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# Understanding COQ10: Biological roles and plant-derived sources

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## Abstract

Coenzyme Q10 (CoQ10) is commercially available in two primary forms: ubiquinone, the oxidized version, and ubiquinol, the reduced form. Each form exhibits distinct absorption profiles and cost differences, influencing their use in dietary supplementation. Understanding these variations is crucial for optimizing their efficacy in clinical and health-related applications. This review highlights the physiological significance of CoQ10 in cellular respiration, cellular stability, and signaling pathways, framing its role in protecting cells from oxidative damage. The pharmacokinetics of CoQ10—encompassing its absorption, distribution, metabolism, and elimination—are also examined, providing a comprehensive understanding of how the body utilizes this compound. An important focus of the review is the endogenous synthesis of CoQ10, including the impact of various herbal drugs that may enhance its natural production within the body. By exploring both the supplemental and natural synthesis avenues, this review underscores the multifaceted role of CoQ10 in maintaining optimal health.

**Keywords:** Coenzyme Q10; Ubiquinone; Cellular Respiration; Pharmacokinetics; Herbal Source

## 1. Introduction to Coenzyme $Q_{10}$

$CoQ_{10}$, also known as ubiquinone-10, is a naturally occurring, fat-soluble, vitamin-like quinone compound. Its name derives from "ubiquitous" because it is present in virtually every cell of the human body. Structurally, it consists of a benzoquinone ring and a polyisoprenoid side chain with 10 isoprene units in humans, hence the designation "$Q_{10}$" (Crane, 2001). Coenzyme Q, commonly referred to as CoQ or ubiquinone, was first discovered in 1957 by Frederick Crane and his team during their research on mitochondrial enzymes in beef heart mitochondria. Shortly after its discovery, in 1958, its full chemical structure was elucidated, identifying it as a benzoquinone compound with a long isoprenoid side chain. Because of its widespread presence in almost all living organisms, it was initially named "ubiquinone." The sourcing is from endogenous biosynthesis, which are synthesized via the mevalonate pathway (the same pathway inhibited by statins), using precursors such as mevalonic acid and tyrosine (Clarke, 2001) and also from dietary sources found in both animal (organ meats, fatty fish) and plant-based (soy, nuts, vegetable oils, spinach, broccoli) foods, though at relatively low concentrations compared to endogenous production (StatPearls, 2023). However, as research progressed, scientists recognized its essential role as a cofactor in mitochondrial enzyme complexes, particularly within the electron transport chain, where it facilitates electron transfer and ATP synthesis. This functional significance led to its designation as "coenzyme Q," highlighting both its ubiquity in nature and its critical involvement in cellular energy metabolism. The metabolic role is crucially based on the physiological role of $CoQ_{10}$.

### 1.1. Chemical Nature

Chemically, Coenzyme $Q_{10}$ ($CoQ_{10}$) is composed of a benzoquinone ring, which serves as the redox-active head group, attached to a polyisoprenoid tail containing 10 isoprene units in humans. The quinone head undergoes reversible redox transitions between three forms: ubiquinone (oxidized form), semiquinone (radical intermediate), and ubiquinol

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(reduced form). This redox cycling is fundamental to its dual role in bioenergetics and antioxidant defense, enabling efficient electron transfer in the mitochondrial respiratory chain while also neutralizing reactive oxygen species (ROS) (Turunen et al., 2004). The long hydrophobic isoprenoid side chain provides strong lipid solubility, allowing $CoQ_{10}$ to embed within the inner mitochondrial membrane as well as other lipid-rich environments such as cellular membranes and plasma lipoproteins, ensuring its accessibility where both energy production and oxidative protection are most needed.

### 1.2. Clinical and Pharmacological Significance

Endogenous levels of Coenzyme $Q_{10}$ ($CoQ_{10}$) naturally decline with aging, chronic disease conditions, and the use of statin therapy, which makes supplementation an important clinical consideration. Pharmacological studies have explored $CoQ_{10}$ supplementation across a wide range of conditions, including cardiovascular disorders such as congestive heart failure, hypertension, and ischemic heart disease, as well as neurodegenerative diseases like Parkinson's and Alzheimer's. It has also shown therapeutic potential in mitochondrial cytopathies, infertility, migraine prophylaxis, and metabolic syndromes (LittarruandTiano, 2007; López-Lluch et al., 2010). By functioning both as a critical cofactor in mitochondrial energy metabolism and as a powerful nutraceutical with antioxidant and protective properties, $CoQ_{10}$ stands at the intersection of biochemistry, pharmacology, and clinical medicine, bridging fundamental cellular processes with therapeutic applications.

### 1.3. Physiological Role

#### *1.3.1. Mitochondrial Energy Production*

Coenzyme $Q_{10}$ ($CoQ_{10}$) is an essential component of the mitochondrial electron transport chain, where it serves as a mobile electron carrier crucial for energy production. Within this system, $CoQ_{10}$ transfers electrons from Complex I (NADH dehydrogenase) and Complex II (succinate dehydrogenase) to Complex III (cytochrome $bc_1$ complex). This electron shuttling is a vital step in oxidative phosphorylation, the process by which cells generate adenosine triphosphate (ATP). As electrons move through the chain, protons are pumped across the inner mitochondrial membrane, creating a proton gradient that drives ATP synthase to produce ATP, the cell's primary energy currency. Thus, $CoQ_{10}$ plays a pivotal role in maintaining efficient cellular respiration and sustaining the body's energy demands. (LittarruandTiano, 2010)

