidants) and more particularly in Hydroxytyrosol and Tyrosol (self-defense).

The ecological suffering of the olive tree, makes him give the best of himself to protect itself and protect us giving us the following benefits: antioxidants, anti-aging, anti-atheroma, anti-inflammatory.

In addition, there are beautiful concentrations of Oleic Acid, an excellent carrier for the vegetal calcium of our foods, olives, almonds, walnuts, hazelnuts, parsley and all the fruits and vegetables of the season.

Not to mention Vitamin E, that of fertility and youth who plays such a good role to "oil our neurons".

This book is of great scientific value. I warmly congratulate my colleagues who bring in addition to their experience, many scientific evidence, the best of world literature.

I tasted this golden oil, it accompanies all family and friendly menus and I will prescribe widely, without prescription, but with insistence, in my profession of cancer surgeon Professor.

"In fact, olive oil has specific anti-cancer effects in women having breast cancer. It lowers recurrences, and most likely (although not yet scientifically proven) in men with prostate cancer or who want to avoid it.

An in-vitro study of breast cancer cells, demonstrated in January 2005 that oleic acid, the main mono-unsaturated fatty acid in olive oil, tends to normalize the overexpression of a gene of the breast cancer, the oncogene Her-2 / neu, promoter of a severe form (1 in 5 patients) of breast cancer. (source: How to stop the epidemic of breast cancer and recurrence - Prof. Henri Joyeux and Dr. Berengaria Arnal - Ed. FX de Guibert 2010.)

Chicago researchers (Javier Menendez *et al* in *Annals of Oncology*, January 2005) have found a molecular mechanism that explains the protective effects of olive oil against breast cancer in women consumers. In addition, oleic acid stimulates the activity of Herceptin which is the treatment of choice that targets the Her-2 / neu gene. Oleic acid reduces the oncogene and Herceptin by 46% by 48%. Together (oleic acid + Herceptin), there is a synergy of effect with 70% reduction. It is therefore the Herceptin like effect of oleic acid and the olive polyphenols against cancer."

All these basic science data are consistent with the results of epidemiological studies that have shown that Mediterranean dietary habits have significant effects against cancer, cardiovascular disease and even to prevent some effects of aging.

Pr Henri JOYEUX

Surgeon Cancer Professor.

International specialist in Prevention
of civilization diseases through nutrition
Faculty of Medicine of Montpellier / FRANCE.

CLINICAL STUDIES

Made on Olivie Products

January 2019

We made 6 clinical studies on the OLIVIE powder. More than 500.000 US\$ spent on science for the benefits of the consumers. Just the Joints anti-inflammation study costed 140.000 US\$. In the next pages you will find all the clinical studies about the OLIVIE products.

As matter of fact, OLIVIE products are backed to deep sciences as we have realized 6 clinical studies on:

- lowering **diabetes**
- lowering pain and inflammation for patient suffering from **joints inflammation** (3 studies realized in this).
- lowering **cancer** tumor growth
- **anti-microbial** effect.

Last but not least, the story behind this powder is unique:

We produce the OLIVIE powder from suffering olive trees in a rocky desert. Because of high temperatures (up to 52°C our 127°F in summer), a lot of rocks in the soil making the trees not able to grow their roots to look for nutrients, nearly no rain throughout the year, the olive trees stress and think they will die. So they trigger a self-defense mechanism through which they product

abnormally high quantity of antioxidants. We think these antioxidants, born because of this harsh environment, are more active, more potent and this is the main reason why we obtained excellent results (illustrated by the clinical studies we made) for anti-inflammation, anti-pain, anti-diabetic effect, and anti-microbial.

Before



Olive trees growing in a harsh desert environment produce abnormally high quantity of antioxidants to survive.

After



CLINICAL STUDY N° 1

IN THE COURSE OF
PUBLICATION IN A RENOWNED
SCIENTIFIC REVIEW.

Supplementation with a rich-polyphenols olive tree powder reduces circulating inflammatory markers, disease activity, and pain intensity in patients with rheumatoid arthritis: a 9-week randomized, double-blind, placebo-controlled clinical trial

Dr. Shavon Jackson-Michel, *Director of Medical and Scientific Affairs-D. O. Company, United States of America (USA).*

Dr. Adrian Lopresti, *Clinical Psychologist, Australia.*

Ghanam Jamal and Benlemlih Mohammed, *Biotechnology Laboratory, Faculty of Science Dhar El Mahraz, P.O. Box 1796, Atlas-Fez, University Sidi Mohammed Ben Abdellah, Fez, Morocco.*

ABSTRACT

Background- Notwithstanding the way that olive fruits polyphenols and olive leafs polyphenols have been known for their natural anti-inflammatory effect in the Mediterranean countries, there is little deep scientific study to confirm these benefits.

Objective- To assess the effect of rich-polyphenols olive tree powder (made of leafs, baby leafs, olive fruit and olive oil) made from olive trees planted in the middle of a

rocky desert on inflammatory process and pain intensity, a randomized, double-blinded, placebo-controlled trial was conducted on human subjects with rheumatoid arthritis (RA).

Methods- Seventy-nine RA patients were randomized to get either 1 g per day of olive tree powder or 1 g of placebo powder during 9 weeks. Laboratory analysis, questionnaires administration, pain intensity, disease activity score, and inflammatory biomarkers were determined at the baseline and at the end of the trial. Specialists have monitored eventual side effects and antagonistic impacts of taking the olive tree powder through the period of the study.

Results- Good compliance (over 95%) with the treatment was observed, without any side effect or study-intervention adverse. Significant decrease in disease activity score has shown at the end of intervention within the treated group, and between groups ($P < 0.0001$). Compared with the placebo group, inflammatory biomarkers decreased significantly in treated participants ($P < 0.0001$). Here are the changes noticed from baseline in treated group were -1.25 mg/L (CI, -1.75 to -0.75), -2.09 pg/mL (CI, -2.63 to -1.54), -0.82 pg/mL (CI, -1.14 to -0.49) and -1769 pg/mL (CI, -2254 to -1283) for hs-CRP, IL-6, TNF- α and PGE2 respectively. Additionally, it is important to note that pain relief and global participants satisfaction increased significantly ($P < 0.0001$) after 9 weeks of olive tree powder supplementation.

Conclusion- A net improvement in circulating inflammatory markers, disease activity, and pain intensity was observed in RA patients allocated to rich-polyphenols olive tree powder food supplement.

Keywords: Rheumatoid arthritis; olive tree powder; Inflammatory biomarkers; Pain intensity; Disease activity.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic, autoimmune disease associated with joint deterioration, pain, stiffness, and swelling. Fatigue, fever, and weight loss are also common symptoms. As the illness progresses, non-joint structures can also be affected including the skin, eyes, lungs, and heart. RA is the most common autoimmune disease, occurring in 0.7 to 1% of the population worldwide. It is estimated that approximately 75% of RA patients are women (Hresko *et al.*, 2018; Prado *et al.*, 2018). The etiology of RA is not completely understood although several risk factors have been identified. Genetic factors are predicted to contribute to approximately 50% of RA with an increased risk in people with a family history of RA. Several single-nucleotide polymorphisms and genes of the inherited tissue type major histocompatibility complex antigen HLA-DR4 are also associated with increased disease risk (Smolen *et al.*, 2016). Modifiable risk factors associated with RA include smoking, obesity, low fish intake, and periodontal disease, which are predicted to contribute to approximately 40% of its etiology (Nielen *et al.*, 2004; Rantapaa-Dahlqvist *et al.*, 2003).

Modification of the cytokine network, which are mediators of chronic inflammation is often targeted in the clinical management of inflammatory diseases like RA. This is demonstrated by a movement away from traditional treatments comprising nonsteroidal anti-inflammatory drugs (NSAIDs) toward disease-modifying anti-rheumatic and biological drugs (Hresko *et al.*, 2018). However, while these medications have demonstrated clinical efficacy, they are associated with several adverse immune-related

effects including an increased risk of serious infections and tuberculosis (Rondaan *et al.*, 2014). Consequently, there is increasing scientific interest in naturally-sourced ingredients as an additional anti-inflammatory and pain-relieving treatment option for RA (Suroowan and Mahomoodally, 2018).

Promising findings via *in vitro*, *in vivo*, and clinical studies have demonstrated RA anti-inflammatory and pain-relieving effects from olive tree polyphenols and Mediterranean diets, of which olives comprise a major component. For example, it was shown that adherence to a Mediterranean diet decreased inflammatory activity, increased physical function, and improved vitality in RA patients (Skoldstam *et al.*, 2003). In another study, adherence to a Mediterranean diet resulted in significant reductions in pain, early morning stiffness, and improvements in general health up to 6 months later (McKellar *et al.*, 2007). Further direct evidence of the potential benefits of olive tree polyphenols in RA is obtained from a study demonstrating faster reductions in cell damage, restoration of oxidative balance, and improvements in interleukin(IL)-6 suppression from the combined administration of a dry olive leaf extract and methotrexate during high disease activity in early-phase RA (Cabarkapa *et al.*, 2016). Moreover, several *in vitro* studies have confirmed the anti-inflammatory effects of hydroxytyrosol, tyrosol and oleuropein which are polyphenols derived from olive leaves, baby leaves, olive fruits, and olive oil. These polyphenols act on prostaglandin E2 (PGE2), leukotriene B4 (LTB4), tumor necrosis factor- α (TNF- α), IL-6, IL-1, and high-sensitivity C-reactive protein (hs-CRP) (Camargo *et al.*, 2014; Richard *et al.*, 2011; Zhang *et al.*, 2009b). Moreover, similar anti-inflammatory actions of oleocanthal, a component found in olive oil,

and the NSAID ibuprofen was identified (Beauchamp *et al.*, 2005).

Although anti-inflammatory effects from olive tree polyphenols have been identified, these results are primarily derived from in vitro and preclinical studies. Therefore efficacy from robust clinical trials are needed to substantiate the potential therapeutic efficacy of olive tree polyphenols in patients with RA. Consequently, the aim of this study was to examine whether supplementation with an olive tree powder (OTP) rich in polyphenols (TruOliv®) could improve clinical and laboratory parameters of disease activity in patients with RA.

METHODS

Study population

79 male and female patients aged between 20 and 80 years were recruited during July 2018 from patients referred to a rheumatology clinic (ESSEHA) located in Casablanca, Morocco. To be eligible for enrolment, patients required a diagnosis of rheumatoid arthritis for greater than one year based on the criteria established by the American College of Rheumatology (ACR) and the European League Against Rheumatism (EULAR) (Aletaha *et al.*, 2010). The details of this study were explained to all volunteers and a written consent was obtained from all voluntary participants prior to study enrollment. Patients were ineligible for study participation if they were smokers, pregnant, lactating, taking the contraceptive pill, diagnosed with metabolic syndrome as defined by the Adult Treatment Panel III, suffered from an inflammatory disorder, were taking NSAIDs and/or cytokine inhibitors, or had a history of an allergy or intolerance to olive products. Participants were also excluded if that had a white blood cell count $\leq 3.5 \times 10^9/L$, hemoglobin level

≤ 8.5 g/dl, platelet count $\leq 100 \times 10^9/L$, creatinine level ≥ 2.0 mg/dl or an aspartate aminotransferase level ≥ 2.5 times the upper normal limit. Participants also agreed to avoid the consumption of olive tree products (e.g., olive oil and olive fruits), other antioxidant supplements, nutrients high in omega-3 polyunsaturated fatty acids (e.g., fish), and herbs and nutraceutical supplements known to affect inflammation and immune function for at least 3 weeks prior to study commencement and then throughout the study duration. Participants were also required to maintain their normal diet throughout the study duration.

Study design and intervention

This was a 9-week, randomized, double-blind, placebo-controlled study. The study design is summarized in figure 1 and the Eligible participants were randomly assigned to take capsules containing OTP or a placebo using a computer-generated random-number sequence. Investigators and participants were blinded to treatment allocation.

Following an overnight fast of at least 12 hours, participants attended the clinic to undergo a screening visit which included a tender and swollen joints examination, completion of self-report questionnaires (the Mediterranean Diet Questionnaire and International Physical Activity Questionnaire), blood draw, urine collection, and an anthropometric and blood pressure measurement. Participants were also asked to record their dietary intake for 3 days prior to their screening visit. Study personnel provided necessary explanations about food intake estimations. All assessments were repeated at the end of the study (9 weeks later). Participants and all study personnel (including investigators) had free and continuous access to clinic services for advice and consultation during this study.

Participants received vegetable capsules (hydroxypropyl methylcellulose) containing 500mg of OTP (TruOliv®) or a matching placebo (maltodextrin excipient). All participants received instructions about capsule intake and storage and were asked to take one capsule, twice daily (1gram a day) prior to their meal. Supplement and placebo intake was weekly controlled. The OTP (TruOliv®) was manufactured by Atlas Olive Oils and is an extract derived from olive leaves, olive baby leaves, olive fruit, and olive oil using a physical extraction process without the use of solvents, purification processes or any chemicals. The extraction utilizes a freeze-drying process to optimize polyphenol levels. It is worth noting that this OTP is derived from olive trees planted in a specific rocky desert and drought-dominant environment in Morocco where temperatures reach 127°F in the summer. Moreover, this highly rocky environment restricts the roots of the olive tree from sourcing nutrients in the soil. These olive trees are under stress and produce abnormally high quantity of antioxidants (mainly hydroxytyrosol) to defend themselves and survive.

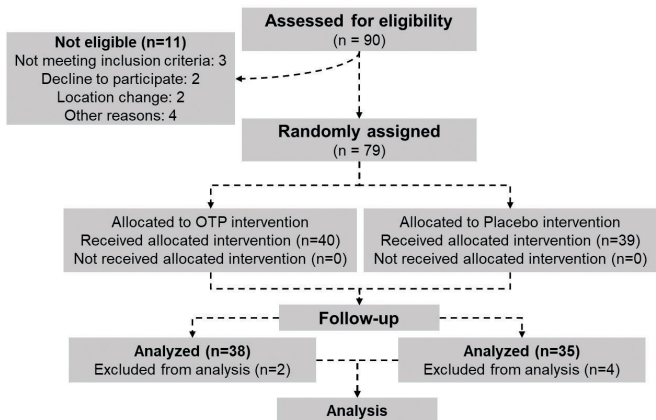


Figure 1. Study flow diagram.

OUTCOME MEASURES

An 8ml fasting blood sample was collected at baseline and week 9 from each participant's antecubital vein. Blood samples were collected in EDTA and SST tubes. All erythrocytes, plasma, serum and urine samples were stored as 1 mL aliquots at 80°C until analysis.

Primary Outcome Measures 1: Inflammatory Measures

Serum quantification of PGE2, LTB4, TNF- α , and cytokines IL-1 and IL-6 was performed using high-sensitivity enzyme-linked immunosorbent assay kits (DIA, Belgium), while serum hs-CRP level was determined by a turbidometric assay using a commercial kit at a wavelength of 500 nm.

Primary Outcome Measure 2: Measures of Disease/Pain Activity:

The visual analog scale (VAS), a clinically validated subjective measure of pain, was used to evaluate pain intensity by participants, according to the protocol devised by (DeLoach *et al.*, 1998). Participants were instructed to draw a line to a maximum of 100 millimeters (mm) depicting their pain intensity (0mm equals no pain and 100 mm equals very severe pain).

A verbal rating scale (VRS) was also used to assess the extent of pain relief using a 5-point VRS where 0 equals no relief, 1 equals a little (perceptible) relief, 2 equals some (meaningful) relief, 3 equals a lot of relief, and 4 equals complete relief. The VRS is validated and commonly-used subjective measure of pain intensity (Jensen *et al.*, 1986).

A Disease Activity Score (DAS28) was calculated by the European League Against Rheumatism (EULAR) (Wells *et al.*, 2009). This validated outcome measure for RA is based on the number of tender and swollen joint, serum hs-

CRP concentration, and the global health (GH) results as calculated by the patient's 100mm VAS score (converted to cm). The calculation of DAS28 is shown below:

$$\text{DAS28 (CRP)} = [0.56 \sqrt{\text{TJC}}] + [0.28 \sqrt{\text{SJC}}] + [0.36 \ln (\text{CRP} + 1)] + [0,014 (\text{GH})]$$

Secondary Outcome Measures:

Anthropometric measures: A calibrated scale and wall-mounted stadiometer with a precision of 0.1cm, and a semi-automatic oscillometer (Boso Medicus smart Semi-automatic Blood Pressure Monitor, Germany) were used to measure anthropometric parameters and blood pressure.

Measure of compliance to capsule intake:

Urinary hydroxytyrosol content, considered an objective estimate of OTP intake, was measured by High Performance Liquid Chromatography (HPLC). First, hydroxytyrosol was extracted from acidified urine (hydrochloric acid, 0.6 N of final concentration) and then quantified by a Shimadzu chromatograph device equipped with a reverse phase C18 column (250mm L. × 4.6 mm I.D., 5 µm) according to the protocol described by Visioli *et al.* (2000).

Measure of adverse effects: Possible adverse effects of OTP administration throughout the study period (e.g., oral symptoms, digestive disorders, fullness, allergic skin response, and other intervention-related symptoms) were assessed by medical practitioners and study personnel. In addition, a 5-point scale (0 = poor, 1 = fair, 2 = good, 3 = very good, and 4 = excellent) was used to assess the global satisfaction assessment in response to treatment (GAST).

Measures of Dietary Intake and Physical Activity: Participants were asked to complete a 3-day food diary at baseline, week 4, and week 9. andbased on this dietary recordusing Participants were also asked to complete the

Mediterranean Diet questionnaire (Estruch *et al.*, 2006) at baseline and week 9 to examine level of adherence to the Mediterranean diet. This measure provides a validated estimate of adherence to a Mediterranean diet (ref). Moreover, physical activity was assessed using the psychometrically-validated International Physical Activity Questionnaire (physical exercise was categorized as high, moderate, or low) (Craig *et al.*, 2003).

STATISTICAL ANALYSIS

Data were statistically analyzed using GraphPad Prism version 6.00 (GraphPad Prism Inc, San Diego, California). For the baseline characteristics, continuous variables are expressed as mean values \pm standard deviation (SD), and categorical variables are expressed as frequencies (percent). For inflammatory biomarkers, pain intensity, and pain relief mean values are expressed with 95% confidence intervals (CIs). Normal distribution of data was checked using the Kolmogorov-Smirnov test. The difference between baseline groups characteristic was performed using the independent-samples T-test for normally continuous data, the Mann-Whitney U test for non-normally continuous data, and the χ^2 test for categorical data. The independent-samples T-test was also used to compare mean changes from baseline to the end of the study (9 weeks) between OTP and placebo groups. Results with two-sided p-values of <0.05 were considered statistically significant.

RESULTS

Study compliance and adverse effects

Ninety patients were screened for study inclusion, with 11 not meeting eligibility criteria. Reasons for ineligibility are detailed in Figure 1. Seventy-nine participants were enrolled in the study and data from 73 participants was

available for statistical analysis. Data from six participants was not included in analyses (2 in OTP-group and 4 in placebo-group) as they did not follow the study protocol. No adverse effects related to the intervention were observed and an average 95% compliance to capsule intake was reported. Results shown in figure 2 illustrate the changes in urinary hydroxytyrosol concentrations (a biomarker of compliance) for both placebo and OTP groups. The content of hydroxytyrosol found in urine of OTP participant's group was significantly higher ($P<.0001$) compared to that of placebo group. However, it is worth noting that literature data regarding olive phenols metabolism and excretion are inconsistent (Covas *et al.*, 2006; Visioli *et al.*, 2003).

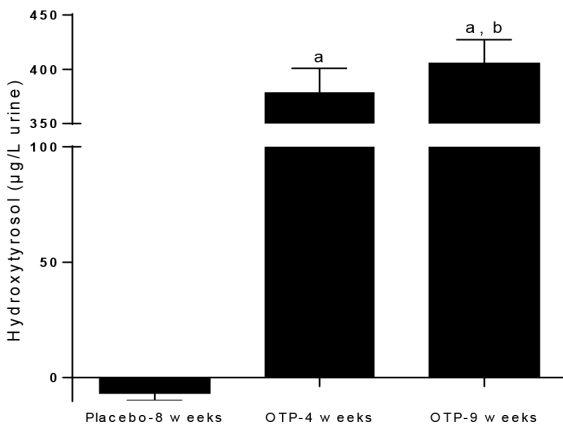


Figure 2. Change from baseline in urinary hydroxytyrosol excretion. Mean with 95% CI. ^a $P<.0001$, between OTP-group (at 4 or 8 weeks); ^b $P= .003$, between OTP-group at 4 and 8 weeks.

Baseline characteristics

The baseline characteristics of the 79 participants randomized into OTP and placebo groups are shown in

table 2. No significant differences were identified between the two study groups for all the baseline parameters. This included adherence to the Mediterranean diet (p=.296).

Table 2. Baseline characteristics of participants.

| Parameter | OTP group (n=40) | Placebo group (n=39) | P value ^a |
|-----------------------------------|------------------|----------------------|----------------------|
| Age (years) | 56.73 ± 1.61 | 54.31 ± 1.97 | .306 |
| Female, n (%) | 32 (80) | 27 (69.23) | .935 |
| Weight (kg) | 65.43 ± 3.06 | 63.54 ± 4.34 | .957 |
| BMI (kg/m ²) | 28.17 ± 1.662 | 27.83 ± 1.815 | .901 |
| Disease duration (years) | 7.77 ± 0.42 | 6.33 ± 0.56 | .356 |
| Medical history of disease, n (%) | 15 (37.50) | 12 (30.76) | .142 |
| Family history of disease, n (%) | 8 (20) | 10 (25.64) | .708 |
| Exercise activity habits, n (%) | 16 (40) | 18 (45) | .822 |
| Alcohol drinking habits, n (%) | 2 (5) | 3 (7.69) | .233 |
| 15-item Mediterranean diet score | 2.04 ± 0.20 | 1.91 ± 0.15 | .307 |
| DAS28 | 4.07 ± 0.67 | 4.40 ± 0.71 | .911 |
| Pain VAS (0–100 mm) | 77.11 ± 9.84 | 75.65 ± 9.12 | .710 |

Value are expressed as mean ± standard deviation or in percentage.
^a P value (<.05) by independent t-test or Mann-Whitney test.

Primary Outcome Measure 1: Inflammatory markers

Changes in measured inflammatory markers from baseline to week 9 are illustrated in figure 3. As measured by the independent-samples T-test, there were significant decreases in hs-CRP of participants allocated to OTP

treatment compared to those in the placebo group ($p = .014$ and $<.0001$ after 4 and 9 weeks, respectively). Mean changes from baseline in the hs-CRP levels were -0.56 (CI, -0.91 to -0.18) and -1.25 mg/L (CI, -1.75 to -0.74 mg/L) after 4 and 9 weeks, respectively in the OTP group. There were greater reductions in IL-6 ($p=.014$ at week 4 and $p<.0001$ at week 9), TNF- α ($p=.025$ at week 4 and $p<.0001$ at week 9), PGE2 ($p=.002$ at week 4 and $p<.0001$ at week 9), and LTB4 ($p=.0004$ at week 4 and $p<.0001$ at week 9) in the OTP group compared to the placebo group, as measured by the independent-samples T-test. The adjusted within-group changes for the OTP group in IL-6 and TNF- α were -2.08 pg/mL (CI, -2.63 to -1.53) and -0.81 pg/mL (CI, -1.14 to -0.49). As assessed by the independent-samples T-test, there were no significant between-group differences in changes in IL-1 (p -value of 0.413 and 0.084 at 4 and 9 weeks).

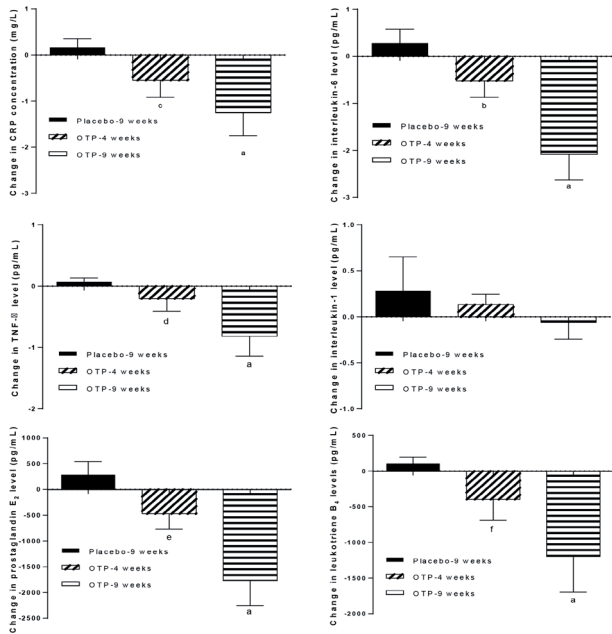


Figure 3. Change in circulating inflammatory concentrations over time in the two study groups. Error bars are 95% CIs. ^a($P<.0001$), ^b($P=.014$), ^c($P=.009$), and ^d($P=.0247$), ^e($P=.0017$), ^f($P=.0004$).

Primary Outcome Measure 2: Pain intensity and disease activity

Table 4 contains a summary of changes from baseline in pain intensity, pain relief, and DAS28 in both OTP and placebo groups. VAS (100-mm pain scale) values for the OPT group (50.41 ± 8.86 mm) were significantly lower than those of the placebo group (76.03 ± 10.46 mm) at 9 weeks ($P<.0001$). Similarly, pain relief score was significantly higher in the treated group compared to the placebo ($P<.0001$), even after 4 weeks of intervention

(Table 4). At week 9, more than 30% of the OTP-group members reported a high pain relief score (≥ 3), while the remaining participants reported a meaningful pain relief (score ≥ 2).

Table 4. Change from baseline in pain intensity, pain relief, DAS28. Data are expressed as mean and (95% CIs).

| Parameter | OTP group (n=38) | Placebo group (n=35) | P value |
|----------------|---------------------------|------------------------|---------|
| Pain intensity | -26.70 (-30.39 to -20.90) | 0.38 (-2.26 to 3.02) | <0.0001 |
| Pain relief | 2.14 (2.13 to 2.71) | -0.11 (-0,21 to -0,11) | <0.0001 |
| DAS28 | -1.84 (-2.43 to -2.03) | -0,13 (-0,21 to 0,09) | <0.0001 |
| GART* | 3.21 (2.93 to 3,48) | 0.47 (0.28 to 0.65) | <0.0001 |

* Global satisfaction assessment in response to treatment. Only the average value measured at the end of the study.

Data for DAS28 show a significant decrease in disease activity reported by the treated participants compared to those allocated to the placebo ($P<.0001$). Patients in OTP group with baseline active RA (DAS28 score ≥ 3.2) showed a good therapeutic response by the end of the study (DAS28 score of 2.23 ± 0.54), which indicates an RA remission (DAS28 score ≤ 2.6). Table 4 shows also the global satisfaction assessment in response to treatment, included the assessment of patient's anxiety. Very good satisfaction regarding the intervention (score of 3.21 of the 5-point categorical scale) was reported by participants received OTP, compared ($P<0.0001$) to those of placebo group. High degree of participant's satisfaction was correlated to a significant decrease in circulating inflammatory biomarkers level, pain intensity, and disease

activity score, indicating the efficacy of the treatment with OTP.

FOOD, ENERGY, AND NUTRIENT INTAKE

Results shown in table 3 demonstrate that there was no significant change in dietary/nutrient intake during the study period for both the OTP and placebo groups. In general, all participants have met the daily recommended diet for this study, and the consumption of olive products and any other products known to have anti-inflammatory effects was avoided.

Table 3. Mean energy/nutrient intake and weight change over the 9-week study period.

| Parameter | OTP group (n=45) | Placebo group (n=45) |
|----------------------|------------------|----------------------|
| Energy (cal) | | |
| Baseline | 1355.00 ± 209,54 | 1809.00 ± 130.3 |
| 9 weeks | 1402.00 ± 205,11 | 1695.00 ± 318.4 |
| P value ^a | 0.603 | 0.445 |
| Fat (g) | | |
| Baseline | 63.90 ± 11.40 | 78.32 ± 13.47 |
| 9 weeks | 64.17 ± 11.95 | 75.06 ± 12.95 |
| P value ^a | 0.747 | 0.833 |
| PUFAs (g) | | |
| Baseline | 11.33 ± 2.01 | 11.90 ± 1.22 |
| 9 weeks | 12.77 ± 2.91 | 10.67 ± 1.43 |
| P value ^a | 0.711 | 0.802 |
| MUFAs (g) | | |
| Baseline | 22.15 ± 1.87 | 23.22 ± 1.34 |
| 9 weeks | 23.52 ± 2.23 | 22.54 ± 1.57 |
| P value ^a | 0.193 | 0.114 |
| SFAs (g) | | |
| Baseline | 13.11 ± 1.52 | 12.93 ± 1.97 |
| 9 weeks | 15.86 ± 1.62 | 15.57 ± 2.11 |
| P value ^a | 0.515 | 0.749 |

| Parameter | OTP group (n=45) | Placebo group (n=45) |
|----------------------|------------------|----------------------|
| Weight (kg) | | |
| Baseline | 65.43 ± 3.06 | 63.54 ± 4.34 |
| 9 weeks | 66.01 ± 4.77 | 63.97 ± 4.66 |
| P value ^a | 0.794 | 0.906 |

Data are expressed as mean ± standard deviation. PUFAs, polyunsaturated fatty acids; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids. ^a Paired Student t test (p<0.05).

Physical activity and Mediterranean diet??

DISCUSSION

In the present study, patients with rheumatoid arthritis (according to the ACR/ELUAR criteria) were treated with a 1g daily dose of a phenolic OTP (TruOliv®) for 9 weeks. The OTP was well tolerated with no reported adverse reactions by study participants. We found that supplementation with this natural OTP displayed strong therapeutic actions against inflammation (via reductions in PGE2, LTB4, TNF- α , IL-6, but not IL-6), disease activity, and joint pain in patients with RA.

RA is characterized by a continuous and excessive influx of inflammatory cells into the synovial membrane. Inflammation of synovial membranes are believed to be the main cause of RA with high concentrations of circulating inflammatory markers, such as cytokines (IL-6 and TNF- α) and hs-CRP correlated with a propensity to pain, warmth, and redness associated with joint destruction (Liu *et al.*, 2018; Wei *et al.*, 2015). Chronic inflammation leads to cartilage damage and bone destruction (mediated by osteoclasts), which eventually causes a loss of joint function. However, inflammatory reactions and osteoclast differentiation are both mediated by a complex network of cytokines, mainly TNF- α , IL-6, IL-1, as well as other simple molecules such as eicosanoids (PGE2 and LTB4) (Boissier

et al., 2012; Smolen and Redlich, 2014). RA treatment most commonly comprises biologic treatments targeting specific immunologic pathways. In particular, it has been reported that the inhibition of TNF- α and IL-6 has a greater effect on inflammation compared to IL-1 (Smolen and Redlich, 2014). The findings from this study demonstrate that supplementation with an OTP (containing 14% total polyphenols and 10% hydroxytyrosol) reduced circulating concentrations of TNF- α , IL-6, hs-CRP, PGE2, and LTB4 in patients with RA.

Olive products contain several polyphenols including hydroxytyrosol, tyrosol oleuropein, and oleocanthal which are responsible for its anti-inflammatory effects. In particular, the polyphenols in the administered OTP (particularly hydroxytyrosol), has been shown to act directly on DNA to reduce the expression of inflammatory mediators and/or inhibit their biosynthesis pathways through a similar mechanism as glucocorticoids and/or NSAIDs. For example, several studies have confirmed an inhibitory effect of hydroxytyrosol on PGE2 levels through the suppression of inducible cyclooxygenase (COX-2, key enzyme of PGE2 biosynthesis pathway from arachidonic acid) in isolated human monocytes (Lu and Wahl, 2005; Rosignoli *et al.*, 2013; Zhang *et al.*, 2009a) and murine macrophages (Richard *et al.*, 2011). Moreover, hydroxytyrosol and oleuropein displayed a strong *in vivo* inhibitory effect against COX-2 and PGE2 in mice with dextran sulfate sodium-induced colitis (Giner *et al.*, 2011; Sanchez-Fidalgo *et al.*, 2012). Additionally, results from other cell culture models show that hydroxytyrosol in its pure form or carried in a natural matrix (e.g. *via* an OTP or olive oil) can inhibit the synthesis of LTB4, TNF- α , IL-6, IL-1 and hs-CRP (Bitler *et al.*, 2005; Camargo *et al.*, 2014; Maiuri *et al.*, 2005; Richard *et al.*, 2011; Zhang *et al.*, 2009b). Findings from clinical studies have demonstrated

such inhibitory effects against inflammatory markers in patients with stable coronary disease (Estruch *et al.*, 2006; Fito *et al.*, 2007). The results of the current study were consistent with previous *in vitro* and *in vivo* investigations demonstrating the positive effects of olive oil and a Mediterranean diet rich in olive tree polyphenols in patients with RA. (Cabarkapa *et al.*, 2016; McKellar *et al.*, 2007; Skoldstam *et al.*, 2003). However, in our study we demonstrated the therapeutic and anti-inflammatory effects of an OTP as a stand-alone treatment for RA. We note that the observed changes were not caused by dietary changes over the course of treatment as there were no nutritional/dietary changes observed, as measured by our diet questionnaire and 3-day food record. In particular, there were no changes in PUFAs which have been shown to have a therapeutic effect in RA (Park *et al.*, 2013).

To further understand the potential mechanisms of OTP polyphenols, it is important to note that NSAIDs work by inhibiting the activity of cyclooxygenase enzymes (COX-1 and/or COX-2). However, COX inhibition with NSAIDs (celecoxib, rofecoxib, diclofenac) has been shown to cause an increase in TNF- α levels in rheumatoid synovial membrane cultures as well as in blood (Page *et al.*, 2010; Rosignoli *et al.*, 2013). In contrast, we found that the OTP resulted in a significant decrease in TNF- α . This suggests that hydroxytyrosol and/or other OTP's polyphenols target differing immunological pathway(s) leading to the decreased levels of IL-6 and TNF- α . Killeen *et al.* (2014) highlighted the potential of hydroxytyrosol to drive new therapeutic opportunities by reducing nuclear factor kappa β (NF- $\kappa\beta$) activation and its nuclear translocation. NF- $\kappa\beta$ triggers the expression of more than 150 genes including those encoding cytokines, TNF- α , IL-1, and IL-6 (Makarov, 2001). Richard *et al* (2011) found that the decrease of cytokines levels in murine macrophages

following treatment with hydroxytyrosol was correlated with a low expression of NF- κ B p65. Hydroxytyrosol has also been shown to influence NF- κ B activity in endothelial (Scoditti *et al.*, 2012) and neural cells (St-Laurent-Thibault *et al.*, 2011). This suggests that the anti-inflammatory effects of OTP's polyphenols may be by inhibiting COX-2 enzyme activity and/or reducing the expression of NF- κ B.

Chronic inflammation in RA induces proliferation of the synovium leading to formation of pannus and joint destruction, where neovascularization (angiogenesis) is a major contributor (Lee *et al.*, 2001; Semerano *et al.*, 2011). A high correlation between RA progression and an important pro-angiogenic factor, vascular endothelial growth factor (VEGF) has been observed in RA patients (Lee *et al.*, 2001; Sone *et al.*, 2001). Pro-angiogenic factors VEGF and angiopoietins (Ang)-1 activation in the synovial membrane are a multi-targeted mechanism involving the cytokines IL-1 β , TNF- α , and COX-2 (Pettit *et al.*, 2001; Scoditti *et al.*, 2012). Our unpublished investigations suggest that hydroxytyrosol derived from the studied OTP, modulates the angiogenic response of endothelial cells by repressing VEGF (isoforms A, B, and C), Ang-1 and Ang-2 gene expression (Fortesa *et al.*, 2012; Scoditti *et al.*, 2012).

In RA, pain intensity is strongly correlated with high PGE2 level (Kamei *et al.*, 2004; Prochazkova *et al.*, 2009; Scher *et al.*, 2007), explaining the effectiveness of NSAIDs as pain relief agents. Similar pain relief effect of the NSAID, ibuprofen has been reported for oleocanthal by Beauchamp *et al.* (2005). The decrease in circulating inflammatory markers, particularly in PGE2 level, is likely a major contributor of pain reduction observed in our study.

Study Limitations and Directions for Future Research

Although our study demonstrated the positive effects of an OTP on inflammation and RA symptoms, there remain several unanswered questions that require investigation in larger-scale studies. Our study revealed the efficacy of an OTP over a 9-week period, however, its benefits, tolerability, and safety over a longer duration is uncertain. Symptomatic changes and inflammatory effects following treatment discontinuation also requires investigation. Moreover, the efficacy of the OTP as an adjunct to pharmacological medications would be important to examine, particularly in unresponsive RA patients or those exhibiting only moderate improvements from traditional treatments. We also only used a single dose of 1g a day, so its efficacy at either a lower or higher dose is uncertain. The dose-escalating effects in non-responders or those exhibiting only a partial treatment response will be also helpful. The effects of the OTP in different populations, particularly in those where the consumption of olive products is less common will further substantiate the therapeutic effects of the OTP, as we recruited RA patients from Morocco where olive consumption is high. Finally, the effects of the OTP in patients with early-diagnosed RA versus long-standing RA, and its therapeutic efficacy compared to standard olive oil, or other olive tree extracts will be important to examine. RA is also associated with differences in intestinal microbial composition compared to healthy controls (du Teil Espina *et al.*, 2018). A Mediterranean diet and olive consumption have been shown to alter microbial compositions, potentially presenting as another therapeutic mechanism of action (Martin-Pelaez *et al.*, 2017; Mitsou *et al.*, 2017). An examination of microbial changes along with its relationship to symptomatic improvement may help to further clarify the physiological actions of an OTP.

CONCLUSION

In summary, chronic inflammation and pain are hallmark features of RA. Our findings demonstrate that the administration of rich-polyphenols extract from the olive tree was associated with significant decreases in circulating inflammatory markers, pain intensity, and disease activity in RA patients. We suggest that the anti-inflammatory effect of olive polyphenols, as natural components of OTP, may be linked to i) NF- κ B-dependent inhibition of cytokines (IL-6 and TNF- α), ii) similar actions to NSAIDs comprising the inhibition of COX-2, and iii) VEGF and Ang-1 repression. Further research should focus on the anti-angiogenic activity of hydroxytyrosol in synovial membrane, as a future target of new anti-inflammatory drugs based on hydroxytyrosol structure.

