

## Oleic Acid (Omega-9)

### A Multifunctional Monounsaturated Fatty Acid in Metabolic, Cardiovascular, Neuroprotective, and Dermatological Health

#### Abstract

Oleic acid (OA), the predominant omega-9 monounsaturated fatty acid, is a critical lipid influencing cellular structure, metabolic regulation, and systemic health.

Although not essential due to endogenous synthesis, OA exerts multiple beneficial effects across diverse physiological systems.

It enhances membrane fluidity and stability, suppresses inflammatory pathways (NF- $\kappa$ B, COX-2, iNOS), and augments antioxidant defenses.

OA promotes insulin sensitivity through GLUT-4 translocation, AMPK activation, and PPAR regulation, while contributing to favorable lipid profiles and endothelial protection.

Clinical and experimental studies highlight its cardio-protective, hepato-protective, and neuroprotective roles, including reduced hepatic steatosis, enhanced myelin integrity, and modulation of neuro-inflammation.

Additionally, OA supports skin barrier repair and hydration, contributing to dermatological resilience. Rich dietary sources include extra virgin olive oil, avocado, macadamia oil, and nuts, with evidence strongly supporting its role in Mediterranean dietary patterns.

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Collectively, OA represents a key nutritional component in metabolic health, cardiovascular prevention, and neuro-dematological protection.

### **Keywords**

Oleic acid (OA) ; Omega-9 fatty acid ; Membrane fluidity ; Anti-inflammatory effects ; Antioxidant defense ; Insulin sensitivity ; Cardiovascular protection ; Hepatic steatosis ; Neuroprotection ; Skin barrier integrity ; Mediterranean diet

**Oleic acid (OA)** is a monounsaturated fatty acid (MUFA) classified within the omega-9 (n-9) family.

While it is not an essential fatty acid - since it can be synthesized endogenously via stearoyl-CoA desaturase - it plays critical roles in cellular structure, metabolic homeostasis, inflammation regulation, and cardio-metabolic health.

## **I A Key Structural Lipid in Membranes and Lipoproteins**

Oleic acid is one of the most abundant fatty acids in human adipose tissue, cell membranes, and plasma lipoproteins.

- **Monounsaturates confers fluidity and stability:**

Its single cis double bond (C18:1 n-9) provides membrane flexibility while maintaining oxidative stability superior to polyunsaturated fatty acids (PUFAs).

- **Balances membrane saturation:**

Oleic acid acts as a buffer between saturated fatty acids and highly unsaturated PUFAs, preserving membrane integrity across a range of physiological conditions.

- **Modulates lipid raft composition:**

OA affects microdomain dynamics involved in receptor clustering, insulin signaling, and immune responses.

✓ *Stubbs C.D., Smith A.D. (1984). The modification of mammalian membrane polyunsaturated fatty acid composition in relation to membrane fluidity and function. Biochim Biophys Acta, 779(1):89–137.*

## II Anti-Inflammatory and Antioxidant Properties

### 1) Inhibits Pro-Inflammatory Gene Expression

- Oleic acid suppresses NF-κB pathway activation, thereby reducing transcription of inflammatory cytokines such as TNF-α, IL-6, and IL-1β.
- It decreases COX-2 and iNOS expression, leading to lower prostaglandin and nitric oxide production under oxidative stress.

## 2) Enhances Endogenous Antioxidant Defense

- OA upregulates antioxidant enzymes including superoxide dismutase (SOD) and glutathione peroxidase (GPx).
- Protects lipids from peroxidation by stabilizing membrane phospholipids, particularly in the liver and endothelial tissue.

✓ *Carrillo C., Cavia Mdel M., Alonso-Torre S.R. (2012). Role of oleic acid in immune system; mechanism of action; a review. Nutr Hosp, 27(4):978–990.*

## III Metabolic Regulation and Insulin Sensitivity

- OA enhances GLUT-4 translocation and AMPK activation, improving cellular glucose uptake and insulin responsiveness.
- Promotes PPAR- $\alpha$  and PPAR- $\gamma$  activity, supporting lipid oxidation and adipocyte metabolic flexibility.
- Substituting saturated fats with OA has been shown to lower fasting insulin and HOMA-IR in clinical studies.