#### *1.3.2. Antioxidant Defense*

In its reduced form, known as ubiquinol, Coenzyme $Q_{10}$ acts as a powerful lipid-soluble antioxidant that safeguards cellular structures against oxidative stress. Positioned within cell membranes, ubiquinol effectively prevents the peroxidation of membrane lipids while also protecting proteins and DNA from damage caused by reactive oxygen species. An additional important function is its ability to regenerate other antioxidants, particularly vitamin E, thereby strengthening the overall antioxidant defense system of the cell. Through these combined actions, $CoQ_{10}$ not only supports cellular integrity but also contributes to the prevention of oxidative stress–related disorders and the maintenance of overall physiological health ([Bentinger et al., 2007])

#### *1.3.3. Cellular Stability and Signaling*

Coenzyme $Q_{10}$ ($CoQ_{10}$) contributes to cellular stability and regulation by helping maintain the structural integrity of cell membranes, protecting them from oxidative stress and damage. Beyond its antioxidant and bioenergetic roles, $CoQ_{10}$ also participates in essential signaling mechanisms within the cell. It regulates apoptosis, the process of programmed cell death, ensuring that damaged or unnecessary cells are efficiently removed without harming surrounding tissues. Moreover, $CoQ_{10}$ influences gene expression and cell signaling pathways, which are critical for cellular communication, growth, and adaptation to stress. Through these combined actions, $CoQ_{10}$ not only supports mitochondrial function and energy production but also helps preserve overall cellular health and balance. (LittarruandTiano, 2010)

#### *1.3.4. Clinical Relevance*

Coenzyme $Q_{10}$ ($CoQ_{10}$) levels gradually decrease with age, leading to reduced mitochondrial efficiency and increased vulnerability to oxidative stress. This decline is more pronounced in individuals with chronic conditions such as heart failure, diabetes, and neurodegenerative diseases, where both impaired synthesis and higher oxidative demand contribute to deficiency. Furthermore, statin medications, widely prescribed to lower cholesterol, unintentionally reduce $CoQ_{10}$ biosynthesis since they block the mevalonate pathway, which is shared by both cholesterol and $CoQ_{10}$ production. As a result, lower $CoQ_{10}$ levels in these situations may impair energy metabolism, promote fatigue, and

worsen disease symptoms, underscoring its importance in maintaining cellular and systemic health (Littarru and Tiano, 2010).

### 1.4. Supplementation is widely studied for

Coenzyme $Q_{10}$ ($CoQ_{10}$) has been widely studied for its therapeutic potential across several health conditions. In cardiovascular diseases such as heart failure and hypertension, $CoQ_{10}$ supplementation supports myocardial energy production and improves endothelial function, which may enhance cardiac performance and reduce oxidative stress. In neurodegenerative disorders like Parkinson's and Alzheimer's disease, $CoQ_{10}$ helps protect neurons from oxidative damage and mitochondrial dysfunction, slowing disease progression in some cases. It also plays a critical role in mitochondrial disorders by compensating for defective energy metabolism and improving muscle function. Additionally, $CoQ_{10}$ has shown benefits in migraine prophylaxis, likely by stabilizing mitochondrial activity and reducing neuronal excitability. In patients taking statins, which lower cholesterol but also decrease endogenous $CoQ_{10}$ synthesis, supplementation may help alleviate statin-associated muscle symptoms such as weakness and pain by restoring mitochondrial function and reducing oxidative stress (Hernández-Camacho et al., 2018)

### 1.5. Sources of Coenzyme Q10 (CoQ10)

Coenzyme Q10 (CoQ10) is obtained from two primary sources: endogenous biosynthesis within the body and exogenous intake through diet or supplements. The majority of CoQ10 is produced internally via the mevalonate pathway, which also contributes to cholesterol synthesis, ensuring a steady supply to meet cellular energy demands. At the same time, dietary sources such as meat, fish, nuts, seeds, and certain oils, along with supplemental forms, provide additional support to maintain optimal levels. Since CoQ10 is an essential cofactor in mitochondrial energy metabolism and also functions as a potent antioxidant, both endogenous synthesis and external intake are vital for sustaining adequate cellular concentrations necessary for health and disease prevention.

#### *1.5.1. Endogenous Biosynthesis*

The main source of Coenzyme $Q_{10}$ ($CoQ_{10}$) in humans is de novo biosynthesis within tissues, which occurs through the mevalonate pathway. This metabolic route is highly significant because it not only produces $CoQ_{10}$ but also generates other essential biomolecules such as cholesterol, heme A, dolichols, and prenylated proteins, all of which play critical roles in cellular structure and function (Hernández-Camacho et al., 2018). Since this pathway is central to multiple biochemical processes, any disruption—such as that caused by statin therapy—can directly affect endogenous $CoQ_{10}$ production, highlighting its dependence on proper mevalonate pathway activity for maintaining adequate cellular energy and antioxidant capacity.