REFERENCES

- Aletaha, D., Neogi, T., Silman, A.J., Funovits, J., Felson, D.T., Bingham, C.O., 3rd, Birnbaum, N.S., Burmester, G.R., Bykerk, V.P., Cohen, M.D., Combe, B., Costenbader, K.H., Dougados, M., Emery, P., Ferraccioli, G., Hazes, J.M., Hobbs, K., Huizinga, T.W., Kavanaugh, A., Kay, J., Kvien, T.K., Laing, T., Mease, P., Menard, H.A., Moreland, L.W., Naden, R.L., Pincus, T., Smolen, J.S., Stanislawski-Biernat, E., Symmons, D., Tak, P.P., Upchurch, K.S., Vencovsky, J., Wolfe, F., Hawker, G., 2010. 2010 Rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. *Arthritis Rheum* 62, 2569-2581.
- Beauchamp, G.K., Keast, R.S., Morel, D., Lin, J., Pika, J., Han, Q., Lee, C.H., Smith, A.B., Breslin, P.A., 2005. Phytochemistry: ibuprofen-like activity in extra-virgin olive oil. *Nature* 437, 45-46.
- Bitler, C.M., Viale, T.M., Damaj, B., Crea, R., 2005. Hydrolyzed olive vegetation water in mice has anti-inflammatory activity. *J Nutr* 135, 1475-1479.
- Boissier, M.C., Semerano, L., Challal, S., Saidenberg-Kermanac'h, N., Falgarone, G., 2012. Rheumatoid arthritis: from autoimmunity to synovitis and joint destruction. *J Autoimmun* 39, 222-228.

Cabarkapa, A., Zivkovic, L., Borozan, S., Zlatkovic-Svenda, M., Dekanski, D., Jancic, I., Radak-Perovic, M., Bajic, V., Spremo-Potparevic, B., 2016. Dry Olive Leaf Extract in Combination with Methotrexate Reduces Cell Damage in Early Rheumatoid Arthritis Patients-A Pilot Study. *Phytother Res* 30, 1615-1623.

Camargo, A., Rangel-Zuniga, O.A., Haro, C., Meza-Miranda, E.R., Pena-Orihuela, P., Meneses, M.E., Marin, C., Yubero-Serrano, E.M., Perez-Martinez, P., Delgado-Lista, J., Fernandez-Real, J.M., Luque de Castro, M.D., Tinahones, F.J., Lopez-Miranda, J., Perez-Jimenez, F., 2014. Olive oil phenolic compounds decrease the postprandial inflammatory response by reducing postprandial plasma lipopolysaccharide levels. *Food Chem* 162, 161-171.

Covas, M.I., de la Torre, K., Farre-Albaladejo, M., Kaikkonen, J., Fito, M., Lopez-Sabater, C., Pujadas-Bastardes, M.A., Joglar, J., Weinbrenner, T., Lamuela-Raventos, R.M., de la Torre, R., 2006. Postprandial LDL phenolic content and LDL oxidation are modulated by olive oil phenolic compounds in humans. *Free Radic Biol Med* 40, 608-616.

Craig, C.L., Marshall, A.L., Sjostrom, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., Oja, P., 2003. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 35, 1381-1395.

DeLoach, L.J., Higgins, M.S., Caplan, A.B., Stiff, J.L., 1998. The visual analog scale in the immediate postoperative period: intrasubject variability and correlation with a numeric scale. *Anesth Analg* 86, 102-106.

du Teil Espina, M., Gabarrini, G., Harmsen, H.J.M., Westra, J., van Winkelhoff, A.J., van Dijk, J.M., 2018. Talk to your gut: the oral-gut microbiome axis and its immunomodulatory role in the etiology of rheumatoid arthritis. *FEMS Microbiol Rev*.

Estruch, R., Martinez-Gonzalez, M.A., Corella, D., Salas-Salvado, J., Ruiz-Gutierrez, V., Covas, M.I., Fiol, M., Gomez-Gracia, E., Lopez-Sabater, M.C., Vinyoles, E., Aros, F., Conde, M., Lahoz, C., Lapetra, J., Saez, G., Ros, E., Investigators, P.S., 2006. Effects of a Mediterranean-style diet on cardiovascular risk factors: a randomized trial. *Ann Intern Med* 145, 1-11.

Fito, M., de la Torre, R., Covas, M.I., 2007. Olive oil and oxidative stress. *Mol Nutr Food Res* 51, 1215-1224.

Fortesa, C., García-Vilasa, J.A., Quesada, A.R., Medina, M., 2012. Evaluation of the anti-angiogenic potential of hydroxytyrosol and tyrosol, two bio-active phenolic compounds of extra virgin olive oil, in endothelial cell cultures. *Food Chemistry* 134, 134-140.

Giner, E., Andujar, I., Recio, M.C., Rios, J.L., Cerda-Nicolas, J.M., Giner, R.M., 2011. Oleuropein ameliorates acute colitis in mice. *J Agric Food Chem* 59, 12882-12892.

Hresko, A., Lin, T.C., Solomon, D.H., 2018. Medical Care Costs Associated With Rheumatoid Arthritis in the US: A Systematic Literature Review and Meta-Analysis. *Arthritis Care Res (Hoboken)* 70, 1431-1438.

Jensen, M.P., Karoly, P., Braver, S., 1986. The measurement of clinical pain intensity: a comparison of six methods. *Pain* 27, 117-126.

Kamei, D., Yamakawa, K., Takegoshi, Y., Mikami-Nakanishi, M., Nakatani, Y., Oh-Ishi, S., Yasui, H., Azuma, Y., Hirasawa, N., Ohuchi, K., Kawaguchi, H., Ishikawa, Y., Ishii, T., Uematsu, S., Akira, S., Murakami, M., Kudo, I., 2004. Reduced pain hypersensitivity and inflammation in mice lacking microsomal prostaglandin e synthase-1. *J Biol Chem* 279, 33684-33695.

Killeen, M.J., Linder, M., Pontoniere, P., Crea, R., 2014. NF-kappabeta signaling and chronic inflammatory diseases: exploring the potential of natural products to drive new therapeutic opportunities. *Drug Discov Today* 19, 373-378.

Lee, S.S., Joo, Y.S., Kim, W.U., Min, D.J., Min, J.K., Park, S.H., Cho, C.S., Kim, H.Y., 2001. Vascular endothelial growth factor levels in the serum and synovial fluid of patients with rheumatoid arthritis. *Clin Exp Rheumatol* 19, 321-324.

Liu, T.J., Chang, C.C., Chen, L.C., Chu, H.Y., Hsu, C.S., Chang, S.T., 2018. Relationship of HS CRP and Sacroiliac Joint Inflammation in Undifferentiated Spondyloarthritis. *Open Med (Wars)* 13, 113-118.

Lu, Y., Wahl, L.M., 2005. Oxidative stress augments the production of matrix metalloproteinase-1, cyclooxygenase-2, and prostaglandin E2 through enhancement of NF-kappa B activity in lipopolysaccharide-activated human primary monocytes. *J Immunol* 175, 5423-5429.

Maiuri, M.C., De Stefano, D., Di Meglio, P., Irace, C., Savarese, M., Sacchi, R., Cinelli, M.P., Carnuccio, R., 2005. Hydroxytyrosol, a phenolic compound from virgin olive oil, prevents macrophage activation. *Naunyn Schmiedeberg Arch Pharmacol* 371, 457-465.

Makarov, S.S., 2001. NF-kappa B in rheumatoid arthritis: a pivotal regulator of inflammation, hyperplasia, and tissue destruction. *Arthritis Res* 3, 200-206.

Martin-Pelaez, S., Mosele, J.I., Pizarro, N., Farras, M., de la Torre, R., Subirana, I., Perez-Cano, F.J., Castaner, O., Sola, R., Fernandez-Castillejo, S., Heredia, S., Farre, M., Motilva, M.J., Fito, M., 2017. Effect of virgin olive oil and thyme phenolic compounds on blood lipid profile: implications of human gut microbiota. *Eur J Nutr* 56, 119-131.

McKellar, G., Morrison, E., McEntegart, A., Hampson, R., Tierney, A., Mackle, G., Scoular, J., Scott, J.A., Capell, H.A., 2007. A pilot study of a Mediterranean-type diet intervention in female patients with rheumatoid

arthritis living in areas of social deprivation in Glasgow. *Ann Rheum Dis* 66, 1239-1243.

Mitsou, E.K., Kakali, A., Antonopoulou, S., Mountzouris, K.C., Yannakoulia, M., Panagiotakos, D.B., Kyriacou, A., 2017. Adherence to the Mediterranean diet is associated with the gut microbiota pattern and gastrointestinal characteristics in an adult population. *Br J Nutr* 117, 1645-1655.

Nielen, M.M., van Schaardenburg, D., Reesink, H.W., van de Stadt, R.J., van der Horst-Bruinsma, I.E., de Koning, M.H., Habibuw, M.R., Vandenbroucke, J.P., Dijkmans, B.A., 2004. Specific autoantibodies precede the symptoms of rheumatoid arthritis: a study of serial measurements in blood donors. *Arthritis Rheum* 50, 380-386.

Page, T.H., Turner, J.J., Brown, A.C., Timms, E.M., Inglis, J.J., Brennan, F.M., Foxwell, B.M., Ray, K.P., Feldmann, M., 2010. Nonsteroidal anti-inflammatory drugs increase TNF production in rheumatoid synovial membrane cultures and whole blood. *J Immunol* 185, 3694-3701.

Park, Y., Lee, A., Shim, S.C., Lee, J.H., Choe, J.Y., Ahn, H., Choi, C.B., Sung, Y.K., Bae, S.C., 2013. Effect of n-3 polyunsaturated fatty acid supplementation in patients with rheumatoid arthritis: a 16-week randomized, double-blind, placebo-controlled, parallel-design multicenter study in Korea. *J Nutr Biochem* 24, 1367-1372.

Pettit, A.R., Ji, H., von Stechow, D., Muller, R., Goldring, S.R., Choi, Y., Benoist, C., Gravallese, E.M., 2001. TRANCE/RANKL knockout mice are protected from bone erosion in a serum transfer model of arthritis. *Am J Pathol* 159, 1689-1699.

Prado, M.G., Iversen, M.D., Yu, Z., Miller Kroouze, R., Triedman, N.A., Kalia, S.S., Lu, B., Green, R.C., Karlson, E.W., Sparks, J.A., 2018. Effectiveness of a Web-Based Personalized Rheumatoid Arthritis Risk Tool With or Without a Health Educator for Knowledge of Rheumatoid Arthritis Risk Factors. *Arthritis Care Res (Hoboken)* 70, 1421-1430.

Prochazkova, M., Zanvit, P., Dolezal, T., Prokesova, L., Krsiak, M., 2009. Increased gene expression and production of spinal cyclooxygenase 1 and 2 during experimental osteoarthritis pain. *Physiol Res* 58, 419-425.

Rantapaa-Dahlqvist, S., de Jong, B.A., Berglin, E., Hallmans, G., Wadell, G., Stenlund, H., Sundin, U., van Venrooij, W.J., 2003. Antibodies against cyclic citrullinated peptide and IgA rheumatoid factor predict the development of rheumatoid arthritis. *Arthritis Rheum* 48, 2741-2749.

Richard, N., Arnold, S., Hoeller, U., Kilpert, C., Wertz, K., Schwager, J., 2011. Hydroxytyrosol is the major anti-inflammatory compound in aqueous olive extracts and impairs cytokine and chemokine production in macrophages. *Planta Med* 77, 1890-1897.

Rondaan, C., de Haan, A., Horst, G., Hempel, J.C., van Leer, C., Bos, N.A., van Assen, S., Bijl, M., Westra, J., 2014. Altered cellular and humoral immunity to varicella-zoster virus in patients with autoimmune diseases. *Arthritis Rheumatol* 66, 3122-3128.

Rosignoli, P., Fuccelli, R., Fabiani, R., Servili, M., Morozzi, G., 2013. Effect of olive oil phenols on the production of inflammatory mediators in freshly isolated human monocytes. *J Nutr Biochem* 24, 1513-1519.

Sanchez-Fidalgo, S., Sanchez de Ibarguen, L., Cardeno, A., Alarcon de la Lastra, C., 2012. Influence of extra virgin olive oil diet enriched with hydroxytyrosol in a chronic DSS colitis model. *Eur J Nutr* 51, 497-506.

Scher, J.U., Pillinger, M.H., Abramson, S.B., 2007. Nitric oxide synthases and osteoarthritis. *Curr Rheumatol Rep* 9, 9-15.

Scoditti, E., Calabriso, N., Massaro, M., Pellegrino, M., Storelli, C., Martines, G., De Caterina, R., Carluccio, M.A., 2012. Mediterranean diet polyphenols reduce inflammatory angiogenesis through MMP-9 and COX-2 inhibition in human vascular endothelial cells: a potentially protective mechanism in atherosclerotic vascular disease and cancer. *Arch Biochem Biophys* 527, 81-89.

Semerano, L., Clavel, G., Assier, E., Denys, A., Boissier, M.C., 2011. Blood vessels, a potential therapeutic target in rheumatoid arthritis? *Joint Bone Spine* 78, 118-123.

Skoldstam, L., Hagfors, L., Johansson, G., 2003. An experimental study of a Mediterranean diet intervention for patients with rheumatoid arthritis. *Ann Rheum Dis* 62, 208-214.

Smolen, J.S., Aletaha, D., McInnes, I.B., 2016. Rheumatoid arthritis. *Lancet* 388, 2023-2038.

Smolen, J.S., Redlich, K., 2014. Rheumatoid arthritis, In: Rose, N., Mackay, I. (Eds.), *The Autoimmune Diseases*, Fifth Edition ed. Academic Press.

Sone, H., Sakauchi, M., Takahashi, A., Suzuki, H., Inoue, N., Iida, K., Shimano, H., Toyoshima, H., Kawakami, Y., Okuda, Y., Matsuo, K., Yamada, N., 2001. Elevated levels of vascular endothelial growth factor in the sera of patients with rheumatoid arthritis correlation with disease activity. *Life Sci* 69, 1861-1869.

St-Laurent-Thibault, C., Arseneault, M., Longpre, F., Ramassamy, C., 2011. Tyrosol and hydroxytyrosol, two main components of olive oil, protect N2a cells against amyloid-beta-induced toxicity. Involvement of the NF-kappaB signaling. *Curr Alzheimer Res* 8, 543-551.

Suroowan, S., Mahomoodally, F., 2018. Herbal Products for Common Auto-Inflammatory Disorders - Novel Approaches. *Comb Chem High Throughput Screen* 21, 161-174.

Visioli, F., Galli, C., Grande, S., Colonnelli, K., Patelli, C., Galli, G., Caruso, D., 2003. Hydroxytyrosol excretion differs between rats and humans and depends on the vehicle of administration. *J Nutr* 133, 2612-2615.

Wei, S.T., Sun, Y.H., Zong, S.H., Xiang, Y.B., 2015. Serum Levels of IL-6 and TNF-alpha May Correlate with Activity and Severity of Rheumatoid Arthritis. *Med Sci Monit* 21, 4030-4038.

Wells, G., Becker, J.C., Teng, J., Dougados, M., Schiff, M., Smolen, J., Aletaha, D., van Riel, P.L., 2009. Validation of the 28-joint Disease Activity Score (DAS28) and European League Against Rheumatism response criteria based on C-reactive protein against disease progression in patients with rheumatoid arthritis, and comparison with the DAS28 based on erythrocyte sedimentation rate. *Ann Rheum Dis* 68, 954-960.

Zhang, X., Cao, J., Jiang, L., Zhong, L., 2009a. Suppressive effects of hydroxytyrosol on oxidative stress and nuclear Factor-kappaB activation in THP-1 cells. *Biol Pharm Bull* 32, 578-582.

Zhang, X., Cao, J., Zhong, L., 2009b. Hydroxytyrosol inhibits pro-inflammatory cytokines, iNOS, and COX-2 expression in human monocytic cells. *Naunyn Schmiedeberg Arch Pharmacol* 379, 581-586.

Supplementation with rich-polyphenols olive tree powder improves fasting blood glucose and insulin resistance in patients with type 2 diabetes mellitus: a 14-weeks randomized, double-blind, placebo-controlled clinical trial

Jamal GHANAM & Mohammed BENLEMLIH*

Biotechnology Laboratory, Faculty of Science Dhar El Mahraz, P.O. Box 1796, Atlas-Fez, University

Sidi Mohammed Ben Abdellah, Fez, Morocco.

*Corresponding author: Benlemlih Mohammed

ABSTRACT

Background- Despite the fact that olive tree extracts have been used for long time as antidiabetics in Mediterranean folk medicine, there are few studies on olive polyphenols providing support to this view.

Objectif- To assess the effect of rich-polyphenols olive extract on glucose metabolism and cardiovascular risk factors, a randomized, double-blinded, placebo-controlled trial was conducted in human subjects with type 2 diabetes.

Methods- Eighty T2D patients were randomized to receive either a daily dose of 3 g of olive tree powder

(6 capsules, 500 mg each) or placebo during 14 weeks. Anthropometric measures, glucose and insulin profiles, lipid profile and questionnaires administration were determined at the baseline and at the end of the trial. Doctors assessed potential adverse effects of olive tree powder through the period of study.

Results- Good compliance (over 94%) with the treatment was observed, without any study-intervention adverse and without any side effect observed. The lipid profile levels of treated group decrease significantly ($p < 0.0001$ vs. placebo group), while the value of HDL-cholesterol raise to 51.5 ± 9.4 mg/dL ($p = 0.007$ vs. placebo). The daily administration of rich-polyphenols olive tree powder results in a significant reduction (vs. placebo) in HbA1c ($p < 0.0001$), fasting glucose ($p < 0.0001$), insulin resistance ($p = 0.0002$). The average value of fasting glucose decreases to 114.2 ± 15.2 mg/dL, which is under to the normal range defined by the American Diabetic Association.

Conclusion- The supplementation with a rich-polyphenols powder from the olive tree was associated in a net improvement in fasting plasma glucose, insulin resistance and lipid profile in subjects with type 2 diabetes, suggesting the potential therapeutic effect of this extract as an antidiabetic.

Keywords: Type 2 diabetes mellitus; Olive tree powder; Olive tree extract; Glucose control; Randomized clinical trial.

INTRODUCTION

The most recent data published by the World Health Organization suggest that 422 million people already had diabetes by 2014 [1], while the projections predict

a continuous increase in the global incidence of diabetes to reach 552 million patients by 2030 [2]. This makes the pandemic of type 2 diabetes one of the enormous public health problems. T2DM is a chronic degenerative disease of metabolic disorders (most notably glucose metabolism), that progressively affects the optimal function of cardiovascular system, eyes, kidneys, nervous system and other organs such as the skin, liver and gut[2].

Regarding T2DM, one third of patients use alternative medicine to delay the disease outcomes, even without any scientific evidence supporting these uses (Yeh *et al.*, 2003). Data from comprehensive meta-analyses reported, in fact, inverse correlations between adherence to Mediterranean diet and risk of type 2 diabetes, as well as significant improvements in glycemic control (Babio *et al.*, 2014; Esposito *et al.*, 2009). The main features of this kind of diets is the predominance of plant foods and -notably- the high consumption of olive products (REF). Olive polyphenols are reportedly responsible for the health benefits associated with the Mediterranean diet (Martínez- González *et al.*, 2012; Babio *et al.*, 2009; Esturch *et al.*, 2006), as the analysis of the results from the PREDIMED trial showed an inverse correlation between polyphenol excretion and fasting glucose (Medina-Remón *et al.*, 2015). The most well studied phenolic compounds present in olive tree products are the catecholic derivatives, oleuropein and hydroxytyrosol, which show -according to in vitro and animal studies- antioxidant, anti-inflammatory, hypoglycemic, antihypertensive, antimicrobial, and anti-atherosclerotic properties (El and Karakaya, 2009).

For this reason, – in 2012 – the European Union recognize that a daily intake of 20 g of virgin olive oil containing, at least, 5 mg of hydroxytyrosol and its derivatives (notably,

oleacein), contributes to improve human health and well-being (EEC, 2012).

Additionally, the European Food Safety Authority has already endorsed the health claim that “the consumption of olive oil polyphenols contributes to the protection of blood lipids to oxidative damage” in 2006 (Bach-Faig *et al.*, 2011). This make exploring of the potential health benefits of olive products (rich in polyphenols) an expanding nutraceutical market. However, more studies on cultured cells, animals and - notably - humans are needed to provide compelling evidence that olive polyphenols are possible candidates for prevention and therapy of metabolic syndrome, particularly T2D.

For this purpose, we conducted a randomized, double-blinded, placebo-controlled, trial to assess the effect of olive tree powder on glucose metabolism in human subjects with T2DM. The main monitored outcomes were glycemic control and plasma biomarkers involved in the development of cardiovascular disease.

MATERIALS AND METHODS

Subjects

Men and women were recruited from October 2016 to February 2017 among of those referred to an outpatient clinic in Fez, Morocco. To be enrolled in the current study, subjects had to have been diagnosed with Type 2 Diabetes (T2DM) since at least one year based on the American Diabetes Association (ADA) criteria for the diagnosis of diabetes (A hemoglobin A1c (HbA1c) level of 6.5% or higher; A fasting plasma glucose (FPG) level of 126 mg/dL or higher; A 2-hour plasma glucose level of 200 mg/dL or higher during a 75-g oral glucose tolerance test (OGTT); A random plasma glucose of 200 mg/dL or higher

in a patient with classic symptoms of hyperglycemia or hyperglycemic crisis). Study was thoroughly explained to the voluntary participants. Patients were not eligible if :

- they were under the age of 20 years or over the age of 80 years;
- >1 hour of physical activity per week with participation in weight-reduction programs;
- on insulin therapy;
- they had hepatic or renal dysfunction;
- they had history of malignancy;
- they had a clinically important hematological disorder or severe autoimmune disease;
- they were pregnant (or planned to be), or breastfeeding during the trial period; lactating;
- they were receiving contraceptive;
- they were smoking; drug or alcohol abuse.

Exclusion criteria involved also the consumption of olive antioxidants or other antioxidant supplements ≤ 3 weeks before the intervention, history of allergy or intolerance to olive products. Before to be enrolled to this study, written informed consent was obtained from all voluntary participants.

Study design and intervention

The current study was planned as a double-blind, randomized, placebo-controlled trial (Fig. 1). It was directed according to the guidelines approved by Helsinki Declaration and the protocol was approved by the local ethics committee of the University Sidi Mohammed Ben Abdellah. Eligible participants were randomly assigned to Olive Tree Powder (OTP) supplement group or placebo group using a computer-generated random-number sequence. Researchers, participants and clinical staff

were blinded to the treatment codes of each group. The enrolled participants were invited by telephone to the clinic after an overnight fasting (between 8 and 14 h) to attend a screening visit (baseline analyses) including the assessment of adherence to the Mediterranean Diet (according to the modified questionnaire of Estruch *et al.* (2006)) and the evaluation of physical exercise by the International Physical Activity Questionnaire (Physical exercise was categorized as high, moderate, or low).

Participants were asked to maintain their habitual diet during the period of study, and avoid the consumption of olive products (including olive oil, olive table), and the use of all herbs or products known to affect glucose metabolism (synthetic or natural antioxidants). Dietary changes were monitored trough a 3-day dietary records at baseline and 14 weeks after intervention. Necessary explanations were provided about how to estimate food intake and record the estimations. We repeated all examinations and measurements after 14 weeks.

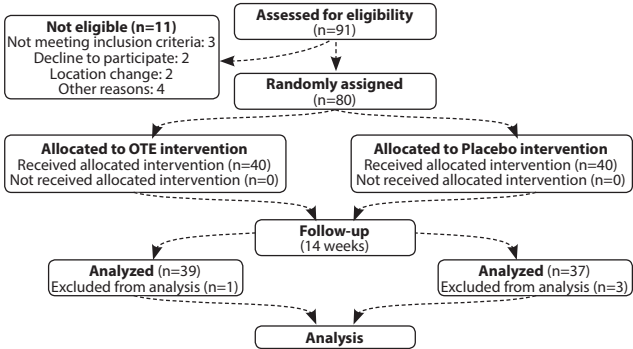


Figure 1. Study flow diagram.

During the study, all participants and investigators had free and continuous access to clinic for advice and consultation.

Participants who fulfilled all the inclusion criteria were received 500-mg study capsules (identical capsules for supplement and placebo group). Participants received also instructions concerning capsules taking and storage. Patients were asked to administrate 6 capsules per day before each meal and they were contacted every week to monitor supplement intake. Olive tree powder (OTP) was enclosed in soluble vegetal capsules. The placebo capsules contained only maltodextrin. OTP was obtained from different olive tree parts, fruits, olive tree young branches, and leaves using a purely natural and physical extraction (Laaboudi *et al.*, 2015). These specific olive trees are planted in the middle a rocky desert of Morocco, free of pollution, free of industrial activity, and under drought-stress (with temperatures up to 52°C). OTP is encapsulated in slight variations through the brand OLIVIE such as for example OLIVIE RICH/FORCE and marketed in Belgium as OLIVIE RICHE (see more in www.olivie.ma). Table 1 illustrate the main components of OTP extract.

LABORATORY MEASUREMENTS

Anthropometric measures were performed using calibrated scales and wall-mounted stadiometer with a precision of 0.1 cm; systolic and diastolic blood pressure were measured using a semi-automatic oscillometer (BosoMedicus smart Semi automatic Blood Pressure Monitor, Germany). Energy, nutrient intake and participants' diets assessment was carried out by Nutritionist 4.3 software (First Databank, Hearst Corp, San Bruno, CA). Blood samples were collected in EDTA and SST tubes. The obtained erythrocytes, plasma, serum and urine samples were aliquoted into 1 mL microtubes and stored at -80°C until further analysis. The fasting plasmagluco(mg/dl) was assayed by the glucose oxidase method (Beckman Glucose Analyzer).The following parameters were measured: HbA1C (%), TC (mg/dl),

HDL cholesterol (HDL-c) (mg/dl), LDL cholesterol (LDL-c) (mg/dl), TGs (mg/dl), hemoglobin (g/dl), hematocrit (%) and erythrocytes (mil./mm³). TC, VLDL and TG were measured using enzymatic tests in a contract clinical laboratory. LDL-c levels were calculated by the Friedewald equation, HDL-c was measured by using the heparin-manganese precipitation method. High-sensitivity enzyme-linked immunosorbent assay kits (DiaSource, Belgium) were used to quantify serum levels of insulin according to the manufacturer's guidelines. Fasting insulin resistance was assessed with homeostasis model assessment and calculated with the following formula, according to Matthews *et al.* (1985): $\text{fasting plasma glucose (mg/dL)} \times \text{fasting serum insulin } (\mu\text{U/mL}) / 405$. High scores indicate high insulin resistance. Urinary hydroxytyrosol was quantified by High Performance Liquid Chromatography (HPLC) as markers of OTP intake. Briefly, hydroxytyrosol was extracted from acidified urine (hydrochloric acid, 0.6 N of final concentration) as described previously (Visioli *et al.*, 2000) and analyzed in a Shimadzu chromatograph device equipped with a reverse phase C18 column (250 mm L. \times 4.6 mm I.D., 5 μm).

Doctors assessed potential adverse effects of OTP administration over the period of study including mouth symptoms, digestive disorders, fullness, allergic skin response, and other intervention-related symptoms. Finally, global satisfaction assessment in response to treatment (GAST) (including anxiety) was evaluated using a 5-point categorical scale (0 = poor, 1 = fair, 2 = good, 3 = very good, and 4 = excellent).

STATISTICAL ANALYSIS

Data were statistically analyzed using GraphPad Prism version 5.00 (GraphPad Prism Inc, San Diego, California). For the baseline characteristics, continuous variables are

expressed as mean values \pm standard deviation (SD), and categorical variables are expressed as frequencies (percent). Normal distribution of data was checked using the Kolmogorov-Smirnov test. The difference between baseline groups characteristic was performed by, the independent t test, the Mann-Whitney U test, and the χ^2 test for normally continuous data, not normally continuous data, and categorical data, respectively. the independent t test was also used to compare the mean changes from baseline to the end of the study between treated and placebo groups. Results with two- sided P values of <0.05 were considered statistically significant.

RESULTS

Baseline characteristics

Ninety-one eligible patients were enrolled, and 11 were excluded from the study for several reasons (Figure 1). Four participants were dropped out of analysis because they were unable to follow study protocol (Figure 1), due to higher fasting plasma glucose, total cholesterol and LDL-C levels than participants who completed the study. Good compliance was showed in treated-group (94.6%) and placebo-group (92.3%), without any observed study-intervention adverse. Urinary hydroxytyrosol determined as biomarker of compliance was quantified by HPLC. Results of the Figure 2 graph illustrate the changes from pre-intervention periods for placebo and treated (at 4 and at the end of study) group. The concentration of hydroxytyrosol founded in urine of treated participants was significantly higher ($P<0.0001$) compared to that of placebo group. However, it is worth noting that literature data on olive phenols absorption, metabolism, and excretion are not in agreement (Covas *et al.*, 2006; Visioli *et al.*, 2003).

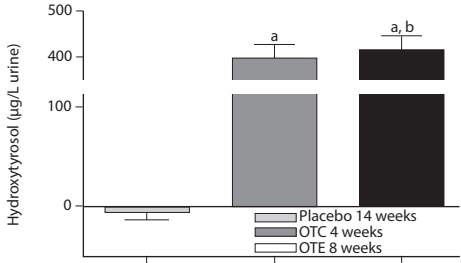


Figure 2. Change from baseline in urinary hydroxytyrosol excretion. Mean with SD. ^aP<0.0001, between OLF-group (at 4 or 8 weeks); ^bP=0.003, between OLF-group at 4 and 8 weeks.

Table 2 shows the baseline characteristics of the 80 participants who randomized into the treated and placebo group. Statistical analysis reveals no significant differences in demographic and clinical measurements among the two study groups, including the degree of adherence to Mediterranean Diet (*P*=0.326).

Table 1. Baseline characteristics of participants.

| Parameter | Intervention group (n=40) | Placebo group (n=40) | P value ^a |
|-------------------------------------|---------------------------|----------------------|----------------------|
| Age (years) | 53.27 ± 1.61 | 55.73 ± 1.97 | 0.346 |
| Female, n (%) | 17 (42.5) | 15 (37.5) | 0.915 |
| Weight (Kg) | 88.81 ± 3.55 | 86.15 ± 4.06 | 0.631 |
| BMI (Kg/m ²) | 30.5 ± 5.1 | 29.8 ± 4.7 | 0.175 |
| BMI >30 (Kg/m ²), n (%) | 28 (70) | 24 (60) | 0.632 |
| BMI <25 (Kg/m ²), n (%) | 7 (17.5) | 9 (22.5) | 0.539 |
| Disease duration (y) | 4.67 ± 1.4 | 3.50 ± 0.7 | 0.366 |
| Family history of disease, n (%) | 9 (22.5) | 10 (25.0) | 0.699 |
| Diet, n (%) | 7 (17.5) | 9 (22.5) | 0.813 |
| OAH + Diet, n (%) | 33 (82.5) | 31 (77.5) | 0.784 |
| HbA1C (%) | 7.79 (0.8) | 7.46 (1.1) | 0.663 |

| | | | |
|----------------------------------|--------------|--------------|-------|
| HbA1c level > 7%, n (%) | 27 (67.5) | 23 (57.5) | 0.558 |
| Glucose (mg/dL) | 166.9 ± 10.8 | 162.4 ± 9.8 | 0.764 |
| Insulin (μU/mL) | 13.1 (5.6) | 14.1 (6.4) | 0.432 |
| HOMA-IR | 5.4 (2.8) | 5.7 (3.1) | 0.698 |
| Total cholesterol | 201.7 ± 14.6 | 199.3 ± 18.3 | 0.923 |
| LDL-C | 127.7 ± 13.8 | 133.9 ± 14.9 | 0.765 |
| HDL-C | 45.9 ± 6.2 | 43.6 ± 5.2 | 0.784 |
| TGs | 131.5 ± 11.7 | 127.1 ± 11.5 | 0.799 |
| Systolic BP (mm Hg) | 130.9 ± 11.4 | 129.3 ± 12.4 | 0.589 |
| Diastolic BP (mm Hg) | 81.3 ± 7.2 | 80.7 ± 7.7 | 0.643 |
| 15-item Mediterranean diet score | 2.05 ± 0.15 | 2.40 ± 0.20 | 0.326 |

Value are expressed as mean ± standard deviation or in percentage.

*P value (<0.05) by independent t-test or Mann-Whitney test.

BP: Blood Pressure; BMI: Body Mass Index; HbA1c: Hemoglobin A1c; HDL: High-Density Lipoprotein; HOMA-IR : Homeostasis Model Assessment of Insulin Resistance; OAH: Oral Antihyperglycemic agents.

Results of dietary questionnaires represented in table 3 show that there was no significant difference in diet intake at the baseline and after 14 weeks of OLF and placebo supplement. The MUFAs and PUFAs – main components of the Mediterranean Diet – intake was maintained constant, which was good for the study since these nutrients affect (positively) plasma lipids and glucose metabolism of T2DM patients (Schwingshackl et Strasser, 2011; Esposito *et al.*, 2009). We also reported in table 3 change in participant's weight, with a slight decrease observed at the end of the intervention period in participant of treated group (but still not significant, $P = 0.176$). The level of macronutrient intakes was held constant during the study course and all participants met the daily diet recommended by the researchers by avoiding consumption of olive products and any other products known to affect glucose metabolism.

Table 2. Change in energy and macronutrients intake at baseline and end of the study for tow study groups. Data are expressed as mean \pm standard deviation.

| Parameter | OLF group (n=45) | Placebo group (n=45) |
|----------------------|------------------|----------------------|
| Energy (cal) | | |
| Baseline | 1755 \pm 209.8 | 1809 \pm 200.7 |
| 14 weeks | 1832 \pm 202.3 | 1445 \pm 318.6 |
| P value a | 0.506 | 0.695 |
| Fat (g) | | |
| Baseline | 75.90 \pm 9.9 | 69.2 \pm 12.4 |
| 14 weeks | 69.7 \pm 12.4 | 71.4 \pm 15.4 |
| P value ^a | 0.507 | 0.680 |
| PUFAs (g) | | |
| Baseline | 9.2 \pm 1.4 | 8.9 \pm 1.3 |
| 14 weeks | 9.7 \pm 2.9 | 10.7 \pm 1.9 |
| P value ^a | 0.711 | 0.651 |
| MUFAs (g) | | |
| Baseline | 22.7 \pm 1.5 | 20.1 \pm 1.7 |
| 14 weeks | 21.7 \pm 2.9 | 21.6 \pm 1.2 |
| P value ^a | 0.510 | 0.450 |
| SFAs (g) | | |
| Baseline | 15.3 \pm 1.9 | 13.6 \pm 2.7 |
| 14 weeks | 15.2 \pm 1.6 | 14.1 \pm 2.9 |
| P value ^a | 0.655 | 0.844 |
| Weight (kg) | | |
| Baseline | 88.81 \pm 3.55 | 86.15 \pm 4.06 |
| 14 weeks | 86.31 \pm 3.87 | 87.31 \pm 3.46 |
| P value ^a | 0.176 | 0.359 |

PUFAs, polyunsaturated fatty acids; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids.a Paired Student t test (p<0.05).

CLINICAL MEASUREMENT

At the end of the 12-week study period, weight and BMI were reduced in the intervention group, but with no significant difference compared to the control group (Table).

Table 3. Results from generalized linear model analysis describing changes in clinical and laboratory measurements between baseline and 14-month follow-up examinations. See legend of table 1 for the abbreviations.

| Variable | Intervention group (n=39) | | Placebo group (n=37) | | P value ^a |
|---------------------------|---------------------------|-------------|----------------------|-------------|----------------------|
| | 14-weeks | Δ study end | 14-weeks | Δ study end | |
| Weight (Kg) | 86.3 ± 3.8 | ↓ 2.5 | 87.3 ± 3.4 | ↑ 1.2 | 0.593 |
| BMI (Kg/m ²) | 28.1 ± 4.6 | ↓ 2.4 | 30.8 ± 3.9 | ↑ 1 | 0.332 |
| HbA1C (%) | 6.08 ± 1.2 | ↓ 1.3 | 8.6 ± 1.3 | ↑ 1.04 | <0.0001 |
| Glucose (mg/dL) | 111.2 ± 15.2 | ↓ 55.7 | 172.7 ± 17.1 | ↑ 10.3 | <0.0001 |
| Insulin (μU/mL) | 14.5 ± 2.5 | ↑ 1.4 | 13.6 ± 3 | ↓ 0.5 | 0.251 |
| HOMA-IR | 3.9 ± 1.2 | ↓ 1.4 | 5.8 ± 2.0 | ↑ 0.1 | 0.0002 |
| Total cholesterol (mg/dL) | 150.9 ± (26.4) | ↓ 50.8 | 234.8 ± 37.3 | ↑ 35.5 | <0.0001 |
| LDL-C (mg/dL) | 106.9 ± 20.1 | ↓ 20.8 | 150.9 ± 26.4 | ↑ 17 | <0.0001 |
| HDL-C (mg/dL) | 51.5 ± 9.4 | ↑ 5.6 | 41.7 ± 11 | ↓ 1.9 | 0.007 |
| TGs (mg/dL) | 87.1 ± 11.2 | ↓ 44.4 | 148.8 ± 19.4 | ↑ 21.7 | <0.0001 |
| GAST | 3.4 ± 0.6 | | 2.2 ± 0.4 | | 0.04 |

However, the lipid profile levels of treated group decrease significantly (vs placebo group) for Total cholesterol ($p < 0.0001$), LDL-C ($p < 0.0001$), and TGs ($p < 0.0001$), while the value of HDL-C raise to 51.5 ± 9.4 mg/dL ($p = 0.007$). The daily supplementation with the rich-polyphenols olive tree extract was associated to a significant reduction (vs. placebo) in HbA1c ($p < 0.0001$), fasting glucose ($p < 0.0001$), HOMA ($p = 0.0002$). The average value of fasting glucose raises to 114.2 ± 15.2 mg/dL at the end the intervention, which is to the normal range defined by the ADA (13). The fasting insulin levels increased over time for the treated group (even the difference still no significant compared to the placebo

group $p = 0.251$), suggesting an improve in insulin secretion as well (taking together with the decrease in fasting glucose).

