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Extraction, Purification and Quantification of Quercetin from Different Sources with Insights into Economic Significance

Siddharth Joshi* **and Rutu J Kothari**

Department of Bioprocessing and Biotechniques, SRM Institute of Science and Technology, Tamil Nadu, India

Abstract

This study explores the extraction, purification and quantification of quercetin from various natural sources, including fruits, vegetables and medicinal plants. Utilizing solvent extraction, followed by chromatographic techniques, we achieved high purity and yield of quercetin, assessed through UV-Vis spectroscopy. Our findings indicate that sources like onions and apples yield significant amounts of quercetin, highlighting their potential as natural supplements. Economic analysis reveals that quercetin's growing market demand, driven by its antioxidant properties and health benefits, presents lucrative opportunities for agricultural producers and the nutraceutical industry. By identifying optimal extraction methods and sources, this research underscores the importance of quercetin in both health promotion and economic development. These insights could inform future studies and commercial ventures aimed at enhancing the availability and application of this valuable flavonoid.

Keywords: Quercetin • Extraction • Purification • Quantification • Natural sources

Introduction

In an age where health and well-being have become paramount concerns, the quest for natural remedies and preventive measures has taken center stage. Nutraceuticals, a class of bioactive compounds derived from natural sources, have emerged as a promising frontier in the field of healthcare. Harnessing the healing power of nature, nutraceuticals offer a holistic approach to promoting health and preventing diseases, presenting a unique blend of nutrition and pharmaceutical benefits. Among these compounds, quercetin has captured significant attention due to its multifaceted health benefits and therapeutic potential [1].

Quercetin, a flavonoid abundantly found in fruits, vegetables and other plant-based foods, has been extensively studied for its diverse medicinal properties. From antioxidant and anti-inflammatory effects to its role in supporting cardiovascular health and immune function, quercetin has earned its reputation as a potent nutraceutical. Beyond its inherent benefits, the isolation of quercetin from natural sources has spurred an intriguing supply and demand dynamic within the market economy, driving both scientific research and commercial interest [2].

This paper delves into the significance of nutraceuticals in modern healthcare, focusing on the extraordinary properties of quercetin and its journey from natural sources to isolated compounds in the market economy. By examining the importance of nutraceuticals and the complexities surrounding quercetin's supply and demand, we aim to shed light on the potential impact of these bioactive substances on human health and their role in shaping the evolving landscape of healthcare and commerce [3]. Ultimately, this exploration seeks to underscore the importance of integrating nature's healing power into our lives while navigating the intricacies of the market economy in a responsible and sustainable manner [4].

Materials and Methods

Nutraceuticals

The term “nutraceutical” combines the two words “nutrient,” which is a nourishing food component and “pharmaceutical,” which is a medical drug. Nutraceutical products can be considered non-specific biological therapies used to promote general well-being, control symptoms and prevent malignant processes. Their role in human nutrition is one of the most important areas of investigation, with wide-

***Address for Correspondence:** *Siddharth Joshi, Department of Bioprocessing and Biotechniques, SRM Institute of Science and Technology, Tamil Nadu, India, Tel: 919916473064; E-mail: siddharthjoshi.bt20@rvce.edu.in*

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ranging implications for consumers, healthcare providers, regulators, food producers and distributors. These products can be classified on the basis of their natural sources, pharmacological conditions, as well as the chemical constitution of the products [5]. Over the past several years, nutraceuticals have attracted considerable interest due to their potential nutritional, safety and therapeutic effects. These products could have a role in a plethora of biological processes, including antioxidant defenses, cell proliferation, gene expression and safeguarding of mitochondrial integrity. Nutraceuticals are also known to improve health, prevent chronic diseases, postpone the aging process and in turn increase life expectancy or just support the functions and integrity of the body [6].