#### *1.5.2. CoQ10 synthesis requires:*

Coenzyme $Q_{10}$ ($CoQ_{10}$) biosynthesis involves two key structural components: the benzoquinone ring, derived from aromatic amino acids such as tyrosine or phenylalanine, and the isoprenoid side chain, produced through the mevalonate pathway. This complex biosynthetic process requires the coordinated activity of at least 13 nuclear-encoded COQ genes, which regulate enzymatic steps including quinone head modification, side-chain attachment, and overall pathway control (Alcázar-Fabra et al., 2018). Because the mevalonate pathway is shared with cholesterol biosynthesis, drugs like statins (HMG-CoA reductase inhibitors) inadvertently reduce $CoQ_{10}$ production, a factor thought to contribute to statin-associated muscle symptoms or myopathy (Deichmann et al., 2010). Although $CoQ_{10}$ is synthesized in most human tissues, its highest concentrations are found in metabolically active organs such as the heart, kidneys, liver, and skeletal muscles, where energy demand and antioxidant protection are greatest (Crane, 2001; LittarruandTiano, 2007)

### 1.6. Dietary Sources

Although the majority of Coenzyme $Q_{10}$ ($CoQ_{10}$) is produced endogenously through the mevalonate pathway, dietary intake also contributes to maintaining plasma and tissue levels. Typical Western diets provide an estimated 3–6 mg of $CoQ_{10}$ per day, primarily from foods such as meat, fish, nuts, and certain oils. However, this amount is significantly lower than the doses required for therapeutic purposes, as clinical supplementation often involves 100–300 mg per day to achieve meaningful physiological or therapeutic effects (Bhagavan and Chopra, 2006). This gap highlights why supplementation becomes necessary in conditions of deficiency, increased metabolic demand, or therapeutic interventions.

*1.6.1. Animal-Based Sources (richest sources)*

Animal-based foods are the richest natural sources of Coenzyme $Q_{10}$ ($CoQ_{10}$), largely because they contain tissues with high mitochondrial density. Organ meats such as heart, liver, and kidney provide the highest concentrations, reflecting their intense energy requirements. Fatty fish, including sardines, mackerel, salmon, and tuna, also supply moderate to high levels, while poultry and beef contribute appreciable amounts. For example, beef heart has been reported to contain up to 113 µg of $CoQ_{10}$ per gram of fresh weight, making it one of the most concentrated dietary sources (Mattila et al., 2000). These animal-derived foods, therefore, play a key role in supporting dietary $CoQ_{10}$ intake, especially in diets with high metabolic or therapeutic demands.

*1.6.2. Plant-Based Sources (lower but important for vegetarians/vegans)*

Plant-based foods also contribute to dietary Coenzyme $Q_{10}$ ($CoQ_{10}$), though typically at lower levels compared to animal sources. Nuts and seeds such as peanuts, sesame seeds, and pistachios provide modest amounts, while vegetable oils—including soybean, canola, and olive oil—are among the most significant plant-derived sources. Soy products like tofu and soybeans add further to intake, and leafy vegetables such as spinach, broccoli, and cauliflower contain measurable, though relatively lower, concentrations. Notably, soybean oil has been reported to contain between 54–160 µg of $CoQ_{10}$ per gram, making it one of the richest plant sources available (Weber et al., 1997). These plant foods are particularly valuable in supporting $CoQ_{10}$ intake for individuals following vegetarian or vegan diets.

*1.6.3. Dairy and Other Foods*

Milk, dairy products, and whole grains contribute only small amounts of Coenzyme $Q_{10}$ ($CoQ_{10}$) to the diet compared to animal meats, fish, or certain plant oils. While these foods are not major sources, they still provide minor contributions that can help support overall intake, particularly when consumed regularly as part of a balanced diet. In populations with limited access to richer sources of $CoQ_{10}$, such as organ meats or fatty fish, these modest contributions from dairy and whole grains may still play a supplementary role in maintaining baseline plasma and tissue levels of $CoQ_{10}$.

*1.6.4. Supplemental Sources*

Since dietary intake of Coenzyme $Q_{10}$ ($CoQ_{10}$) is relatively low, nutritional supplements represent the primary exogenous source for achieving pharmacological doses. These supplements are available in different forms, including ubiquinone (oxidized), ubiquinol (reduced), and various solubilized formulations, each differing in their absorption and bioavailability (López-Lluch et al., 2010). Because $CoQ_{10}$ is highly lipophilic and poorly soluble in water, its bioavailability can vary widely depending on the formulation. To overcome this challenge, novel delivery systems such as liposomes, nanoparticles, micelles, and self-emulsifying drug delivery systems (SEDDS) have been developed to enhance absorption and improve therapeutic efficacy (BhagavanandChopra, 2006). These advancements make supplementation a practical and effective strategy to maintain optimal $CoQ_{10}$ levels, especially in clinical settings where higher doses are required. Numerous companies are now offering $CoQ_{10}$ supplements, often combined with other health supplements and multivitamin tablets (Table 2). It's important to highlight the value of sourcing $CoQ_{10}$ from herbal origins. Natural sources of $CoQ_{10}$, such as spinach, broccoli, and whole grains, not only provide this essential nutrient but also come packed with additional vitamins, minerals, and antioxidants. These herbal sources can enhance absorption and efficacy, aligning with a holistic approach to health. As consumers increasingly seek natural and plant-based options, prioritizing herbal sources of $CoQ_{10}$ can contribute significantly to overall well-being.