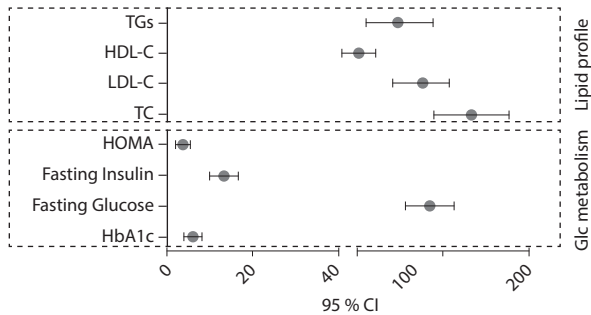


Figure. The horizontal line joins the lower and upper limits of the 95% Clof each corresponding parameter measured in the intervention group.

Additionally, almost all of the treated group participants have reported a very good satisfaction of the treatment, evaluated by the GASTquestionnaire (Table 3).

DISCUSSION

In this placebo-controlled trial, patient with T2D were allocated to a treatment by an aqueous olive tree extract during 14 weeks, by receiving a daily dose of 3 g (6 capsules, 500 mg each). No adverse signs and laboratory parameters fluctuation have been observed during the study period and within the three post-intervention weeks (data not shown). We found that the supplementation with rich-polyphenols OTE modulates carbohydrate and lipid metabolism, attenuate hyperglycemia, dyslipidemia and insulin resistance.

T2DM is an endocrine disease related impaired carbohydrate metabolism and insulin resistance [4]. Several authors reported that Mediterranean Diet (rich

in olive polyphenols) and polyphenol-rich foods (olive oil, tea, cocoa, cinnamon, grapes, and berries) modulate carbohydrate metabolism, and attenuate hyperglycaemia, dyslipidemia and insulin resistance [Elhayany *et al.*, Esposito *et al.*, 2009; 21, 22]. We have already shown -as well as many others authors- that a daily supplementation with olive polyphenols exert a hypoglycemic response in animal models [Laaboudi *et al.*, 2016; 23,24,25]. Furthermore, diabetic rats consuming 0.5 mg/kg olive leaf extract for 30 days showed improved blood glucose, and insulin secretion (26). More interesting, the anti-hyperglycemic effects of olive polyphenols were also demonstrated in prediabetics and diabetics human volunteers by several research groups [27,28,29,76].

The first goal of T2D treatment is to target glycemic control by maintaining HbA1c as close as possible to normal value ($\leq 7\%$). Here, OTP supplementation for 14 weeks was associated with a reduction of HbA1c by $\approx 22\%$ (more than 62% of participants have had a normal value at the end of the intervention). Similar effect was also observed in diabetic patients consuming a daily dose of olive leaves extract of 500 mg for 14 weeks, but the HbA1c values decreased only by 10% (Wainstein *et al.*, 2012). It is to be noted that the OTP represent the full spectrum of the tree, not only a single part of the olive tree such as isolated leafs. As we said in the beginning, OTP comes from olive tree leafs, baby leafs, olive fruit as well as olive oil. There is a positive synergetic effect produced by the mix of all the polyphenols present inside the olive tree in their natural proportions. How polyphenols influence the level of circulating glycated plasma proteins is still not so clear. However, it was suggested that the antioxidant properties might diminish the production of advanced glycosylated end products such as HbA1c (Xiao and Högger, 2015). T2DM is also associated with

deregulation of lipid metabolism, which can be positively targeted by olive polyphenols. In the well-known large multi-centre crossover trial (200 healthy men), Estruch *et al.* demonstrated the dose dependent improvements in plasma HDL status after administration of increasing polyphenol concentrations in olive oils. Supplementary, modulation of glucose metabolism would reduce the accumulation of lipids in the liver (as observed in a cholesterol fed rat model) and potentially offset *de-novo* lipogenic pathways (Jemai *et al.*, 2008). This might explain reduced dyslipidaemia (reduction in total cholesterol, LDL-C, TGs, and improvement in HDL-C) of the participants allocated to OTE. The supplementation with rich-polyphenols olive leaf extract improves fasting glucose in T2D diabetic subjects (Wainstein *et al.*, 2012), and both insulin sensitivity and secretion in overweight middle-agedmen (deBock *et al.*, 2013). Similar effects were observed at the end of this intervention with an improvement in fasting glucose, insulin resistance, and insulin secretion by over 33, 27 and 11%, respectively. We should underline, in fact, that we have used an olive tree powder (not an olive leaf extract) at high daily dose in comparison to de Bock' and Wainstein' studies. Additionally, the treatment by OTP might have an exaggerated response in patients who had already T2D compared to prediabetic subjects (deBock *et al.*, 2013), which can explain the results herein obtained. However, we all assume that polyphenols contained in our powder are responsible of the observed hypoglycemic effects. In this sense, it has been reported that a daily supplementation with rutin (500 mg) reduces fasting glucose levels by over 10% in diabetic patients at 4 and 8 weeks.

Because T2DM is a multifactorial disease, olive polyphenols might have multifaceted anti-hyperglycemic effects. Firstly, hydroxytyrosol and oleuropein have been

shown, *in vitro*, a strong inhibition of amylase and α -glucosidase (Adefegha *et al.*, 2012; Xiao *et al.*, 2013). Actually, our unpublished data show the same effect of the studied olive tree extract (rich in hydroxytyrosol) on α -glucosidase and α -mannosidase. On the other hand, polyphenols can act as direct suppressors of the proteins involved in the intestinal transport of dietary carbohydrate (Hanhineva *et al.*, 2010). This would result in the suppressed digestion of starch and therefore a lower glycemic response to foods. Furthermore, Polyphenols might affect glucose metabolism via a reduction of glucose release from the liver or a stimulation of cellular glucose uptake, which lead to reduced plasma glucose (Hanhineva *et al.*, 2010; Gonzalez *et al.*, 1992). Oleuropein and hydroxytyrosol (two phenols abundant in the studied extract) enhance glucose induced insulin secretion following oral glucose challenge in human subjects (de Bock *et al.*, 2013), and protect insulin-secreting β -cells against toxic H₂O₂ by maintaining normal redox homeostasis during an oxidative stress (Cumaoglu *et al.*, 2011).

CONCLUSION

Overall, results herein obtained demonstrate that the administration of rich- polyphenols extract from olive tree was associated to significant hypoglycemic effects in patients with type 2 diabetes. We suggest that olive polyphenols -as natural components of olive tree powder- exert an hypoglycemic effect, mainly by i) improving glucose-induced insulin secretion, and ii) increasing peripheral glucose uptake. Further research should compare hypoglycemic effect of pure polyphenols (from this olive tree powder) to conventional T2DM therapy (e.g. metformin) to better understanding the mechanism(s) by which these molecules contribute to glucose metabolism control.

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REFERENCES

- [1] World Health Organization. W.H.O. Global Report On Diabetes. Available online: pqs.who.int/iris/bitstream/10665/204871/1/9789241565257_eng.pdf (accessed on 11 January 2017).
- [2] Whiting DR, Guariguata L, Weil C, Shaw J. IDF Diabetes Atlas: Global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Research and Clinical Practice* 2011; 94: 311–321.
- [3] Yeh GY, Eisenberg DM, Kaptchuk TJ, Phillips RS. Systematic review of herbs and dietary supplements for glycemic control in diabetes. *Diabetes Care* 2003; 26:1277–1294.
- [4] Babio N, Toledo E, Estruch R, Ros E, Martínez-Gonzalez MA, Castaner O, Bullo M, Corella D, Aros F, Gomez-Gracia E, et al. Mediterranean diets and metabolic syndrome status in the PREDIMED randomized trial. *Canadian Medical Association journal* 2014; 186: E649–E657.
- [5] Esposito K, Maiorino MI, Ciotola M, Di Palo C, Scognamiglio P, Gicchino M, Petrizzo M, Saccomanno F, Beneduce F, Ceriello A, Giugliano D. Effects of a Mediterranean-style diet on the need for antihyperglycemic drug therapy in patients with newly diagnosed type 2 diabetes: a randomized trial. *Annals of Internal Medicine* 2009; 151(5): 306–14.
- [6] Martínez-González MÁ, Corella D, Salas-Salvadó J, Ros E, Covas MI, Fiol M, Wärnberg J, Arós F, Ruiz-Gutiérrez V, Lamuela-Raventós RM, et al. Cohort profile: Design and methods of the PREDIMED study. *International Journal of Epidemiology* 2012; 41: 377–385.
- [7] Estruch R, Martínez-Gonzalez MA, Corella D, Salas-Salvadó J, Ruiz-Gutiérrez V, Covas MI, et al. Effects of a Mediterranean-Style Diet on Cardiovascular Risk Factors: A Randomized Trial. *Annals of Internal Medicine* 2006; 145: 1–11.
- [8] Medina-Remón A, Tresserra-Rimbau A, Pons A, Tur JA, Martorell M, Ros E et al. Effects of total dietary polyphenols on plasma nitric oxide and blood pressure in a high cardiovascular risk cohort. The PREDIMED randomized trial. *Nutrition, Metabolism & Cardiovascular Diseases* 2015; 25: 60–67.
- [9] El SN, Karakaya S. Olive tree (*Olea europaea*) leaves: potential beneficial effects on human health. *Nutrition Reviews* 2009; 67: 632–638.

- [10] European Commission Regulation EEC/432/2012 of 16 May 2012 establishing a List of permitted health claims made on foods, other than those referring to the reduction of disease risk and to child. *Official Journal of European Communities* 2012; L136: 1–40.
- [11] Agostoni CV. Scientific Opinion on the substantiation of health claims related to polyphenols in olive and protection of LDL particles from oxidative damage (ID 1333, 1638, 1639, 1696, 2865), maintenance of normal blood HDL cholesterol concentrations (ID 1639), maintenance of normal blood pressure (ID 3781), antiinflammatory properties (ID 1882), contributes to the upper respiratory tract health (ID 3468), can help to maintain a normal function of gastrointestinal tract (3779), and contributes to body defences against external agents (ID 3467) pursuant to Article 13 (1) of Regulation (EC) No 1924/2006. *EFSA Journal* 2011; 9: 2033.2031–2033.2025.
- [12] Association, A.A.D. Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care* 2014; 37: S81–S90.
- [13] Laaboudi W, Ghanam J, Merzouki M, and Benlemlih M. Eco-Extraction of Phenolic Compounds from Moroccan Olive Fruits and Leaves and their Potential use as Antimicrobial Agents. *European Journal of Scientific Research* 2015; 132: 255–265.
- [14] Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985; 28: 412–9.
- [15] Visioli F, Galli C, Bornet F, Mattei A, Patelli R, Galli G, *et al.* Olive oil phenolics are dose-dependently absorbed in humans. *FEBS Letters* 2000; 468:159–160.
- [16] Covas MI, de la Torre K, Farre-Albaladejo M, Kaikkonen J, Fitò M, Lopez-Sabater C, *et al.* Postprandial LDL phenolic content and LDL oxidation are modulated by olive oil phenolic compounds in human. *Free Radical Biology and Medicine* 2006; 40: 608–16.
- [17] Visioli F, Galli C, Grande S, Colonnelli K, Patelli C, Galli G, *et al.* Hydroxytyrosol excretion differs between rats and humans and depends on the vehicle of administration. *Journal of Nutrition* 2003; 133: 2612–2615.
- [18] Schwingshackl L, Strasser B, Hoffmann G. Effects of monounsaturated fatty acids on glycaemic control in patients with abnormal glucose metabolism: a systematic review and meta-analysis. *Annals of Nutrition and Metabolism* 2011; 58: 290–296.
- [19] Elhayany A, Lustman A, Abel R, Attal-Singer J, Vinker S. A low carbohydrate Mediterranean diet improves cardiovascular risk factors and diabetes control among overweight patients with type 2 diabetes mellitus: a 1-year prospective randomized intervention study. *Diabetes, Obesity and Metabolism* 2010; 12: 204–209.
- [20] Bahadoran Z, Mirmiran P, Azizi F. Dietary polyphenols as potential nutraceuticals in management of diabetes: A review. *Journal of Diabetes & Metabolic Disorders* 2013; 12: 43.

- [21] Hanhineva K, Törrönen R, Bondia-Pons I, Pekkinen J, Kolehmainen M, Mykkänen H, Poutanen K. Impact of Dietary Polyphenols on Carbohydrate Metabolism. *International Journal of Molecular Sciences* 2010; 11:1365–1402.
- [22] Laaboudi W, Ghanam J, Ghomari O, Merzouki M, and Benlemlih M. Hypoglycemic and hypolipidemic effects of phenolic olive tree extract in streptozotocin diabetic rats. *International Journal of Pharmacy and Pharmaceutical Sciences* 2016; 12: 287–291.
- [23] Komaki E, Yamaguchi S, Maru I, Kinoshita M, Kakehi K, Ohta Y, Tsukada Y. Identification of Anti-ALPHA Amylase Components from Olive Leaf Extracts. *Food Science and Technology Research* 2003; 9: 35–39.
- [24] Gonzalez M, Zarzuelo A, Gamez MJ, Utrilla MP, Jimenez J, Osuna I. Hypoglycemic activity of olive leaf. *Planta Medica* 1992; 58: 513–515.
- [25] Hashmi MA, Khan A, Hanif M, Farooq U, Perveen S. Traditional Uses, Phytochemistry, and Pharmacology of *Olea europaea* (Olive). *Evidence-based Complementary and Alternative Medicine* 2015; 2015: 541591.
- [26] Ismail I, Ghanema A, Sadek KM. Olive leaves extract restored the antioxidant perturbations in red blood cells hemolysate in Streptozotocin induced diabetic rats. *International Journal of Biological Sciences* 2012; 6: 181–187.
- [27] Violi F, Loffredo L, Pignatelli P, Angelico F, Bartimoccia S, Nocella C, Cangemi R, Petruccioli A, Monticcolo R, Pastori D, et al. Extra virgin olive oil use is associated with improved post-prandial blood glucose and LDL cholesterol in healthy subjects. *Nutrition & Diabetes* 2015; 5: e172.
- [28] De Bock M; Derraik JGB, Brennan CM, Biggs JB, Morgan PE, Hodgkinson SC, Hofman PL, Cutfield WS. Olive (*Olea europaea* L.) Leaf Polyphenols Improve Insulin Sensitivity in Middle-Aged Overweight Men: A Randomized, Placebo-Controlled, Crossover Trial. *PLoS ONE* 2013; 8: e57622.
- [29] Wainstein J, Ganz T, Boaz M, Bar Dayan Y, Dolev E, Kerem Z, Madar Z. Olive leaf extract as a hypoglycemic agent in both human diabetic subjects and in rats. *Journal of Medicinal Food* 2012; 15: 605–610.
- [30] Ibrahim A, Al Jamal AR. Effects of olive oil on lipid profiles and blood glucose in type 2 diabetic patients. *International Journal of Diabetes and Metabolism* 2011; 19: 19–22.
- [31] Xiao JB, Högger P. Dietary polyphenols and type 2 diabetes: current insights and future perspectives. *Current Medicinal Chemistry* 2015; 22: 23–38.
- [32] Jemai H, El Feki A, Sayadi S. Antidiabetic and antioxidant effects of hydroxytyrosol and oleuropein from olive leaves in alloxan-diabetic rats. *Journal of Agricultural and Food Chemistry* 2009; 57: 8798–8804.
- [33] Sattanathan K, Dhanapal CK, Umarani R, Manavalan R. Beneficial health effects of rutin supplementation in patients with diabetes mellitus. *Journal of Applied Pharmaceutical Science* 2011; 1: 227–231.
- [34] Xiao J, Ni X, Kai G, Chen X. A review on structure-activity relationship of dietary polyphenols inhibiting alpha-amylase. *Critical Reviews in Food Science and Nutrition* 2013; 53: 497–506.

- [35] Adefegha SA, Oboh G. In vitro inhibition activity of polyphenol-rich extracts from *Syzygium aromaticum* (L.) Merr. & Perry (Clove) buds against carbohydrate hydrolyzing enzymes linked to type 2 diabetes and Fe(2+)-induced lipid peroxidation in rat pancreas. *Asian Pacific Journal of Tropical Biomedicine* 2012; 2:774–781.
- [36] Hanhineva K, Törrönen R, Bondia-Pons I, Pekkinen J, Kolehmainen M, Mykkänen H, Poutanen K. Impact of Dietary Polyphenols on Carbohydrate Metabolism. *International Journal of Molecular Sciences* 2010; 11:1365–1402.
- [37] Cumaoglu A, Rackova L, Stefek M, Kartal M, Maechler P, Karasu C. Effects of olive leaf polyphenols against H₂O₂ toxicity in insulin secreting β -cells. *Acta Biochimica Polonica* 2011; 58: 45–50.

Hypoglycemic and hypolipidemic effects of phenolic olive tree extract in streptozotocin diabetic rats

Wafa Laaboudi*, Jamal Ghanam¹, Oumaima Ghoumari¹, Fatiha Sounni¹, Mohammed Merzouki¹, Mohamed Benlemlih¹

¹Biotechnology, Laboratory, Faculty of Science, Dhar, El Mahraz, University Sidi Mohamed, Ben Abdellah – Fez – Morocco

ABSTRACT

Objective: The aim of the present study was to determine the effects of an olive tree extract with high polyphenols content on blood glucose level and other related parameters in streptozotocin-induced diabetic rats.

Methods: Diabetes was induced in rats by intraperitoneal injection of streptozotocin (55 mg/kg bw). 72h after injection, rats with fasting blood glucose higher than 2 g/l were used for the experiments. Olive tree extract was administered for 28 d and blood glucose level was measured every 4 d. Total cholesterol, triglycerides, HDL-cholesterol, creatinine, urea, total protein, uric acid, aspartate aminotransferase and alanine aminotransferase levels, were determined at the end of the experiment.

Results: The oral administration of olive tree extract contributes to blood glucose level decreasing in diabetic rats group, which was significantly lower at 4th week compared to the diabetic control rats. Moreover, supplementation by olive tree extract decreased significantly ($p < 0.05$) the values of total cholesterol, triglycerides, HDL-cholesterol, creatinine, urea, total protein, uric acid, aspartate aminotransferase and alanine aminotransferase resulting from damage caused by streptozotocin treatment. Beside this, significant reduce ($p < 0.05$) in heart disease risk ratio was observed for treated group (4.1 ± 0.14) compared to untreated group (7.64 ± 0.36), which was quite similar to normal rats (4.50 ± 0.36). Studied olive tree extract effects were similar to those of glibenclamide, a well-known antidiabetic drug.

Conclusion: Results herein obtained reveal the hypoglycemic effect of this olive tree extract, suggesting his potential use as a natural antidiabetic agent.

Keywords: Olive leaves, Olive fruit, Polyphenols, Antidiabetic, Streptozotocin, *In vivo*.

INTRODUCTION

There has been a tragic increase in diabetes mellitus across the world. Diabetes mellitus is caused by complete or partial deficiencies in insulin production and/or insulin action coupled with chronic hyperglycemia and metabolism disruption [1]. It is considered as one of the most important clinical risk factors involved in some disorders like nephropathy, retinopathy, neuropathy, and cardiovascular diseases, which its prevalence is predicted to be increased daily [2-6]. Therefore, it is great urgency to find better treatments and novel prevention strategies regarding this worldwide health problem.

The most common treatment is insulin and drugs with hypoglycemic effects [7]. However, there is an increasing demand by patients to use natural products, due to the side effects associated with insulin and oral hypoglycemic agents [8, 9]. The study of such products may offer a natural alternative to diabetes management in the future.

Among the plants used for their antidiabetic effect, an olive tree (*Olea europaeae*) is of paramount importance. Currently, the implication of the olive tree byproduct extracts in pharmacology and food industries is due to the presence of some important phenolic components. The olive tree has been recognized for a long time as a source of bioactive polyphenols, such as oleuropein, hydroxytyrosol, oleuropein aglycone, and tyrosol [10-12]. Furthermore, olive wastes are considered as a cheap raw material for extracting of high-added value products [13]. Several studies have shown that olive tree possessed a wide range of pharmacological and health-promoting properties including the reduction of coronary heart disease risk [14, 15], anti-inflammatory [16-20], antitumor, anti-proliferative [21, 22], antidiabetic [23-26], antibacterial and antifungal properties [27-30]. Many of these properties have been described as resulting from the antioxidant character of polyphenols [31]. Gonzalez *et al.* [1] have previously reported that olive polyphenols had an antihyperglycemic effect on diabetic rats, although the mechanism by which they attenuate hyperglycemia is still not well known. However, particular attention has been paid to hydroxytyrosol [32], which occurs naturally in olive byproducts. This *o*-diphenol, like the majority of the olive polyphenols such as tyrosol, has been proven to have significant antitumor, anti-proliferative [21, 22] and antiviral activities [33].

Since the waste of olive has been recommended in the literature [23-26], as a remedy for the treatment of diabetes, it was considered worthwhile to investigate the influence of an olive tree extract, administered orally during 4 w, in normal and streptozotocin- induced diabetic rats. For this purpose, serum glucose level, lipids, renal and hepatic profiles were measured during the current study.

MATERIALS AND METHODS

Plant material and chemicals

Streptozotocin; glucose; glibenclamide (glyburide) were purchased from Sigma-Aldrich (Paris, France). Glucometer (BIONIME blood glucose monitoring system right GM300) and strips (BIONIME blood glucose test strip rightet GS300) were purchased from Bionime distributor (Casablanca, Morocco).

The olive tree extract (OTE) was obtained from Moroccan olive fruits and leaves using an eco-extraction, free of chemical solvents or toxic additives, according to the previously described protocol [19]. OTE is marketed in the world as under the brand name OLIVIE FORCE/OLIVIE RICHE (see more in www.olivie.ma).

Animals

Male adult 'Wistar' rats (200-250 g) obtained from the animal breeding unit (located in the Faculty of Science Dhar El Mahraz - Fez - Morocco) were used in this study. The animals were housed in clean plastic cages and maintained under environmentally controlled breeding room (temperature, 22 ± 2 °C; humidity, $40\pm 5\%$; 12 h dark/light cycle) and had free access to food and water. Housing conditions and *in vivo* experiments were approved according to the guidelines established by the European Union on Animal care (CEE Council 86/609).

The animals were used after an acclimatization period of two weeks to the laboratory environment and fasted overnight before experiments.

Experimental design

Diabetes was induced in rats by single intraperitoneal injection of a freshly prepared solution of streptozotocin (55 mg/kg body weight) in citrate buffer 0.1M (pH 4.5). For three days, rats received 5% of glucose in the drinking water. 72h after injection, rats with fasting blood glucose higher than 2 g/l were used for the experiments and received daily the adequate treatment for a period of 4 w.

Rats were divided into four different groups (10 rats in each group n= 10). "Control rats": negative control rats were received orally 10 ml/kg of 0.9% NaCl solution; "Diabetic rats": positive control rats were administered orally 10 ml/kg of 0.9% NaCl solution; "Diabetic rats+glibenclamide": rats were treated by 0.3 mg/kg of glibenclamide and "Diabetic rats+OTE": rats received daily oral dose of 1 g/kg of OTE.

Biochemical analysis

During this study, blood glucose level was measured every 4 d, at the same time in the morning. Glycemia was measured in blood from the tail vein using the commercial glucometer.

After 28 d of treatments, bold samples were collected into heparinized tubes and centrifuged at 3000 tr/min for 10 min. Plasma samples were separated and transferred in Eppendorf tubes for analysis. Total cholesterol (Total CT), triglycerides (TG), high density lipoproteins cholesterol (HDL-CT), creatinine, urea, total protein, uric acid, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels, were determined using

commercial kits (Sigma-Aldrich; Paris, France) according to the manufacturer's guidelines. Low lipoproteins cholesterol (LDL-CT) level was calculated by the following Friedewald equation [34]:

$$LDL \cdot CT = Total \cdot CT - HDL \cdot CT - \frac{TG}{5}$$

Statistical analysis

Statistical analyses were performed using GraphPad Prism software version 6.00 (GraphPad Inc., San Diego, California). Data were analyzed by analysis of variance (ANOVA Analysis of Variance). Values between groups were considered statistically significant for at $P < 0.05$.

RESULTS

Blood glucose level

Results plotted in the graph of fig. 1 illustrates an OTE's effect on blood glucose through the period of treatment. The blood glucose levels of normal and diabetic (untreated) rats were between 0.9 ± 0.11 and 4.5 ± 0.62 g/l, and 1.1 ± 0.10 and 5.23 ± 0.66 g/l throughout the period of treatment. However, a significant decrease in blood glucose levels was observed in supplemented diabetic rats from the first intake of OTE (after 4 d). Diabetic rats in the treated (by OTE) group reach the normal blood glucose after 20 d of OTE administration (1 g/kg), while this level decreases to the same value of normal rats (~ 1 g/l) at the end of the study. Thus, the OTE was found to have a similar hypoglycemic effect to glibenclamide effect at the end of the study.

Lipid profile

Total cholesterol, triglycerides and HDL-cholesterol levels were measured at the end of the experiment; obtained results are showed in the graph of fig. 2.

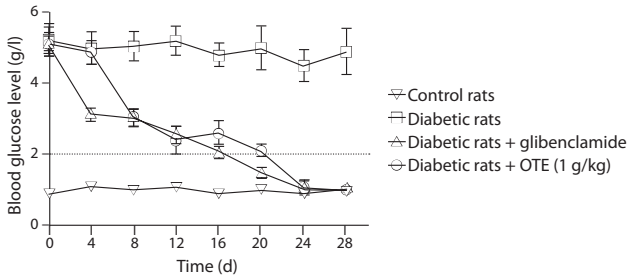


Fig. 1: Effect of OTE on blood glucose levels in diabetic and non-diabetic rats after 4 w of daily admission (n= 10).

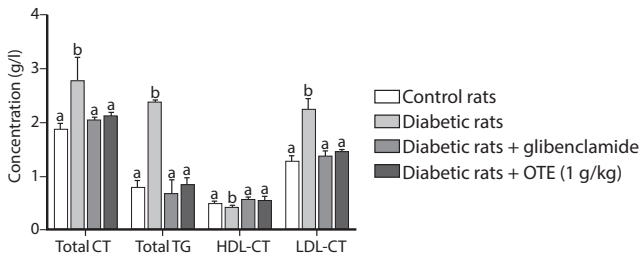


Fig. 2: Effect of OTE on total cholesterol (CT), triglycerides (TG), high-density lipoproteins cholesterol (HDL-CT) and low lipoproteins cholesterol (LD-CT) in diabetic and normal rats after 4 w of daily admission (n= 10). Different letters a–b indicate significant differences ($p < 0.05$).

The analytical values of TC (2.75 ± 0.44 g/l), TG (2.36 ± 0.03 g/l) and LDL-CT (2.23 ± 0.18 g/l) recorded in untreated diabetic rats showed a significant ($p < 0.05$) increase at the end of the study compared to those of rats in control or treated groups (fig. 2). However, the values of TC, TG and LDL-CT drop significantly ($p < 0.05$) to 2.1 ± 0.01 , 0.81 ± 0.14 and 1.43 ± 0.04 g/l, respectively, in the blood of rats supplemented by 1g/kg of studied olive tree extract. As a net result, OTE administration was able to restore the lipid profile and correct the hypercholesterolemia associated with hyperglycemia.

Nevertheless, OTE administration had no significant effect on HDL-CT of treated diabetic rats (0.51 ± 0.12 g/l) compared to control rats (0.45 ± 0.04 g/l) or diabetic rats treated by glibenclamide (0.54 ± 0.07 g/l).

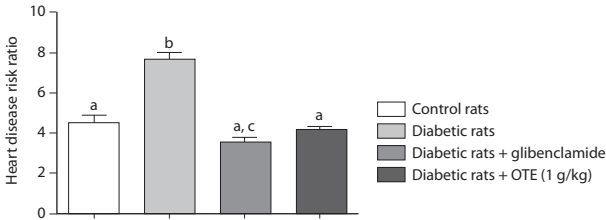


Fig. 3: Heart disease risk ratio in diabetic and normal rats after 4 w of OTE daily admission (n=10). Different letters a–b indicate significant differences ($p<0.05$).

On the other hand, the overall improvements in the blood lipid profile of rats treated by OTE had positively influenced heart disease risk ratio parameter (Total CT/HDL-CT) [35]. In this sense, results of fig. 3 show a significant difference ($p<0.05$) in favor of rats treated by OTE (4.1 ± 0.14) and glibenclamide (3.53 ± 0.21) compared to untreated diabetic rats (7.64 ± 0.36). We should also underline that the heart disease risk parameter of rats supplemented for 28 d by the studied olive tree extract was quite similar to that of control animals (4.50 ± 0.36).

Renal function tests

Table 1 shows the effect of OTE on creatinine, urea, total protein and uric acid in rats allocated to the study groups. The results showed that creatinine, urea, and uric acid increased in streptozotocin- induced diabetic rats compared with control rats ($p<0.05$).

However, OTE and glibenclamide administration have significantly ($p<0.05$) stabilized these parameters at the normal values compared to rats in control group. These

results suggest, in fact, that supplementation by OTE has an appropriate regulating effect directed to each of the biochemical parameters associated with hyperglycemia. Moreover, serum levels of AST and ALT (and AST/ALT ratio) are commonly measured clinically as biomarkers for liver health. Results showed in table 2 (combined with those of table 1) indicate that OTE administration had no adverse effect on renal function of treated rats.

DISCUSSION

Streptozotocin is the most prominent diabetogenic chemical agent in diabetes research. In 1963, Rakietyen *et al.* reported that streptozotocin is diabetogenic [36]. Since then, it has been chosen for diabetes mellitus induction in animal models [37]. Actually, streptozotocin inhibits insulin secretion and causes a state of insulin-dependent diabetes mellitus, due to its specific chemical properties, namely its alkylating potency [37]. Streptozotocin has been known to cause specific necrosis of the pancreatic beta cells, which is similar to the feature of the later stage of type 2 diabetes [38, 39] Results of this study showed that blood glucose of diabetic rats increases significantly three days after the intraperitoneal streptozotocin injection. This was similar with the researches that have been done throughout the world for diabetes induction [37, 40, 41].

A significant decrease in blood glucose of diabetic rats treated by OTE –compared with that of the diabetic rats– was observed from the first day of the study to the 28 d (first OTE intake). The OTE was found to have a similar hypoglycemic effect to glibenclamide at the end of the study. The OTE's hypoglycemic activity may result from two mechanisms: (i) potentiation of glucose-induced insulin release, and (ii) increasing peripheral uptake of

Table 1: Effect of OTE on Creatinine, urea, total protein and uric acid in diabetic rats after 4 w of daily administration.

| | Control rats | Diabetic rats | Diabetic rats+glibenclamide | Diabetic rats+OTE (1 g/kg) |
|----------------------|------------------------|------------------------|-----------------------------|----------------------------|
| Creatinine (mg/l) | 6±1 ^a | 11±1.73 ^b | 6±1 ^a | 6±1 ^a |
| Urea (g/l) | 0.28±0.03 ^a | 0.45±0.06 ^b | 0.22±0.05 ^c | 0.29±0.03 ^a |
| Total proteins (g/l) | 74±4.36 ^a | 59±3.46 ^b | 77±3.60 ^a | 76±2 ^a |
| Uric acid (mg/l) | 40±2 ^a | 72±1 ^b | 44±3.60 ^a | 45±4 ^a |

^{a-c}Values in the same row for each rats group with different superscripts are significantly different ($p<0.05$) [mean±SD, n= 10].

Table 2: Effect of OTE on aspartate aminotransferase (AST) and alanine aminotransferase (ALT) in diabetic rats after 4 w of daily administration.

| | Control rats | Diabetic rats | Diabetic rats+glibenclamide | Diabetic rats+OTE (1 g/kg ¹) |
|-----------|----------------------|----------------------|-----------------------------|--|
| AST (U/l) | 22±2.64 ^a | 86±1.73 ^b | 31±4 ^c | 36±2.64 ^c |
| ALT (U/l) | 28±2.28 ^a | 90±5.56 ^b | 35±4.58 ^a | 40±3.60 ^a |

^{a-c}Values in the same row for each rats group with different superscripts are significantly different ($p<0.05$) [mean±SD, n= 10].

glucose [1]. Beside this, OTE – like olive leaf extract– might produce its hypoglycemic effect is through the inhibition of pancreatin amylase activity [24]. In this sense, olive leaf extract was found to inhibit the activities of α -amylases from human saliva and pancreas [24]. In Animal models studies, the hypoglycemic effect of OTE could be facilitated by the reduction of starch digestion and absorption. Moreover, hydroxytyrosol, oleuropein and their Seco iridoids derivatives – major phenolic compounds of OTE [42] – had a hypoglycemic and antioxidant *in vitro* and in rats [23]. These compounds may (i) protect pancreatic cells from progressive damage caused by streptozotocin, (ii) enhance insulin secretion by several mechanisms [43], (iii) active some enzymes – hexokinase and pyruvate kinase – implicated in glucose metabolism [23], and (iv) protect pancreatic cells from oxidative damage – through their strong antioxidant activity – caused by the increase of insulin secretion [44].

The lipid profile levels are usually raised in diabetics, which represents a risk factor for coronary heart disease [45]. It has been showed that high levels of total cholesterol and LDL-cholesterol are cardiovascular risk factors. However, increased level of HDL- cholesterol assured anti-inflammatory properties [46]. The present results showed that OTE exhibited a significant decrease in the level of lipid parameters in diabetic rats. OTE improves lipid profile because of high concentration of phenolic compounds having a lipid lowering action and prevented LDL-cholesterol oxidation. Epidemiological studies also suggested that the Mediterranean diet, rich in polyphenol, decreases the cardiovascular disease risk factors [47-49].

The total protein level was decreased in diabetic rats. This may lead to muscle wasting and an increased release

of purine, the main source of uric acid as well as in the activity of xanthine oxidase. Moreover, the increase of uric acid level may be due to a metabolic disturbance in diabetes reflected in the high activities of xanthine oxidase, lipid peroxidation, and triglycerides and cholesterol increasing [50]. However, results herein presented show that the OTE decreases the creatinine, serum urea, and uric acid levels and increase total protein level in diabetic rats. In fact, elevation of the serum's urea and creatinine, as significant markers, are related to renal dysfunction in diabetic hyperglycemia [51].

Serum enzymes, including AST and ALT, are studied to evaluate the hepatic profile. An increase in these enzyme activities reflected liver damage. High transaminases levels are caused by hepatocellular inflammation [52]. Streptozotocin treatment has a significant role in the alteration of liver functions since the activity of AST and ALT were significantly higher than those of normal values. In the present study, a reduction in AST and ALT levels were found in diabetic rats treated by OTE. It may be the result of the olive polyphenols anti-inflammatory activity, which allowed OTE to regulate transaminases levels [19, 20].

By the end of the study period, all of the evaluated parameters in rats treated by OTE exhibited a significant restoration, which was similar to the normal control rats. In our previous studies, we found that OTE was endowed with important antioxidant and anti-inflammatory activities [19, 42]. These properties allow OTE to be efficient in the protection against some metabolic diseases related to oxidative stress such as diabetes. In fact, it has been demonstrated that antioxidant-based therapy is promising to minimize the complications associated with oxidative stress in diabetes mellitus [42, 53-56].

CONCLUSION

Based on the findings of this study, we demonstrate that olive tree extract with high polyphenols content has the same effects – in comparison with glibenclamide – regarding blood glucose and other related parameters regulation in diabetes illnesses. The current findings are in agreement with those obtained *in vitro* or *in vivo* in several pre-clinical and clinical studies about anti-diabetic effects of olive polyphenols and/or olive tree extracts, suggesting the potential role of these natural compounds for “functional foods” conception to help in diabetes management.

CONFLICTS OF INTERESTS

All authors have none to declare

REFERENCES

1. Gonzalez M, Zarzuelo A, Gamez MJ, Utrilla MP, Jimenez J, Osuna I. Hypoglycemic activity of olive leaf. *Planta Med.* 1992;58:513-5.
2. Oberley LW. Free radicals and diabetes. *J. Biol. Chem.* 1988;5:113-24.
3. Jennings PE, McLaren M, Scot NA, Saniabadi AR, Belch JFF. The relationship of oxidative stress to the thrombotic tendency in type I diabetic patients with retinopathy. *Diabetic Med.* 1991;8:860-5.
4. Lyons TJ. Oxidized low-density lipoproteins: a role in the pathogenesis of atherosclerosis in diabetes? *Diabetic Med.* 1999;8:411-9.
5. Valezquez E, Wincour PH, Kesteven P, Alberti KGMM, Laker MF. Relation of lipid peroxides to macrovascular disease in type 2 diabetes. *Diabetic Med.* 1991;8:752-8.
6. Duckworth WC. Hyperglycemia and cardiovascular disease. *Curr. Atheroscler.* 2001;3:383-91.
7. Thirupathi BK, Sivastava AK. Diabetes mellitus: complication and therapeutic. *Med. Sci. Monit.* 2006;12:130-47.
8. Holman RR, Turner RC. Oral agents and insulin in the treatment of NIDDM. In: Textbook of Diabetes. Pickup J, Williams G. eds. Blackwell: Oxford; 1991.
9. Rupeshkumar M, Kavitha K, Haldar PK. The role of herbal plants in the diabetes mellitus therapy: an overview. *Int. J. Appl. Pharm.* 2014;6:1-3.