Quercetin

Quercetin, deriving its name from the Latin term "Quercetum," meaning Oak Forest, belongs to the class of flavonoids that cannot be synthesized within the human body. This yellow-hued compound exhibits unique solubility characteristics, being poorly soluble in hot water, quite soluble in alcohol and lipids and insoluble in cold water. Widely acclaimed as one of the most utilized bioflavonoids for treating metabolic and inflammatory disorders, quercetin is a natural flavonoid found abundantly in vegetables and fruits. As a dietary polyphenolic compound, quercetin holds great promise for its potential beneficial effects on health. Extensive research has primarily focused on uncovering quercetin's remarkable antioxidant properties, its interactions with various enzyme systems and its profound influence on essential biological pathways linked to carcinogenesis, inflammation and cardiovascular diseases [7]. Functioning as a versatile antioxidant, quercetin safeguards against tissue injury induced by diverse drug toxicity, thus imparting a host of beneficial antioxidant attributes, including cardiovascular protection, anticancer potential, antitumor properties, anti-ulcer effects, allergy relief, antiviral activity, anti-inflammatory action, anti-diabetic effects, gastro protective benefits, antihypertensive qualities, immunomodulatory effects and anti-infective properties [8].

Structure of quercetin

Quercetin's chemical structure, also known as 3,3',4',5,7-pentahydroxyflavone, falls within the flavonol subclass of flavonoids. This polyphenolic compound possesses five hydroxyl groups attached to the flavone backbone [9]. These hydroxyl groups contribute to quercetin's potent antioxidant properties and play a vital role in determining its diverse biological activities. As a result, quercetin's molecular structure underpins its versatility and valuable role in promoting human health (Figure 1).

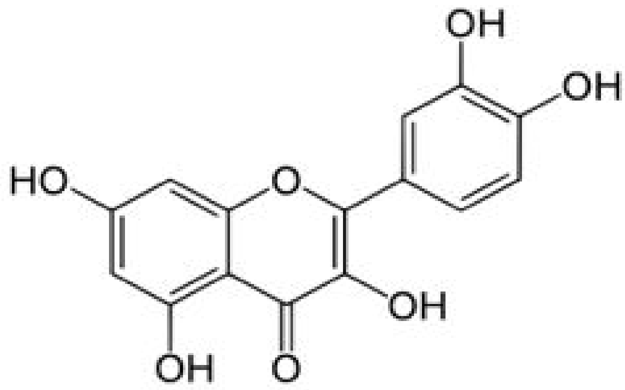

Figure 1. Quercetin chemical structure.

Sources of quercetin

A diet centered around these quercetin-rich foods help incorporate a well-balanced diet which not only supports our health but also adds a delightful variety of flavors and textures to our culinary experiences. By savoring the goodness of nature's quercetin-filled offerings, we can take a proactive step towards nurturing our bodies and enjoying a more vibrant and energetic lifestyle.

- Onions: Onions, particularly red onions, are rich in quercetin. They are among the most abundant sources of this flavonoid.
- Apples: Apples, especially the skin, contain quercetin. Red and purple apples tend to have higher concentrations of this compound.
- Berries: Berries like cranberries, blueberries, raspberries and blackberries are good sources of quercetin.
- Citrus fruits: Citrus fruits such as oranges, grapefruits, lemons and limes contain quercetin, though in smaller amounts compared to other sources.
- Leafy greens: Dark leafy greens like kale, spinach and broccoli are known for their quercetin content.
- Tomatoes: Tomatoes, especially in their uncooked form, are a source of quercetin.
- Red grapes: Red grapes and red wine (in moderation) contain quercetin.
- Green tea: Green tea is a beverage that contains quercetin, among other beneficial compounds.

Importance properties of quercetin

Antioxidant properties: Quercetin's primary role lies in its powerful antioxidant capabilities. As an antioxidant, it acts as a scavenger, neutralizing harmful free radicals in the body. Free radicals are unstable molecules that can damage cells and contribute to oxidative stress. Prolonged oxidative stress has been associated with a range of chronic diseases, as well as the aging process itself. Quercetin's ability to combat free radicals makes it a valuable ally in promoting cellular health and reducing the risk of age-related conditions.

Anti-inflammatory effects: In addition to its antioxidant prowess, quercetin also possesses anti-inflammatory properties. Chronic inflammation is a key factor in the development of various health issues, including cardiovascular diseases, diabetes and certain cancers. Quercetin's anti-inflammatory effects have shown promise in reducing inflammation and its related detrimental effects. By calming the body's inflammatory response, quercetin may contribute to safeguarding against a spectrum of chronic conditions [10].

Immune system support: The immune system plays a critical role in defending the body against infections and diseases. Quercetin has been found to have immunomodulatory effects, which means it can regulate the immune response. Studies suggest that quercetin may help boost the immune system's overall function, making it more effective in fending off pathogens. Additionally, its ability to modulate the immune response may offer potential benefits in autoimmune disorders, providing a balanced immune reaction.