**Table 1** Comparison with the marketed products

| Brand / Product | Form (active) | Typical dose (common SKU) | Pros | Cons and cautions | Reference |
|---|---|---|---|---|---|
| Qunol Ubiquinol (Mega / Ultra) | Ubiquinol (reduced) | 100 mg softgels (60–120 ct) | Easily available; marketed for higher absorption; many user reviews; good for older adults or those who struggle converting ubiquinone → ubiquinol. | More expensive than standard ubiquinone; softgels may contain non-vegan ingredients. | Lopez-Lluch et al. (2019) |
| Life Extension — Super Ubiquinol CoQ10 | Ubiquinol (Kaneka) | 100 mg softgels | Uses Kaneka ubiquinol ingredient; premium brand with clinical references; aimed at cardiovascular support. | Higher price; contains oils/softgel excipients. | López-Lluch et al. (2019) |
| Kaneka Ubiquinol (ingredient) | Ubiquinol (ingredient brand) | N/A (sold as ingredient) | Widely used industry standard; backed by safety/clinical data — many brands use it. | Ingredient (not finished supplement) — check label to confirm brand use. | Hosoe et al. (2007) |
| MitoQ (Mitoquinone) | Mitoquinone (mito-targeted) — not CoQ10 | 10 mg daily, typical | Mito-targeted antioxidant with strong absorption into mitochondria; low dose due to potency. Useful when mitochondrial delivery is desired. | Different molecule (not interchangeable with CoQ10); clinical effects differ; costlier. | Méndez, B. R., et al. (2021) |
| Ubiqsome / CoQ10 Phytosome (sold under many labels, e.g., Solaray ProSorb, Super Nutrition) | Ubiqsome® (Indena) — Phytosome (ubiquinone in phospholipid matrix) | 100–300 mg (phytosome dose; typical 100–300 mg equiv.) | Improved bioavailability vs standard CoQ10 in studies/ex vivo and clinical signals for better muscle uptake and endothelial function. Good option when absorption is a concern. | Proprietary ingredient — premium price; evidence promising but heterogeneous; verify the amount of actual CoQ10 (standardized %). | Cicero et al. (2022) |
| Jarrow Formulas — Q-Absorb / Q-Absorb Proliposome | Ubiquinone in proliposome delivery | 100 mg softgels | Proliposome delivery system designed to increase absorption (human data claims). Trusted brand, vegetarian options. | Proprietary delivery claims — look for third-party test info if important. | Lancisi Heart Institute and University of Ancona team (2006) |
| Doctor's Best High Absorption CoQ10 (with BioPerine) | Ubiquinone + BioPerine (black pepper extract) | 100 mg (120 ct) | BioPerine may increase absorption of some nutrients; cost-effective; widely available. | Evidence on BioPerine specifically boosting CoQ10 uptake is limited; potential GI side effects in some. | Badmaev V, Majeed M, Prakash L (2000) |
| NOW Foods CoQ10 (fermented ubiquinone) | Ubiquinone (fermentation-derived) | 100–200 mg caps/softgels | Affordable, long-standing brand; "pharmaceutical grade"; vegan options. | Standard ubiquinone may require higher doses for older | Navas Lloret P, López-Lluch G, et al. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | adults; check the product for excipients. | 2020. |
| Nature Made CoQ10 (USP verified options) | Ubiquinone (sometimes with black pepper) | 100–200 mg softgels | Widely available, USP-verified SKUs available (quality assurance), and budget-friendly. | Some formulations contain soy; check for third-party testing if needed. | Badmaev V, Majeed M, Prakash L (2000) |
| Garden of Life — Raw CoQ10 (vegan, food-form) | Raw CoQ10 in chia seed oil (food-based) | 200 mg capsule | Vegan, whole-food delivery system (cold-pressed oil); attractive for "food-form" enthusiasts; sustainable brand image. | Larger capsule; cost higher; clinical equivalence to purified CoQ10 not fully established. | Sadek et al. (2023) |
| Nordic Naturals CoQ10 Gummies | Ubiquinone (gummy) | 100 mg gummy (per gummy) | Tasty, vegan/gelatin-free options; easier for people who dislike pills; third-party tested options. | Gummies may include sugar; dosing inflexibility; often more expensive per mg. | Mantle D, Dybring A, 2020 |
| Thorne / Q-Best (Thorne CoQ10) | Ubiquinone (optimized absorption) | 100 mg gelcaps | Clinician-favored brand; clean labeling, high quality control; professional channel availability. | Pricier; often sold via practitioners. | Judy WV (2022) |
| Puritan's Pride — Q-Sorb / Q-SORB™ | Rapid-release CoQ10 formulations | 100–200 mg softgels | Very budget-friendly; large pack sizes; accessible. | Variable third-party testing; cheaper formulations may use lower-grade excipients. | Hernandez, M. L., et al. (2007) |
| Life-stage / fertility combos (e.g., FullWell, Needed, Garden of Life fertility formulas) | CoQ10 + antioxidants / omega-3 / vitamins | CoQ10 100–400 mg + other fertility ingredients | Formulated for fertility (improves oocyte quality in some studies); convenient multi-nutrient approach. | Harder to attribute effects to CoQ10 alone; costlier; check for clinical evidence and interactions (e.g., high vitamin A in pregnancy). | Jordan, V.,andShowell, M. G. (2020) |
| Mito-targeted alternatives summary (MitoQ repeated) | Mitoquinone | 10 mg daily, typical | MitoQ is intended for mitochondrial delivery; lower doses needed; distinct mechanism and clinical literature. | Not a direct substitute for CoQ10 in trials — consider mechanistic differences and check indications. | Jenkins, T. Carrell, D. T. (2019) |

## 2. Physiological distribution after intake

Following dietary or supplemental intake, Coenzyme $Q_{10}$ ($CoQ_{10}$) is absorbed in the small intestine, a process that requires the presence of dietary fat to facilitate its uptake due to its lipophilic nature. Once absorbed, it is incorporated into chylomicrons and transported through the lymphatic system before entering the bloodstream. In circulation, $CoQ_{10}$ is distributed primarily via plasma lipoproteins, including LDL, HDL, and VLDL, which act as carriers (Bhagavan and Chopra, 2006). Tissue uptake is greatest in organs with high energy demands, such as the heart, skeletal muscle, kidneys, and liver, reflecting its essential role in mitochondrial energy metabolism and antioxidant defense within these metabolically active tissues.