10. De Marco E, Savarese M, Paduano A, Sacchi R. Characterization and fractionation of phenolic compounds extracted from olive oil mill wastewaters. *Food Chem.* 2007;104:858-67.
11. Richard N, Arnold S, Hoeller U, Kilpert C, Wertz K, Schwager J. Hydroxytyrosol is the major anti-inflammatory compound in aqueous olive extracts and impairs cytokine and chemokine production in macrophages. *Planta Med.* 2011;77:1890-7.
12. Fortes C, García-Vilas J, Quesada A, Medina M. Evaluation of the anti-angiogenic potential of hydroxytyrosol and tyrosol, two bioactive phenolic compounds of extra virgin olive oil, in endothelial cell cultures. *Food Chem.* 2012;134:134-40.
13. Briante R, Patumi M, Terenziani S, Bismuto E, Febbraio F, Nucci R. Olea europaea L. leaf extract and derivatives: antioxidant properties. *J. Agric. Food Chem* 2002;17:4934-40.
14. Fitó M, Cladellas M, Torre R, Martí J, Muñoz D, Schröder H. Anti-inflammatory effect of virgin olive oil in stable coronary disease patients: a randomized, crossover, controlled trial. *Eur. J. Clin. Nutr.* 2007;62:570-4.
15. Covas MI, Nyssonen K, Poulsen HE, Kaikkonen J, Zunft HJ, Kiesewetter H. The effect of polyphenols in olive oil on heart disease risk factors: a randomized trial. *Ann. Intern. Med.* 2006;145:333-41.
16. Rahman I, Biswas SK, Kirkham PA. Regulation of inflammation and redox signaling by dietary polyphenols. *Biochem. Pharmacol.* 2006;72:1439-52.
17. Brunelleschi S, Bardelli C, Amoroso A, Gunella G, Ieri F, Romani A, et al. Minor polar compounds extra-virgin olive oil extract (Mpc-Ooe) inhibits Nf-Kb translocation in human Monocyte/Macrophages. *Pharmacol. Res.* 2007;56:542-9.
18. Pacheco YM, Bermudez B, Lopez S, Abia R, Villar J, Muriana FJG. Minor compounds of olive oil have postprandial anti- inflammatory effects. *Br. J. Nutr.* 2007;98:260-3.
19. Laaboudi W, Ghanam J, Aissam H, Merzouki M, Benlemlih M. Anti-inflammatory and analgesic activities of olive tree extract. *Int. J. Pharm. Pharm. Sci.* 2016;8:414-9.
20. Ghanam J, Laaboudi W, Benlemlih M. Effects of rich polyphenols olive tree extract on inflammation and pain in patients with rheumatoid arthritis: an 8-weeks randomized, double-blind, placebo-controlled clinical trial. *Int. J. Biol. Pharm. Res.* 2015;2:51-61.
21. Fabiani R, De Bartolomeo A, Rosignoli P, Servili M, Montedoro G, Morozzi G. Cancer chemoprevention by hydroxytyrosol isolated from virgin olive oil through G1 cell cycle arrest and apoptosis. *Eur. J. Cancer Prev.* 2002;11:351-38.
22. Bouallagui Z, Han J, Isoda H, Sayadi S. Hydroxytyrosol rich extract from olive leaves modulates cell cycle progression in Mcf-7 human breast cancer cells. *Food Chem. Toxicol.* 2011;49:179-84.
23. Hamden K, Allouche N, Damak M, Elfeki A. Hypoglycemic and antioxidant effects of phenolic extracts and purified hydroxytyrosol from olive mill waste *in vitro* and in rats. *Chem. Biol. Interact.* 2009;180:421-32.

24. Wainstein J, Ganz T, Boaz M, Bar-Dayana Y, Dolev E, Kerem Z, *et al.* Olive leaf extract as a hypoglycemic agent in both diabetic human subjects and in rats. *J. Med. Food* 2012;15:605-10.
25. Eidi A, Eidi M, Darzi R. Antidiabetic effect of *Olea europaea* L. in normal and diabetic rats. *Phytother. Res.* 2009;23:347-50.
26. Mousa HM, Farahna M, Ismail MS, Al-Hassan AA, Ammar AS, Abdel-Salam AM. Anti-diabetic effect of olive leaves extracts in alloxan-diabetic rats. *J. Agric. Vet. Sci.* 2014;7:183-92.
27. Karaosmanoglu H, Soyer F, Ozen B, Tokatli F. Antimicrobial and antioxidant activities of Turkish extra virgin olive oils. *J. Agric. Food Chem.* 2010;58:8238-45.
28. Zhao G, Yin Z, Dong J. Antiviral efficacy against hepatitis b virus replication of oleuropein isolated from *Jasminum Officinale* L. Var. *Grandiflorum*. *J. Ethnopharmacol.* 2009;125:265-8.
29. Battinelli L, Daniele C, Cristiani M, Bisignano G, Saija A, Mazzanti G. *In vitro* antifungal and anti-elastase activity of some aliphatic aldehydes from *Olea europaea* L. fruit. *Phytomedicine* 2006; 13:558-63.
30. Medina E, De Castro A, Romero C, Brenes M. Comparison of the concentrations of phenolic compounds in olive oils and other plant oils: correlation with antimicrobial activity. *J. Agric. Food Chem.* 2006;54:4954-61.
31. Visioli F, Poli A, Galli C. Antioxidant and other biological activities of phenols from olives and olive oil. *Med. Res. Rev.* 2002;22:65-75.
32. Manna C, Della Ragione F, Cucciola V, Borriello A, D'Angelo S, Galletti P, *et al.* Biological effects of hydroxytyrosol, a polyphenol from olive oil endowed with antioxidant activity. *Adv. Exp. Med. Biol.* 1999;472:115-30.
33. Yamada K, Ogawa H, Hara A, Yoshida Y, Yonezawa Y, Karibe K, *et al.* Mechanism of the antiviral effect of hydroxytyrosol on influenza virus appears to involve a morphological change of the virus. *Antiviral Res.* 2009;83:35-44.
34. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin. Chem.* 1972;18:499-502.
35. Lemieux I, Lamarche B, Couillard C, Pascot A, Cantin B, Bergeron J, *et al.* Total cholesterol/HDL cholesterol ratio vs LDL cholesterol/HDL cholesterol ratio as indices of ischemic heart disease risk in men: the quebec cardiovascular study. *Arch. Med. Res.* 2001;161:2685-92.
36. Rakićen N, Rakićen ML, Nadkarni MV. Studies on the diabetogenic action of streptozotocin (NSC-37917). *Cancer Chemother. Rep.* 1963;29:91-8.
37. Lenzen S., The mechanisms of alloxan and streptozotocin, induced diabetes. *Diabetologia* 2008;51:216-26.
38. Reed MJ, Meszaros K, Entes LJ, Claypool MD, Pinkett JG, Gadbois TM, *et al.* A new rat model of type 2 diabetes: the fat-fed, streptozotocin-treated rat. *Metabolism* 2000;49:1390-4.
39. Srinivasan K, Viswanad B, Asrat L, Kaul CL, Ramarao P. Combination of high-fat-diet-fed and low-dose streptozotocin-treated rat: a model for type 2 diabetes and pharmacological screening. *Pharmacol. Res.* 2005;52:313-20.

40. Szkudelski T. The mechanism of alloxan and streptozotocin action in B cells of the rat pancreas. *Physiol. Res.* 2001;50:537-46.
41. Putta S, Chedalawada V. Dose-dependent effect on hypoglycemic and antihyperglycemic activities of the chloroform extract of physalis minima in streptozotocin- induced diabetic rats. *Int. J. Curr. Pharm. Res.* 2014;6:61-5.
42. Laaboudi W, Ghanam J, Merzouki M, Benlemlih M. Eco- extraction of phenolic compounds from Moroccan olive fruits and leaves and their potential use as antimicrobial agents. *Eur. J. Sci. Res.* 2015;132:255-65.
43. Silvestre RA, Egido EM, Hernandez R, Marco J. Tungstate stimulates insulin release and inhibits somatostatin output in the perfused rat pancreas. *Eur. J. Pharmacol.* 2005;519:127-34.
44. Nivitashekan SN, Asad M, Prasad VS. Pharmacodynamic interaction of Momordica charantia with rosiglitazone in rats. *Chem. Biol. Interact.* 2009;177:247-53.
45. Rhoads GG, Gulbrandsen CL, Kagan A. Serum lipoproteins and coronary heart disease in a population study of Hawaii Japanese men. *New Engl. J. Med.* 1976;294:293-8.
46. Camargo A, Rangel-Zuñiga OA, Haro C, Meza-Miranda ER, Peña-Orihuela P, Meneses ME, et al. Olive oil phenolic compounds decrease the postprandial inflammatory response by reducing postprandial plasma lipopolysaccharide levels. *Food Chem.* 2014;162:161-71.
47. Hu FB. The Mediterranean diet and mortality-olive oil and beyond. *New Engl. J. Med.* 2003;348:2595-6.
48. Estruch R, Martínez-González MA, Corella D, Salas-Salvadó J, Ruiz-Gutiérrez V, Covas MI. Effects of a mediterranean-style diet on cardiovascular risk factors: a randomized trial. *Ann. Intern. Med.* 2006;145:1-11.
49. Scoditti E, Calabriso N, Massaro M, Pellegrino M, Storelli C, Martines G. Mediterranean diet polyphenols reduce inflammatory angiogenesis through MMP-9 and COX-2 inhibition in human vascular endothelial cells: a potentially protective mechanism in atherosclerotic vascular disease and cancer. *Arch. Biochem. Biophys.* 2012;527:81-9.
50. Madianov IV, Balabolkin MI, Markov DS, Markova TN. Main causes of hyperuricemia in diabetes mellitus. *Ter Arkh* 1999;72:55-8.
51. Almadal TP, Vilstrup H. Strict insulin treatment normalizes the organic nitrogen contents and the capacity of urea-N synthesis in experimental diabetes in rats. *Diabetologia* 1988;3:114-8.
52. Pratt DS, Kaplan MM. Evaluation of abnormal liver-enzyme results in asymptomatic patients. *New Eng. J. Med.* 2000;342:1266-71.
53. Davie SJ, Gould BJ, Yudkin JS. Effect of vitamin C on glycosylation of proteins. *Diabetes* 1992;41:167-73.
54. Sinclair AJ, Girling AJ, Gray L, Lunec J, Barnett AH. An investigation of the relationship between free radical activity and vitamin C metabolism in elderly diabetic subjects with retinopathy. *Gerontology* 1992;38:268-74.

55. Lean ME, Noroozi M, Kelly I, Burns J, Talwar D, Sattar N, *et al.* Dietary flavonols protect diabetic human lymphocytes against oxidative damage to DNA. *Diabetes* 1999;48:176-81.
56. Mercuri F, Quagliaro L, Ceriello A. Review paper: oxidative stress evaluation in diabetes. *Diabetes Technol. Ther.* 2000;2:589-600.

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Anti-inflammatory and analgesic activities of olive tree extract

Wafa Laaboudi*, Jamal Ghanam¹, Hala Aissam¹,
Mohammed Merzouki¹, Mohamed Benlemlih¹

¹Biotechnology Laboratory, Faculty of Science Dhar El Mahraz, University Sidi Mohamed Ben Abdellah – Fez – Morocco

ABSTRACT

Objective: The aim of this study was the *in vivo* evaluation of analgesic and anti-inflammatory effect of an olive tree extract with high polyphenols content.

Methods: This olive tree extract was obtained from Moroccan olive fruits and leaves using an eco-extraction free of chemical solvents and toxic additives. Anti-inflammatory activity was evaluated using carrageenan and histamine-induced paw edema methods. Analgesic activity of the olive tree extract was estimated against a hot plate, acetic acid induced writhing and formalin tests.

Results: The extracts showed significant anti-inflammatory and analgesic activities with a dose-dependent manner. Anti-inflammatory activity of olive tree extract at 250 and 500 mg/kg doses was more important compared to the used standard drugs ($p < 0.05$), in both carrageenan and histamine-induced paw edema

tests. In analgesic assays, results showed that 500 mg/kg dose of olive tree extract has a significant analgesic effect through both peripheral and central mechanisms.

Conclusion: Our findings suggest that olive tree extract is safe and has potential anti-inflammatory and analgesic activities, which promote this use as a food supplement against pain and inflammation related to inflammatory diseases.

Keywords: Olive leaves, Olive fruit, Polyphenols, Anti-inflammatory, and Analgesic, *In vivo*.

INTRODUCTION

The correlation between inflammatory response and many chronic diseases like rheumatoid arthritis, cardiovascular diseases and some types of cancer has been reported [1, 2]. Excessive production and accumulation of oxygen and reactive nitrogen species (ROS and RONS), and arachidonic acid metabolites play a key role in the pathogenesis of cardiovascular diseases and cancer [3, 4]. In the process of inflammation, arachidonic acid is converted by cyclooxygenase (COX) and lipoxygenase (LOX) to prostaglandins, thromboxanes, prostacyclin, and leukotrienes [5]. These inflammatory mediators are responsible for pain and other inflammatory symptoms. C-reactive protein concentration rises during inflammation [6]. Plasma thromboxane B₂ (TXB₂) increases platelet aggregation and leukotrienes B₄ (LTB₄) promotes migration of neutrophils to inflamed tissue [7]. Oxidative stress enhances inflammation by activating nuclear factor kappa B (NF- κ B) and activator protein-1 (AP-1) transcription factors and affecting cellular signaling processes [8]. NF- κ B activation is associated with cancer progression. Thereby, ROS, COX-1/2 and NF- κ B inhibitors,

may have a potential therapeutic effect on inflammation-depending diseases [9, 10].

In this sense, olive phenolic compounds are well known for their potential health benefits including the reduction of coronary heart disease risk, the prevention of some cancers and for their anti- inflammatory properties [11-13]. In fact, olive phenolic compounds are considered to possess anti-inflammatory properties, and therefore, were proposed as a alternative natural approach to prevent and/or treat chronic inflammatory diseases [14, 15]. Anti- inflammatory mechanisms of olive polyphenols are suggested to include: inhibition of pro-inflammatory enzymes, such as COX-2, LOX [16]. Its also inducible nitric oxide synthase (iNOS); inhibition of phosphoinositide 3-kinase (PI 3-kinase), tyrosine kinases, NF-kB, and AP-1; and down-regulation of various pro-inflammatory cytokines such as chemokines, tumor necrosis factor alpha (TNF-a), interleukins including (IL-1 b, IL-6, IL-8), and monocyte chemotactic protein-1 (MCP-1) [14, 17-21]. It is reported that olive polyphenols relieved pain and have an analgesic activity in the case of some inflammatory diseases [22, 23].

In the present study, we have examined the possible antinociceptive and anti-inflammatory effects of a phenolic olive tree extract using *in vivo* experimental models. Namely, the carrageenan and histamine- induced hind paw oedema model tests for the anti-inflammatory activity and hot plate, acetic acid-induced abdominal writhing and formalin tests to assess the analgesic activity. Indomethacin and diclofenac sodium (with known anti-inflammatory effects), and tramadol hydrochloride and acetylsalicylic (with known analgesic properties) were used as positive controls.

MATERIALS AND METHODS

Plant materials

The olive tree extract (OTE) was ecologically obtained from Moroccan olive fruits and olive leaves/young sprouts, according to the previously described protocol [24]. They have been taken from stressed olive trees planted in a rocky desert harsh environment of Morocco. These suffering olive trees belong to a farm of the renowned Company Atlas Olive Oils. Actually, OTE is marketed in the world (France, Switzerland, Belgium, etc.) under the brand name OLIVIE FORCE/OLIVIE RICHE (see more at www.olivie.ma).

Chemicals

Carrageenan; histamine; indomethacin; diclofenac sodium (DFS); acetylsalicylic acid (ASA); tramadol hydrochloride (Tramadol Hcl); formalin; acetic acid were purchased from Sigma-Aldrich (Paris, France).

Animals

For studying the acute toxicity and the *in vivo* activities, male adult Wistar rats (120-180 g) and Swiss albino mice (20-25 g) of both sexes were obtained from the animal breeding unit of the Faculty of Science Dhar El Mahraz-Fez-Morocco. They were housed in polypropylene cages with free access to food and water. The animals were maintained under controlled conditions of temperature ($22\pm 2^{\circ}\text{C}$) with a 12 h light-dark cycle. The animals were used after an acclimatization period of 7 d in the laboratory environment. Housing conditions and *in vivo* experiments were approved according to the guidelines established by the European Union on Animal care (CEE Council 86/609). Animals fasted overnight before any experiments.

Acute toxicity study

Swiss albino mice (male) weighing 20-25 g were divided into two groups (five per group). Mice in the experimental group were received increasing OTE's dose (100, 250, 500 and 1000 mg/kg) while those in the control group received only 0.9% NaCl solution (10 ml/kg). The mortality rate was determined and the LD50 was estimated within the 24h following orally administration, according to the method described by Creton *et al.* [25].

In vivo anti-inflammatory activity

Carrageenan-induced rat paw oedema

OTE's anti-inflammatory activity was evaluated using carrageenan- induced paw oedema in rats. Male Wistar rats were divided into 8 groups of five animals each. (1) Control group (10 ml/kg of 0.9% NaCl solution); (2) and (3) groups received reference drugs (10 mg/kg of indomethacin and diclofenac sodium); (4), (5), (6), (7) and groups (8) were orally administered OTE in 50, 100, 250, 500 and 1000 mg/kg doses, respectively.

Animals were pre-treated with drug and OTE 60 min before injection of carrageenan. Inflammation of the hind paw was induced by injecting 0.1 ml of 0.5% carrageenan suspension into the sub- plantar surface of the right hind paw. Measures of the paw circumference were determined at 3, 4, 5 and 6h (after edematogenic agent injection) intervals later (St) using the method of Bamgbose and Noamesi [26]. The difference between St (3, 4, 5 and 6h) and S0 was taken as the oedema size. The inhibition percentage of the inflammatory reaction was determined for each animal by comparison with controls and calculated by the following equation:

$$\% \text{ inhibition} = \frac{(St - S0)_{\text{control}} - (St - S0)_{\text{treated}}}{(St - S0)_{\text{control}}} \times 100$$

Histamine-induced rat paw oedema

Eight groups of rats (five rats each) were used for this test. Group (1) served as a control group (10 ml/kg of 0.9% NaCl solution), animals in groups (2) and (3) were orally treated with indomethacin and diclofenac sodium (10 mg/kg), while rats in groups (4), (5), (6), (7) and (8) received the OTE at doses of 50, 100, 250, 500 and 1000 mg/kg, respectively.

Animals were treated by drug controls and OTE 1h before histamine injection (0.1 ml of a 1% solution in 0.9% NaCl solution) into the plantar region of the right-hand paw. Paw size was measured before injection of histamine and at 3, 4, 5 and 6h, after injection. The paw oedema was measured using the cotton thread method according to Farshid *et al.* [27]. The average increase in paw size of each group was determined. The percentage inhibition was obtained using this formula:

$$\% \text{ inhibition} = \frac{(St - SO)_{\text{control}} - (St - SO)_{\text{treated}}}{(St - SO)_{\text{control}}} \times 100$$

With St = the paw size for each group after histamine treatment. And SO = paw size for each group before histamine injection.

In vivo analgesic activity

Hot plate test

Twenty-five Swiss albino mice (20-25 g) were divided into 5 groups of five mice per group. Group (1) received control solution (0.9% NaCl solution), group (2) received tramadol hydrochloride (10 mg/kg), while groups (3), (4) and (5) received 100, 250 and 500 mg/kg of OTE, respectively. 1h after the orally administration, mice were placed onto a hot plate (55±2 °C), and the reaction time for licking of paw or jumping for the control and treated

mice was recorded (in seconds) [28]. A cutoff time of 15 s was used to avoid damage to the paw [29]. The percentage increase in reaction time was determined thus:

$$\% \text{ increase in reaction time} = \frac{T_t - T_0}{T_0} \times 100$$

Aceta writhing test

Overnight fasted mice were divided into five groups of five each. Groups (1) and (2) received control solution (0.9% NaCl solution) and acetylsalicylic acid (10 mg/kg), while groups (3), (4) and (5) received 100, 250 and 500 mg/kg of OTE, respectively. 1h after, the animals were intraperitoneally injected with acetic acid (0.6%, v/v in 0.9% NaCl solution) [30], the analgesic activity was quantified by counting the total number of writhes over a period of 25 min after a latency period of 5 min [31]. The percentage of analgesic activity was calculated as follows:

$$\% \text{ inhibition} = \frac{\text{number of writhes (control)} - \text{number of writhes (test)}}{\text{number of writhes (control)}} \times 100$$

Formalin licking test

Formalin licking test was carried out using male mice under same experimental conditions of acetate writhing test. 1h after orally OTE administration, 20 µl of 1 % formalin solution (in 0.9% NaCl solution) was injected subcutaneously into the plantar surface of the right hind paw of each mouse. Licking the injected paw time was measured over 30 min divided into two phases. The early phase was observed during the first 5 min and the late phase was recorded in 15-30 min [32]. These phases represented neurogenic and inflammatory pain responses, respectively [33]. The percentage of inhibition was obtained by the following formula:

$$\% \text{ inhibition} = \frac{\text{reaction time (control)} - \text{reaction time (treated)}}{\text{reaction time (control)}} \times 100$$

Statistical analysis

Statistical analyzes were performed using GraphPad Prism software version 6.00 (GraphPad Inc., San Diego, California). Data were analyzed by analysis of variance (ANOVA Analysis of Variance) followed by posthoc Dunnet test if the sample distribution follows a normal distribution or by the Kruskal-Wallis if the sample distribution does not follow the normal law. Values between groups were considered statistically significant for at $P < 0.05$.

RESULTS

Toxicity test

Results (data not shown) showed no signs of toxicity which could be attributed to the administrated material (OTE), even at high doses. On the other hand, OTE, containing more than 15% of polyphenols (w/w), had no evidence of toxicity in mice and rats (mortality, tremor, convulsions, loss of reflex, sedation, and diarrhea). This, in fact, was in concordance with Soni *et al.* (2006) findings, that reported NOAEL (No Observed Adverse Effect Level) in rats after aqueous olive fruit extract administration (with high polyphenols content), even though at high doses as 2 g/kg/day. As a result, we suppose that OTE's orally administration (to mice) at the doses of 100, 250 and 500 mg/kg will be safe.

Anti-inflammatory activity

Results plotted in tables 1 and 2 illustrate the dose-dependent OTE's effect on paw oedema formation after induction by carrageenan (table 1) and histamine (table 2).

Table 1: Effect of olive tree extract on carrageenan-induced rat paw oedema in rats.

| Dose (mg/kg) | Inhibition (%) | | |
|---------------------|-------------------------|-------------------------|-------------------------|
| | 3h | 4h | 5h |
| 50 | ^a 0.27±0.13 | ^a 10.00±2.20 | ^a 20.21±2.21 |
| 100 | ^b 44.45±3.45 | ^b 60.00±2.33 | ^b 64.24±2.22 |
| 250 | ^b 50.27±3.61 | ^b 75.00±2.76 | ^c 73.40±1.56 |
| 500 | ^c 66.76±3.69 | ^c 80.00±2.11 | ^c 78.73±1.72 |
| 1000 | ^c 67.81±5.06 | ^c 81.97±2.63 | ^d 78.79±1.18 |
| Indomethacin * | ^d 19.05±2.20 | ^b 53.24±2.54 | ^d 60.99±2.33 |
| Diclofenac sodium * | ^b 47.11±2.22 | ^b 69.34±3.25 | ^d 63.12±1.65 |

^{a-e}Values in the same column with different superscripts are significantly different ($p < 0.05$) [mean±SD, n= 6].

*Reference drugs (indomethacin 10 mg/kg and diclofenac sodium 10 mg/kg).

Table 2: Effect of olive tree extract on histamine-induced rat paw oedema in rats.

| Dose (mg/kg) | Inhibition (%) | | |
|-------------------|-------------------------|-------------------------|-------------------------|
| | 3h | 4h | 5h |
| 50 | ^a 0.13±0.03 | ^a 8.90±0.55 | ^a 18.96±0.59 |
| 100 | ^b 25.00±2.43 | ^b 52.00±1.54 | ^b 60.50±1.35 |
| 250 | ^c 51.00±2.39 | ^c 70.90±1.67 | ^c 69.00±2.22 |
| 500 | ^c 62.70±0.84 | ^c 76.00±2.03 | ^d 76.30±0.70 |
| 1000 | ^c 63.98±0.57 | ^d 78.22±1.18 | ^d 77.10±0.86 |
| Indomethacin | ^e 15.50±0.50 | ^b 51.00±0.59 | ^b 56.80±1.04 |
| Diclofenac sodium | ^d 43.90±1.01 | ^e 64.96±1.66 | ^b 58.60±1.09 |

^{a-e}Values in the same column with different superscripts are significantly different ($p < 0.05$) [mean±SD, n= 6].

*Reference drugs (indomethacin 10 mg/kg and diclofenac sodium 10 mg/kg).

The subplantar injection of carrageenan-induced a progressive local oedema reaching its peak at the 3rd hour (table 1). The orally administration of the OTE showed a dose-dependent reduction in carrageenan-induced paw oedema from the 3rd to the 6th hour. The highest OTE's inhibition activity (80%) was recorded after 4h at 500 mg/kg dose, compared to reference drugs indomethacin (53.24%) and diclofenac (69.34%) ($p<0.05$). Besides, no significant difference ($p<0.05$) was observed when the treatment dose, rise to 1 g/kg (compared to 500 mg/kg dose).

Similarly, the paw oedema induced by histamine was reduced after OTE administration (table 2). High inhibition activity was observed for the 500 and 1000 mg/kg doses (76.00 and 78.22%), but with no significant difference ($p<0.05$). Thus, OTE's administration has a significant anti-inflammatory effect compared to the used reference drugs, even at low doses like 250 mg/kg.

Analgesic activity

Graphs of fig. 1, 2 and 3 show results related to the OTE's analgesic activity assessed by means of the hot plate, acetic acid-induced abdominal writhing and formalin *in vivo* tests. Considering the results of anti-inflammatory tests, analgesic tests were performed at three OTE's doses (100, 250 and 500 mg/kg).

OTE administration has increased the insensibility to pain without loss of consciousness (analgesic activity) in mice placed onto the hot plate (55 ± 2 °C). The observed OTE's analgesic effect was dose - dependent, reaching its maximum (36.77%) at 500 mg/kg dose (fig. 1). This effect was, however, compared to that observed (35.84%) for tramadol hydrochloride (no significant difference at $p<0.05$).

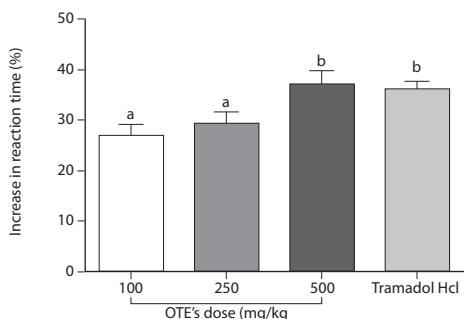


Fig. 1: Effect of olive tree extracted on hot plate-induced pain in mice. Data is expressed as means \pm SD [n= 5]. Different letters indicate significant differences ($p<0.05$)

On the writhing response in mice, OTE induced a potent dose- dependent antinociceptive activity at all used doses (fig. 2). This activity was up to 68% for 500 mg/kg dose, which was similar to that shown by the reference drug significantly (no differences at $p<0.05$).

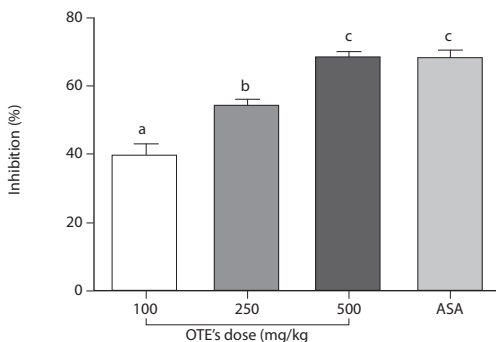


Fig. 2: Olive tree extract's analgesic activity in mice treated with acetic acid. Data are expressed as means \pm SD [n= 5]. Different letters (a-c) indicate significant differences ($p<0.05$)

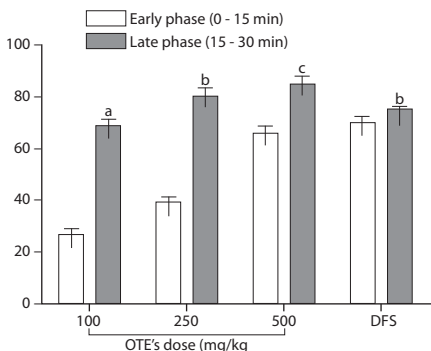


Fig. 3: Effects of olive tree extract on the formalin-induced licking response in mice. Data is expressed as means \pm SD [n= 5]. Different letters (a-c) indicate significant differences ($p < 0.05$)

Two phases showed in fig. 3 represented neurogenic and inflammatory pain responses, respectively [31]. The subcutaneous injection of formalin solution into the plantar surface of the right hind paw of mice produced an analgesic response of licking of the treated paw. OTE showed dose-dependent effect in both early and late phases. The OTE's analgesic activity was incomparable to that of reference drug (diclofenac sodium) during the early phase (corresponding to the neurologic pain) (fig. 3). However, this effect was significantly higher in mice treated with 500 mg/kg dose (84.70

%) compared to diclofenac sodium (75.20 %) ($p < 0.05$) in the late phase (corresponding to the inflammatory pain).

DISCUSSION

The carrageenan-induced paw oedema is frequently used as an experimental model for acute inflammation studying [34]. The inflammatory reaction carrageenan-induced (in rats) is a biphasic response, (i) oedema

formation involving the production of inflammatory mediators such as histamine, serotonin, and kinins; (ii) the biosynthesis of prostaglandin and other autacoids release and attributed to the induction of cyclooxygenase (COX)-2 in the tissue [35-37]. Actually, the results of this study suggest that the OTE could antagonize the action and/or inhibit the production of the circulating inflammation mediators. On injection, histamine acts as an inflammatory mediator, which increases vascular permeability [38-40]. Results herein presented show the anti-oedomatogenic effect of orally administered olive tree extract in rats injected by Histamine. This could be, in fact, attributed to the anti-inflammatory activity of studying extract through an antihistamine mechanism. The rich phenolic olive tree extracted may act by inhibiting the release and/or histamine action, which can explain its inhibitory activity on oedema development.

Thus, observed OTE's Anti-inflammatory effects could be related to its phenolic composition. Actually, OTE is a rich phenolic extract (15%, w/w), particularly hydroxytyrosol (2%, w/w). In general, olive phenolic compounds have been known to inhibit both COX-1/2 inflammatory enzymes (in a dose-dependent manner) more efficiently than ibuprofen drug [16]. In a clinical trial, Ghanam *et al.* [14] recently reported that olive tree extract relieved pain in rheumatoid arthritis patients and decreased the circulating inflammatory biomarkers such as hs-CRP, IL-6, TNF- α , and PGE2 significantly.

Moreover, hydroxytyrosol impedes PGE2 synthesis by indirectly blocking of inducible nitric oxide synthase and COX-(2) enzymes. This effect was raised by the prevention of transcription factors activation as NF- κ B, interferon regulatory factor-1 and transducer and activator of transcription 1a, which prevents the

activation of mouse macrophages J774 [41]. It is also known that hydroxytyrosol is capable of bringing about arylating/alquilant adducts in the cysteine residues of NF- κ B. The action of hydroxytyrosol on this factor blocks COX-(2) and 5-lipoxygenase transcription, reducing the PGE2 synthesis and, thus, the chronic inflammation associated with inflammatory diseases such as cancer [42]. Beside this, hydroxytyrosol possesses significant anti-inflammatory actions in inflammation animal models through the inhibition of pro-inflammatory cytokines expression (TNF- α and IL-1 β) [20, 23].

Results from the current study reveal the effectiveness of natural OTE as oedema inhibitor compared to reference drugs (indomethacin and diclofenac sodium). These classical non-steroidal anti-inflammatory drugs (NSAIDs) mainly inhibit COXs. However, they have side effects such as irritation of the gastric mucosa, caused by the inhibition of prostaglandin biosynthesis, which has a protective role in the gastrointestinal tract. Many NSAIDs are also acids that may cause additional harm in the gastrointestinal tract [43]. Thus, the use of natural anti-inflammatory agents is one of the proposed solutions to overcome problems caused by side effects of NSAIDs.

Hot plate test was selected to investigate the central analgesic effect of OTE, which is known to elevate the pain threshold of mice towards heat [44]. It also indicates narcotic involvement with opioid receptor and measures the complex response to a non-inflammatory acute nociceptive input [45, 46]. The high percentage inhibition (36.77%) shown by OTE in this test suggests that OTE is a centrally acting analgesic. Acetic acid-induced writhing response is useful for the evaluation of peripherally acting analgesics. Acetic acid stimulates the tissue to produce several inflammatory mediators such as histamine,

serotonin, cytokines, and eicosanoids with an increase in peritoneal fluid levels of these mediators [47]. In this sense, OTE inhibited mice abdominal writhes, suggesting that OTE's antinociceptive activity could be related to the reduction of inflammatory mediator's liberation and/or to direct blockage of receptors resulting in peripheral analgesic response.

The formalin test is a valid model of pain and analgesic research for clinical pain compared to tests using phasic thermal or mechanical stimulation. It has two distinctive phases, reflecting different types of pain [45]. The early phase (0–5 min) reflects centrally mediated pain, which was a result of direct stimulation of nociceptors and believed to be a non-inflammatory pain.

The late phase (15–30 min) persistent period caused by local tissue inflammation. Experimental results demonstrated that substance P and bradykinin participate in the early phase, while histamine, serotonin, prostaglandins, nitric oxide, and bradykinin are believed to be involved in the late phase of the formalin test response. Our results show that OTE has an inhibitory effect on the analgesic response of both early and late phases of the formalin test. Moreover, significant pain relief activity observed in the late phase (compared to the early phase) indicates the peripherally acting protective effect of OTE, which was correlated with anti-inflammatory tests results. In that way, OTE attenuate pain response better than diclofenac sodium (NSAID), commonly used as a reference due to its anti-inflammatory and analgesic effects. This drug has the ability to reduce inflammation, swelling and pain by inhibiting either the release of arachidonic acid or the prostaglandin synthesis [48, 49]. This fact corroborates with published data about, *in vivo*, phenolic compounds antinociceptive effects, mainly attributed to flavonoids

[50, 51] and hydroxytyrosol [52]. It has also reported in a rodent model of opiate tolerance, that antiradical activity of olive phenolic compounds (hydroxytyrosol and oleuropein, amongst others) reinstates the analgesic action of morphine [22].

CONCLUSION

Results of pharmacological tests performed in the present study suggest that olive tree extract with high polyphenols content is safe and presented potential anti-inflammatory and analgesic activities, which are comparable with the reference drugs. This might be correlated with the phenolic compound composition of this extract, particularly hydroxytyrosol. Considering high consumer demand due to the beneficial health effects, olive tree extract can be beneficially used as a natural food supplement to contend inflammation and pain in the case of inflammatory diseases.

CONFLICTS OF INTERESTS

All authors have none to declare.

REFERENCES

1. Ferrucci L, Corsi A, Lauretani F, Bandinelli S, Bartali B, Taub DD, *et al.* The origins of the age-related proinflammatory state. *Blood* 2005;105:2294-9.
2. Balkwill F, Mantovani A. Inflammation, and cancer: back to Virchow? *Lancet* 2001;357:539-45.
3. Williams CS, Mann M, DuBois RN. The role of cyclooxygenases in inflammation, cancer and development. *Oncogene* 1999;18:7908.
4. Moreno JJ. Effect of olive oil minor components on oxidative stress and arachidonic acid mobilization and metabolism by macrophages RAW 264.7. *Free Radical Biol. Med.* 2003;35:1073-81.
5. Petroni A, Blasevich M, Salami M, Servili M, Montedoro GF, Galli C. A phenolic antioxidant extracted from olive oil inhibits platelet aggregation and arachidonic acid metabolism *in vitro*. *World Rev. Nutr. Diet.* 1994;75:169-72.