Cardiovascular health: Several studies have investigated quercetin's impact on cardiovascular health. Evidence suggests that it can improve blood vessel function, reduce blood pressure and enhance overall heart health. By promoting healthy blood flow and reducing the risk of endothelial dysfunction, quercetin may contribute to a reduced incidence of heart disease and related complications [11].

Allergy relief: Seasonal allergies can be bothersome and disruptive to daily life. Quercetin has been studied for its potential to alleviate allergy symptoms. It can inhibit the release of histamine, a compound involved in allergic responses. As a result, quercetin may provide a natural alternative to conventional antihistamine medications, offering relief from sneezing, itching and other allergy symptoms.

Potential cancer protection: While the research is still in its early stages, there is growing interest in quercetin's potential as a cancer-fighting compound. Studies have indicated that quercetin may help inhibit the growth of certain cancer cells and reduce the risk of tumor formation. Although more research is needed to establish its efficacy, the early findings are promising and warrant further investigation [12].

Neuroprotective effects: The brain's health and function are essential for overall well-being. Quercetin has demonstrated neuroprotective effects in various studies, showing its potential to protect nerve cells from damage and inflammation. As such, quercetin's neuroprotective properties may have implications in supporting brain health and potentially reducing the risk of neurodegenerative diseases.

Quercetin extraction

The extraction of quercetin from various sources is done to obtain this beneficial compound in its pure form. Quercetin is a powerful antioxidant found in onions that offers various health benefits, such as reducing inflammation and protecting against certain diseases. By extracting quercetin, researchers and manufacturers can study its properties and create standardized products like supplements and medicines with consistent doses. This process also helps improve quercetin's absorption in the body. Overall, quercetin extraction from onions is crucial for advancing health research and developing products that promote well-being [13].

Onions are the best source for quercetin extraction

Onions are considered one of the best sources for extracting quercetin due to their high quercetin content and easy availability. They contain significant amounts of this bioactive compound, making them an efficient and cost-effective source for extraction. Additionally, onions are commonly consumed in various cuisines worldwide, which means they are widely cultivated and readily accessible. The abundance of quercetin in onions allows for large-scale extraction, making it feasible for commercial applications in industries like pharmaceuticals, nutraceuticals and functional foods. Moreover, onion peelings, which are often discarded as waste, can be utilized for quercetin extraction, promoting sustainability and reducing environmental impact. The combination of high quercetin content, widespread availability and sustainable use makes onions an ideal choice for obtaining this valuable compound [14].

Methodology for extracting quercetin

Objective: To extract quercetin in its purest form from onions and optimize the process for maximum yield and efficiency.

Materials required:

- Dried onion peelings
- Red onion peels
- Spring onion peels
- Edible red onion parts
- Distilled water and Ice
- Ethyl acetate and Methanol
- Four layers of cheesecloth
- Separating funnel
- Rotary evaporator
- UV spectroscopy equipment

Procedure for quercetin extraction:

- Collect dried onion peelings and cut them into small pieces to increase the surface area for extraction.
- Take about 2 g of the chopped onion peelings and mix them with 50 ml of distilled water in a beaker.
- Heat the mixture at a temperature of 80°C for 15 to 30 minutes to facilitate extraction. This step allows the quercetin compounds to dissolve into the water.
- After heating, cool the extract on ice to prevent degradation of the quercetin compound.
- Filter the cooled extract through four layers of cheesecloth to remove any solid residues and obtain a clear supernatant.
- For quercetin extraction, add an equal volume of ethyl acetate in a separating funnel containing the clear supernatant.
- Perform thorough mixing through liquid-liquid extraction. Take care while shaking the funnel and vent the separating funnel every 2 times of shaking to relieve vapor pressure.

- Allow the mixture in the separating funnel to undergo phase separation for about 10 minutes without disturbing it, placing the funnel on a tripod to ensure stability.
- Collect the ethyl acetate layer, which contains the extracted quercetin, from the separating funnel.
- Subject the collected ethyl acetate layer to concentration using a rotary evaporator at a temperature of 55°C. This process evaporates the solvent, leaving behind a more concentrated quercetin solution [15].
- After evaporation, it is possible to obtain crude quercetin in the form of a powder or semi-solid in the RB flask from the rotary evaporator.
- To detect quercetin, solubilize the crude quercetin in a minimal volume of methanol (2 ml). Perform UV spectroscopy at a wavelength of 360 nm to identify and quantify the presence of quercetin in the solution (Figure 2).