✓ *Pérez-Martínez P., García-Ríos A., Delgado-Lista J., et al. (2011). Mediterranean diet rich in olive oil improves glucose metabolism in healthy and diabetic subjects. Mol Nutr Food Res, 55(12):1771–1780.*

#### IV Cardiovascular Protection

- **Improves lipid profiles:**

Replacing saturated fats with OA lowers LDL-C and maintains or increases HDL-C.

- Reduces endothelial dysfunction by enhancing nitric oxide (NO) bioavailability and suppressing adhesion molecules (e.g., ICAM-1, VCAM-1).

- **Anti-thrombotic effects:**

OA downregulates platelet aggregation and thromboxane A2 formation.

✓ *Schwingshackl L., Hoffmann G. (2014). Monounsaturated fatty acids and risk of cardiovascular disease: systematic review and meta-analysis of cohort studies. *Lipids Health Dis*, 13:154.*

✓ *Estruch R., Ros E., Salas-Salvadó J., et al. (2013). Primary prevention of cardiovascular disease with a Mediterranean diet. *N Engl J Med*, 368(14):1279–1290.*

#### V Supports Liver Function and Reduces Hepatic Steatosis

- OA enhances fatty acid  $\beta$ -oxidation and reduces hepatic de novo lipogenesis.
- Promotes VLDL clearance and reduces triglyceride accumulation in hepatocytes.
- In NAFLD models, OA-rich diets are associated with reduced liver fat, inflammation, and oxidative markers.

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- ✓ *Paniagua J.A., de la Sacristana A.G., Sánchez E., et al. (2007). A MUFA-rich diet improves hepatic fat oxidation in insulin-resistant subjects. J Clin Endocrinol Metab, 92(8):3046–3052.*

## **VI Neuroprotective Effects and Cognitive Function**

- OA serves as a precursor for nervonic acid, essential for myelin sheath formation and neuronal membrane maintenance.
- Exhibits anti-apoptotic effects in neural tissues by modulating caspase-3 activity and mitochondrial function.
- May reduce risk of neurodegenerative diseases by suppressing neuroinflammation and enhancing brain-derived neurotrophic factor (BDNF) expression.

- ✓ *González-Domínguez R., Sayago A., Fernández-Recamales Á. (2020). Fatty acid profiles and neurodegeneration: implications for nutritional strategies. J Pharm Biomed Anal, 190:113514.*

## **VII Skin Health and Barrier Integrity**

- OA enhances stratum corneum permeability and ceramide synthesis, improving skin hydration and resilience.
- Has been shown to aid in wound healing, keratinocyte proliferation, and protection against UV-induced inflammation.

- Topical or oral supplementation may benefit eczema, psoriasis, and barrier-damaged skin.

✓ *Lin T.K., Zhong L., Santiago J.L. (2018). Anti-inflammatory and skin barrier repair effects of topical application of some plant oils. Int J Mol Sci, 19(1):70.*

## VIII Oleic Acid in Dietary Sources and Supplementation

- Richest in extra virgin olive oil (55–83%), macadamia oil, avocado oil, and high-oleic sunflower oil.
- Also found in nuts (almonds, hazelnuts), chicken fat, and some animal fats.
- Recommended in Mediterranean-style diets for its stability and health-promoting effects when used in place of saturated fats.

## IX Omega-9 and Omega-6/Omega-3 Balance

Although omega-9 fatty acids are non-essential, they play a **buffering role** in lipid balance:

- OA does not interfere with the competitive enzymatic pathways ( $\Delta 6$ -desaturase) between omega-6 (LA) and omega-3 (ALA);

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- It can dilute the pro-inflammatory potential of excessive omega-6 intake when included in high-quality dietary fats;
- In formulations, OA helps stabilize PUFA-rich blends and supports lipid structure homeostasis.

✓ *Gillingham L.G., Harris-Janz S., Jones P.J. (2011). Dietary monounsaturated fatty acids are protective against metabolic syndrome and cardiovascular disease risk factors. *Lipids*, 46(3):209–228.*