6. Fito M, Cladellas M, De la Torre R, Marti J, Munoz D, Schroder H, *et al.* Anti-inflammatory effect of virgin olive oil in stable coronary disease patients: a randomized, crossover, controlled trial. *Eur. J. Clin. Nutr.* 2008;62:570-4.
7. Bogani P, Galli C, Villa M, Visioli F. Postprandial anti- inflammatory and antioxidant effects of extra virgin olive oil. *Atherosclerosis* 2007;190:181-6.
8. Rahman I, Biswas SK, Kirkham PA. Regulation of inflammation and redox signaling by dietary polyphenols. *Biochem. Pharmacol.* 2006;72:1439-52.
9. Killeen M, Linder M, Pontoniere P, Crea R. NF- κ B signaling and chronic inflammatory diseases: exploring the potential of natural products to drive new therapeutic opportunities. *Drug Discovery Today* 2014;19:373-8.
10. Yamamoto Y, Gaynor RB. Therapeutic potential of inhibition of the NF-kappaB pathway in the treatment of inflammation and cancer. *J. Clin. Invest.* 2001;107:135-42.
11. Visioli F, Galli C. Biological properties of olive oil phytochemicals. *Crit. Rev. Food Sci. Nutr.* 2002;42:209-21.
12. Keys A. Mediterranean diet and public health: Personal reflections. *Am. J. Clin. Nutr.* 1995;61:1321-3.
13. Stark AH, Madar Z. Olive oil as a functional food: epidemiology and nutritional approaches. *Nutr. Rev.* 2002;60:170-6.
14. Ghanam J, Laaboudi W, Benlemlih M. Effects of rich polyphenols olive tree extract on inflammation and pain in patients with rheumatoid arthritis: an 8-weeks randomized, double-blind, placebo-controlled clinical trial. *Int. J. Biol. Pharm. Res.* 2015;2:51-61.
15. Sergent T, Piront N, Meurice J, Toussaint O, Schneider YJ. Anti- inflammatory effects of dietary phenolic compounds in an *in vitro* model of the inflamed human intestinal epithelium. *Chem. Biol. Interact.* 2010;188:659-67.
16. Beauchamp GK, Keast RSJ, Morel D, Lin J, Pika J, Han Q, *et al.* Phytochemistry: ibuprofen-like activity in extra-virgin olive oil. *Nature* 2005;437:45-6.
17. Esposito E, Mazzon E, Paterniti I, Dal Toso R, Pressi G, Caminiti R, *et al.* A contributes to the anti-inflammatory activity of verbascoside in a model of inflammatory bowel disease in mice. *PPAR Res.* 2010. Doi:10.1155/2010/917312. [Article in Press]
18. Speranza L, Franceschelli S, Pesce M, Reale M, Menghini L, Vinciguerra I, *et al.* Antiinflammatory effects in THP-1 cells treated with verbascoside. *Phytother. Res.* 2010;24:1398-404.
19. Pastore S, Potapovich A, Kostyuk V, Mariani V, Lulli D, De Luca C, *et al.* Plant polyphenols effectively protect HaCaT cells from ultraviolet C-triggered necrosis and suppress inflammatory chemokine expression. *Ann. NY Acad. Sci.* 2009;1171:305-13.
20. Zhang X, Cao J, Zhong L. Hydroxytyrosol inhibits proinflammatory cytokines, iNOS, and COX-2 expression in human monocytic cells. *Naunyn Schmiedebergs Arch. Pharmacol.* 2009;379:581-6.
21. Brunelleschi S, Bardelli C, Amoruso A, Gunella G, Ieri F, Romani A, *et al.* Minor polar compounds extra-virgin olive oil extract (MPC-OOE) inhibits NF-kB translocation in human monocyte/macrophages. *Pharmacol. Res.* 2007;56:542-9.
22. Muscoli C, Lauro F, Dagostino C, D'Agostino C, Ilari S, Giancotti LA, *et al.* Olea Europea-derived phenolic products attenuate antinociceptive morphine

- tolerance: an innovative strategic approach to treat cancer pain. *J. Biol. Regul. Homeostatic Agents* 2014;28:105-16.
23. Gong D, Geng C, Jiang L, Cao J, Yoshimura H, Zhong L. Effects of hydroxytyrosol-20 on carrageenan-induced acute inflammation and hyperalgesia in rats. *Phytother. Res.* 2009;23:646-50.
 24. Laaboudi W, Ghanam J, Merzouki M, Benlemlih M. Eco- extraction of phenolic compounds from Moroccan olive fruits and leaves and their potential use as antimicrobial agents. *Eur. J. Sci. Res.* 2015;132:255-65.
 25. Creton S, Dewhurst IC, Earl LK, Gehen SC, Guest RL, Hotchkiss JA, et al. Acute toxicity testing of chemicals-Opportunities to avoid redundant testing and use alternative approaches. *Crit. Rev. Toxicol.* 2010;40:50-83.
 26. Bamgbose SOA, Noamesi BK. Studies on cryptolepine. Inhibition of carrageenan-induced edema by cryptolepine. *Planta Med.* 1981;42:392-6.
 27. Farshid A, Tamaddonfard E, Morvaridi A. Effects of histidine and dexamethasone on the local inflammation induced by histamine in rats. *Vet. Res. Forum* 2011;2:31-6.
 28. Sutar NG, Pal SC. Evaluation of analgesic activity of leaf extracts of *pergularia daemia* [forsk] in experimental animals. *Int. J. Pharm. Pharm. Sci.* 2014;6:137-9.
 29. Omisore NOA, Adewunmi CO, Iwalewa EO, Ngadjui BT, Watchueng J, Abegaz BM, et al. Antinociceptive and anti- inflammatory effects of *Dorstenia barteri* (Moraceae) leaf and twig extracts in mice. *J. Ethnopharmacol.* 2004;95:7-12.
 30. Dahiya RS, Kaur P, Kashyap P, Katoh N, Gupta S. Pharmacological evaluation of hydroalcohol and chloroform extracts of *nyctanthes arbour-tristis* L. for antioxidant, anti-inflammatory and analgesic activity. *Int. J. Pharm. Pharm. Sci.* 2014;6:460-5.
 31. Koster R, Anderson M, De Beer E. Acetic acid for analgesic screening. *Fed. Proc.* 1959;18:412.
 32. Mahgoub AA. Grapefruit juice potentiates the anti- inflammatory effects of diclofenac on the carrageenan-induced Rat's Paw oedema. *Pharmacol Res.* 2002;45:1-4.
 33. Hunskaar S, Hole K. The formalin test in mice: dissociation between inflammatory and non-inflammatory pain. *Pain* 1987;30:103-14.
 34. Raman R, Parthiban S, Karthikeyan S, Muthuraman MS, Sivasubramanian A. Antimicrobial and anti-inflammatory studies on *sargassum wightii* extracts. *Int. J. Pharm. Pharm. Sci.* 2014;6:611-4.
 35. Ribeiro IA, Rocha J, Sepodes B, Mota-Filipe H, Ribeiro MH. Effect of naringin enzymatic hydrolysis towards naringenin on the anti-inflammatory activity of both compounds. *J. Mol. Catal. B: Enzym.* 2008;52:8-13.
 36. Vineger R, Truax JF, Selph JL. Quantitative studies of the pathway to acute carrageenan inflammation. *Fed. Proc.* 1976;35:2447-56.
 37. Di Rosa M, Giroud JP, Willoughby DA. Studies of the mediators of the acute inflammatory response induced in rats in different sites by carrageenan and turpentine. *J. Pathol.* 1971;104:15-29.
 38. Vasudevan M, Gunman KK, Parle M. Antinociceptive and anti- inflammatory effects of *Thespesia populnea* bark extract. *J. Ethnopharmacol* 2007;109:264-70.

39. Linardi A, Costa SKP, DeSilva GR, Antunes E. Involvement of kinins, mast cells, and sensory neurons in the plasma exudation and paw edema induced by staphylococcal enterotoxin B in the mouse. *Eur. J. Pharmacol.* 2002;399:235-42.
40. Cuman RKN, Bersani-Amadio CA, Fortes ZB. Influence of type 2 diabetes on the inflammatory response in the rat. *Inflam. Res.* 2001;50:460-5.
41. Maiuri MC, De Stefano D, Di Meglio PP, Irace C, Savarese M, Sacchi R. Hydroxytyrosol, a phenolic compound from virgin olive oil, prevents macrophage activation. *Naunyn Schmiedeberg Arch. Pharmacol.* 2005;371:457-65.
42. Cornwell DG, Ma J. Nutritional benefit of olive oil: the biological effects of hydroxytyrosol and its arylating quinone adducts. *J. Agric. Food. Chem.* 2008;56:8774-86.
43. Smith CJ, Zhang Y, Koboldt CM, Muhammad J, Zweifel BS, Shaffer A. Pharmacological analysis of cyclooxygenase-1 in inflammation. *Proc. Natl. Acad. Sci. USA* 1998;95:13331-8.
44. Hiruma-Lima C, Gracioso J, Bighetti E, Germansen Robineou L, Souza Brito A. The juice of fresh leaves of *Boerhaavia diffusa* L. (Nyctaginaceae) markedly reduces pain in mice. *J. Ethnopharmacol.* 2000;71:267-74.
45. Zakaria ZA, Ghani ZDFA, Nor RNSRM, Gopalan HK, Sulaiman MR, Jais AMM, et al. Antinociceptive, anti-inflammatory, and antipyretic properties of an aqueous extract of *Dicranopteris linearis* leaves in experimental animal models. *J. Nat. Med.* 2008;62:179-87.
46. Turner RA. Screening methods in pharmacology. *Acad. Press NY*; 1965.
47. Sofidiya MO, Oloruntola OM, Sofola I, Fageyinbo MS. Antinociceptive activity of *Euadenia trifoliolata* (Schum. & Thonn.) Oliv. Leaves and roots in mice. *Journal of Traditional Complementary Medicine* 2015;1-5. Doi:10.1016/j.jtcm.2015.07.006. [Article in Press]
48. Garcia R, Ferreira JP, Costa G, Santos T, Branco F, Caramona M. Evaluation of anti-inflammatory and analgesic activities of *Cymbopogon citratus* *in vivo*-polyphenols contribution. *J. Med. Plants Res.* 2015;9:1-13.
49. Mbagwu H, Anene R, Adeyemi O. Analgesic, antipyretic and anti-inflammatory properties of *Mezoneuron benthamianum* Baill (Caesalpiniaceae). *Niger Q. J. Hosp. Med.* 2007;17:35-41.
50. Vidyalakshmi K, Kamalakannan P, Viswanathan S, Ramaswamy S. Antinociceptive effect of certain dihydroxy flavones in mice. *Pharmacol. Biochem. Behav.* 2010;96:1-6.
51. Valerio DA, Georgetti SR, Magro DA, Casagrande R, Cunha TM, Vicentini FT, et al. Quercetin reduces inflammatory pain: Inhibition of oxidative stress and cytokine production. *J. Nat. Prod.* 2009;72:1975-9.
52. Haloui E, Marzouk B, Marzouk Z, Bouraoui A, Fenina N. Hydroxytyrosol and oleuropein from olive leaves: potent anti-inflammatory and analgesic activities. *J. Food Agric. Environ.* 2011;9:128-33.

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Eco-Extraction of Phenolic Compounds from Moroccan Olive Fruits and Leaves and their Potential use as Antimicrobial Agents

Wafa Laaboudi

Corresponding Author, Biotechnology Laboratory, Faculty of Science Dhar El Mahraz
University Sidi Mohamed Ben Abdellah - Fez - Morocco

Jamal Ghanam

Biotechnology Laboratory, Faculty of Science Dhar El Mahraz
University Sidi Mohamed Ben Abdellah - Fez - Morocco

Mohammed Merzouki

Biotechnology Laboratory, Faculty of Science Dhar El Mahraz
University Sidi Mohamed Ben Abdellah - Fez - Morocco

Mohamed Benlemlih

Biotechnology Laboratory, Faculty of Science Dhar El Mahraz
University Sidi Mohamed Ben Abdellah - Fez - Morocco

ABSTRACT

In Morocco, the olive harvest generates regenerates a lot of waste such as leaves and olive fruits.

Valuation by the extraction of polyphenols from this waste could be a promising source. In our work, we have prepared an olive tree extract from this waste,

our extract contains 148 g/l of polyphenols, 8.4 g/l of flavonoids and 39.11 g/l of o-diphenols. Polyphenols, major natural antioxidants play a key role in hundreds biological reactions. The antioxidant activity test revealed great antioxidant potential of our extract with high ORAC value 3 848 100 $\mu\text{mol Te/kg}$. The present work has as objective to evaluate the antimicrobial activity. The olive tree extract showed broad- spectrum antibacterial activity against *Escherichia coli*, *Escherichia coli* TG1, *Escherichia coli* DH5 α , *Staphylococcus aureus*, *Bacillus cereus*, *Bacillus cereus* MED5 and *Streptococcus agalactiae*. While pure phenolic compounds (caffeic acid, ascorbic acid and quercetin) showed more limited activity. The antifungal effect of the olive tree extract exceed the antibiotics at a concentration of 3 mg/disc ($p<0.05$). Industrial technology can therefore exploit this extract, rich in polyphenols, in order to use instead of a synthetic antioxidants and antibiotics that could be dangerous. This would lead Morocco to enhance the olive harvest waste as an important economic source.

Keywords: Olive leaves; Olive fruit; Polyphenols; Antioxidants; Antibacterial; Antifungal.

INTRODUCTION

The olive oil industry is very important in the Mediterranean area, both in terms of wealth and tradition, where Spain, Italy, Greece, Tunisia and Morocco are the main producing countries. In Morocco, the olive harvest generates large amounts of waste such as leaves and olives fruits. This waste has the ability to become a low-cost starting materiel rich in polyphenols. Which can be extracted and used as natural antibiotics and antioxidants. Its valorization of by production of natural active compounds can be an important source economic and a good way to capitalize on this problematic waste.

Several studies have shown that olive polyphenols have various biological activities, such as inflammatory (Pacheco Y.M., 2007; Brunelleschi S., 2007 ; Rahman I., 2006 ; Martínínez- Domínguez E., 2001), anti-diabetic (Hamden K., 2009), antitumor, anti-proliferative (Bouallagui Z., 2011; Fabiani R., 2002) and anti-atherogenic activities (Covas M.I., 2006). However, act as natural antioxidants to prevent human diseases.

In addition to these activities, phenolic compounds also have antiviral, antibacterial and antifungal properties (Karaosmanoglu H, 2010; Yamada K, 2009; Zhao G, 2009; Battinelli L., 2006; Medina E., 2006). Moreover, several studies have shown the capacity of hydroxytyrosol to delay and/or inhibit the growth of a range spectrum of bacteria and fungi, including pathogenic bacteria (human pathogens). It was reported that the water fruit resulting from olive oil extraction was toxic to phytopathogenic bacteria such as *Pseudomonas syringae* (Gram-negative) and *Corynebacterium michiganense* (Gram-positive) (Capasso *et al.*, 1995). Bisignano *et al.* (1999) studied the in vitro susceptibility of several pathogens from human's respiratory and intestinal tract to hydroxytyrosol and oleuropein. The minimum inhibitory concentration (MIC) reported in this study showed a wide antimicrobial activity of hydroxytyrosol against these bacterial strains (MIC between 0.24 and 7.85 mg/ml for standard strains and between 0.97 and 31.25 mg/ml for clinically isolated strains). These results suggest that hydroxytyrosol may be useful in the antimicrobial treatment of intestinal and respiratory tracts in human infections.

Thus, the aim of the present study was to describe the olive tree extraction and identification. In addition, it deals with the evaluation of antioxidant potential and the determination of antibacterial and antifungal

activities of this extract, polyphenols standards as well as antibiotics.

MATERIALS AND METHODS

Material and Chemicals

Folin–Ciocalteu reagent, Anhydrous sodium carbonate, Methanolic aluminum trichloride, Sodium molybdate dehydrate, 2,2 -diphenyl-1-picrylhydrazyl Mueller Hinton, Potato dextrose broth, Dextrose and Methylene blue were purchased from Sigma-Aldrich Chemie (Paris, France). Trolox, gallic acid, quercetin, ascorbic acid, hydroxytyrosol and caffeic acid were supplied by Sigma-Aldrich Chemie (Paris, France).

Bacterias: *Escherichia coli*, *Escherichia coli* TG1, *Escherichia coli* DH5 α , *Staphylococcus aureus*, *Bacillus cereus*, *Bacillus cereus* MED5 and *Streptococcus agalactiae* and fungus: *Candida albicans* and *Aspergillus niger* were originally obtained from Biotechnology Laboratory collection (Faculty of Science Dhar El Mahraz - Fez - Morocco).

All antimicrobial disks: Amoxicillin/Ac. Clavulanic (20/10 μ g); Chloramphenicol (30 μ g); Flucloxacillin (5 μ g); Kanamycin (30 μ g); Gentamicin (10 μ g), Amphotericin B (10 μ g) and ketoconazole (15 μ g) were obtained from Sigma-Aldrich Chemie (Paris, France).

Phenolic Extract Preparation - Fresh leaves and olives (RI:1,88) were obtained during the harvest from the company ATLAS OLIVE OILS (Atlas Olive Oils Ltd., 110 Bd. Yacoub El Mansour, 20370 Casablanca, Morocco). They were transported to the laboratory and intensively washed with distilled water at 20°C. Leaves and olives are oven-dried (BENDER oven) at 40°C (away from light) until loss of 70% of the total weight. Then the leaves and fruits,

dried, were ground using a propeller mill, type "electric coffee grinder" in order to obtain an olive powder (flour).

The solid-liquid extraction of the phenolic compounds was carried out three times by water at 45°C. The mixture of olive powder/water (w/v, 10, 20 and 30%) was stirred at room temperature, protected from light, for 24 hours. Total polyphenols were determined in the supernatant after centrifugation (6000 tr/min, 20 min) and oil removing (n-hexane, 2v/v) each 2h during extraction. All the collected supernatants (aqueous phase) were concentrated in a rotary evaporator at 40°C and freeze-dried to remove water. An extract of olive powder as obtained.

Physicochemical Characterization of Extract - Total solids, mineral matter and fat content were determined according to the experimental protocol described in Rodier (2009). All the experiments were carried out in triplicate.

Determination of Total Phenol Content - Total phenols were determined according to the modified Folin–Ciocalteu (FC) method (De Marco E., 2007). A 100µl aliquot of the olive tree extract was added to a 9,9ml of water. FC reagent (0.5 ml) was added and the contents were mixed thoroughly. After 5 min, 2 ml of a 20%, anhydrous sodium carbonate solution (w/v) was added, and then the mixture was allowed to stand for 30 min. The absorbance of the blue-coloured samples was measured at 750 nm. The total phenolic content was determined as gallic acid equivalents (GAE) and values are expressed as g of gallic acid /l.

Determination of Flavonoids Content - The amount of total flavonoids in the extracts was measured following a previously reported method (Goulas, V., 2010) 1 ml of 2% methanolic aluminum trichloride

(AlCl_3) solution was mixed with the same volume of the olive tree extract. After incubation at room temperature for 15 min, the absorbance of the reaction mixture was measured at 430. The concentrations of flavonoid compounds expressed as mg quercetin equivalent per g (mg QE/g) of extract were calculated according to the standard quercetin graph.

Determination of o-Diphenols Content - The determination of o-diphenols was performed according to the method used by Mateos (Mateos, 2001). A mixture of 4 mL of the olive tree extract with 1 mL of a 5% solution of sodium molybdate dihydrate in ethanol/water (1:1) was shaken vigorously. After 15 min, the absorbance at 370 nm was measured. A blank was obtained by measuring a mixture of 4 mL of phenolic solution with 1 mL of ethanol/water (1:1).

The measurements were repeated on triplicate samples.

HPLC Analysis of the Olive Tree Extract - Phenolic compounds of olive tree extract were analyzed by reverse HPLC using a binary gradient elution. The HPLC (Shimadzu prominence) device consisted of two pumps LC-10ADVP, a photodiode array detector SPD-20A/20AV (UV-VIS Detectors) operating in the range of 190–900 nm, and an automatic injector SIL-10ADVP. The modified method of Hrncirik and Fritsche (2004) was used to separate the mixture on reverse phase C18 Shimadzu column CLC-ODS (M) (250 mm L. \times 4.6 mm I.D., 5 μm) at 27°C with a flow rate of 1 mL/min and a mixture of 0.5% orthophosphoric acid (v/v) in water (solution A) and methanol/acetonitril (50:50, v/v) (solution B). The following gradient program (in %) with a total analysis time of 75 min was used: A/B = 95/5; t = 15 min, A/B = 70/30; t = 15 min, A/B = 65/35; t = 7 min, A/B = 60/40; t = 13 min, A/B = 30/70; t = 5 min, A/B = 0/100, held for 5 min, starting ratio (for 7 min)

and the column equilibration (8 min). Components were detected at 280 nm.

Determination of Antioxidant Activity - The antioxidant activity was measured in terms of hydrogen donating or radical scavenging ability, using the stable radical, DPPH• (2,2-diphenyl-1-picrylhydrazyl) (Berrin Bozan, 2008). Briefly, 3.9 ml from DPPH (63.4 mM) solution added to a series of different concentrations of the olive tree extract (375– 2.5 mg/l). The mixtures were incubated at 37°C for 30 min in dark, and then analyzed in the spectrophotometer at 517 nm. Ascorbic acid was used as positive control and hydroxytyrosol was tested as a pure phenolic compound for comparison to the olive extract. All determinations were performed in triplicate. The percentage inhibition of the DPPH radical by the samples was calculated according to the formula:

$$\text{Scavenging activity (\%)} = [(A_{\text{control}} - A_{\text{sample}})/A_{\text{control}} \times 100\%$$

Where A_{control} is the absorbance of the control at $t=0$ min, and A_{sample} the absorbance of the antioxidant at $t=30$ min. The results were compared to the DPPH radical-scavenging activity of standard concentrations of Trolox, assuming as unit of ORAC the DPPH radical-scavenging activity of 1 mmol of Trolox (Zullo and Ciafardini, 2008).

Determination of Antimicrobial Activity - Antimicrobial activity was tested against a panel of microorganisms, including seven bacteria strains: *Escherichia coli*, *Escherichia coli* TG1, *Escherichia coli* DH5 α , *Staphylococcus aureus*, *Bacillus cereus*, *Bacillus cereus* MED5 and *Streptococcus agalactiae* and two fungus *Candida albicans* and *Aspergillus niger*.

The disc diffusion method was used to determine the antimicrobial activities of the olive tree extract and polyphenol standards (caffeic acid, ascorbic acid and quercetin). On Mueller Hinton agar for Bacterias and on Mueller Hinton supplemented with 2% dextrose and 0.5 mg/L methylene blue for fungus. The bacterial test organisms were grown in nutrient broth for 24h and used for further study. The fungal organisms are grown on potato dextrose broth (PDB) for 72h and used for further experiment. Mueller Hinton agar plates are prepared, sterilized and solidified. After solidification, 100µl overnight culture of each organism was spreaded on the petriplates using a sterile glass rod to prepare bacterial lawns. Microbial cultures were diluted in sterile distilled water in order to give a population of approximately 10^6 CFU/plate. Four sterile paper disks (6 mm in diameter) were placed on the surface of each agar plate and 10 µl of each standard, extract or controls was added to the paper discs. Disks embedded as the final concentration for the olive tree extract and polyphenols standards were 0.5 mg/disk, 1 mg/disk, 2 mg/disk, 3 mg/disk, and 4 mg/disk, respectively.

Each experiment was carried out in triplicate. Petri dishes were incubated at 37°C for 16–18h for bacteria, at 35°C for 24h for fungi. The diameter of the inhibition zone was measured in mm (including disc) with callipers, three replicates were performed (three different plates) and the average was taken. A disk impregnated with sterile distilled water served as negative controls and disks with an antibiotics served as a positive control. Five antimicrobial disks were included for antibacterial activity: Amoxicillin/Ac. Clavulanic (20/10 µg); Chloramphenicol (30 µg); Flucloxacillin (5 µg); Kanamycin (30 µg); Gentamicin (10 µg). And amphotericin B (10 µg) and ketoconazole (15 µg) were used for antifungal activity.

Statistical Analysis

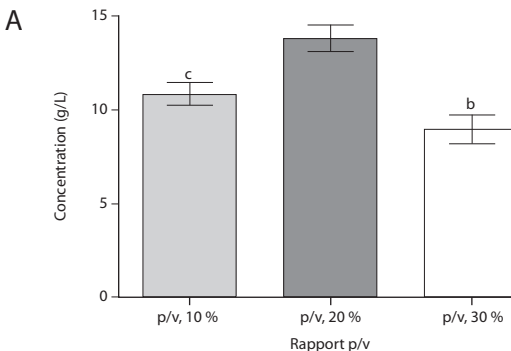
Statistical analyzes were performed using GraphPad Prism software version 6.00 (GraphPad Inc., San Diego, California). Data were analyzed by analysis of variance (ANOVA Analysis of Variance) followed by post-hoc Dunnet test if the sample distribution follows normal distribution or by the Kruskal-Wallis if the sample distribution does not follow the normal law. Values between groups were considered statistically significant for at $P < 0.05$.

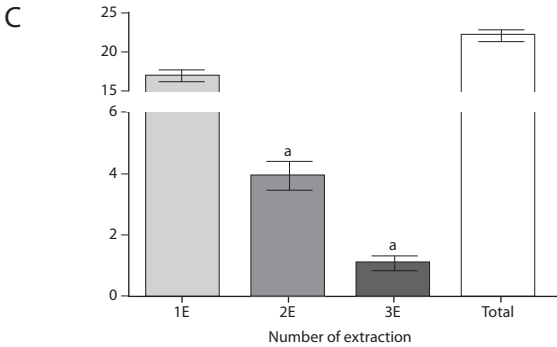
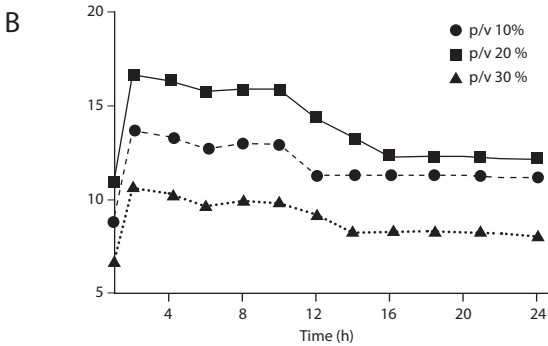
RESULTS AND DISCUSSIONS

Olive Phenolic Extract

Results plotted on the first graph of the figure 1 show that the extract obtained with 20% ratio (w/v) contains a significantly high amount of polyphenols compared to other used ratios ($P < 0.05$ and < 0.01 compared to the 10 and 30% ratios).

Figure 1: Optimization of extraction conditions of polyphenols from olive powder, (a) p/v, (b) time of extraction and (c) number of extraction cycles. Mean \pm standard deviation. The letters indicate the significance of the difference compared to controls, ^a $P < 0.001$, ^b $P < 0.01$ and ^c $P < 0.05$.





The evolution of total polyphenol concentration of the three used ratios was studied through 24 hours. The curves of the figure 1b show that the temporal evolution of the polyphenol content of these three extracts has followed similar pace. Thus, the system (olive powder/water) tends towards equilibrium after two hours for the three used ratios (w/v), where the polyphenols content of the olive extract is higher.

Retaining the optimal extraction conditions (w/v ratio of 20% and 2 hours of extraction) we chose to perform extractions from a larger quantity of olive powder in order

to exhaust the plant material. For that reason, 100 g of olive powder was extracted three times with tepid water (45°C) for 2 hours in the dark and at room temperature. To avoid the phenomena of possible degradation of bioactive compounds, the resulting extract was collected (and stored carefully) after each cycle and only the plant matrix will undergo a new extraction cycle. The figure (1c) shows the results recorded for the three extraction cycles. As can we deduced, over 77% of olive extract polyphenols was obtained during the first extraction cycle compared to the last two cycles ($P < 0.001$). The three fractions were, therefor, combined and subsequently concentrated using rotary evaporation at 40 °C (Buchi Rotavapor). Table below presents the average values of the main constituents of the olive extract.

The gross characterization of the extract is summarized in Table 1. The prepared extract was a Dark brown powder with a characteristic odor of processed olives.

Table 1: Organoleptic characteristics of the olive extract.

| Description | Characteristic |
|-------------|-------------------|
| Appearance | Dark brown powder |
| Odor | Processed olives |
| Solubility | 98% |
| pH | 5,64 |

The eco-extraction of bioactive compounds from olive powder was carried out by the water at 45 °C (laundering) for 2 hours using a w/v ratio of 20%. The physical and chemical characterization (table 2) revealed that the olive extract is rich in polyphenols (over 15%), especially hydroxytyrosol (2%) without having to resort to any purification treatment.

Table 2: Total phenols and main constituents of olive phenolic extract. Mean \pm standard deviation.

| Biophenol content | Concentration |
|-----------------------------------|------------------|
| Dry matter (g/100g of powder) | 97.96 \pm 7.83 |
| Mineral matter (g/100g of powder) | 12.9 \pm 0.7 |
| Fat (g/100g of powder) | < 1 |
| Total phenolic content (g GAE/l) | 159.8 \pm 1.9 |
| Flavonoids (g QE/l) | 8.4 \pm 0.6 |
| o-Diphenols (g CAE/l) | 39.11 \pm 0.9 |
| Hydroxytyrosol (g GAE/l) | 2.09 \pm 1.4 |

Actually, the olive fruit has been known for several years as a source of phenolic compounds with high biological activities. However, combining the olive fruits and leaves to extract bioactive molecules (ecologically without use of chemical solvents) not only contributes to the improvement (quantitative and qualitative) of extraction yield, but also is a way to valuate of olive leaves generated during the olive harvest (10% of the total weight of olives produced) and trees pruning. Leaves and olive fruits were dried moderately, at a temperature of 40 ± 2 °C until loss of 70% of their weight. In fact, desiccation allows the reduction of the water content, the inhibition of the cellular enzymes activity (hydrolases and oxidases) and therefore increasing the extraction yield (Ahmad et al-Qasem, 2013. Groubert, 1984). Simple drying at 40 °C, although slow, allows the preservation of the original content bioactive molecules from the plant material compared to other recently used techniques (drying under hot air flow or infrared and lyophilization) (Ahmad- Qasem *et al.*, 2013). Furthermore, use of tepid water (at 45°C) as extraction solvents induces, also, enzymes inactivation (denaturation) and increases the permeability of the cell membranes, the solubility of the extracted material and the diffusion coefficient. Finally, the temperature decreases the viscosity of the obtained phases (water and oil), which

not only facilitates the passage of water through the mass of the solid substrate, but also the subsequent operations of separation (Leybros and Frémeaux 1990 Binbenet, *et al.*, 2007). On the other hand, the rotary evaporation by vacuum concentration at 40°C will increase the final concentration of the polyphenols but also the protection of hydroxytyrosol and other phenolic compounds, who the stability is proportional with their concentration in a aqueous medium (Zafra-Gómez *et al.*, 2011).

Biophenols Content

The table 3 shows the phenolic retention time of the olive tree extract.

Table 3: The polyphenol compound retention time.

| Polyphenol | Retention time (min) |
|---------------------|----------------------|
| Acide gallique | 0,698 |
| Rutine | 0,769 |
| Myricetine | 0,976 |
| Quercetine | 1,493 |
| Lutéoline | 1,643 |
| Kaempferole | 2,252 |
| Acide Chlorogenique | 2,459 |
| Acide Caféique | 2,524 |
| Apigénine | 2,642 |
| Isorhamnetin | 2,642 |
| Acide p-Comairique | 3,508 |
| Hydroxytyrosol | 3,893 |
| Acide Férulique | 4,310 |
| Tyrosol | 5,190 |
| Oleuropéine | 12,400 |

These results analysis revealed a complex mixture of phenolic compounds, among which the components identified as oleuropein, hydroxytyrosol (3', 4'-DHPEA), tyrosol (p-DHPEA) were the most intense. Flavonoids

such as rutin, quercetin, luteolin and apigenin were also founded. It is worth noting that oleuropein and these secoiridoid derivatives are the predominant phenol commonly found in *Olea europaea* fruits, leaves and virgin olive oil (Mateos *et al.*, 2001).

In fact, the most important source of these compounds is the olive fruit (Montedoro *et al.*, 1993). However, they are also present in the leaves (Japón-Luján *et al.*, 2007). The most abundant polyphenols identified in extracts of leaves and olive fruits were oleuropein, hydroxytyrosol and its secoiridoids derivative, and flavonoids (Benavente-García *et al.*, 2000). This explains these results, where hydroxytyrosol, tyrosol, apigenin, luteolin and caffeic acid was the major phenolic compounds in the olive extract. Furthermore, these molecules provide a strong antioxidant activity to olive extract, resulting in high ORAC value (table). Moreover, these compounds impart several biological properties for olive extracts, such as antioxidant (Benavente-García *et al.*, 2000), antiproliferative (Taamalli *et al.*, 2012) and antimicrobial (Micol *et al.*, 2005).

The olive tree extract also showed strong antioxidant resulting high ORAC value, which $3848100 \pm 38481 \mu\text{mol Te/kg}$ (tested using DPPH radical assay according to the protocol described by Zullo and Ciafardini (2008)). Actually, in the past decade, polyphenol-rich foods and herbs have become a topic of increasing interest not only to food and health science researchers or medical experts, but also to the general public. It has received particular attention due to their various biological effects including antioxidant activity. The phenolic compounds found in olives, olive oil, and Olive Mill Waste Water have been reported to possess strong antioxidant activity (Obied HK, 2007; Lafka T-A, 2011).

Antimicrobial Activity

The results of the study of the antimicrobial effect of the olive extract, obtained after 24 and 72h of incubation for bacteria and fungi, are summarized in Table 3.

The results of Table 3 show that the antimicrobial effect of the olive tree extract is dose- dependent, where the maximum activity was recorded for the dose of 4 mg/disc. At this dose, the antimicrobial activity of the olive extract was significantly higher ($P < 0.05$) compared to that of antibiotics used as positive controls. However, surprisingly, none of the standard molecules used in the current study had a significant effect on microorganism growth (data not show). Moreover, none of the strains studied (bacteria and fungi) showed resistance to olive extract, even at low concentrations, 0.5 (data not shown) and 1 mg/disc. This behavior could be due to the fact that the aqueous extract of the olive tree (subject of study) is rich in bioactive molecules with antimicrobial effect; i.e. phenolic compounds whose antimicrobial and antifungal activity has been elucidated by several authors (Medina *et al.*, 2009; Keceli *et al.*, 2002; Capasso *et al.*, 1995).

Generally, the antimicrobial activity of an extract (or essential oils) is closely related to its chemical composition, particularly the minor compounds that act synergistically. Thus, the results obtained in this study show that the olive tree extract has a significant antimicrobial activity against the tested bacteria and fungi. This activity is probably due to its chemical composition rich in phenolic compounds, especially hydroxytyrosol, oleuropein and secoiridoids derivatives (dialdehydic form of decarboxymethyl oleuropein/ligstrosid aglycon). Actually, bactericidal, bacteriostatic and antifungal effect of these molecules has been reported in several studies (Karaosmanoglu *et al.*, 2010; Medina *et al.*, 2006; Battinelli *et al.*, 2006).

However, Romero *et al* (2007) have reported that only the dialdehydic forms of oleuropein and ligstroside (aglycons) showed inhibitory activity towards *Helicobacter pylori*. In addition, these authors have correlated the antimicrobial activity of the olive oils and extracts to their phenolic profiles and, more particularly, to the synergistic effect of these molecules.

Furthermore, several studies have shown that the phenolic compounds of the olive have antimicrobial properties by denaturing proteins and microbial enzymes (Cushnie and Lamb, 2005). This activity is strongly related to their structure (aromatic ring attached to the hydroxyl groups in different positions). Ultee *et al.* (2002) showed that this structure allows these compounds to form hydrogen bonds with the SH-groups in the active sites of target enzymes, which leads to the deactivation of these enzymes in *Bacillus cereus*.

Moreover, Medina *et al.* (2009) compared the antibacterial activity of the dialdehydic form of oleuropein and ligstroside (3, 4-DHPEA-EDA and *p*-HPEA-EDA) to the glutaraldehyde and ortho- phthalaldehyde (OPA and GTA, known biocides), which had a similar dialdehydic structure. OPA and GTA interact, strongly, with the amino acids, proteins and membrane molecules (lipids), which increases the permeability of the membrane and causes cell lysis (Simoes *et al.*, 2006). The results showed that the antibacterial activity (on a range of bacteria, including *Staphylococcus aureus*) of phenolic compounds with dialdehydic residues in their structure was higher than that of other polyphenols and, surprisingly, similar to that of two commercial biocides (OPA and GTA). Although dialdehydic structure is essential for their antimicrobial activity, the rest of the molecule also influences this activity since the OPA has a stronger activity than GTA.

Table: Antibacterial and antifungal activities of olive tree extract. Results expressed as diameter of the inhibition zone (mm). Mean values (standard deviation).

| | Olive extract concentrations (mg/disc) | | | | Antibiotics (μg/disc) | | | | | | |
|-----------------------|--|--------------|--------------|--------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | 1 | 2 | 3 | 4 | Am/Cl (20/10) | Ch (30) | Fl (5) | Ka (30) | Ge (10) | Am (10) | Ke (15) |
| Bacteria | | | | | | | | | | | |
| <i>E. coli</i> | 15.00 (1.00) | 20.33 (1.52) | 25.33 (1.52) | 29.67 (1.52) | ^a 11.66 (0.52) | ^a 11.66 (0.53) | ^a 18.00 (0.00) | ^a 20.00 (0.00) | ^a 11.69 (0.53) | — | — |
| <i>E. coli</i> T61 | 14.00 (1.00) | 19.67 (0.53) | 25.00 (0.00) | 30.33 (0.53) | ^a 19.64 (0.57) | ^a 14.67 (0.53) | ^a 24.66 (0.57) | ^a 23.33 (0.53) | ^a 17.00 (0.00) | — | — |
| <i>E. coli</i> DH5α | 15.33 (0.57) | 20.66 (0.57) | 26.66 (0.57) | 30.33 (0.53) | ^a 23.00 (0.00) | ^a 8.00 (0.00) | ^a 25.67 (0.57) | ^a 25.67 (0.77) | ^a 17.33 (0.53) | — | — |
| <i>S. aureus</i> | 10.33 (0.57) | 13.67 (0.57) | 17.33 (0.57) | 20.66 (0.57) | ^a 17.60 (0.57) | ^a 7.33 (0.53) | ^a 24.00 (0.00) | ^a 21.67 (0.55) | ^a 17.00 (1.00) | — | — |
| <i>B. cereus</i> | 14.67 (0.55) | 16.67 (0.58) | 22.00 (0.00) | 30.33 (0.57) | ^a 13.63 (0.51) | ^a 0.00 (0.00) | ^a 22.33 (0.53) | ^a 21.67 (0.53) | ^a 13.66 (0.57) | — | — |
| <i>B. cereus</i> MED5 | 16.67 (0.53) | 20.63 (0.77) | 25.67 (0.53) | 31.00 (0.00) | ^a 13.00 (0.00) | ^a 9.33 (1.15) | ^a 24.33 (0.53) | ^a 20.00 (0.00) | ^a 15.00 (0.00) | — | — |
| <i>S. agalactiae</i> | 18.00 (0.43) | 20.33 (0.57) | 21.33 (0.58) | 22.33 (0.57) | ^a 18.00 (0.00) | ^a 2.00 (0.00) | ^a 24.00 (0.00) | ^a 23.66 (0.55) | ^a 20.33 (0.55) | — | — |
| Fungi | | | | | | | | | | | |
| <i>A. niger</i> | 10.67 (0.53) | 11.77 (0.55) | 13.67 (1.15) | 16.68 (1.51) | — | — | — | — | — | 18.00 (0.00) | ^a 16.66 (0.53) |
| <i>C. albicans</i> | 10.33 (0.57) | 12.00 (0.21) | 16.67 (1.52) | 19.71 (1.52) | — | — | — | — | — | ^a 14.67 (0.57) | ^a 19.67 (0.57) |

Am/Cl, Amoxicillin/Ac. Clavulanic; Ch, Chloramphenicol; Fl, Flucloxacillin; Ka, Kanamycin; Ge, Gentamicin; Am, Amphotericin; Ke, Ketoconazole.

Letters indicate significant difference at $P < 0.05$; ns, not significant. (—) no effect.

CONCLUSION

Thus, the olive extract, obtained by a simple and environmentally technic, which closes an extraordinary amount of antimicrobial phenolic compounds inhibited the growth of a range of bacteria and fungi (*in vitro*). This inhibition included two ubiquitous opportunistic bacteria frequently responsible for food intoxications, *Staphylococcus aureus* and *Bacillus cereus*. These experimental data, although preliminary, lead us to think about future use of olive bio-extract as a food additive to protect food against these opportunistic germs but also with high nutritional value (through the biological effects of olive polyphenols). However, further work on the determination of minimum inhibitory and bactericidal concentrations (MCI and MCB) as well as the action of this extract mode are needed for this kind of use.