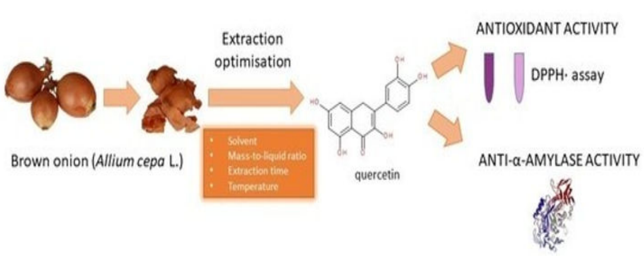

Figure 2. Outline of the procedure for extracting quercetin from onions.

Solvent used in the extraction of quercetin

Ethyl acetate is commonly used as a solvent in the extraction of quercetin and other bioactive compounds from plant materials, including onion peels, due to several reasons:

- Selectivity and solubility: Ethyl acetate has a moderate polarity, making it an effective solvent for extracting a wide range of compounds. It can selectively dissolve a variety of polar and nonpolar compounds, including phenolic compounds like quercetin. This allows for efficient extraction of quercetin while minimizing interference from other components present in the onion peels.
- Non-polar nature of quercetin: Quercetin is a flavonoid compound with a relatively non-polar structure due to the presence of hydrophobic aromatic rings. Ethyl acetate's intermediate polarity allows it to effectively dissolve and extract such non-polar compounds.
- Low toxicity and volatility: Ethyl acetate is considered a relatively safe solvent. It has low toxicity and is less harmful than some other commonly used organic solvents. Its moderate volatility also aids in the extraction process by evaporating quickly after extraction, leaving behind the extracted compounds.
- Compatibility with analytical techniques: Extracted quercetin is often analyzed using techniques like High-Performance Liquid Chromatography (HPLC) or UV-visible spectrophotometry. Ethyl acetate is compatible with these techniques and doesn't interfere significantly with the analysis.
- Ease of removal: After extraction, ethyl acetate can be easily removed from the extract using techniques like evaporation under reduced pressure or rotary evaporation. This leaves behind the extracted quercetin, which can be further purified or used for analysis.
- Economic and availability: Ethyl acetate is commercially available, cost-effective and widely used in laboratories for various extraction purposes. Its availability contributes to its popularity as a solvent for quercetin extraction.

Testing of *in-vitro* antioxidant activity by using DPPH method

DPPH free radical method is an antioxidant assay which assesses how effective quercetin is at neutralizing harmful free radicals, which can cause cell damage and oxidative stress. In the test, a solution of DPPH, a dark purple color, is prepared and when quercetin is added, it reacts with the DPPH radicals, resulting in a color change from dark purple to pale yellow. The extent of this color change is measured using a spectrophotometer, giving us the absorbance value, which indicates the antioxidant activity.

A lower absorbance value implies higher antioxidant capacity, suggesting that quercetin has the potential to protect cells from oxidative damage and promote overall health (Figure 3).

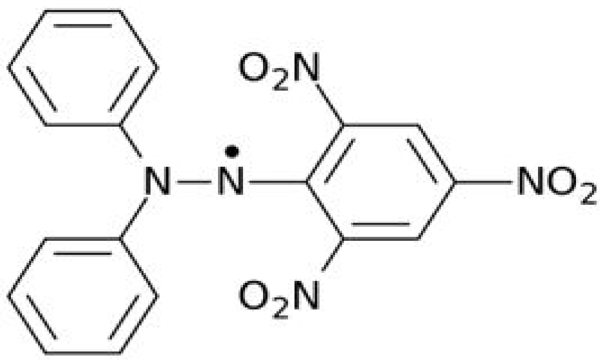

Figure 3. 2,2-diphenyl-1-picrylhydrazyl-hydrate (DPPH) chemical structure.