### 2.1. Pharmacokinetics of Coenzyme Q10

#### *2.1.1. Absorption*

Coenzyme $Q_{10}$ ($CoQ_{10}$) is a highly lipophilic and water-insoluble compound, which makes its intestinal absorption relatively slow and limited (Bhagavan and Chopra, 2006). Its absorption mechanism closely resembles that of dietary lipids and occurs mainly in the small intestine, particularly the jejunum and ileum. For efficient uptake, $CoQ_{10}$ requires emulsification by bile salts and the action of pancreatic enzymes, which facilitate the formation of micelles that can be absorbed by intestinal cells (Miles, 2007). Because of this dependence on lipid digestion, the absorption efficiency of $CoQ_{10}$ significantly improves when it is consumed along with dietary fats, highlighting the importance of formulation and dietary context for optimizing its bioavailability.

#### *2.1.2. Formulation impact*

Powder formulations of Coenzyme $Q_{10}$ ($CoQ_{10}$) generally have poor bioavailability due to the compound's lipophilic and water-insoluble nature, which limits its intestinal absorption. To overcome this limitation, oil-based capsules, emulsified preparations, and solubilized forms of ubiquinone or ubiquinol have been developed, all of which demonstrate significantly improved absorption and plasma bioavailability compared to standard powder forms (López-Lluch et al., 2010). These enhanced formulations are particularly important in clinical and therapeutic contexts, where achieving effective systemic levels of $CoQ_{10}$ is necessary for its bioenergetic and antioxidant benefits.

#### *2.1.3. Bioavailability issues*

The oral bioavailability of Coenzyme $Q_{10}$ ($CoQ_{10}$) in standard crystalline formulations is very low, typically estimated at only 2–3%, largely due to its poor water solubility and limited intestinal absorption. To address this challenge, advanced formulations such as solubilized preparations or nanoparticle-based delivery systems have been developed, which significantly enhance absorption efficiency. These improved systems can increase bioavailability by 2–5 fold compared to conventional crystalline $CoQ_{10}$, making them more effective in raising plasma and tissue levels for therapeutic use (Bhagavan and Chopra, 2006). This highlights the importance of formulation choice in ensuring optimal clinical outcomes with $CoQ_{10}$ supplementation.

### 2.2. Distribution

#### *2.2.1. Plasma transport*

After intestinal absorption, Coenzyme $Q_{10}$ ($CoQ_{10}$) is packaged into chylomicrons and transported through the lymphatic system before entering systemic circulation. Once in the bloodstream, it associates with circulating lipoproteins, which act as carriers for its distribution throughout the body. The majority of plasma $CoQ_{10}$ is bound to low-density lipoproteins (LDL), accounting for about 58–65%, while high-density lipoproteins (HDL) carry around 20–25% of the total $CoQ_{10}$ (Mohr et al., 1992). This lipoprotein-bound transport not only facilitates its delivery to tissues but also links $CoQ_{10}$ closely with lipid metabolism and cardiovascular health.

#### *2.2.2. Tissue distribution*

Coenzyme $Q_{10}$ ($CoQ_{10}$) is widely distributed throughout the body, but its highest concentrations are found in metabolically active tissues with a high density of mitochondria, such as the heart, kidneys, liver, and skeletal muscles. This distribution reflects its critical role in supporting cellular energy production in organs with high energy demands. Within cells, $CoQ_{10}$ is primarily localized in the inner mitochondrial membrane, where it functions as a key electron carrier in the respiratory chain, driving ATP synthesis. In addition, it is also present in other cellular membranes, including plasma membranes, where it contributes to antioxidant defense and membrane stabilization, further extending its protective and regulatory roles beyond mitochondrial energy metabolism.

*2.2.3. Physiological levels*

Under normal physiological conditions, plasma concentrations of Coenzyme $Q_{10}$ ($CoQ_{10}$) typically range between 0.4 and 1.9 μmol/L (Littarru and Tiano, 2007). However, tissue concentrations vary depending on metabolic activity, with the highest levels found in organs that have elevated energy demands. For example, the heart muscle, which relies heavily on continuous ATP production, can contain up to 114 μg of $CoQ_{10}$ per gram of tissue (Crane, 2001). This distribution pattern highlights the close relationship between $CoQ_{10}$ levels and energy metabolism, underscoring its vital role in maintaining optimal function in highly active tissues.

## 2.3. Metabolism

Coenzyme $Q_{10}$ ($CoQ_{10}$) exists in three distinct redox states that enable it to function both in energy production and as an antioxidant. These include ubiquinone, the fully oxidized form; semiquinone, a short-lived radical intermediate; and ubiquinol, the fully reduced form that serves as a powerful antioxidant. In human physiology, the majority of circulating $CoQ_{10}$, approximately 95%, is present in the reduced ubiquinol state, which reflects its critical role in protecting lipids, proteins, and membranes from oxidative damage while simultaneously participating in mitochondrial electron transport (Kagan et al., 1990). This dynamic redox flexibility is central to its dual bioenergetic and protective functions.

*2.3.1. Conversion and recycling*

Coenzyme $Q_{10}$ ($CoQ_{10}$) continuously cycles between its oxidized form (ubiquinone) and reduced form (ubiquinol), a process essential for its dual role in cellular function. In the mitochondrial electron transport chain, this redox cycling allows $CoQ_{10}$ to shuttle electrons between complexes, enabling efficient ATP production. At the same time, the conversion to ubiquinol equips it with strong antioxidant properties, allowing it to neutralize reactive oxygen species and regenerate other antioxidants such as vitamin E. This constant redox interconversion ensures that $CoQ_{10}$ simultaneously supports cellular energy metabolism and protects against oxidative stress, highlighting its importance as both a bioenergetic cofactor and an antioxidant defense molecule.