REFERENCES

- [1] Ahmad-Qasem M.H, Barrajón-Catalán E, Micol V, Mulet A, García-Pérez J.V. 2013. "Influence of freezing and dehydration of olive leaves (var. Serrana) on extract composition and antioxidant potential". *Food Research International* 50, pp. 189-196.
- [2] Battinelli L., Daniele C., Cristiani M., Bisignano G., Saija A., Mazzanti G. 2006. "In vitro antifungal and anti-elastase activity of some aliphatic aldehydes from *Olea europaea* L. fruit". *Phytomedicine* 13, pp. 558-563.
- [3] Benavente-García O, Castillo J, Lorente J, Ortuño A, Del Río J.A. 2000. "Antioxidant activity of phenolics extracted from *Olea europea* L. leaves". *Food Chemistry* 68, pp. 457-462.
- [4] Berrin Bozan, Goksel Tosun, Derya Ozcan 2008. "Study on polyphenol content in the seeds of red grape (*Vitis vinifera* L.) varieties cultivated in Turkey and their antioxydant activity". *Food chemistry* 209, pp. 426-430.
- [5] Bimbenet J. J., Duquenoy A. & Trystam G. 2007. "Génie des procédés alimentaires des bases aux applications", RIA Editions, 2^e édition. Dunod, Paris 575 p.
- [6] Bisignano G, Tomaino A, Lo Cascio R, Crisafi G, Uccella N, Saija A. 1999. "On the in-vitro antimicrobial activity of oleuropein and hydroxytyrosol". *Journal of Pharmacy and Pharmacology* 51, pp. 971-974.
- [7] Bouallagui Z., Han J., Isoda H., Sayadi S., 2011. "Hydroxytyrosol Rich Extract From Olive Leaves Modulates Cell Cycle Progression In Mcf-7 Human Breast Cancer Cells". *Food and Chemistry Toxicology* 49, pp. 179-184.

- [8] Brunelleschi S., Bardelli C., Amoruso A., Gunella G., Ieri F., Romani A., Malorni W., Franconi F., 2007. "Minor Polar Compounds Extra-Virgin Olive Oil Extract (Mpc-Ooe) Inhibits Nf-Kb Translocation In Human Monocyte/Macrophages". *Pharmacological Research* 56, pp. 542–549.
- [9] Capasso R, Evidente A, Schivo L, Orru G, Marcialis MA, Cristinzio G, 1995. "Antibacterial polyphenols from olive oil mill waste waters". *Journal of Applied Bacteriology* 79, pp. 393–398.
- [10] Covas M.I., Nyyssonen K., Poulsen H.E., Kaikkonen J., Zunft H.J., Kieseetter H., Gaddi A., De La Torre R., Mursu J., Baumler H., Nascetti S., Salonen J.T., Fito M., Virtanen J., Marrugat J., 2006. "The Effect of Polyphenols in Olive Oil on Heart Disease Risk Factors: A Randomized Trial", *Annals of Internal Medicine* 145, pp. 333–341.
- [11] Cushnie T.P. Tim, Lamb Andrew J. 2005. "Antimicrobial activity of flavonoids". *International Journal of Antimicrobial Agents* 26, pp. 343–356.
- [12] De Marco E., Savarese M., Paduano A., Sacchi R. 2007. "Characterization and fractionation of phenolic compounds extracted from olive oil mill wastewaters". *Food Chemistry* 104, pp. 858–867.
- [13] Fabiani R., De Bartolomeo A., Rosignoli P., Servili M., Montedoro G., Morozzi G., 2002. "Cancer chemoprevention by hydroxytyrosol isolated from virgin olive oil through G1 cell cycle arrest and apoptosis", *European Journal of Cancer Prevention* 11, pp. 351–358
- [14] Goulas, V., Papoti, V. T., Exarchou, V., Tsimidou, M. Z., & Gerothanassis, I. P. 2010. "Contribution of flavonoids to the overall radical scavenging activity of olive (*Olea europaea*L.) leaf polar extracts". *Journal of Agricultural and Food Chemistry* 58, pp. 3303–3308.
- [15] Groubert A. 1984. "Techniques d'extraction végétale". Montpellier, Pharmacie.
- [16] Hamden K., Allouche N., Damak M., Elfeki A., 2009. "Hypoglycemic And Antioxidant Effects Of Phenolic Extracts And Purified Hydroxytyrosol From Olive Mill Waste In Vitro And In Rats", *Chemico-Biological Interactions* 180, pp. 421–432.
- [17] Hrnčirik Karel and Fritsche Sonja, 2004. "Comparability and reliability of different techniques for the determination of phenolic compounds in virgin olive oil". *European Journal of Lipid Science and Technology* 106, pp. 540–549.
- [18] Japón-Luján R, Luque de Castro M.D. 2007. "Small branches of olive tree: A source of biophenols complementary to olive leaves". *Journal of Agricultural and Food Chemistry* 55, pp. 4584–4588.
- [19] Karaosmanoglu H., Soyer F., Ozen B., Tokatli F. 2010. "Antimicrobial and antioxidant activities of Turkish extra virgin olive oils". *Journal of Agricultural and Food Chemistry* 58, pp. 8238–8245.
- [20] Keceli T, Gordon MH. 2001. "The antioxidant activity and stability of the phenolic fraction of green olives and extra virgin olive oil". *Journal of the Science of Food and Agriculture* 81, pp. 1391–1396.

- [21] Lafka Theodora-Ioanna, Andriana E. Lazou, Vassilia J. Sinanoglou, Evangelos S. Lazos. 2011. "Phenolic and antioxidant potential of olive oil mill wastes". *Food Chemistry*, 125, pp. 92-98.
- [22] Leybros J. et Fremeaux P., 1990. "Extraction solide-liquide, aspect théorique". *Techniques de l'ingénieur J 2780* pp 7-8.
- [23] Martini'Nez-Domi'Nquez E., De La Puerta R., Ruiz-Gutíe'Rez V., 2001. "Protective Effects up on Experimental Inflammation Models Of A Polyphenol-Supplemented Virgin Olive Oil Diet", *Inflammation Research* 50, pp. 102–106.
- [24] Mateos, R.; Espartero, J. L.; Trujillo, M.; Ríos, J. J.; León-Camacho, M.; Alcudia, F.; Cert, A. 2001. "Determination of phenols, flavones, and lignans in virgin olive oils by solid-phase extraction and high-performance liquid chromatography with diode array ultraviolet detection". *Journal of Agricultural and Food Chemistry* 49, pp. 2185-2192
- [25] Medina E., De Castro A., Romero C., Brenes, M. 2006. "Comparison of the concentrations of phenolic compounds in olive oils and other plant oils: correlation with antimicrobial activity". *Journal of Agricultural and Food Chemistry* 54, pp. 4954–4961.
- [26] Medina Eduardo, Brenes Manuel, Garcí'A Aranzazu, Romero Concepcio' N, De Castro Antonio. 2009. "Bactericidal Activity of Glutaraldehyde-like Compounds from Olive Products". *Journal of Food Protection* 72, pp. 2611–2614.
- [27] Micol V, Caturla N, Pérez-Fons L, Más V, Pérez L, Estepa A. 2005. "The olive leaf extract exhibits antiviral activity against viral haemorrhagic septicaemia rhabdovirus (VHSV)". *Antiviral Research* 66, pp. 129-136.
- [28] Montedoro G.F, Servili M, Baldioli M, Selvaggini R, Miniati E, Maccchioni 1993. "A. Simple and hydrolyzable compounds in virgin olive oil. 3. Spectroscopic characterizations of the secoiridoid derivatives". *Journal of Agricultural and Food Chemistry* 41, pp. 2228–2234.
- [29] Obied HK, Allen MS, Bedgood DR. 2007. "Bioscreening of Australian olive mill waste extracts: Biophenol content, antioxidant, antimicrobial and molluscicidal activities". *Food and Chemistry Toxicology* 45, pp. 1238–48.
- [30] Pacheco Y.M., Bermu 'Dez B., Lo'Pez S., Abia R., Villar J., Muriana F.J.G., 2007. "Minor Compounds Of Olive Oil Have Postprandial Anti-Inflammatory Effects", *British Journal of Nutrition* 98, pp. 260–263.
- [31] Rahman I., 2006; Rahman I., Biswas S.K., Kirkham P.A., 2006. "Regulation Of Inflammation And Redox Signaling By Dietary Polyphenols", *Biochemical Pharmacology* 72, pp. 1439–1452.
- [32] Rodier J 2009. "L'analyse de l'eau - eaux naturelles, eaux résiduares, eau de mer", 9^e Édition, Dunod, Paris, 1579 p.
- [33] Romero Concepcioä N, Medina Eduardo, Vargas Julio, Brenes Manuel And De Castro Antonio. "In Vitro Activity of Olive Oil Polyphenols against *Helicobacter pylori*". *Journal of Agricultural and Food Chemistry* 55, pp. 680–686.
- [34] Simões, M., M. O. Pereira, I. Machado, L. C. Simoes, and M. J. Vieira. 2006. "Comparative antibacterial potential of selected aldehyde-based

biocides and surfactants against planktonic *Pseudomonas fluorescens*". *Journal of Industrial Microbiology and Biotechnology* 33, pp. 741–749.

[35] Taamalli A, Arráez-Román D, Barrajón-Catalán E, Ruiz-Torres V, Pérez-Sánchez A, Herrero M, Ibáñez E, Micol V, Zarrouk M, Segura-Carretero A, Fernández-Gutiérrez A. 2012. "Use of advanced techniques for the extraction of phenolic compounds from Tunisian olive leaves: Phenolic composition and cytotoxicity against human breast cancer cells". *Food and Chemistry Toxicology* 50, pp. 1817–1825.

[36] Ultee, A., Bennik, M.H.J., Moezelaar, R. 2002. "The Phenolic Hydroxyl Group of Carvacrol Is Essential for Action against the Food-Borne Pathogen *Bacillus cereus*". *Applied and Environmental Microbiology* 68, pp. 1561–1568.

[37] Yamada K., Ogawa H., Hara A., Et Al., 2009. "Mechanism Of The Antiviral Effect Of Hydroxytyrosol On Influenza Virus Appears To Involve Morphological Change Of The Virus". *Antiviral Research* 83, pp. 35–44.

[38] Zafra-Gómez A, Luzón-Toro B, Capel-Cuevas S, Morales J.C. 2011. "Stability of Hydroxytyrosol in Aqueous Solutions at Different Concentration, Temperature and with Different Ionic Content: A Study Using UPLC-MS". *Food and Nutrition Sciences* 2, pp. 1114–1120.

[39] Zhao G., Yin Z., Dong J., 2009. "Antiviral Efficacy Against Hepatitis B Virus Replication of Oleuropein Isolated From *Jasminum Officinale* L. Var. *Grandiflorum*". *Journal of Ethnopharmacology* 125, 265–268.

[40] Zullo B.A. Ciafardini, G. 2008 "Lipolytic yeasts distribution in commercial extra virgin olive oil *Food Microbiology*" 25, pp. 970-977.

Anticancer effect of an olive tree extract through his cytotoxic, antioxidant and antiangiogenic activities

Laure Eloy², Thierry CRESTEIL^{2,3}, Jamal GHANAM¹, Wafa LAABOUDI¹, and Mohammed BENLEMLIH¹

¹Biotechnology Laboratory, Faculty of Science Dhar El Mahraz University Sidi Mohamed Ben Abdellah, P.O. Box 1796 Atlas, Fez-Morocco.

²ICSN-CNRS UPR 2301, Avenue de la terrasse, 91190 Gif sur Yvette, France.

³IPSIT, Faculté de Pharmacie, Université Paris Sud, 92290 Chatenay-Malabry, France.

ABSTRACT

The aim of the current study was to evaluate the anticancerous potential of a phenolic olive tree extract through his cytotoxic, antioxidant and antiangiogenic activities. The *in vitro* cytotoxic activity of a crude olive tree extract and his major constitutive components has been evaluated against human KB, HL60 cancer cell lines using MTS and flow cytometry. ROS production was estimated with the DCFH- DA assay. Antiangiogenic activity was evaluated *in vitro* on endothelial cells tube formation and the pro-angiogenic factor expression was quantified using qRT-PCR. *In vitro* cellular assays have demonstrated the cytotoxic effect of the crude olive tree extract. This extract

reduces significantly ($p < 0.05$) ROS produced in cells exposed to oxidative stress. Beside this, olive tree extract has demonstrated a strong anti-angiogenic activity, which was correlated with a significant decrease ($p < 0.05$) in VEGF, angiopoietin and HIF1 α expression. Basically, the evaluation of anti- proliferative, antioxidant and anti-angiogenic activities could be the first step to formulate an efficient pharmaceutical product with preventive and/or curative properties against cancer.

Key words: Olive tree extract; Anticancerous; Cytotoxic; Antioxidant; Antiangiogenic.

INTRODUCTION

Olive is a generic name for about 35 species of evergreen shrubs and trees of *Olea* genus and *Oleaceae* family, native to tropical and warm temperate regions. The name is particularly used to describe *Olea europaea* L. space cultivated for its edible fruits (olives). The use of olive fruits and leaves for alimentary, therapeutic and cosmetic purposes was a well-known practice in the Mediterranean basin for more than 7 000 years (Evagelia *et al.*, 2004). Although polyphenols are present in olive leaves, olive fruits has been known for several years as a major source of phenolic compounds with high biological activities (Japón-Luján *et al.*, 2007; Mario-Casas *et al.*, 2003; Visioli *et al.*, 2000). Actually, combined of olive fruits and leaves (10% of the total weight of the olives produced generated during olive harvest and olive tree size) to biophenols extracting enhance both qualitative and quantitative extraction yield.

The phenolic fraction of olive tree (fruits, leaves and very young leaves) is a complex mixture of chemical compounds with different structures and molecular weight obtained using mainly liquid-liquid extraction (methanol-water).

Olive tree polyphenols belong generally to the following classes: (a) tyrosol, hydroxytyrosol and their secoiridoide derivatives; (b) 4-hydroxybenzoic acid, 4-hydroxyphenylacetic acid and 4-hydroxycinnamic acid derivatives; (c) lignans and (d) flavonoids. These various compounds have antioxidant (Nardia *et al.*, 2014; Benavente-García *et al.*, 2000), antimicrobial (Micol *et al.*, 2005) and antiproliferative (Taamalli *et al.*, 2012) properties. Today, data collected from *in vitro*, *in vivo* and clinical studies reveal the benefits of these bioavailable compounds for human health. These antioxidant compounds are useful agents for preventing cellular aging and age-related diseases by improving mitochondrial function (Raederstorff *et al.*, 2010). The benefits of olive phenolic compounds on the cardiovascular system have been well documented (Covas, 2007, 2006; Esturch *et al.*, 2006). Beside, these compounds also modulate the inflammatory response associated to several diseases (Killeen *et al.*, 2014; Scoditti *et al.*, 2012; Richard *et al.*, 2011).

Published data have reported that apoptosis and/or necrosis are implicated in the cytotoxicity of olive tree polyphenols. Thus, it has been demonstrated that oleuropein and hydroxytyrosol induce apoptosis in HT-29 human colon adenocarcinoma, HL-60 promyelocytic leukemia) and MCF-7 breast cancer cell lines (Fabiani *et al.*, 2002, 2006, Han *et al.*, 2009). More recently, LeGendre *et al.*, (2015) stated that oleocanthal rapidly and selectively induces apoptotic or necrotic processes *via* lysosomal membrane permeabilization. Beside this, through an *in vivo* study, Hamdi and Castellon (2005) showed that oleuropein inhibits tumor growth in tumor-bearing mice. Additionally, many epidemiological studies suggest the possible correlation between the consumption of olive products and the incidence of breast cancer (Giacosa *et al.*, 2013).

In the present study, we investigated the cytotoxic effect of an olive tree extract against several cancer cell lines through commonly used cellular assays. Additionally, the current study includes the determination of antiangiogenic and antioxidant effects of olive phenolic compounds contained in their stable and natural matrix.

MATERIALS AND METHODS

Extract preparation

Olive leaves and fruits were mixed to obtain the aqueous olive tree extract (OTE) by solid-liquid extraction 100% natural, 100% mechanical using water (no use of alcohol, no use of ethanol, no use of chemicals). Actually, OTE is marketed in the world (France, Switzerland, Belgium, ...) under the brandname OLIVIE FORCE / OLIVIE RICHE (see more in www.olivie.ma). The extract consists in a dark brown solution whose major constituents have been determined (table 1). It comes from organic olive trees that are planted in the middle of a rocky desert where trees suffer and trigger a self-defence mechanism where they produce abnormally high quantities of anti-oxydants to survive.

Table 1. Total phenols and major constituents of olive tree extract. Mean \pm standard deviation (corresponds to the initial first version of OLIVIE FORCE / OLIVIE RICHE).

| Parameter | Average value (g per100g) |
|--------------------------|---------------------------|
| Density | 1.3 |
| Dry matter | 98.0 \pm 7.8 |
| Mineral matter | 12.9 \pm 0.7 |
| Fat | < 1 |
| Total polyphenols | 7.90 \pm 1.9 |
| Hydroxytyrosol | 2.09 \pm 0.14 |
| ORAC (μ mol Te kg)* | 3848100 \pm 38481 |

*Antioxidant activity determined by ORAC assay (Oxygen Radical Absorbance Capacity).

Cell culture

The HSkMEC (human skin immortalized endothelial cells) was kindly provided by C Kieda (UPR4301 CNRS, Orleans, France) (Kieda 2002), the KB cell line (human nasopharyngeal epidermis carcinoma) was obtained from NCI and HL60 (promyelocytic leukemia) and HT-29 cells (human colon adenocarcinoma) were purchased from ATCC. KB cells in D-MEM, HL60 and HT29 in RPMI and HSkMEC in OPTI-MEM were cultured in complete medium containing 10% (except HSkMEC 2%) fetal bovine serum, penicillin, streptomycin and fungizone in a humidified incubator under 5% CO₂ atmosphere at 37°C. Phenolic compounds (used as reference molecules in this study): oleuropein, hydroxytyrosol, tyrosol, caffeic acid, apigenin, and luteolin were purchased from Sigma Alderich (Paris, France).

MTS assay

HSkMEC, KB and HL60 cell lines were used to determine the cytotoxicity of OTE and reference molecules (phenolic compounds used as standards). Cells were plated in 96-well tissue culture microplates (10^3 to 2.10^3 cells/well in 200 µl of culture medium).

After 24 hours of incubation at 37°C under 5% CO₂ atmosphere, cells were treated with increasing concentrations of OTE (diluted in H₂O) and phenolic compounds dissolved in DMSO (1, 10, and 100 µM). Control cells were treated with either water or DMSO (1% of final volume). These operations were carried out using an automated workstation (Biomek 3000 Laboratory Automation Workstation, Beckman- Coulter). After 72h of exposure to olive tree extract or chemicals, MTS reagent (CellTiter 96® AQueous One, Promega) was added and incubated for 3 h at 37 °C. Experiments were performed in triplicate: the absorbance was monitored

at 490 nm and results were expressed as the inhibition of cell proliferation calculated as the ratio $[(1-(OD_{490} \text{ treated}/OD_{490} \text{ control})) \times 100]$.

FACS analysis

Apoptotic and necrotic cells were analyzed by Fluorescence-Activated Cell Sorting (FACS). KB cells (10^4 cells in 100 μ L medium/well in 96-well microplate) were exposed for 24 and 48 hours at 37°C under 5% CO₂ to olive tree extract at different concentrations. 50nM doxorubicin was used as positive control. Microplates were centrifuged to collect floating cells. Adherent cells were trypsinized, washed with PBS, mixed with floating cells and spun down. Cells were resuspended into 100 μ L medium prior the addition of 50 μ L of freshly prepared reaction mixture consisting in the fluorescent agent 7-aminoactinomycin D (7-AAD) (6.5 μ L of 1 mg/ml ethanol solution) and recombinant human protein annexin-V-PE (6.5 μ L, Bender). After 20 min of incubation in the dark at room temperature, cells were analyzed with a Guava EasyCyte flow cytometer (Millipore). Cells were classified according to their fluorescence and the results were expressed as percentage of cells in each group.

LDH release assay

Necrosis was estimated through the release of LDH in the culture medium. 20.000 KB cells were incubated for 24 and 48 h in the presence of OTE in 96-well microplates containing 100 μ L medium. After centrifugation at 300g for 1 min, 25 μ L of culture medium was added with 25 μ L Cytotox-ONE reagent (Promega) and kept in the dark at room temperature for 20 min. Fluorescence was recorded (exc 560 nm, em 590 nm): results are expressed as the residual activity in the presence of OTE compared to activity in the presence of vehicle alone.

Caspase activity assay

Caspase activity was determined in KB cells after 24 and 48h of treatment by olive tree extract. Cells ($20 \cdot 10^3$ cells in 180 μL of complete medium per well) were plated in a 96-well microplate under 5% CO_2 atmosphere at 37°C . Lysis buffer (20 μL of a 10x stock solution consisting of 250 mM HEPES buffer, pH 7.5, 5 mM EDTA, 0.5% NP40, 0.1% SDS and 50 mM dithiothreitol) was added before adding caspase-3 substrate (DEVD-AMC at final concentration of 50 μM). The plates were incubated at 37°C and fluorescence was recorded (λ_{ex} 360 nm, λ_{em} 465 nm) after 0, 30, 60, 120, and 180 min. The reaction rate was calculated from the slope of the linear regression (fluorescence vs time) and expressed as the ratio of activation compared to the control (cells treated with DMSO). Doxorubicin (1 μM) was used as positive control.

ROS production

HT29 cells were grown in 200 μL RPMI complete medium ($20 \cdot 10^3$ cells/well in black 96-well microplates). After 24 hours, cells were incubated with increasing concentrations of olive tree extract (1 to 100% diluted in H_2O) and 100 μM of reference phenolic compounds (hydroxytyrosol, tyrosol, oleuropein, apigenin, luteolin, caffeic acid dissolved in DMSO). Control cells received DMSO (1% of final volume). The culture medium was removed and cells were washed with PBS buffer before addition of 100 μL of RPMI containing 50 mM of 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA). Cells were subsequently incubated for 30 minutes at 37°C before washing with PBS. The fluorescence was monitored after the addition of 100 μL of PBS (λ_{ex} 485 nm, λ_{em} 530 nm). The positive control was untreated HT29 cells incubated in PBS containing 1 mM of H_2O_2 .

***In vitro* endothelial cell tube formation**

In this study, the *in vitro* test of tube formation on Matrigel was used to assess the anti-angiogenic activity of olive tree extract. The collagen matrix (Matrigel) was diluted in ice-cold Opti-MEM without fetal calf serum and 30µl of this mix were transferred into a 96-well microplate. The plate was incubated at 37°C under 5% CO₂ atmosphere for 60 min to form the gel. HSkMEC cells (50.103 cells/well) were seeded in 200µl medium containing increasing concentrations of olive tree extract and phenolic compounds (100µM). Endothelial cells cultured on Matrigel formed a three- dimensional micro-network of tubes within 16 h of culture. Cell organization was documented photographically with an inverted microscope at 10 magnification.

Quantification of pro-angiogenic factors by qRT-PCR

The quantitative RT-PCR was used to measure expression levels of genes coding for the pro-angiogenic factors, vascular endothelial growth factor (VEGF: A, B and C isoforms), hypoxia-inducible factor (HIF-1α), angiopoietin (ANGPT 1 and 2 isoforms) and VEGF receptor (VEGFR-2) as previously reported (Kieda *et al.*, 2006, Kieda *et al.*, 2013). The cells were lysed and total RNA was extracted from each well of the 96- well microplate using RNA extraction kit according to manufacturer's instructions (Promega, Madison, WI). Two micrograms of RNA were used to prepare cDNA with oligo (dT) and primers of Myeloblastoma Avian Virus (AMV) and reverse transcriptase (Promega). Quantitative real-time PCR was performed using the Roche Light Cycler system and kit FastStart DNA Master SYBR Green-I. Primers were supplied by Qiagen. The data were analyzed with LightCycler 480 Software and values were normalized to the relative amounts of the cDNA of GAPDH gene.

Statistical analysis

All cellular tests were performed in triplicate. Statistical analyzes were performed using GraphPad Prism version 5.00 (GraphPad Inc., San Diego, California). Data were analyzed by analysis of variance (ANOVA Analysis of Variance) followed by post-hoc Dunnet test for normal distributed data or by the Kruskal-Wallis if the sample distribution does not follow the normal law. Differences between groups were considered as statistically significant at $p < 0.05$.

RESULT

OTE cytotoxicity

A cytotoxic extract is defined as a substance (or mixture of several phytochemical compounds) that is toxic for the cell, acting at several levels from simple metabolic disorders to apoptosis and/or necrosis induction. Actually, studying of plant extract's cytotoxicity is essential to determine appropriate dose prior to its biological uses. Nevertheless, the cytotoxic character is often sought in pharmaceutical field during the research for new drugs with various biological properties. The results presented in this section are those obtained with the commercial MTS test, e.g. the formazan formation followed at 490 nm. The measured absorbance values are directly proportional to the number of living cells and the results were expressed as the inhibition of cell proliferation and viability (Figure 1). Due to its intrinsic color which can quench or conceal measurements, serial dilutions of OTE were applied to cells: the highest concentration 100 indicates that the pure OTE was used at a final concentration of 1 μ l OTE into 100 μ l of medium, whereas the lowest concentration 1 indicates that the pure OTE was diluted 1 to 100 and used at a final concentration of 1 μ l diluted OTE into 100 μ l of medium.

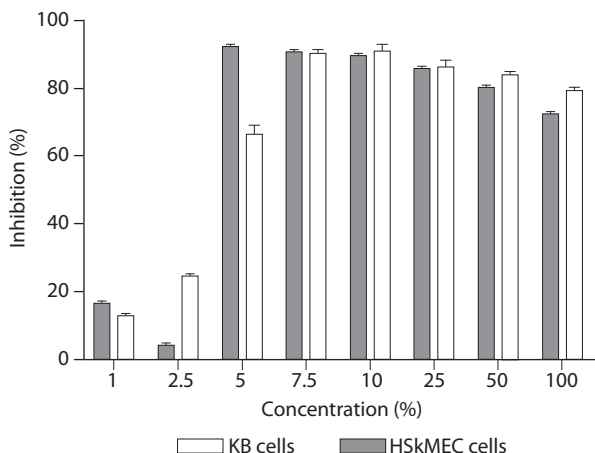


Figure 1. Inhibition of cell viability (%), illustrating the cytotoxicity of olive tree extract in KB cell line.

After 72 hours of treatment, the olive tree extract showed a strong cytotoxic effect on both KB and HSkMEC cell lines. Thus, the olive tree extract was toxic up to 5% dilution with a percentage cell viability inhibition over than 80%. The EC_{50} , concentration of the olive tree extract corresponding to 50% of cell viability inhibition, was subsequently evaluated. KB cells were more sensitive to the olive tree extract ($EC_{50} = 39\%$) than endothelial cells ($EC_{50} = 43\%$), although the observed difference was not significant. Such toxic effect was also observed against other human cancer cells (HL60, MCF-7, HCT116) and non-cancerous cell lines (MRC5 and EPC data not shown). This cytotoxicity activity could be attributed to the phenolic fraction which is present in olive tree extracts (fruits and leaves). Actually, the profile of the olive tree extract revealed a complex mixture of phenolic compounds. Among of them, the components identified as oleuropein, hydroxytyrosol (3',4'-DHPEA) and tyrosol

(*p*-DHPEA) were the most represented and flavonoids such as rutin, quercetin, luteolin and apigenin were present in lower concentrations (Laaboudi *et al.*, 2015). For this reason, oleuropein, hydroxytyrosol, tyrosol, apigenin, luteolin, and caffeic acid were used as pure individual molecules for comparison in the current study (Table 2).

Table 2. Inhibition of cell proliferation induced by pure molecules contained in OTE on KB cells. Results are the mean \pm SD of experiments performed in triplicate and expressed as a percentage of inhibition compared to cells treated with DMSO only.

| Compound | Concentration | | |
|----------------|---------------|------------|------------|
| | 100 μ M | 10 μ M | 1 μ M |
| Caffeic acid | 0 \pm 10 | 3 \pm 5 | 6 \pm 6 |
| Apigenin | 83 \pm 1 | 30 \pm 5 | 5 \pm 1 |
| Luteolin | 81 \pm 1 | 22 \pm 6 | 4 \pm 2 |
| Oleuropein | 0 \pm 9 | 0 \pm 1 | 0 \pm 10 |
| Tyrosol | 0 \pm 6 | 5 \pm 3 | 0 \pm 8 |
| Hydroxytyrosol | 11 \pm 11 | 1 \pm 10 | 0 \pm 6 |

Results of table 2 show, surprisingly, that only flavonoids (apigenin and luteolin) were potent inhibitors of KB cell proliferation, while other molecules (tyrosol, hydroxytyrosol, oleuropein and caffeic acid) had no or negligible effect. However flavonoids have no more antiproliferative activity at 1 μ M. Similar results were obtained with other studied cell lines, including HSkMEK (data not shown). This does not exclude the effect on cell proliferation of non-identified compounds (at this stage) present in OTE, including secoiridoids derivatives of hydroxytyrosol and tyrosol especially oleacein (3',4'-DHPEA-EDA) and oleocanthal (*p*-DHPEA-EDA).

FACS analysis of cell death

Apoptosis and necrosis are two distinct and redundant forms of cell death occurring in response to chemical aggression. These two cellular processes featured different and complementary modes of action: apoptosis (or programmed cell death) is a tightly regulated cell death program that plays a pivotal role in a variety of biological processes, generally executed in animal cells *via* the activation of cellular proteases leading to the cleavage of chromatin into nucleosomal fragments [43], while necrosis involves the destruction of the plasma membrane leading to the release of cytosolic enzymes and cofactors into the external medium. Flow cytometry was used at first to investigate the cell death process: it enabled to discriminate between intact “healthy” cells, apoptotic cells and necrotic cells in an advanced state of degradation.

In line with cytotoxicity experiments, KB cells were treated by diluted OTE (50-1%) for 24 and 48h and analyzed by FACS. According to the fluorescence monitored in FACS, cells can be classified as intact, in early apoptosis, in late apoptosis or necrotic (dead cells). The percentage of cells into each group is shown in Table 3. As it can be inferred from results of table 3, significant changes were observed in cell population distribution after 24 h of exposure to OTE. Intact cell population progressively decreased when the OTE concentration increased, associated with a transient raise in early apoptotic cells at low OTE concentration and a massive outburst of necrotic cells at higher OTE concentrations. After 48h of exposure, the necrotic cell population predominated even with low OTE concentrations to the detriment of intact and early apoptotic cell populations. Therefore it can be concluded that the effects of olive tree extract are dose- and time-dependent.

Table 3. Quantification by FACS of cell death induced in KB cell lines by olive tree extract.

| Concentration (%) | Cell population (%) | | | | | | | |
|-------------------|---------------------|-----|-----------------|-----|----------------|-----|----------|-----|
| | Intact | | Early apoptotic | | Late apoptotic | | Necrosis | |
| | 24h | 48h | 24h | 48h | 24h | 48h | 24h | 48h |
| DMSO | 90 | 90 | 3.1 | 2.1 | 0.5 | 1.2 | 6.5 | 7.2 |
| Doxo 100 mM | 53 | 32 | 36 | 45 | 0.2 | 1.0 | 11 | 21 |
| OTE 50 | 3.4 | 12 | 4.1 | 1.8 | 0.1 | 0.3 | 92 | 86 |
| OTE 25 | 3.6 | 3.9 | 6.6 | 2.2 | 0.8 | 0.3 | 89 | 94 |
| OTE 10 | 20 | 2.3 | 34 | 8.0 | 0.4 | 0.4 | 46 | 89 |
| OTE 7.5 | 37 | 3.4 | 57 | 12 | 0.2 | 0.4 | 6.0 | 84 |
| OTE 5 | 54 | 19 | 42 | 33 | 0.2 | 0.4 | 3.4 | 47 |
| OTE 2.5 | 86 | 84 | 7.6 | 8.1 | 0.7 | 2.0 | 5.4 | 57 |
| OTE 1 | 83 | 82 | 11 | 9.5 | 0.3 | 0.9 | 4.7 | 7.2 |

Caspases (cysteine-aspartic acid proteases) are regarded as the most common apoptotic effector activated during apoptosis in many cell types. It was reported that caspase-3 is the terminal effector in the apoptotic cascade and is the major contributor to cellular DNA fragmentation.[33] To go further in the elucidation of the cell death pathway induced by OTE, the catalytic activity of caspase-3 was explored in KB cells treated for 24 and 48 h with OTE at the same concentrations as in FACS analysis. Caspase-3 activity can be determined by the cleavage of the pro fluorescent DEVD peptide which is catalyzed by both caspase-3 and 7, albeit more efficiently by the former. As expected, 1 μ M doxorubicin elicited a potent activation of caspase-3 activity after a 48 h treatment (figure 3A). Although FACS analysis showed the apoptotic effect of olive tree extract at low concentrations (7.5 and 5%), results of figure 3A show that caspase-3 activity was moderately increased after a 48h exposure of KB cells to OTE. This suggest that apoptotic activity of olive tree extract was marginal compared to its necrotic effect and

led us to evaluate the release of cytosolic release of lactic dehydrogenase used as a hallmark for necrosis.

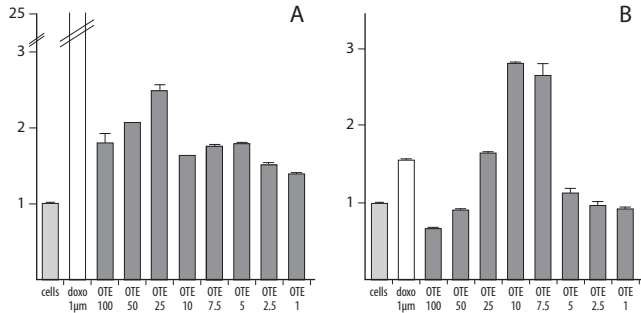


Figure 2. Activation of caspase-3 (A) and release of LDH (B) from KB cells after 48h of treatment with olive tree extract, vehicle only (cells) and doxorubicin (1µM).

Results are expressed as the relative activity in duplicate experiments \pm SD, compared to activity in untreated KB cells.

As shown in figure 2B, the release of LDH was enhanced after 48h of exposure to increasing OTE concentrations, before to decline at high concentrations, indicative of a complete cell destruction. This confirms that the olive tree extract induces a transient and moderate activation of apoptosis preceding a massive necrotic cell death.

ROS production

The production of reactive oxygen species can be estimated with the DCFH-DA assay using the fluorogenic probe 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA). Briefly, the non-fluorescent DCFH-DA diffuses spontaneously into cells and is deacetylated by cellular esterase to 2',7'-Dichlorodihydrofluorescein (DCFH), which is rapidly oxidized by ROS to the highly fluorescent 2',7'-dichlorodihydrofluoresceine (DCF). The emitted fluorescence intensity (Irel) is proportional to the levels of ROS produced into cell cytosol.

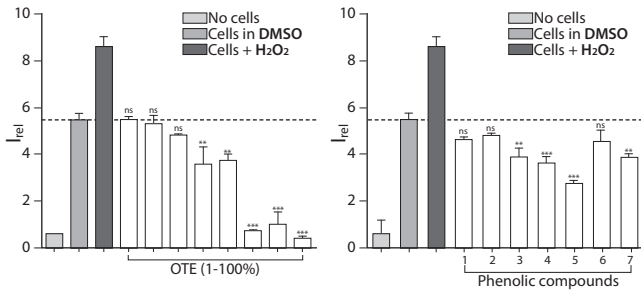


Figure 3. Intracellular ROS production after incubation of HT29 cells for 24h with (A) increasing concentrations of olive tree extract and (B) pure phenol compounds (100 μ M). Results are the mean \pm SD of 3 individual assays. *** ($p < 0.001$), ** ($p < 0.01$) * ($p < 0.05$); ns, not significant from fluorescence produced in cells treated with vehicle only. (1), oleuropein; (2), tyrosol; (3), hydroxytyrosol; (4), apigenin; (5), luteolin; (6), protocatechuic acid; (7) caffeic acid.

In the presence of 1mM H₂O₂, the emitted fluorescence intensity was significantly increased (Figure 3). Conversely, a progressive decrease in the quantity of produced ROS was observed in cells treated with increasing concentrations of OTE to reach an almost complete protection against ROS at highest concentrations. On the other hand, no significant effect on ROS production were noticed with 100 μ M tyrosol, oleuropein and protocatechuic acid, while hydroxytyrosol, apigenin and luteolin significantly reduced the amount of ROS produced during cell incubation. Thus, the anti-radical effect of olive tree extract could be the result of the antioxidant activity (synergistic action) of these phenolic compounds, although the determination of the role of other compounds (not identified at this stage) is required to confirm these observations.

***In vitro* anti-angiogenic effect on tube formation.**

Endothelial cells grown on an extracellular matrix spontaneously form a capillary network in the presence

of growth factors present in the fetal calf serum. This *in vitro* test allow to determine the capacity of a molecule or substance to inhibit the formation of capillary structures. It is considered to be close to *in vivo* tests and to require the proliferation, migration and degradation of the basement membrane of endothelial cells. The photographs taken after a 16h of endothelial cells incubation on Matrigel at 37 °C and 5% CO₂ in the presence of increasing concentrations of olive tree extract and phenolic compounds (100 µM) are presented in figure 4.

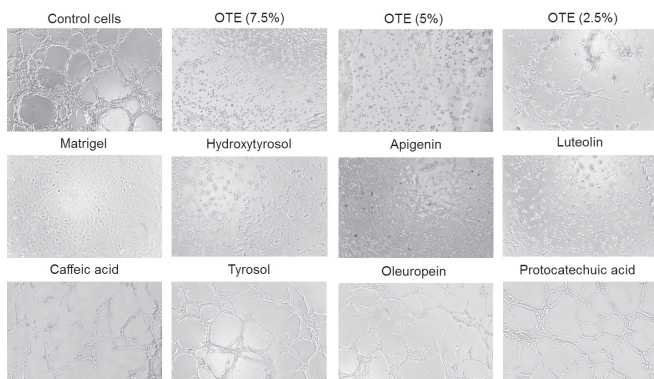


Figure 4. Representative photographs of the network structure formed by endothelial cells (HSkMEC) on Matrigel in the presence of increasing concentrations of olive tree extract and pure phenolic compounds used at 100 µM. Control cells are incubated without Matrigel.