Procedure for preparation of calibration curve using DPPH assay:

- Stock solution of DPPH was made by adding 1 mg of DPPH to 25 ml of distilled water.
- A 1000 µmol stock solution of quercetin was prepared by adding 9.1 mg of quercetin in 30 ml distilled water (Tables 1 and 2).
- 2 ml,4 ml,6 ml and 8 ml respectively of Quercetin stock was added to 4 different test tubes.
- 8 ml,6 ml,4 ml and 2 ml of distilled water was added respectively to each tube to form concentrations of 200,400,600 and 800 µmol solution of Quercetin.
- Centrifuge all tubes at 10,000 rpm for 30 mins at 15 degrees.
- After centrifugation, 5 ml of supernatant of each 200,400,600 and 800 µmol solution was taken and to each test tube 1 ml of DPPH stock solution was added.

- The solution was incubated for 30 mins in the dark.
- Absorbance was observed at 517 nm and a calibration plot was constructed.
- Use a sample of 0.5 mg of DPPH in 12 ml ethanol was observed taking ethanol as blank
- From the absorbance values of the quercetin concentration, it was found that 400 µmol was the optimum concentration as any concentration above that would not follow Beer Lambert's law (Figures 4 and 5).

Identification using UV spectroscopy

Table 1. DPPH calibration.

Quercetin stock solution (ml)	Distilled water (ml)	Concentration (µmol)	Absorbance 517 nm
0	10	0	0.004
2	8	200	0.121
4	6	400	0.253
6	4	600	0.361
8	2	800	0.482
10	0	1000	0.62

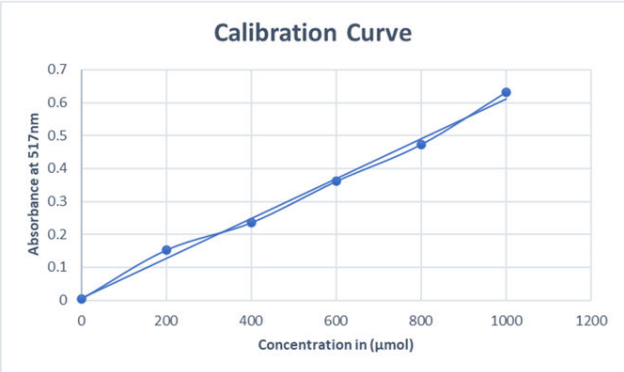

Figure 4. Calibration curve.

Table 2. Observation table.

Type	Absorbance 360 nm	Concentration from the graph (µmol)
Red onion peels	0.482	750
Edible part of red onion	0.251	400
Spring Onion	0.396	600

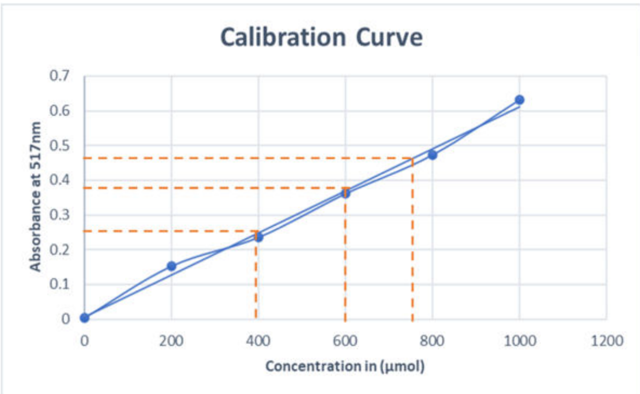

Figure 5. Graph to find the concentration of quercetin.

Results

Based on the data from the DPPH test and the calibration graph, the effectiveness of quercetin as an antioxidant can be assessed by comparing the absorbance values at 360 nm and the corresponding concentrations. A lower absorbance value indicates a higher antioxidant capacity, as it suggests that quercetin is more efficient at neutralizing the DPPH radicals.

In this case, the red onion peels have an absorbance of 0.482 at 360 nm, corresponding to a concentration of 750 µmol. The edible part of red onion has an absorbance of 0.251 at 360 nm, corresponding to a concentration of 400 µmol. Lastly, spring onion has an absorbance of 0.396 at 360 nm, corresponding to a concentration of 600 µmol.

Comparing the absorbance values, the edible part of red onion appears to have the highest antioxidant capacity, as it has the lowest absorbance value among the three samples. Red onion peels and spring onion also show antioxidant activity, but they have slightly higher absorbance values than the edible part of red onion.

However, it's important to note that further studies and additional samples may be required for more conclusive results.