*2.3.2. Hepatic metabolism*

Coenzyme $Q_{10}$ ($CoQ_{10}$) is primarily metabolized in the liver, where it undergoes reduction and various modification processes. During this metabolism, it is converted into derivatives such as $CoQ_{10}$-acids and $CoQ_{10}$-alcohols, which are then conjugated to increase their solubility. These conjugated metabolites are ultimately excreted from the body, mainly through the biliary route and to a lesser extent via urine. This metabolic pathway ensures proper turnover of $CoQ_{10}$ while maintaining homeostasis, allowing the body to regulate its levels in tissues and circulation.

## 2.4. Excretion

The primary route of Coenzyme $Q_{10}$ ($CoQ_{10}$) elimination is through fecal excretion, as its metabolites are secreted via the bile into the gastrointestinal tract. In contrast, urinary excretion plays only a minimal role, with only trace amounts of $CoQ_{10}$ detected in urine. One notable pharmacokinetic feature of $CoQ_{10}$ is its relatively long plasma half-life, which ranges from approximately 33 to 65 hours depending on the formulation used and the dosing regimen (Bhagavan and Chopra, 2006; Miles, 2007). This extended half-life makes it possible to administer $CoQ_{10}$ in a once-daily dosing schedule for most therapeutic applications, improving patient compliance and ensuring steady plasma levels for clinical effectiveness.

## 2.5. Factors Affecting Pharmacokinetics

Several factors influence the absorption and overall bioavailability of Coenzyme $Q_{10}$ ($CoQ_{10}$). Formulation plays a major role, as solubilized forms of ubiquinone or ubiquinol show much higher bioavailability compared to standard crystalline powders. Co-administration with food, particularly fat-containing meals, further enhances absorption because $CoQ_{10}$ is a lipophilic compound. Physiological factors also contribute: endogenous biosynthesis naturally declines with age, leading to reduced tissue levels, while various disease states such as cardiovascular disorders, neurodegenerative conditions, and diabetes are often associated with lower $CoQ_{10}$ concentrations. Drug interactions are another important consideration—statins, for example, decrease endogenous $CoQ_{10}$ synthesis by inhibiting the mevalonate pathway, while certain β-blockers, tricyclic antidepressants, and antihypertensive medications have also been reported to interfere with $CoQ_{10}$ levels. These combined influences highlight the need to optimize supplementation strategies for effective therapeutic outcomes.

## 2.6. Herbal (Plant-Based) Sources of Coenzyme Q10

Dietary intake of Coenzyme $Q_{10}$ ($CoQ_{10}$) in a typical diet is relatively low, averaging around 3–6 mg per day, with the majority coming from animal-based foods such as meat, fish, and poultry. However, individuals following plant-based diets can still obtain about 2–5 mg per day when their diet is optimized with $CoQ_{10}$-rich plant sources like nuts, seeds, soy products, and certain vegetable oils (table 1). While these dietary amounts contribute to maintaining baseline plasma and tissue levels, they remain far below the higher doses required for therapeutic purposes, which are usually achieved through supplementation.

## 2.7. Main Herbal/Plant Sources

### *2.7.1. Vegetable oils*

Vegetable oils are among the richest plant-based sources of Coenzyme $Q_{10}$ ($CoQ_{10}$), as its fat-soluble nature allows it to accumulate in lipid-rich foods. Oils such as soybean, canola, corn, and olive oil are particularly significant contributors, with typical concentrations ranging from 0.5 to 3 mg per 100 g of oil, which translates to about 0.1–0.5 mg per tablespoon. The method of processing also influences $CoQ_{10}$ content, as extra-virgin and cold-pressed oils tend to retain higher levels compared to refined oils, where heat and chemical treatments may reduce their concentration. This makes minimally processed oils an important dietary source of plant-derived $CoQ_{10}$, especially for individuals relying on vegetarian or vegan diets.

**Table 2** Plant Sources / Extracts of CoQ10, Preclinical and Clinical Evidence with References

| Plant / Extract / Isolate | What it is / how obtained | Preclinical studies (model and key finding) | Clinical studies / human data | References |
|---|---|---|---|---|
| Edible oils (soybean, canola, sesame, olive) | Contain CoQ10 naturally; levels vary by oil and processing | Analytical studies show measurable CoQ10, higher in cold-pressed oils | No large RCTs testing oils directly; clinical trials use isolated CoQ10 | Xu et al., 2022; Parmar et al., 2021 ; Testai et al., 2021 |
| Nuts and seeds (peanut, pistachio, sesame, sunflower) | Natural food sources with moderate CoQ10 | Documented in food-composition and biosynthesis reviews | No direct RCTs; supplementation trials rely on purified CoQ10 | Xu et al., 2022 ; Parmar et al., 2021 ; Testai et al., 2021 |
| Leafy greens and crucifers (spinach, broccoli) | Low–moderate CoQ10; studied for biofortification | Plant biotech attempts to increase CoQ10 content in tissues | No direct clinical trials using vegetables as an intervention | Xu et al., 2022 ; Zhu et al., 2022 |
| Tomato — engineered high-CoQ10 | Transgenic tomato lines with elevated CoQ10 | Engineered lines show increased CoQ10 (proof of concept) | No human feeding studies yet | Zhu et al., 2022 |
| Plant-derived isolates/cell cultures | Extraction or metabolic engineering for CoQ10 production | Reviews describe the feasibility of plant-based CoQ10 production; antioxidant activity tested in cell/animal models | Clinical CoQ10 trials use purified forms (microbial/chemical), not directly from plant cell cultures | Parmar et al., 2021 ; Zhou et al., 2021 |
| CoQ10 phytosome (phospholipid complex) | Formulated with plant-derived phospholipids to improve absorption | Preclinical PK studies show improved bioavailability | RCT: CoQ10 phytosome improved fatigue/physical performance in older adults | Fogacci et al., 2024 |
| CoQ10 + plant extracts (e.g., Ginkgo) | Combination nutraceuticals | Preclinical animal/cell models suggest additive antioxidant effects | Small open-label/clinical studies show QoL improvements, but limited evidence | Stojković et al., 2022 ; Silva et al., 2022 |
| Purified CoQ10 (reference) | Isolated ubiquinone/ubiquinol (synthetic or microbial) | Extensive antioxidant/mitochondrial protection in preclinical models | Multiple RCTs: mitochondrial disorders, migraine, HF, statin myopathy; meta-analyses show benefit in glycemic control and CV outcomes | DiMauro et al., 2022 ; Liang et al., 2022 , Testai et al., 2021 |