Photographs of figure 4 show that endothelial cells grew in complete medium containing 2% FCS as a continuous monolayer (figure 4 control cells) whereas they form capillary structures when laid down on Matrigel. This capacity to form capillary structure was severely impaired in the presence of olive tree extract, suggesting its dose-dependent anti-angiogenic effect. The OTE effect has been observed at concentration

2.5% to be complete at concentration 7.5%. Indeed, referring to the antiproliferative capacity of OTE, the anti-angiogenic activity could be due to a direct cytotoxic effect of OTE on HSkMEC cells. However, the results of the cytotoxicity indicate that the olive tree extract diluted at concentration 2.5 does not affect the proliferation and viability of HSkMEC cells, whereas the anti-angiogenic effect was evident at this concentration. Therefore the anti-angiogenic effect of pure molecules identified as major phenolic compounds present in olive tree extract was investigated in the same conditions (figure 4). Among these pure compounds hydroxytyrosol, luteolin, apigenin and to a lesser extent caffeic acid at a 100 μ M concentration elicited a marked inhibitory effect on capillary network formation of HSkMEC cells. On the other hand, tyrosol, oleuropein and protocatechuic acid moderately affect the organization of endothelial cells. Thus, we may conclude that the synergistic action of these molecules on endothelial cells might account for the OTE anti-angiogenic effect.

Indeed, the ability of endothelial cells to organize themselves into three-dimensional space to form new capillaries proceeded through cell migration, proliferation and vessel stabilization governed by the secretion of chemotactile factors (called pro- angiogenic factors). Several proteins are involved to support angiogenesis phenomena, such as VEGF factors (A, B and C isoforms), angiopoietin (1 and 2), HIF and the VEGF receptor-2. The expression rate of genes coding for these pro- angiogenic factors was, therefore, measured using quantitative real time RT-PCR (Figure 5) and summarized in table 4.

Analytical data plotted on figure 5 were consistent with observation of micro-capillary formation on Matrigel. Basically, the expression of pro-angiogenic genes was

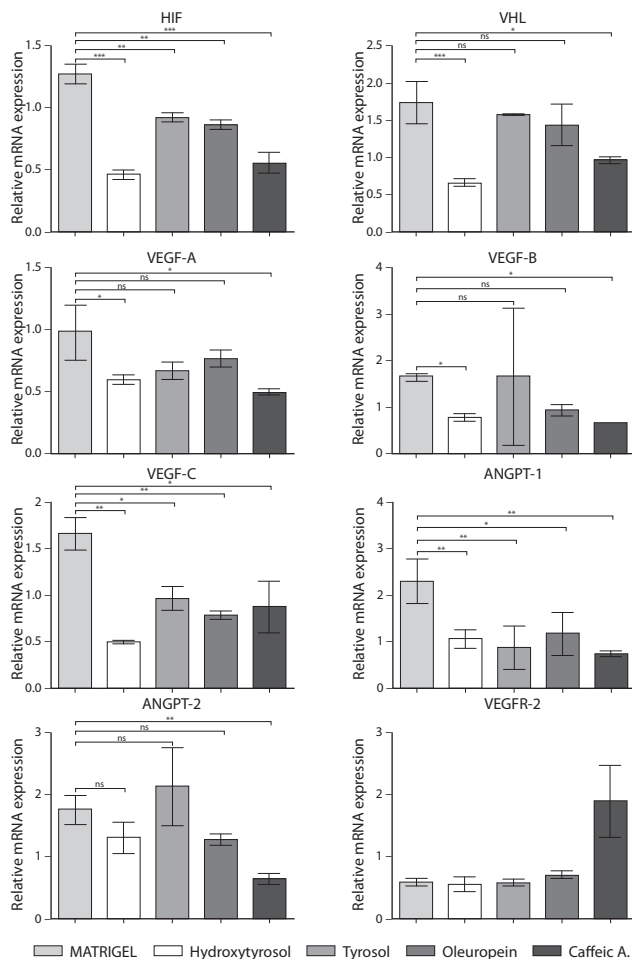
significantly affected in the presence of hydroxytyrosol which was the molecule having the highest inhibitory effect on microtube formation, and to a lesser extent by caffeic acid which is a weaker microtube disruptor. The two modest inhibitors of microtube formation tyrosol and oleuropein did not affect the expression of VEGF A and B. It is noteworthy that none of these compounds modify the expression of the VEGF receptor-2 which binds VEGF-A. VHL is a tumor suppressor which binds to HIF-1 α to allow its degradation by the proteasome. Its expression is regulated by HIF-1 α through an HRE element present in its promoter: thus HIF could promote its own degradation by the induction of VHL gene expression (Luczak *et al.*, 2011, Karhausen *et al.*, 2005). This is consistent with the co-regulation observed in HSkMEC cells exposed to phenolic compounds and presented in figure 5 and table 4.

Table 4. Summay of anti-angiogenic effect of the major polyphenols present in olive tree extract. (+), Inhibitory effect of angiogenesis; (-), No effect.

| Molecule (100 μ M) | HIF | VHL | VEGF- A | VEGF- B | VEGF- C | ANGPT- 1 | ANGPT- 2 | VEGFR- 2 |
|---------------------------|-----|-----|------------|------------|------------|-------------|-------------|-------------|
| Hydroxytyrosol | +++ | +++ | + | + | ++ | ++ | - | - |
| Tyrosol | ++ | - | - | - | + | ++ | - | - |
| Oleuropein | ++ | - | - | - | ++ | + | - | - |
| Caffeic acid | +++ | + | + | + | + | ++ | ++ | - |

All together the lower expression of VEGFs, angiopoietin and HIF-1 α can explain the anti-angiogenic of active phenolic compounds present in the olive tree extract, individually and/or synergistically.

Figure 5. Effect of phenolic compounds in olive tree extract on the expression of pro- angiogenic agents. HIF Hypoxia Inducible Factor-1 α ; VHL protein of Von Hippel- Lindau; VEGF (A, B and C), Vascular Endothelial Growth Factor; ANGPT (1 and 2), Angiotensin; VEGFR-2, cell receptor for VEGF proteins. Values are expressed as mean \pm SD (n = 3). *** ($P < 0.001$), ** ($P < 0.01$) * ($P < 0.05$); ns, not significant difference.



DISCUSSION

The olive tree extract tested in this study, displayed potent cytotoxic activity against human cancer cells through the activation of necrotic and/or apoptotic pathways. This is consistent with several previous studies have reported that crude extracts from olive leaves and phenolic compounds demonstrate high cytotoxic activity against various cancer cell lines derived from blood, colon and breast cancers (Fu *et al.*, 2010; Hashim *et al.*, 2008; Abaza *et al.*, 2007). This cytotoxic activity was, particularly, remarkable in HER-2 positive breast cancer cells. Olive tree extract reduces the overexpression of HER-2 and decreases resistance to trastuzumab, an anti-HER-2 monoclonal antibody used clinically for breast cancer treatment (Menendez *et al.*, 2007). Independently, Taamalli *et al.*, (2012) have shown that the inhibition of breast cancer cells viability was depended on the polyphenol content in an olive leaves extract.

As expected our olive tree extract is rich in hydroxytyrosol and its secoiridoid derivatives (oleacein and oleocanthal), and in flavones such as luteolin and apigenin. Therefore, the individual effect of these compounds to explain the cytotoxicity toward cancer cells of this crude extract deserves more attention in future studies. Interestingly the whole OTE effect might not result from the abundance of a single compound, but rather from the synergistic interaction between different compounds including those that are not already identified. In this respect, authors have recently pointed out that food polyphenols who exert their pharmacological effects through synergistic interactions involve the implication of multiple targets (Efferth and Koch, 2011; Wagner, 2011).

Thus, the effects of molecules abundant in OTE like hydroxytyrosol (50 µg.ml⁻¹) and oleuropein (200 µg.ml⁻¹)

were demonstrated in MCF-7 cells (Han *et al.*, 2009), and confirmed *in vitro* on a variety of human cancer cell lines together with apigenin (Kim *et al.*, 2011; Bulotta *et al.*, 2011; Fabiani *et al.*, 2006, 2002), and *in vivo* in tumor-bearing mice (Hamdi and Castellon, 2005). Moreover, many epidemiological studies suggest a potential correlation between the consumption of olive products (olive fruits and olive oil) and a low incidence of breast cancer in Mediterranean area, suggesting a protective effect of olive compounds against cell proliferation e.g. cancer (Corona *et al.*, 2007). Thus, we can conclude that the OTE's cytotoxic effect is mainly due to these phenolic compounds.

ROS play a crucial role in tumorigenesis as suggested by Sabharwal and Schumacker (2014) who reported that signaling pathway(s) triggered by ROS contributes to proliferation and tumor survival of many cancers. These authors propose that improving mitochondria potential redox is a promising target for future cancer therapies. In accordance with Nardi *et al.*, (2014), we reported herein that olive tree extract and some of its phenolic components showed elevated antioxidant activity in HT-29 cells, giving them a central role in the fight against carcinogenic risks. Likewise, Deiana *et al.* (1999) reported that hydroxytyrosol reduced biochemical effects of peroxynitrite, such as the deamination of adenine and guanine in certain cell lines. ROS generated during oxidative stress may be directly involved in DNA damage and/or in the intrinsic apoptotic pathway induction (mitochondria- dependent). Thus, the intracellular accumulation of ROS may be involved in the partial disruption of the mitochondrial membrane causing the release of mitochondrial material (cytochrome-c, pro-apoptotic factors) in the cytosol, finally leading to the activation of the caspase cascade (Eloy *et al.*, 2012). Moreover, cellular ROS production by different

metabolic pathways has been associated with cell aging phenomenon call the "radical" hypothesis of aging (Barouki, 2006). Thus, we can postulate the antioxidant activity of OTE and these phenolic compounds has a double effect, i) the elimination of carcinogenic ROS and ii) the prevention of cell aging.

Angiogenesis is a critical process implicated in the proliferation and dissemination of cancer cells by metastasis. The fast and limitless multiplication of cancer cell requires an important and incremental supply in oxygen and nutrients through the blood circulation. The spreading of circulating cancer cells is highly facilitated by the density of blood vessels and the cell aggressiveness enabling the metastasis formation.

Angiogenesis is under the control of multiple regulation pathways, among them are the vascular endothelial growth factors which stimulate vasculogenesis and angiogenesis (Jiang *et al.*, 2000) and facilitate the formation of new capillary vessels in association with angiopoietins reviewed by Rak *et al.*, 2000. The transcription of VEGF is stimulated by Hypoxia Inducing Factor 1- α present in the cytosol as a heterodimer with VHL allowing its degradation by the proteasome. The key role of VEGFs was also highlighted by a clinical report which positively correlated polymorphism in the VEGF-A gene (-1154 A/G, -2578 C/A and -460 T/C) and the lower susceptibility to develop breast cancer in Moroccan individuals (Rahoui *et al.*, 2014).

Data reported herein clearly demonstrate the inhibitory effect of olive tree extract and of some of its phenolic components (hydroxytyrosol, apigenin, luteolin and caffeic acid) on the formation of new capillaries from human endothelial cells. This inhibition was consistent

with previous observations made on various human cells, animal tumors and in silico (Ambasta *et al.*, 2015; Simon Silvan *et al.*, 2013; Fortes *et al.*, 2012; Gacche *et al.*, 2011; Engelmann *et al.* 2002). Two mechanisms could explain the anti-angiogenic effect of olive tree extract and phenolic compounds: a severe restriction of cell proliferation reducing the number of endothelial cells required for building the capillary structure and a lack of pro-angiogenic factors production thus restricting cell migration and assembly. Clearly, hydroxytyrosol oleuropein and caffeic acid had no effect on cell proliferation, but are potent down-regulator of HIF, VEGF and angiopoietin suggesting their direct anti-angiogenic effect. Additionally, Kim *et al.* (2011) had shown that apigenin has an anti-angiogenesis effect through a down-regulation of VEGF and MMP-8 release in hepatocellular carcinoma cells. Therefore, OTE's effect is the result of the cumulative effect of individual phenolic compounds reducing the cell supply and thus restricting the tumor growth.

On the other hand, an excessive angiogenesis ensues from progression of inflammatory process in synovium, and leads to pannus proliferation and rheumatoid arthritis symptoms complication. Angiogenesis is a major contributor in the development and maintain of inflammation in rheumatoid arthritis (Semerano *et al.*, 2011), and a correlation between rheumatoid arthritis progression and VEGF level has been observed in patient with RA (Sone *et al.*, 2001). Thus, the inhibition of angiogenesis could be a potential therapeutic target for the treatment of rheumatoid arthritis (Ghanam *et al.*, 2015). However, the VEGF-dependent antiangiogenic effect of olive tree polyphenols, in both cancer and rheumatoid arthritis diseases, need to be confirmed in future *in vivo* studies.

CONCLUSION

The cellular assays have demonstrated the effectiveness of phenolic olive tree extract as an antioxidant in cells exposed to oxidative stress. This extract has also demonstrated a strong VEGF-dependent antiangiogenic activity. Indeed, ROS elimination, apoptosis and/or necrosis activation and angiogenesis inhibition make this extract an excellent agent to prevent cancer diseases. The characterization of bioactive molecules in this extract, as well as the contribution of each to the global biological activity, could provide the chemical basis for the development of new anticancer drugs. Further studies are needed to extent the antiangiogenic activity of phenolic compounds derived from studied olive tree extract (hydroxytyrosol, oleacein and oleocanthal) in case of angiogenesis-dependent diseases.

REFERENCES

- Semerano L, Clavel G, Assier E, Denys A, Boissier MC. Blood vessels, a potential therapeutic target in rheumatoid arthritis? *Jt Bone Spine* 2011; 78: 118-123.
- Sone H, Kawakamib Y, Sakauchic M, Nakamurad Y, Takahashia A, Shimano H *et al.* Neutralization of Vascular Endothelial Growth Factor Prevents Collagen-Induced Arthritis and Ameliorates Established Disease in Mice. *Biochem. Biophys. Res. Commun.* 2001; 281: 562–568.
- Abaza L, Talorete T.P.N, Yamada P, Kurita Y, Zarrouk M, Isoda H. Tunisian Gerboui olive leaf extract induces growth inhibition and differentiation of human leukemia HL-60 cells. *J. Biosci. Biotechnol. Biochem.* (2007); 7: 1306–1312.
- Ambasta RK, Jha SK, Kumar D, Sharma R, Jha NK, Kumar P. Comparative study of anti-angiogenic activities of luteolin, lectin and lupeol biomolecules. *J. Transl. Med.* 2015, 13, 307.
- Barouki R. Stress oxydant et vieillissement. *Medecine Sciences* (2006); 22: 266-72.
- Benavente-García O, Castillo J, Lorente J, Ortuño A, Del Río J.A. Antioxidant activity of phenolics extracted from *Olea europea* L. leaves. *Food Chem.* (2000); 68: 457-462.
- Bulotta S, Corradino R, Celano M, D'Agostino M, Maiuolo J, Oliverio M, Procopio A, Iannone M, Rotiroti D, Russo D. Antiproliferative and antioxidant effects on

breast cancer cells of oleuropein and its semisynthetic peracetylated derivatives. *Food Chem.* (2011); 127: 1609–1614.

Corona G, Tzounis X, Dessi M.A, Deiana M, Debnam E.S, Visioli F, Spencer J.P.E. The fate of olive oil polyphenols in the gastrointestinal tract: implications of gastric and colonic microflora dependent biotransformation. *Free Radical Res.* (2006); 40:647–658.

Covas M. I. Olive oil and the cardiovascular system. *Pharmacol. Res.* 2007, 55, 452 175–186.

Covas MI, de la Torre K, Farre-Albaladejo M, Kaikkonen J, Fito M, Lopez-Sabater C. (2006). Postprandial LDL phenolic content and LDL oxidation are modulated by olive oil phenolic compounds in human. *Free Radic. Biol. Med.*, 40, 608–16.

Deiana M, Aruoma OI, Bianchi MDLP, Spencer JPE, Kaur H, Halliwell B, Aeschbach R, Banni S, Dessi MA, Corongiu FP (1999). Inhibition of peroxyxynitrite dependent DNA base modification and tyrosine nitration by the extra virgin olive oil-derived antioxidant hydroxytyrosol. *Free Radical Biology and Medicine.* 26: 762–769.

Efferth T, Koch E. Complex interactions between phytochemicals. The multi-target therapeutic concept of phytotherapy. *Curr. Drug Targets* (2011); 12: 122–132.

Eloy L, Jarrousse AS, Teyssot ML, Gautier A, Morel L, Jolival C, Cresteil T, Roland S. Anticancer Activity of Silver–N-Heterocyclic Carbene Complexes: Caspase-Independent Induction of Apoptosis via Mitochondrial Apoptosis-Inducing Factor (AIF). *Chem. Med. Chem.* 2012, 7, 805 – 814.

Engelmann C, E. Blot, Y. Panis, S. Bauer, V. Trochon, H. J. Nagy, H. Lu, C. Soria. Apigenin – strong cytostatic and anti-angiogenic action *in vitro* contrasted by lack of efficacy *in vivo*. *Phytomedicine* 9: 489–495, 2002.

Estruch R, Martinez-Gonzalez MA, Corella D, Salas-Salvadó J, Ruiz-Gutiérrez V, Covas MI. (2006). Effects of a Mediterranean-Style Diet on Cardiovascular Risk Factors: A Randomized Trial. *Ann. Intern. Med.*, 145, 1-11.19.

Evagelia T, Harris N. Lazarides and Konstantinos B (2004). Olive Mill Wastewater Treatment. Petrotos Aristotle University of Thessaloniki, Department of Food Science and Technology, 54006, Thessaloniki, Greece.

Fabiani R, De Bartolomeo A, Rosignoli P, Servili M, Montedoro G.F, Morozzi G. Cancer chemoprevention by hydroxytyrosol isolated from virgin olive oil through G1 cell cycle arrest and apoptosis. *Eur. J. Cancer Prev.* (2002); 11: 351–358.

Fabiani R, De Bartolomeo A, Rosignoli P, Servili M, Montedoro G.F, Morozzi G. Virgin olive oil phenols inhibit proliferation of human promyelocytic leukemia cells (HL60) by inducing apoptosis and differentiation. *J. Nutr.* (2006); 136: 614–619.

Fortes C, García-Vilas J, Quesada A, Medina M. Evaluation of the anti-angiogenic potential of hydroxytyrosol and tyrosol, two bio-active phenolic compounds of extra virgin olive oil, in endothelial cell cultures. *Food Chem.* 2012; 134: 134–140.

Fu S, Arráez-Roman D, Segura-Carretero A, Menéndez J.A, Menéndez-Gutiérrez M.P, Micol V, Fernández-Gutiérrez A. Qualitative screening of phenolic

compounds in olive leaf extracts by hyphenated liquid chromatography and preliminary evaluation of cytotoxic activity against human breast cancer cells. *Anal. Bioanal. Chem.* (2010); 397: 643–654.

Gacche RN, Shegokar HD, Gond DS, Yang Z, Jadhav AD. Evaluation of selected flavonoids as antiangiogenic, anticancer, and radical scavenging agents: an experimental and in silico analysis. *Cell Biochem. Biophys.* 2011, 61, 651-63.

Ghanam J., Laaboudi W., Benlemlih M. Effect of rich polyphenols olive tree extract on inflammation and pain in patients with rheumatoid arthritis: a 8-week randomized, double blind, placebo-controlled clinical trial. *American Journal of Biological and Pharmaceutical Research.* 2015; 2(2): 51-61.

Giacosa A, Barale R, Bavaresco L, Gatenby P, Gerbi V, Janssens J, Johnston B, Kas K, La Vecchia C, Mainguet P, *et al.* Cancer prevention in Europe: the Mediterranean diet as a protective choice. *Eur. J. Cancer Prev.* 2013; 22:90-5.

Hamdi K.H & Castellon R. Oleuropein, a non-toxic olive iridoid, is an anti-tumor agent and cytoskeleton disruptor. *Biochem. Bioph. Res. Co.* (2005); 334: 769-778.

Han J, Talorete TP, Yamada P, Isoda H. Anti-proliferative and apoptotic effects of oleuropein and hydroxytyrosol on human breast cancer MCF-7 cells. *Cytotechnology* (2009); 59: 45–53.

Hashim Y.Z, Rowland I.R, McGlynn H, Servili M, Selvaggini R, Taticchi A, Esposto S, Montedoro G, Kaisalo L, Wähälä K, Gill C.I. Effects of olive oil phenolics on invasion in human colon adenocarcinoma cells *in vitro*. *Int. J. Cancer.* (2008); 122: 495–500.

Japón-Luján R, Luque de Castro M.D. Small branches of olive tree: A source of biophenols complementary to olive leaves. *J. Agric. Food Chem.* (2007); 55: 4584-4588.

Jiang BH, Zheng JZ, Aoki M, Vogt PK. Phosphatidylinositol 3-kinase signaling mediates angiogenesis and expression of vascular endothelial growth factor in endothelial cells. *Proc. Natl. Acad. Sci. USA* 97: 1749-1753, 2000.

Karhausen J, Kong T, Narravula S, Colgan SP. Induction of the von Hippel-Lindau tumor suppressor gene by late hypoxia limits HIF-1 expression. *J. Mol. Biochem.* 2005, 95, 1264-1275.

Kieda C, El Hafny-Rahbi B, Collet G, Lamerant-Fayel N, Grillon C, Guichard A, Dulak J, Jozkowicz A, Kotlinowski J, Fylaktakidou KC, Vidal A, Auzeloux P, Miot-Noirault E, Beloeil JC, Lehn JM, Nicolau C. Stable tumor vessel normalization with pO₂ increase and endothelial PTEN activation by inositol tris pyrophosphate brings novel tumor treatment. *J. Mol. Med. (Berl).* 2013, 91, 883-899.

Kieda C, Greferath R, Crola da Silva C, Fylaktakidou KC, Lehn JM, Nicolau C. Suppression of hypoxia-induced HIF-1 α and of angiogenesis in endothelial cells by myo-inositol tris pyrophosphate-treated erythrocytes. *Proc. Natl. Acad. Sci. U S A.* (2006) 103, 15576-81.

Kieda C, Paprocka M, Krawczyński A, Zalecki P, Dupuis P, Monsigny M, Radzikowski C, Duš D. New human microvascular endothelial cell lines with specific adhesion molecules phenotypes. *Endothelium*. (2002), 9, 47-61.

Killeen M, Linder M, Pontoniere P, Crea R. NF- κ B signaling and chronic inflammatory diseases: exploring the potential of natural products to drive new therapeutic opportunities. *Drug Discov. Today* (2014); 19: 373-378.

Kim B.R, Jeon Y.K, Nam M.J. A mechanism of apigenin-induced apoptosis is potentially related to anti-angiogenesis and anti-migration in human hepatocellular carcinoma cells. *Food Chem. Toxicol.* (2011); 49: 1626-1632.

LeGendre O, Breslin P A S, Foster D A. (-)-Oleocanthal rapidly and selectively induces cancer cell death via lysosomal membrane permeabilization (LMP). *Molecular & Cellular Oncology*, 2:4, e1006077.

Łuczak MW, Roszak A, Pawlik P, H Kedzia H, M Lianeri M, Jagodzinski PP. Increased expression of HIF-1A and its implication in the hypoxia pathway in primary advanced uterine cervical carcinoma. *Oncol. Rep.*, 2011, 26, 1259-1264.

Mario-Casas E, Covas MI, Farre M, Fito M, Ortuno J, Weinbrenner T, Roset P, de la Torre R. Hydroxytyrosol disposition in humans. *Clinical Chem.* (2003a); 49: 945-952.

Menendez J.A, Vazquez-Martin A, Colomer R, brunet J, Carrasco-Pancorbo A, Garcia-Villalba R, Fernandez-Gutierrez A, Segura-Carretero A. Olive oil's bitter principle reverses acquired autoresistance to trastuzumab (Herceptin) in HER2-overexpressing breast cancer cells. *BMC Cancer* (2007); 7: 80.

Micol V, Caturla N, Pérez-Fons L, Más V, Pérez L, Estepa A. The olive leaf extract exhibits antiviral activity against viral haemorrhagic septicaemia rhabdovirus (VHSV). *Antiviral Res.* (2005); 66: 129-136.

Montedoro G.F, Servili M, Baldioli M, Selvaggini R, Miniati E, Maccchioni A. Simple and hydrolyzable compounds in virgin olive oil. 3. Spectroscopic characterizations of the secoiridoid derivatives. *J. Agric. Food Chem.* (1993); 41: 2228-2234.

Nardi M, Bonacci S, De Luca G, Maiuolo J, Oliverio M, Sindona G, Procopio A. Biomimetic synthesis and antioxidant evaluation of 3,4-DHPEA-EDA [2-(3,4-hydroxyphenyl) ethyl (3S,4E)-4-formyl-3-(2-oxoethyl) hex-4-enoate]. *Food Chem.* (2014); 162: 89-93.

Raederstorff D, Wang-schmidt Y, Wertz K (2010). Use of hydroxytyrosol as anti-aging agent. Pub. No. : US 2010 0130621 A1.

Rahoui J, Laraqui A, Sbitti Y, Touil N, Ibrahimi A, Ghrab B, Al Bouzidi A, Moussaoui D, Rahali, Dehayni M, Ichou M, Zaoui F, Mrani S. Investigating the association of vascular endothelial growth factor polymorphisms with breast cancer: a Moroccan case-control study. *Medical Oncology* 2014, 31:193.

Rak J, Yu JL, Klement G, Kerbel RS. Oncogenes and angiogenesis: signaling three-dimensional tumor growth. *Journal of Investigative Dermatology Symposium Proceedings* (2000) 5, 24-33.

Rashmi K. Ambasta, Saurabh Kumar Jha, Dhiraj Kumar, Renu Sharma, Niraj Kumar Jha, Pravir Kumar. Comparative study of anti-angiogenic activities of luteolin, lectin and lupeol biomolecules. *J. Transl. Med.* (2015) 13:307.

Richard N, Arnold S, Hoeller U, Kilpert C, Wertz K, Schwager J. Hydroxytyrosol Is the Major Anti-Inflammatory Compound in Aqueous Olive tree extracts and Impairs Cytokine and Chemokine Production in Macrophages. *Planta Medica* (2011); 77:1890-1897.

Sabharwal S. & Schumacker P.T. Mitochondrial ROS in cancer: initiators, amplifiers or an Achilles' heel? *Nat. Rev. Cancer* (2014); 14: 709–721.

Scoditti E, Calabriso N, Massaro M, Pellegrino M, Storelli C, Martines G. (2012). Mediterranean diet polyphenols reduce inflammatory angiogenesis through MMP -9 and COX-2 inhibition in human vascular endothelial cells: a potentially protective mechanism in atherosclerotic vascular disease and cancer. *Arch. Biochem. Biophys.*, 527, 81-89.

Silvan S, Manoharan S. Apigenin prevents deregulation in the expression pattern of cell-proliferative, apoptotic, inflammatory and angiogenic markers during 7,12- dimethylbenz[a]anthracene-induced hamster buccal pouch carcinogenesis. *Arch. Oral Biol.* 2013, 58, 94-101.

Taamalli A, Arráez-Román D, Barrajón-Catalán E, Ruiz-Torres V, Pérez-Sánchez A, Herrero M, Ibáñez E, Micol V, Zarrouk M, Segura-Carretero A, Fernández-Gutiérrez A. Use of advanced techniques for the extraction of phenolic compounds from Tunisian olive leaves: Phenolic composition and cytotoxicity against human breast cancer cells. *Food Chem. Toxicol.* (2012); 50: 1817–1825.

Visioli F, Galli C, Bornet F, Mattei A, Patelli R, Galli G, et al. Olive oil phenolics are dose-dependently absorbed in humans. *FEBS Lett* (2000); 468:159–160.

Wafa Laaboudi, Jamal Ghanam, Mohammed Merzouki and Mohamed Benlemlih. Eco-Extraction of Phenolic Compounds from Moroccan Olive Fruits and Leaves and their Potential use as Antimicrobial Agents. *European Journal of Scientific Research.* (2015); 132: 255-265.

Wagner H. Synergy research: approaching a new generation of phytopharmaceuticals. *Fitoterapia* (2011); 82: 34–37.

Effects of rich polyphenols olive tree extract on inflammation and pain in patients with rheumatoid arthritis: A-8-week randomized, double-blind, placebo-controlled clinical trial

Ghanam Jamal, Laaboudi W and Benlemlih M*

Biotechnology Laboratory, Faculty of Science Dhar El Mahraz, P.O. Box 1796, Atlas-Fez, University Sidi Mohammed Ben Abdellah, Fez, Morocco.

ABSTRACT

Olive tree polyphenols have been known as natural anti-inflammatory agents. The aim of the current clinical trial was to assess the therapeutic effect of an olive tree extract with high polyphenols content on inflammatory process and pain intensity in rheumatoid arthritis (RA) patients. This is a randomized, double-blind, placebo-controlled clinical trial. Ninety RA patients were randomized into two groups; treated group received a daily dose of 3 g of olive extract (6 capsules, 500 mg each) during 8 weeks, while patients in placebo group received capsules with maltodextrin. Laboratory analysis, questionnaires administration, pain intensity, and inflammatory biomarkers were determined at the baseline and the end of the trial. Doctors assessed potential adverse effects of olive tree extract through the

period of study. Significant decrease in disease activity score has shown at the end of intervention in the treated group and between groups ($P < 0.0001$). Compared to the placebo group, inflammatory biomarkers decreased significantly in treated participants ($P < 0.0001$). The changes from baseline in treated group were -1.37 mg/L (CI, - 2.71 to -1.57 mg/L), -2.14 pg/mL (CI, -2.71 to -1.57), -1.046 pg/mL (CI, -1.50 to -0.59) and -1795 pg/mL (CI, -2283 to -1308) for hs-CRP, IL-6, TNF- α and PGE2 respectively. Pain relief and global participants satisfaction increased significantly ($P < 0.0001$) after 8 weeks of olive tree extract supplementation. Results obtained after 2 months of supplementation demonstrate for the first time the potential therapeutic effect of olive tree extract with high polyphenols content against inflammation and associated pain in RA.

INTRODUCTION

Rheumatoid arthritis (RA) is chronic autoimmune inflammatory disease responsible for joint destruction that contributes to functional impairment. RA remain the most common joint illness, occurring in 0.5-1% of worldwide population [1-2]. Several factors are involved to triggering the disease: tobacco [3-4], microbiome [5], hormonal factors [6], genetic background and environmental factors [7]. Schematically, the physiopathology of RA can be divided into three distinct phases: (1) initiation phase, (2) inflammation of the synovial membrane (synovitis), and (3) joint destruction due to the pseudotumoral proliferation of synovial cells under cytokine actions. In fact, chronic synovial inflammation is the hallmark of RA that involves complex interactions between T and B lymphocytes, macrophages, and fibroblast-like synoviocytes, including a network of cytokines, chemokines and others molecules [8-9]. In RA, there is an imbalance between pro and anti-

inflammatory cytokines. For instance, Nuclear Factor kappa β (NF- $\kappa\beta$) is activated in the synovium inflammatory cells and induced cytokines expression, including tumor necrosis factor-alpha (TNF- α), interleukine-1 (IL-1 β), IL-6, IL-15, IL-18, but also metalloproteinase (MMP-1) and small osteochondral destruction molecules like prostaglandin E₂ (PGE₂) and nitric oxide [10]. These inflammatory biomarkers are present with high concentrations in the synovial fluid and serum of patients with RA, which clinically manifests in swelling, pain and tissue destruction.

Through the last few years, blockage of cytokines network has taken a substantial proportion in clinical management of RA, more interestedly inhibition of produced TNF- α , IL-6, and IL-1 [8-11]. Useful molecules blocking these cytokines are mainly represented by the monoclonal antibodies or recombinant proteins (e.g. infliximab, Etanercept) [11-12]. Although their simple clinical use, these substances had some unexpected effects (including, efficacy, toxicity and even pharmacodynamics), e.g. catastrophic effects of the first-into-human administration of TGN1412 [12].

Beside the existing armamentarium therapeutic for RA disease, natural products represent a source of innovative treatments that could revolutionized the management of inflammatory diseases. Salminen *et al.* (2002) [13] reported that 33% to 75% of RA patients believed in alternative and complementary therapies, as dietary food that can delay the disease symptoms [14]. In this sense, several clinical trials have elucidated the effectiveness of olive polyphenols, as principal components of Mediterranean diet, on some inflammatory chronic diseases, including RA [15-16], and stable coronary heart disease [17-18]. Thus, adherence to the Mediterranean diet decreased inflammatory activity, increased in physical function, and improved vitality in RA patients. Hydroxytyrosol

(3,4-DHPEA) is one of the most extensively studied olive polyphenols for its anti-inflammatory properties and various pharmacological activities, suggesting their potential use for the development of functional food [19]. In fact, hydroxytyrosol, tyrosol (*p*-HPEA) and oleuropein (3,4-DHPEA-EA) exert *in vitro* inhibitor effects on PGE₂, LTB₄, TNF- α , IL-6, IL-1 and high-sensitivity C-reactive protein (hs-CRP) [20, 21, 22]. Beauchamp *et al.* (2005) [23] have been signaled that the anti-inflammatory effect of oleocanthal was similar to the NSAID ibuprofen.

Although *in vitro* findings may be the first stitch in the chain of shift from natural product to synthetic molecule based drug, more results from the clinical trials are needed. Thus, we presented here results from randomized clinical trial regarding the effects of an olive tree extract supplementation on the inflammatory biomarkers, pain intensity, and disease activity of Moroccan patients having RA.

MATERIALS AND METHODS

Subjects

Men and women were recruited from October 2012 to April 2013 among of those referred to rheumatology service of a clinic in Fez, Morocco. To be enrolled in the current study, subjects had to have rheumatoid arthritis for more than one year diagnosed based on the American College of Rheumatology (ACR) and the European League Against Rheumatism (EULAR) [24]. Study was thoroughly explained to the voluntary participants. Patients were not eligible if they were under the age of 20 years or over the age of 80 years, pregnant, lactating, receiving contraceptive, smoking, being diagnosed with metabolic syndrome as defined by the Adult Treatment Panel III [25], having inflammatory disorders, receiving NSAIDs and/or cytokine inhibitors, had a white blood cell count

$\leq 3.5 \times 10^9/L$, hemoglobin (Hb) level $\leq 8.5g/dl$, platelet count $\leq 100 \times 10^9/L$, creatinine level ≥ 2.0 mg/dl, and aspartate aminotransferase (AST) levels ≥ 2.5 times the upper limit of normal. Exclusion criteria involved also the consumption of olive antioxidants or other antioxidant supplements ≤ 3 weeks before the intervention, history of allergy or intolerance to olive products. Before to be enrolled to this study, written informed consent was obtained from all voluntary participants.

Study design and intervention

The current study was planned as a double-blind, randomized, placebo-controlled trial (fig. 1). Eligible participants were randomly assigned to Olive Tree Extract (OTE) supplement group or placebo group using a computer-generated random-number sequence. Researchers, participants and clinical staff were blinded to the treatment codes of each group. Candidates were invited by telephone to the clinic after an overnight fasting at last 12h to attend a screening visit including tender and swollen joints examination. The baseline examination included the assessment of adherence to the Mediterranean Diet according to the modified questionnaire of Estruch *et al.* (2006) (appendix table 1), evaluation of physical exercise by the International Physical Activity Questionnaire (Physical exercise was categorized as high, moderate, or low). Participants were asked to maintain their habitual diet during the period of study, and avoid the consumption of olive products (including olive oil, olive table) and nutrients with high n-3 PUFA contents (i.e. fish), the use of all herbs or products known to affect inflammation and immune function (including antioxidant and probiotic supplements). Dietary changes was monitored trough a 3-day dietary records at baseline, 4 and 8 weeks after treatment and placebo intervention. Necessary explanations were provided about how to estimate food intake and record

the estimations. Anthropometric and blood pressure measurements were performed and a sample of 8 ml fasting blood was obtained from each participant's antecubital vein. We repeated all examinations and measurements after 8 weeks.

During the study, all participants and investigators had free and continuous access to clinic for advice and consultation.

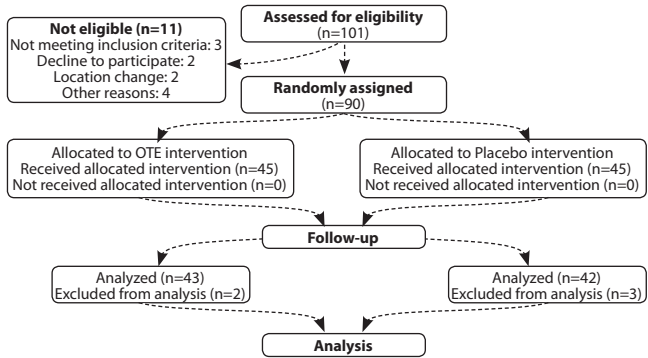


Figure 1. Study flow diagram.

Participants who fulfilled all the inclusion criteria were received 500-mg study capsules (identical capsules for supplement and placebo group). Participants received also instructions concerning capsules taking and storage. Patients were asked to administrate 6 capsules per day before each meal and they were contacted every week to monitor supplement intake. Aqueous olive tree extract (OTE) and maltodextrin excipient were enclosed in soluble vegetal capsules. The placebo capsules contained only maltodextrin. OTE was obtained from different olive tree parts, fruits, olive tree young branches, and leaves using a purely natural and physical extraction. Olive trees are planted in the middle a rocky desert of Morocco, free of

pollution, free of industrial activity, and under drought-stress (temperatures up to 52°C). OTE is OLIVIE FORCE marketed in Belgium as OLIVIE RICHE (see more in www.olivie.ma). Table 1 illustrate the main components of OTE extract.

LABORATORY MEASUREMENTS

Anthropometric measures was performed using calibrated scales and wall-mounted stadiometer with a precision of 0.1 cm; systolic and diastolic blood pressure were measured using a semi-automatic oscillometer (Boso Medicus smart Semi automatic Blood Pressure Monitor, Germany). Blood samples were collected in EDTA and SST tubes. The obtained erythrocytes, plasma, serum and urine samples were aliquoted into 1 mL microtubes and stored at -80°C until further analysis. Energy, nutrient intake and participants' diets assessment was carried out by Nutritionist 4.3 software (First Databank, Hearst Corp, San Bruno, CA).