Estimating the total phenolic content from onion peels

Phenolics include simple phenols, phenolic acid (benzoic and cinnamic acid derivatives), coumarins, flavonoids, stilbenes, hydrolyzable and condensed tannins, ligase and lignins. They act as phytoalexins, attract pollinators and contribute to plant pigmentation, antioxidants and protective agents against UV light among others. Polyphenols in plants react with redox reagents (FC reagent) to from blue complex, which can be quantified at 725 nm. Gallic acid was used for constructing standard curve; results were expressed as μg of gallic acid equivalents/mg of extract.

Materials required: Onion peels (red onion peels, spring onion peels, edible part of red onions), 80% methanol, Standard Gallic acid (100 μg/ml), Folin Ciocalteau (FC) reagent, 5% Sodium Carbonate (Na_2CO_3), centrifuge, centrifuge tubes, test tubes, distilled water and colorimeter.

Preparation of the standard

- Pipette out different aliquots of standard Gallic acid stock solution (30 μg/ml) ranging from 0.0 to 1.0 ml into different test tubes. Make up the volume to 1.0 ml in each test tube with distilled water.
- Add 0.5 ml of FC reagent, mix by inversion and incubate in the dark for 5 min at room temp.
- Add 1 ml 5% $NaCO_3$ solution, mix well and incubate at room temperature for 5 min.
- Measure the absorbance of the solution at 725 nm.
- The graph was plotted with a concentration of gallic acid on the X-axis and optical density on the Yaxis and a calibration graph was drawn

Preparation of the sample

- Homogenize the different onion peels with 80% methanol.
- Centrifuge at 6000 rpm for 5 min at RT.
- Collect supernatant up to 1 ml, add 0.5 ml of FC reagent, mix by inversion and incubate in the dark for 5 min at room temp.
- Add 1 ml 5% Na_2CO_3 solution, dilute the leaf sample only by adding 5 ml of DDW, mix well and incubate at room temperature for 5 min.
- Measure the absorbance of the solution at 725 nm.
- The total amount of total phenolics is estimated using gallic acid as a standard curve (Figure 6).

Identification using UV Spectroscopy

Concentration of standard gallic acid stock solution: 30 μg/ml (Tables 3-5).

Table 3. Observation table.

Concentration of standard (μg/ml)	Volume of standard (ml)	Volume of distilled water (ml)	O.D. at 725 nm
0	0	1	0
6	0.2	0.8	0.172
12	0.4	0.6	0.372
18	0.6	0.4	0.746
24	0.8	0.2	0.806
30	1	0	1.036

Table 4. Observation table for the samples.

Samples	O.D. at 725 nm	Concentration from the standard graph (μg/ml)
Red onion peels	0.69	20.9
Spring onion peels	0.52	15.9
Edible part of red onion	0.265	11

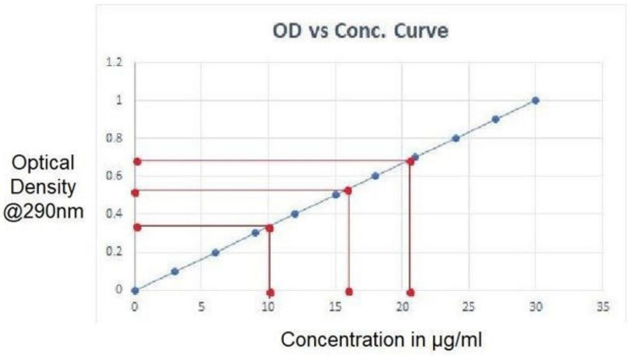

Figure 6. Graph to find out the total phenolics concentration from the samples.

Discussion

The analysis of phenolic concentrations in different parts of the onion reveals significant variations in their phenolic content. Red onion peels exhibited the highest phenolic concentration at 20.9 µg/ml, likely due to the presence of anthocyanins contributing to their antioxidant properties. Spring onion peels, with a concentration of 15.9 µg/ml, demonstrated slightly lower phenolic content, possibly due to their milder flavor and thinner skin. Surprisingly, the edible part of the red onion showed the lowest concentration at 11 µg/ml, potentially due to higher water and carbohydrate content diluting the phenolic concentration.

These findings highlight the potential health benefits of consuming onion peels, particularly red onion peels, as they offer a higher intake of antioxidant-rich compounds. Incorporating such plant components into diets could contribute to antioxidant defenses against oxidative stress-related ailments.