*2.7.2. Nuts and Seeds*

Nuts and seeds are valuable plant-based sources of Coenzyme $Q_{10}$ ($CoQ_{10}$), making them especially useful for individuals following vegetarian or vegan diets. Varieties such as peanuts, pistachios, sesame seeds, sunflower seeds, walnuts, and hazelnuts contain between 0.5 and 3 mg of $CoQ_{10}$ per 100 g, depending on the type. For example, a standard 30 g serving of pistachios or peanuts can provide approximately 0.3–0.8 mg of $CoQ_{10}$, contributing meaningfully to daily intake. Beyond being convenient snack options, nuts and seeds combine $CoQ_{10}$ with other beneficial nutrients like healthy fats, protein, and antioxidants, making them an excellent dietary choice for supporting both general health and $CoQ_{10}$ levels.

*2.7.3. Legumes and Soy Products*

Soy-based foods such as soybeans, tofu, tempeh, and soy milk are important plant sources of Coenzyme $Q_{10}$ ($CoQ_{10}$), particularly in diets where soy products are consumed regularly as staples. Among these, soybeans are especially notable for their contribution, while the processing method significantly influences the final $CoQ_{10}$ content. Fermented soy products like tempeh tend to preserve higher levels of $CoQ_{10}$ compared to more refined products such as soy milk or tofu, where some loss can occur during processing. As a result, incorporating whole or minimally processed soy products can provide a more reliable contribution to dietary $CoQ_{10}$ intake, making them a useful option for individuals following plant-based or vegetarian diets.

*2.7.4. Whole Grains / Cereals*

Whole grains such as wheat germ, oats, rye, and rice bran contain measurable but relatively lower amounts of Coenzyme $Q_{10}$ ($CoQ_{10}$) compared to richer sources like oils, nuts, or animal products. Although the contribution from grains is modest, it becomes meaningful in diets where cereals and grain-based foods form a major component of daily intake. Since these grains are often consumed in substantial quantities, their cumulative effect can help support overall $CoQ_{10}$ levels, particularly in populations that rely heavily on plant-based staples. Thus, while not the richest sources, grains still play a supplementary role in maintaining adequate dietary $CoQ_{10}$.

*2.7.5. Vegetables and Fruits*

Fruits and vegetables such as broccoli, cauliflower, spinach, grapes, oranges, and strawberries contain measurable but relatively small amounts of Coenzyme $Q_{10}$ (generally less than 1 mg per serving). While their individual contribution is minor compared to richer plant sources like oils and nuts, they can still play a supportive role in overall dietary intake, especially in plant-based or vegetarian diets. Since these foods are commonly consumed in large quantities as part of a balanced diet, their cumulative contribution helps enhance total $CoQ_{10}$ levels, adding to the nutritional diversity and antioxidant support provided by other sources.

*2.7.6. Culinary and Medicinal Herbs*

Common culinary and medicinal herbs such as basil, oregano, parsley, green tea leaves, and ginseng contain only trace amounts of Coenzyme $Q_{10}$, which are negligible when consumed in typical dietary portions. Although laboratory analyses confirm the presence of $CoQ_{10}$ in leaves and roots, the concentrations are far too low to make a meaningful contribution compared with richer plant sources like oils, nuts, and legumes. The health-promoting properties of medicinal herbs such as ginseng or ashwagandha are largely due to other bioactive compounds (e.g., ginsenosides, withanolides) rather than their minimal $CoQ_{10}$ content, making them supplementary rather than primary contributors to dietary $CoQ_{10}$ intake.

### 2.8. Bioavailability

Coenzyme $Q_{10}$ is a fat-soluble compound, which means its absorption in the body is significantly enhanced when consumed with dietary fats. This is why oils are not only good sources of $CoQ_{10}$ themselves but also aid in improving the bioavailability of $CoQ_{10}$ from other foods. However, food processing can greatly influence its content—refining oils, excessive heating, or overcooking vegetables may reduce $CoQ_{10}$ levels, lowering their nutritional contribution. To overcome these limitations, fortification strategies such as nanoemulsions, micelles, and water-dispersible formulations are being explored, particularly in plant-based foods, to increase $CoQ_{10}$ intake and absorption in individuals following vegetarian or vegan diets.

## 3. Conclusion

CoQ10 supplementation offers meaningful support for energy metabolism and cardiovascular health, but product choice should be guided by both clinical context and patient needs. Ubiquinol formulations, such as Qunol, may provide superior absorption for older adults or individuals with reduced conversion efficiency, though at a higher cost.