High-sensitivity enzyme - linked immunosorbent assay kits (DiaSource, Belgium) were used to quantify PGE₂, leukotriene B₄ (LTB₄), TNF- α and cytokines IL-1 and IL-6 in serum according to the manufacturer's guidelines. Serum's hs-CRP level was determined by Turbidometric assay (Modular™, Roche Diagnostics, France) using a commercial kits at a wavelength of 500 nm. Clinical indication of disease activity and laboratory parameters of study participants were measured at the baseline and at the end of study according the internal methods of the clinic laboratories.

Urinary hydroxytyrosol was quantified by High Performance Liquid Chromatography (HPLC) as markers of OTE intake. Briefly, hydroxytyrosol was extracted from acidified urine (hydrochloric acid, 0.6 N of final

concentration) as described previously [26] and analyzed in a Shimadzu chromatograph device equipped with a reverse phase C18 column (250 mm L. × 4.6 mm I.D., 5 µm).

Pain intensity was evaluated at baseline, 4 and 8 weeks (end of study), using visual analog scale (VAS) according to the protocol defined by DeLoach *et al.* (1998) [27]. Participants are instructed to indicate pain intensity by marking a 100-mm line, 0= no pain and 100=most severe pain. Pain relief was assessed using a 5-point verbal rating scale (VRS) where 0=no relief, 1=a little (perceptible) relief, 2=some (meaningful) relief, 3=a lot of relief, and 4 = complete relief. Disease Activity Score (DAS28) was determined according to the EULAR [28], based on number of tender and swollen joint (TJC and SJC), serum hs-CRP concentration, and the result of Global Health (GH) assessed by the patient on a 10-cm VAS. DAS28 was calculated as follows:

$$\text{DAS28 (CRP)} = [0.56 \sqrt{\text{TJC}}] + [0.28 \sqrt{\text{SJC}}] + [0.36 \ln (\text{CRP} + 1)] + [0,014 (\text{GH})]$$

Doctors assessed potential adverse effects of OTE administration over the period of study including mouth symptoms, digestive disorders, fullness, allergic skin response, and other intervention-related symptoms. Finally, global satisfaction assessment in response to treatment (GAST) (including anxiety) was evaluated using a 5-point categorical scale (0 = poor, 1 = fair, 2 = good, 3 = very good, and 4 = excellent). The current study was directed according to the guidelines approved by Helsinki Declaration.

STATISTICAL ANALYSIS

Data were statistically analyzed using GraphPad Prism version 5.00 (GraphPad Prism Inc, San Diego, California).

For the baseline characteristics, continuous variables are expressed as mean values \pm standard deviation (SD), and categorical variables are expressed as frequencies (percent). For inflammatory biomarkers, pain intensity, and pain relief mean values are expressed with 95% confidence intervals (CIs). Normal distribution of data was checked using the Kolmogorov-Smirnov test.

The difference between baseline groups characteristic was performed by, the independent t test, the Mann-Whitney U test, and the χ^2 test for normally continuous data, not normally continuous data, and categorical data, respectively. The independent t test was also used to compare the mean changes from baseline to the end of the study (8 weeks) between OTE and placebo group. Results with two-sided P values of <0.05 were considered statistically significant.

RESULTS

One hundred one eligible patients were enrolled, and 11 were excluded from the study for several reasons (Figure 1). Five participants were dropped out of analysis (2 in OTE-group and 3 in placebo-group) because they were unable to follow study protocol. Good compliance was showed in OTE-group (95.55%) and placebo-group (93.33%), without any study-intervention observed adverse. Urinary hydroxytyrosol determined as biomarker of compliance was quantified by HPLC. Results plotted in the graph of figure 2 illustrate the changes from pre-intervention periods for placebo and OTE (at 4 and at the end of study) group. The concentration of hydroxytyrosol determined in urine of OTE participant's group was significantly different ($P<0.0001$) compared to that of placebo group. However, it is worth noting that literature

data on olive phenols absorption, metabolism, and excretion are not in agreement [29-30].

Table 2 shows the baseline characteristics of the 90 participants who randomized into the OTE and placebo group. Statistical analysis reveal no significant differences between the two study groups with regard to any of the baseline characteristics, including the degree of adherence to Mediterranean diet ($P=0.296$).

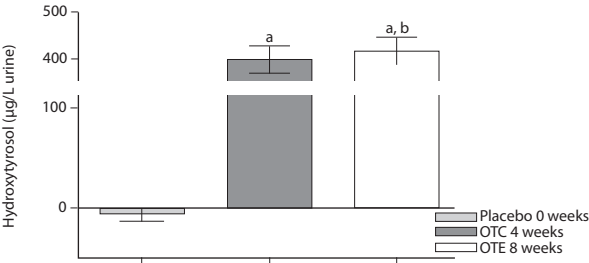


Figure 2. Degree of compliance checked by the change from baseline in urinary hydroxytyrosol excretion. Mean with 95% CI. ^a $P<0.0001$, between OTE-group (at 4 or 8 weeks); ^b $P=0.003$, between OTE-group at 4 and 8 weeks.

Results of dietary questionnaires represented in table 3 show that there was no significant difference in diet intake at the baseline and after eight weeks of OTE and placebo supplement. Result of table 3 show also that the PUFAs intake was maintained constant (P value of 0.611 and 0.741 for OTE and placebo group), since the presence of n-3 PUFAs quantity may be useful for the treatment of inflammatory in RA disease [31]. We also reported in table 3 change in participant's weight, no significant differences has been observed over the period of study for OTE group ($P=0.976$) and placebo group ($P=0.759$). This is appropriate to this study as the adipose tissue is an active endocrine organ that secretes inflammatory cytokines [32]. Generally, the level of macronutrient

intakes was held constant during the study course, which could not affect inflammatory response and biomarkers of inflammation level in the patient's sera. However, a significant difference ($P=0.045$) was reported for MUFAs intake, due to an excessive consumption of olive oil (high content of MUFAs, e.g. oleic acid) at the last week of study intervention by two participants of placebo group that was considered not affect the current study results. Indeed, all participants met the daily diet recommended by the researchers for this study by avoiding the consumption of olive products and any other products known to have anti-inflammatory effects.

Rheumatoid arthritis is a chronic autoimmune inflammatory disease characterized by joint swelling, joint tenderness and destruction of synovial joints. The clinical outcome is pain, warmth, redness, and loss of function. Inflammation of synovial membrane is believed to be the main cause involved in RA outcomes. High concentration of circulating markers of inflammation, such as cytokines (IL-6, IL-1, TNF- α) and hs-CRP correlate with propensity to joint destruction in RA.

Graphs of figure 3 show the changes from baseline values in inflammatory biomarkers IL-6, IL-1, TNF- α , and hs-CRP concentrations in the two study groups. The CRP concentration decreased significantly in participants who were received OTE after 4 ($P=0.014$) and 8 weeks ($P<0.0001$) compared with participants in the placebo group. The average change of hs-CRP levels were -0.55 (CI, -0.92 to -0.18) and -1.37 mg/L (CI, -2.71 to -1.57 mg/L) after 4 and 8 weeks, respectively.

Significant decrease was also observed in plasma levels of IL-6 and TNF- α ($P<0.0001$). The adjusted between-group changes was -2.14 pg/mL (CI, -2.71 to -1.57) and -1.046

pg/mL (CI, -1.50 to -0.59) for IL-6 and TNF- α at the end of the study. Nevertheless, no significant difference from baseline (*P* value of 0.929 and 0.206 at 4 and 8 weeks) was observed for IL-1 concentrations. The significant decrease in plasma IL-6 may leads to the stabilization of circulating IL-1, which can explain the results of figure 3d. Otherwise, RA has often been accompanied by high-intensity chronic pain. Graphs of figure 4 summarized the changes in pain intensity and pain relief from baseline in the OTE and placebo groups.

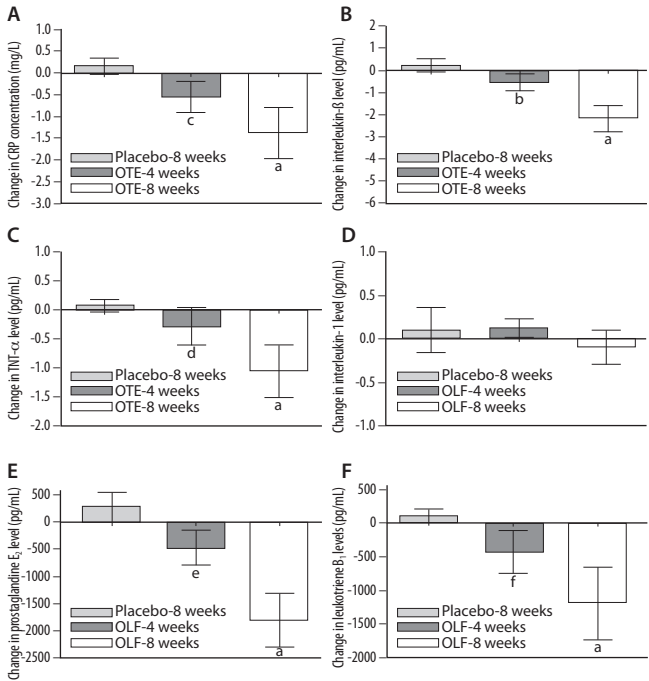


Figure 3. Change from baseline in circulating inflammatory biomarkers level in the tow study groups, (a) hs-CRP, (b) IL-6, (c) TNF- α , (d) IL-1, (e) PGE₂, and (f) LTB₄ (a). Error bars are 95% CIs. ^a*P*<0.0001, ^b*P*=0.014, ^c*P*=0.009, ^d*P*=0.0247, ^e*P*= 0.0004, and ^f*P*=0.0017 vs. placebo group.

Significant decrease ($P<0.0001$) in pain intensity score has been recorded in OTE-group compared to the placebo group. The evaluation of the post-intervention pain intensity shows a decrease of -12.94 ± 4.970 (CI, -15.50 to -10.39) after 4 weeks, and -26.71 ± 9.29 (CI, -31.49 to -21.93) at the end of the trial. Thus, the pain intensity (100-mm pain scale) decrease from 75.51 ± 9.81 to 48.80 ± 4.16 after 8 weeks of OTE intake. A similar trend to pain intensity response was observed for pain relief score. Participants of OTE-group had significantly recorded high pain relief scores compared to those in the placebo group ($P<0.0001$), even after 4 weeks of intervention. Pain relief score increased by 2.61 ± 0.48 (CI, 2.37 to 2.37), which correspond to an average value of 3.26 ± 0.66 (CI, 2.92 to 3.60) in the 5-point VRS after 8 weeks of OTE administration. We should underline that 30% of the OTE-group participants were declared a lot of pain relief (pain relief score ≥ 3), whereas others OTE-group members perceived a meaningful pain relief (pain relief score ≥ 2) at the end of the study. Similarly, significant differences between OTE and placebo groups ($P<0.0001$) have been reported for DAS28 scores. Patients in OTE group with baseline active RA (DAS28 score ≥ 3.2) showed good therapeutic response (decrease in DAS28 by 1.23) (figure 4). DAS28 score recorded at the end of the trial for OTE group was 2.23 ± 0.40 , signaling a RA remission (≤ 2.6). Figure 4 summarized also global satisfaction assessment in response to treatment, including patient's anxiety. Participants who were allocated to OTE-group had a satisfaction score of 3.206 ± 0.53 (corresponding to a very good in the 5 - point categorical scale), compared ($P<0.0001$) with those of placebo group. Such degree of satisfaction correlate with a significant decrease in circulating inflammatory biomarkers level and increase in pain relief score and DAS.

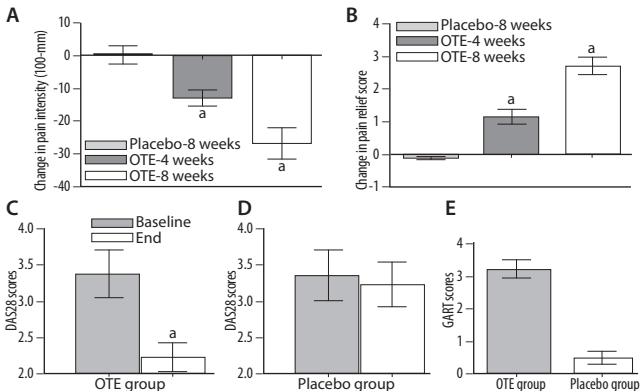


Figure 4. Change from baseline in pain intensity (a), pain relief (b), DAS28 (c, d), and GART (e) scores. Mean with 95% CIs.

^a $P<0.0001$, significant difference between OTE and placebo groups.

Table 1. Main constituents of olive extract (OTE) expressed in percentage (g/100g). Mean \pm standard deviation.

| Parameter | Average value |
|---------------------------|------------------|
| Total solids | 97.96 \pm 7.83 |
| Total volatiles (mineral) | 12.9 \pm 0.7 |
| Total lipids | < 1 |
| Total polyphenols | 15.98 \pm 1.9 |
| Hydroxytyrosol | 2.09 0.14 |

Table 2. Baseline characteristics of participants.

| Parameter | OTE group (n=45) | Placebo group (n=45) | P value ^a |
|-----------------------------------|--------------------|----------------------|----------------------|
| Age (years) | 53.27 \pm 1.61 | 55.73 \pm 1.97 | 0.346 |
| Female, n (%) | 42 (93.33) | 41 (91.11) | 0.915 |
| Weight (kg) | 67.15 \pm 3.86 | 67.65 \pm 3.99 | 0.944 |
| BMI (kg/m ²) | 28.17 \pm 1.662 | 27.83 \pm 1.815 | 0.851 |
| Disease duration (years) | 6.67 \pm 0.421 | 7.50 \pm 0.563 | 0.366 |
| Medical history of disease, n (%) | 19 (40.00) | 15 (33.33) | 0.106 |
| Family history of disease, n (%) | 9 (20.00) | 10 (22.22) | 0.698 |
| Exercise activity habits, n (%) | 14 (31.11) | 13 (28.88) | 0.788 |
| Alcohol drinking habits, n (%) | 4 (8.88) | 2 (4.44) | 0.293 |
| 15-item Mediterranean diet score | 2.05 \pm 0.15 | 2.40 \pm 0.20 | 0.296 |
| DAS28 | 3.374 \pm 0.6625 | 3.392 \pm 0.7132 | 0.940 |
| Pain VAS (0–100 mm) | 75,51 \pm 9,814 | 76.65 \pm 10.12 | 0.741 |

Value are expressed as mean \pm standard deviation or in percentage.
^aP value (<0.05) by independent t-test or Mann-Whitney test, as appropriate.

Table 3. Change in energy and macronutrients intake at baseline and end of the study for tow study groups. Data are expressed as mean \pm standard deviation.

| Parameter | OTE group (n=45) | Placebo group (n=45) |
|-----------------------------|----------------------|----------------------|
| Energy (cal) | | |
| Baseline | 1695.00 \pm 219,80 | 1729.00 \pm 100.7 |
| 8 weeks | 1702.00 \pm 225,30 | 1685.00 \pm 318.6 |
| <i>P</i> value ^a | 0.576 | 0.745 |
| Fat (g) | | |
| Baseline | 65.90 \pm 11.04 | 68.23 \pm 14.37 |
| 8 weeks | 69.07 \pm 12.35 | 70.40 \pm 14.35 |
| <i>P</i> value ^a | 0.547 | 0.780 |
| PUFAs (g) | | |
| Baseline | 13.23 \pm 1.41 | 12.90 \pm 1.33 |
| 8 weeks | 13.73 \pm 2.89 | 13.07 \pm 1.91 |
| <i>P</i> value ^a | 0.611 | 0.741 |
| MUFAs (g) | | |
| Baseline | 20.57 \pm 1.85 | 20.07 \pm 1.77 |
| 8 weeks | 21.57 \pm 2.09 | 21.57 \pm 1.62 |
| <i>P</i> value ^a | 0.110 | 0.045 |
| SFAs (g) | | |
| Baseline | 13.73 \pm 1.49 | 13.73 \pm 2.07 |
| 8 weeks | 14.23 \pm 1.63 | 13.57 \pm 2.09 |
| <i>P</i> value ^a | 0.415 | 0.849 |
| Weight (kg) | | |
| Baseline | 67.15 \pm 3.86 | 67.65 \pm 3.99 |
| 8 weeks | 67.31 \pm 3.87 | 69.31 \pm 3.46 |
| <i>P</i> value ^a | 0.976 | 0.759 |

PUFAs, polyunsaturated fatty acids; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids.

^aPaired Student *t* test (*P* < 0.05).

DISCUSSION AND CONCLUSION

Patient with chronic RA (according to the ACR/ELUAR) were allocated to a treatment by an aqueous olive tree extract during 8 weeks, by receiving a daily dose of 3 g of olive tree extract (6 capsules, 500 mg each). No adverse sign and laboratory parameters fluctuation have been observed during the study and 3 weeks of the post- intervention (data not shown). Results obtained after 2 months of clinical trial demonstrate for the first time the potential therapeutic effect of high polyphenols content extract (OTE) against inflammation in RA disease. Thus, 8 weeks of OTE administration reduced pro-inflammatory cytokines level (TNF- α , IL-6, but not significantly IL-1), hs-CRP concentration and pain intensity.

Through the RA progression, an excessive influx of inflammatory cells has occurred into the synovial membrane (transformed to an autonomous tissue, pannus) where chronic inflammation take place leading to cartilage damage and bone destruction (mediated by osteoclasts). Taken together, the inflammatory process and osteoclasts differentiation were the consequence of cytokines activation, particularly TNF- α , IL-6, IL-1 and other inflammation mediators such as eicosanoids (especially PGE₂ and LTB₄) (Smolen et Redlich, 2014; Boissier *et al.*, 2012). Thus, inhibition of the overproduction of pro-inflammatory cytokines is the principal target of anti-inflammatory agents, including glucocorticoids and NSAIDs. Smolen et Redlich (2014) reported that inhibition of TNF- α and IL-6 production seems to be more important to predict inflammation, while IL-1 inhibition appears to be minor. Results herein obtained show that the supplementation by a rich polyphenols extract (15% of total polyphenols and 2% of hydroxytyrosol) contribute to the reduction of TNF- α , IL-6, hs-CRP, PGE₂, and LTB₄ (figure 3) in patients with RA.

This result may be a direct consequence of OTE polyphenols (particularly hydroxytyrosol), who act directly on DNA to reduce expression of inflammatory mediators or inhibit their biosynthesis pathways through a similar mechanism of glucocorticoids and/or NAIDs. In this sense, hydroxytyrosol inhibit the expression of inducible cyclooxygenase (COX-2) (key enzyme that catalyzed biosynthesis of PGE₂ from arachidonic acid during inflammation process) and, therefore, PGE₂ level in isolated human monocytes [22, 33, 34] and murine macrophages [21]. Similar effect on COX-2 and PGE₂ was observed *in vivo* when mice with DSS- induced colitis are treated by olive oil with high hydroxytyrosol content [35] or by oleuropein [36]. Beside this, pure hydroxytyrosol or contained in its natural matrix (olive products such as, aqueous olive tree extracts and olive oil) exerts an inhibitor effect on LTB₄, TNF- α , IL-6, IL-1 and hs-CRP [20, 21, 22, 37]. The effect of olive polyphenols on inflammatory markers has been emphasized in patients with stable coronary heart disease who received olive oil with different polyphenols concentrations [17-18]. Results of the current study were in agreement with the *in vitro* and *in vivo* investigations (literature cited above), suggesting the therapeutic effect of hydroxytyrosol and other OTE polyphenols against inflammation in RA. Additionally, the decrease in both PGE₂, LTB₄, TNF- α , IL-6, IL-1 and hs-CRP concentration may be the direct consequence of COX-2 inhibition. However, the repression of COX-2 gene leads to a decrease in IL-6 production and a relationship between increased macrophage PGE₂ and IL-6 level is reported *in vitro* [38-39]. In turn, one of the known biological roles of IL-6 is the activation of produced inflammatory proteins, which can explain the decrease in hs-CRP level. Similar mechanism has already described for NSAID drugs. Nevertheless, NSAIDs (celecoxib, rofecoxib, diclofenac) increased TNF- α production in rheumatoid synovial membrane cultures [33-40], while

our results indicate a significant decrease in plasma TNF- α . This could be due to another signaling pathway induced by hydroxytyrosol and/or other OTE polyphenols. By assuming that, the potential effect of hydroxytyrosol (and other olive polyphenols) on NF- κ B has been previously elucidated by several authors. NF- κ B occupied a central upstream position in the inflammatory process, since it triggers the expression of more than 150 genes [41]. Among of them, those encoding cytokines, TNF- α , IL-1, and IL-6 herein studied. Hydroxytyrosol from aqueous olive extract inhibit the expression of NF- κ Bp65, and the authors suggest that this inhibitor effect may be the cause of cytokines reduction in murine macrophages [21]. Furthermore, hydroxytyrosol suppressed NF- κ B expression in human monocyte (THP-1) and altered its translocation into the nucleus [42]. Beside this, hydroxytyrosol decreases NF- κ B activity in endothelial [43] and neural cells [44]. Thus, aqueous olive extract (OTE) most likely exert its anti-inflammatory effect in patients with RA by reducing the expression of NF- κ B and/or COX-2 enzyme.

On the other hand, an excessive angiogenesis ensues from progression of inflammatory process in synovium, and leads to pannus proliferation and RA symptoms complication. Neovascularization (angiogenesis) represent a major contributor in the development and maintain of inflammation in RA [45], and a correlation between RA progression and VEGF level (Vascular Endothelial Growth Factor, most important pro-angiogenic factor) has been observed in patients with RA [46]. The activation of VEGF and Angiopoietins-1 (Ang-1), another pro-angiogenic factor, is a shared and multi-targeted mechanism, including cytokines dependent NF- κ B (IL-1 β and TNF- α) and COX-2 expression [43-47]. Our unpublished data elucidate that Hydroxytyrosol from olive fruit inhibit, *in vitro*, angiogenic response of endothelial cells, by repressing VEGF (isoforms

A, B, and C), Ang-1 and Ang-2 gene expression. This was in agreement with results of previous studies [43-48]. Otherwise, pain intensity has been long since known as main clinical manifests of inflammatory process in RA. Pain intensity in RA was associated to an increase of PGE₂ level [49-50], which explain the effectiveness of NSAIDs as pain relief agents. Beauchamp et al (2005) [23] have reported similar findings for oleocanthal (phenolic compound from olive oil). As a result, the decrease in circulating inflammatory markers, particularly in PGE₂ level, is likely the major cause of pain intensity reduction observed in OTE-group.

In conclusion, results from clinical trial suggest the effectiveness of olive tree extract with high polyphenols content as anti-inflammatory agents in patients with RA. The resolution of inflammatory process in RA is exerted through plausible mechanisms, including cytokines (IL-6 and TNF- α) dependent NF- κ B inhibition, COX-2, VEGF and Ang-1 repression. The net outcomes are decrease in pain intensity, disease activity score and joint protection.

This provides evidence the pleiotropic effects of hydroxytyrosol on inflammation, particularly when it was transported in its natural environment (the olive tree as a whole). Despite their various targets, more information are needed regarding anti-angiogenic activity of hydroxytyrosol in synovial membrane, which could represent a future target of new anti-inflammatory drugs based on hydroxytyrosol structure. In addition, the potential effect of olive polyphenols on T-cell co-stimulation and B- cell depletion must be clarified. The current findings are in agreement with those obtained *in vitro* or *in vivo* in several clinical studies about anti-inflammatory effects of olive polyphenols, suggesting the potential role of these natural compounds for “functional foods” conception.

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REFERENCES

1. Helmick CG, Felson DT, Lawrence RC, Gabriel S, Hirsch R, Kwoh CK. (2008). Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part I. *Arthritis Rheum*, 58, 15-25.
2. Eriksson JK, Neovius M, Ernestam S, Lindblad S, Simard JF, Askling J. (2013). Incidence of rheumatoid arthritis in Sweden: a nationwide population-based assessment of incidence, its determinants, and treatment penetration. *Arthritis Care Res.*, 65, 870-878.
3. Ruiz-Esquivé V, Sanmartí R. (2012). Tobacco and Other Environmental Risk Factors in Rheumatoid Arthritis. *Reumatol. Clin.*, 8, 342-350.
4. Glossop JR, Dawes PT, Matthey DL. (2006). Association between cigarette smoking and release of tumor necrosis factor alpha and its soluble receptors by peripheral blood mononuclear cells in patients with rheumatoid arthritis. *Rheumatology* (Oxford), 45, 1223-1229.
5. Wu HJ, Ivanov II, Darce J, Hattori K, Shima T, Umesaki Y. (2010). Gut-residing segmented filamentous bacteria drive autoimmune arthritis via T helper 17 cells. *Immunity*, 32, 815-827.
6. Berglin E, Kokkonen H, Einarsdottir E, Agren A, Rantapää Dahlqvist S. (2010). Influence of female hormonal factors, in relation to autoantibodies and genetic markers, on the development of rheumatoid arthritis in northern Sweden: a case- control study. *Scand. J. Rheumatol.*, 39, 454-60.
7. Packard CJ, Bezlyak V, McLean JS, Batty GD, Ford I, Burns H. (2011). Early life socioeconomic adversity is associated in adult life with chronic inflammation, carotid atherosclerosis, poorer lung function and decreased cognitive performance: a cross-sectional, population-based study. *BMC Public Health*, 11, 42.
8. Smolen JS, and Redlich K. (2014). Rheumatoid arthritis. In Rose N & Mackay I (Eds): *The Autoimmune Diseases* (Fifth Edition); 2014. p. 511-523.
9. Boissier MC, Semerano L, Challal S, Saitenberg-Kermanach N, Falgarone G. (2012). Rheumatoid arthritis: from autoimmunity to synovitis and joint destruction: a review. *J. Autoimmun.*, 39, 222-8.
10. Killeen M, Linder M, Pontoniere P, Crea R. (2014). NF- κ B signaling and chronic inflammatory diseases: exploring the potential of natural products to drive new therapeutic opportunities. *Drug Discov. Today*, 19, 373-378.
11. Smolen J, Aletaha D, Redlich K. (2012). The pathogenesis of rheumatoid arthritis: new insights from old clinical data? *Nat. Rev. Rheumatol.*, 8, 235-43.

12. Strand V, Kimberly R, Isaacs J. (2007). Biologic therapies in rheumatology: lessons learned, future directions. *Nat. Rev. Drug Discov.*, 6, 75–92.
13. Salminen E, Heikkilä S, Poussa T, Lagstrom H, Saario R, Salminen S. (2002). Female patients tend to alter their diet following the diagnosis of rheumatoid arthritis and breast cancer. *Prev. Med.*, 34, 529–35.
14. Cernadas L, Rodríguez-Romero B, Carballo-Costa L. (2014). Importance of nutritional treatment in the inflammatory process of rheumatoid arthritis patients; a review. *Nutr. Hosp.*, 29, 237–45.
15. McKellar G, Morrison E, McEntegart A, Hampson R, Tierney A, Mackle G. (2007). A pilot study of a Mediterranean-type diet intervention in female patients with rheumatoid arthritis living in areas of social deprivation in Glasgow. *Ann. Rheum. Dis.*, 66, 1239–1243.
16. Sköldstam L, Hagfors L, Johansson G. (2003). An experimental study of a Mediterranean diet intervention for patients with rheumatoid arthritis. *Ann. Rheum. Dis.*, 62, 208–214.
17. Fitó M, Cladellas M, Torre R, Martí J, Muñoz D, Schröder H. (2007). Anti-inflammatory effect of virgin olive oil in stable coronary disease patients: a randomized, crossover, controlled trial. *Eur. J. Clin. Nutr.*, 62, 570–574.
18. Estruch R, Martínez-González MA, Corella D, Salas-Salvadó J, Ruiz-Gutiérrez V, Covas MI. (2006). Effects of a Mediterranean-Style Diet on Cardiovascular Risk Factors: A Randomized Trial. *Ann. Intern. Med.*, 145, 1–11.
19. Hu T, He XWW, Jiang JGG, Xu XLL. (2014). Hydroxytyrosol and its potential therapeutic effects: a review. *J. Agric. Food Chem.*, 62, 1449–55.
20. Camargo A, Rangel-Zuñiga O, Haro C, Meza-Miranda E, Peña-Orihuela P, Meneses M. (2014). Olive oil phenolic compounds decrease the postprandial inflammatory response by reducing postprandial plasma lipopolysaccharide levels. *Food Chem.*, 162, 161–171.
21. Richard N, Arnold S, Hoeller U, Kilpert C, Wertz K, Schwager J. (2011). Hydroxytyrosol Is the Major Anti-Inflammatory Compound in Aqueous Olive Extracts and Impairs Cytokine and Chemokine Production in Macrophages. *Planta Medica*, 77, 1890–1897.
22. Zhang X, Cao J, Jiang L, Zhong L. (2009a). Suppressive effects of hydroxytyrosol on oxidative stress and nuclear factor- κ B activation in THP-1 cells. *Biol. Pharm. Bull.*, 32, 578–582.
23. Beauchamp GK, Russell SJK, Diane M, Jianming L, Jana P, Qiang H. (2005). Phytochemistry: Ibuprofen-like activity in extra-virgin olive oil. *Nature*, 437, 45–46.
24. Aletaha D, Neogi T, Silman A, Funovits J, Felson D, Bingham III CO. (2010). The 2010 American College of Rheumatology/European League Against Rheumatism Classification Criteria for Rheumatoid Arthritis. *Ann. Rheum.*, 69, 1580–1588.
25. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* (2001), 285, 2486–2497.
26. Visioli F, Galli C, Bornet F, Mattei A, Patelli R, Galli G. (2000). Olive oil phenolics are dose-dependently absorbed in humans. *FEBS Lett.*, 468, 159–160.

27. DeLoach LJ, Higgins MS, Caplan AB, Stiff JL. (1998). The visual analog scale in the immediate postoperative period: intra subject variability and correlation with a numeric scale. *Anesth. Analg.*, 86, 102–106.
28. Wells G, Becker JC, Teng J, Dougados M, Schiff M, Smolen J. (2009). Validation of the 28-joint Disease Activity Score (DAS28) and European League Against Rheumatism response criteria based on C-reactive protein against disease progression in patients with rheumatoid arthritis, and comparison with the DAS28 based on erythrocyte sedimentation rate. *Ann. Rheum. Dis.*, 68, 954–60.
29. Covas MI, de la Torre K, Farre-Albaladejo M, Kaikkonen J, Fitó M, Lopez-Sabater C. (2006). Postprandial LDL phenolic content and LDL oxidation are modulated by olive oil phenolic compounds in human. *Free Radic. Biol. Med.*, 40, 608–16.
30. Visioli F, Galli C, Grande S, Colonnelli K, Patelli C, Galli G. (2003). Hydroxytyrosol excretion differs between rats and humans and depends on the vehicle of administration. *J. Nutr.*, 13, 2612–2615.
31. Park Y, Lee A, Shim S-C, Lee J, Choe J-Y, Ahn H. (2013). Effect of n-3 polyunsaturated fatty acid supplementation in patients with rheumatoid arthritis: a 16-week randomized, double-blind, placebo-controlled, parallel-design multicenter study in Korea. *J. Nutr. Biochem.*, 24, 1367–72.
32. Lu B, Hiraki L, Sparks JA, Malspeis S, Chen CY, Awosogba JA. (2014). Being overweight or obese and risk of developing rheumatoid arthritis among women: a prospective cohort study. *Ann. Rheum. Dis.*, 73, 205–459.
33. Rosignoli P, Fuccelli R, Fabiani R, Servili M, Morozzi G. (2013). Effect of olive oil phenols on the production of inflammatory mediators in freshly isolated human monocytes. *J. Nutr. Biochem.*, 24, 1513–1519.
34. Lu Y, Wahl LM. (2005). Oxidative stress augments the production of matrix metalloproteinase -1, cyclooxygenase-2, and prostaglandin E2 through enhancement of NF-kappa β activity in lipopolysaccharide-activated human primary monocytes. *J. Immunol.*, 175, 5423–9.
35. Sánchez-Fidalgo S, Sánchez de Ibarguén L, Cárdeno A, Alarcón de la Lastra C. (2011). Influence of extra virgin olive oil diet enriched with hydroxytyrosol in a chronic DSS colitis model. *Eur. J. Nutr.*, 51, 497–506.
36. Giner E, Andújar I, Recio M, Ríos J, Cerdá-Nicolás J, Giner R. (2011). Oleuropein ameliorates acute colitis in mice. *J. Agric. Food Chem.*, 59, 12882–92.
37. Maiuri M, Stefano D, Meglio P, Irace C, Savarese M, Sacchi R. (2005). Hydroxytyrosol, a phenolic compound from virgin olive oil, prevents macrophage activation. *Naunyn Schmiedeberg's Arch. Pharmacol.*, 371, 457–465.
38. Inoue H, Takamori M, Shimoyama Y, Ishibashi H, Yamamoto S, Koshihara Y. (2002). Regulation by PGE2 of the production of interleukin-6, macrophage colony stimulating factor, and vascular endothelial growth factor in human synovial fibroblasts. *Br. J. Clin. Pharmacol.*, 136, 287–295.
39. Hinson R, Williams J, Shacter E. (1996). Elevated interleukin 6 is induced by prostaglandin E2 in a murine model of inflammation: possible role of cyclooxygenase-2. *Proc. Nat. Sci. Acad.*, 93, 4885–4890.
40. Page TH, Turner JJ, Brown AC, Timms EM, Inglis JJ, Brennan FM. (2010). Nonsteroidal anti-inflammatory drugs increase TNF production in rheumatoid synovial membrane cultures and whole blood. *J. Immunol.*, 185, 3694–3701.

41. Makarov S. (2001). NF-kappa β in rheumatoid arthritis: a pivotal regulator of inflammation, hyperplasia, and tissue destruction. *Arthritis Res.*, 3, 200–206.
42. Zhang X, Cao J, Zhong L. (2009b). Hydroxytyrosol inhibits pro-inflammatory cytokines, iNOS, and COX-2 expression in human monocytic cells. *Naunyn Schmiedebergs Arch. Pharmacol.*, 379, 581–6.
43. Scoditti E, Calabriso N, Massaro M, Pellegrino M, Storelli C, Martines G. (2012). Mediterranean diet polyphenols reduce inflammatory angiogenesis through MMP-9 and COX-2 inhibition in human vascular endothelial cells: a potentially protective mechanism in atherosclerotic vascular disease and cancer. *Arch. Biochem. Biophys.*, 527, 81–89.
44. St-Laurent-Thibault C, Arseneault M, Longpré F, Ramassamy C. (2011). Tyrosol and hydroxytyrosol, two main components of olive oil, protect N2a cells against amyloid- β -induced toxicity. Involvement of the NF- κ B signaling. *Curr. Alzheimer Res.*, 8, 543–551.
45. Semerano L, Clavel G, Assier E, Denys A, Boissier MC. (2011). Blood vessels, a potential therapeutic target in rheumatoid arthritis? *Jt Bone Spine*, 78, 118–123.
46. Sone H, Kawakamib Y, Sakauchic M, Nakamurad Y, Takahashia A, Shimano H. (2001). Neutralization of Vascular Endothelial Growth Factor Prevents Collagen-Induced Arthritis and Ameliorates Established Disease in Mice. *Biochem. Biophys. Res. Commun.*, 281, 562–568.
47. Pettit AR, Ji H, von Stechow D, Müller R, Goldring SR, Choi Y. (2001). TRANCE/RANKL knockout mice are protected from bone erosion in a serum transfer model of arthritis. *Am. J. Pathol.*, 159, 1689–1699.
48. Fortes C, Garcia-Vilas J, Quesada A, Medina M. (2012). Evaluation of the anti-angiogenic potential of hydroxytyrosol and tyrosol, two bio-active phenolic compounds of extra virgin olive oil, in endothelial cell cultures. *Food Chem.*, 134, 134–140.
49. Prochazkova M, Zanvit P, Doleial T, Prokesova L, Krsiak M. (2009). Increased gene expression and production of spinal cyclooxygenase 1 and 2 during experimental osteoarthritis pain. *Physiol. Res.*, 58, 419–25.
50. Scher J, Pillinger M, Abramson S. (2007). Nitric oxide synthases and osteoarthritis. *Curr. Rheumatol. Rep.*, 9, 9–15.

Author Profile

Mohammed Benlemlih- Is a Professor of biology in the Faculty of Sciences (Sidi Mohammed Ben Abdellah University of Fez - Morocco) for the last 25 years. He was the head of Biotechnology Laboratory and author of a hundreds of scientific papers. Prof. Benlemlih is currently the dean of the Faculty of Sciences Dhar El Mahraz (Fez University).

Jamal Ghanam- Received the PhD degree in biological sciences from Sidi Mohammed Ben Abdellah University of Fez-Morocco in 2014. As part of biotechnology Laboratory team (Faculty of Sciences, Fez University) he was interested in olive tree biophenols and their effects on human health (2009-2014). Dr. Ghanam is now in postdoctoral position and associated member of Biotechnology Laboratory.

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DESERT OLIVE TREES ANTIOXIDANTS

Pr **M. BENLEMLIH** & Dr **J. GHANAM**

The natural polyphenols coming from the olive trees planted in the middle of the Moroccan desert are highly bioavailable and highly bioactive molecules. This gives them multiple benefits for human health. These compounds are part of the family of antioxidants. They make it possible to fight against free radicals that have negative effects on our body: cell aggression, DNA modification, lipid oxidation.

Thus, recent studies have shown that hydroxytyrosol found in the desert olive trees improves mitochondrial function that prevents cell aging and, therefore, aging of the body.

This allows us to confirm that this compound is a useful agent for the prevention of aging and senescence-related diseases.

The polyphenols found in the olive trees also help protect and treat certain types of cancer. In this context, it has been shown that hydroxytyrosol and oleuropein have an anti-cancer effect on: colon cancer, blood cancer, breast cancer... These famous compounds act against cancer by several anti-proliferative mechanisms and apoptotic.

In addition, the benefits of these phenolic compounds on the cardiovascular system have been elucidated by several authors. As a matter of fact, the polyphenols in the olive oil promote the reduction of the presence of cell adhesion molecules, increase the availability of nitric oxide, suppress platelet aggregation, protect LDL against oxidation to delay atherosclerosis and reduce inflammatory reactions.

Currently, other virtues of polyphenols from olive oil are recognized, including their antibacterial effect, treatment and prevention of diabetes and Alzheimer's disease.

Some of the enclosed clinical studies recently realized will hopefully enlighten you in this way...

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