Ubiquinone formulations, including Thorne's Q-Best with optimized delivery systems, remain a reliable and well-studied option, particularly when sourced from high-quality brands with rigorous testing. Ultimately, balancing factors such as bioavailability, price, accessibility, and practitioner oversight allows for more personalized and effective CoQ10 use in clinical and consumer settings.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest to be disclosed.

## References

[1] Alcázar-Fabra M, Trevisson E, Brea-Calvo G. Clinical syndromes associated with coenzyme Q10 deficiency. Essays Biochem. 2018;62(3):377–398.

[2] Bentinger, M., Brismar, K., and Dallner, G. (2007). The antioxidant role of coenzyme Q. Mitochondrion, 7 Suppl, S41–S50. [PubMed](https://pubmed.ncbi.nlm.nih.gov/17234331/)

[3] Bhagavan HN, Chopra RK. Coenzyme Q10: Absorption, tissue uptake, metabolism, and pharmacokinetics. Free Radic Res. 2006;40(5):445–453.

[4] Bhagavan HN, Chopra RK. Plasma coenzyme Q10 response to oral ingestion: A review. Free Radic Res. 2006;40(5):445–453.

[5] Bhagavan, H. N.,andChopra, R. K. (2006). Coenzyme Q10: Absorption, tissue uptake, metabolism, and pharmacokinetics. Free Radical Research, 40(5), 445–453. [PubMed](https://pubmed.ncbi.nlm.nih.gov/16522929/)

[6] Campisi, L., et al. (2022). The use of Coenzyme Q10 as a food supplement: A review. Nutrients. [https://doi.org/10.3390/nu14163357] (https://doi.org/10.3390/nu14163357)

[7] Clarke, C. F. (2001). Coenzyme Q: From biosynthesis to therapeutics. Clinical Biochemistry, 34(5), 341–345. [PubMed](https://pubmed.ncbi.nlm.nih.gov/11421284/)

[8] Crane FL. Biochemical functions of coenzyme Q10. J Am Coll Nutr. 2001;20(6):591–598.

[9] Crane, F. L. (2001). Biochemical functions of coenzyme Q10. Journal of the American College of Nutrition, 20(6), 591–598. [PubMed](https://pubmed.ncbi.nlm.nih.gov/11437459/)

[10] Deichmann R, Lavie C, Andrews S. Coenzyme Q10 and statin-induced mitochondrial dysfunction. Ochsner J. 2010;10(1):16–21.

[11] Hernández-Camacho JD, Bernier M, López-Lluch G, Navas P. Coenzyme Q10 supplementation in aging and disease. Front Physiol. 2018;9:44.

[12] Hernández-Camacho, J. D., Bernier, M., López-Lluch, G., y Navas, P. (2018). Coenzyme Q10 supplementation in aging and disease. Frontiers in Physiology, 9, 44. [PubMed](https://pubmed.ncbi.nlm.nih.gov/29116177/)

[13] Kagan VE, et al. Recycling of ubiquinol and ubiquinone in mitochondria. Free Radic Biol Med. 1990;9(2):117–126.

[14] Lenaz G, Genova ML. Structure and organization of mitochondrial respiratory complexes: A new understanding of coenzyme Q10 role. FEBS Lett. 2010;584(14):1795–1801.

[15] Linus Pauling Institute – Micronutrient Information Center. Coenzyme Q10 (Dietary Sources and Health Effects). Oregon State University.

[16] Littarru GP, Tiano L. Clinical aspects of coenzyme Q10: An update. Nutrition. 2007;23(7-8):722–740.

[17] Littarru, G. P.,andTiano, L. (2010). Clinical aspects of coenzyme Q10: An update. Nutrition, 26(3), 250–254. [PubMed](https://pubmed.ncbi.nlm.nih.gov/20001727/)

[18] López-Lluch G, Del Pozo-Cruz J, Sánchez-Cuesta A, Cortés-Rodríguez AB, Navas P. Bioavailability of coenzyme Q10 supplements depends on carrier lipids and solubilization. Nutrition. 2010;26(10):1082–1086.

[19] Mattila P, Kumpulainen J. Coenzymes Q9 and Q10: Contents in foods and dietary intake. J Food Comp Anal. 2000;13(4):409–417.

[20] Miles MV. The uptake and distribution of coenzyme Q10. Mitochondrion. 2007;7\:S72–S77.

[21] Mohr D, et al. Plasma concentrations of ubiquinol-10 and ubiquinone-10 in humans. Biochem Biophys Res Commun. 1992;187(1):335–340

[22] Pravst, I., Žmitek, K.,andŽmitek, J. (2010). Coenzyme Q10 contents in foods and fortification strategies. Critical Reviews in Food Science and Nutrition, 50(4), 269–280. [https://doi.org/10.1080/10408390902773037](https://doi.org/10.1080/10408390902773037)

[23] SciPub Review. (2016). Coenzyme Q10 and its effective sources

[24] StatPearls. (2023). Coenzyme Q10. National Center for Biotechnology Information. [NCBI Bookshelf](https://www.ncbi.nlm.nih.gov/books/NBK531491/)

[25] Turunen M, Olsson J, Dallner G. Metabolism and function of coenzyme Q. Biochim Biophys Acta. 2004;1660(1-2):171–199.

[26] Weber C, Bysted A, Hølmer G. Coenzyme Q10 in the diet–daily intake and relative bioavailability. Mol Aspects Med. 1997;18:251–254.

[27] Xu, J., et al. (2022). Engineering plant biosynthesis of coenzyme Q10. Current Biology.