However, the observed differences could also be influenced by varietal and methodological factors. Thus, understanding the distribution of phenolic compounds within onions underscores the importance of informed dietary choices to maximize the potential health benefits associated with these natural bioactive constituents.

The impact of quercetin on the market economy

The global quercetin market size was valued at USD 1,296 million in 2022 and is expected to grow at a CAGR of 12.4% from 2022 to 2032. Overall quercetin sales are anticipated to total a market valuation of USD 3,968 million by the end of 2032. North America is the largest market for quercetin, followed by Europe and Asia-Pacific. The growth of the market in North America is being driven by the increasing demand for quercetin from the dietary supplement and pharmaceutical industries. The growth of the market in Europe is being driven by the increasing awareness of the health benefits of quercetin and the rising prevalence of chronic diseases. The growth of the market in Asia-Pacific is being driven by the growing demand for quercetin from the functional foods and beverages and cosmetics industries (Figure 7).

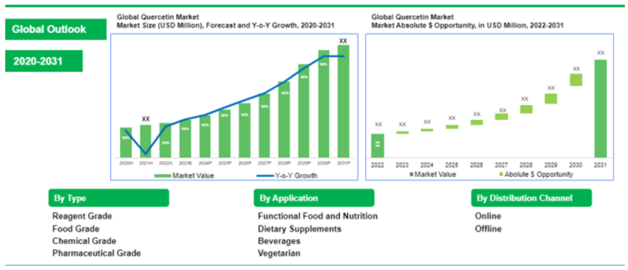

Figure 7. Global quercetin market size and forecast.

Factors affecting the growth of quercetin market

The quercetin market has experienced significant growth due to several key factors. Firstly, as consumers become increasingly health-conscious, there is a growing demand for natural solutions to support overall well-being. This has led to an increased interest in plant-based nutraceuticals, including quercetin, which is known for its potential health benefits. The nutraceutical industry, as a whole, has been witnessing substantial growth and quercetin's potential health benefits have contributed to its popularity in this sector. Research on quercetin's health benefits and potential applications has also played a crucial role in driving consumer interest and demand for products containing this flavonoid.

Quercetin's use in functional foods and beverages has further propelled its market growth. With its antioxidant properties and associated health benefits, quercetin has found its way into various functional food and beverage products, catering to health-conscious consumers. The rising prevalence of chronic diseases, such as cancer, cardiovascular disease and Alzheimer's disease, has prompted research into quercetin-based therapies. The potential use of quercetin in targeting these conditions has further fueled the demand for quercetin-containing products.

A supportive regulatory environment, where quercetin has generally been recognized as safe for use in dietary supplements, has facilitated its incorporation into a wide range of products. This regulatory acceptance has given manufacturers the confidence to explore quercetin's potential in various applications. Additionally, companies have been actively engaging in product innovation to enhance the bioavailability and effectiveness of quercetin supplements. By improving formulations and delivery methods, they have attracted more consumers to the market.

Market challenges of quercetin production

Despite the significant growth in the quercetin market, there are several challenges that need to be addressed:

- Quercetin's bioavailability can be a challenge in certain formulations, impacting its effectiveness in the body. Strategies to improve quercetin's bioavailability, such as combination with other compounds, need to be explored.
- While quercetin is generally considered safe, it can cause side effects such as nausea, vomiting and diarrhea in some individuals. Understanding and managing these side effects are essential for consumer safety.

- Many consumers may not be familiar with quercetin, its potential health benefits or its natural sources. Raising awareness and providing consumer education about quercetin's benefits could drive market growth.
- Compliance with varying regulatory standards and approval processes across different countries and regions can pose challenges for companies seeking global market presence.
- Intellectual property rights and patents related to quercetin extraction methods or formulations can impact market access and product availability.
- Quercetin faces competition from other antioxidants and flavonoids, both natural and synthetic. Maintaining price competitiveness is vital in the market.

Future prospects and opportunities

Despite the challenges, quercetin's future prospects remain promising, driven by increasing health consciousness and demand for natural and sustainable products. Research on quercetin's potential health benefits continues to uncover new applications, opening opportunities in various industries. Advancements in extraction and production technologies will likely lead to more cost-effective and environmentally friendly processes. Additionally, collaborations and partnerships between industry players and research institutions can accelerate innovation and product development. As the global interest in quercetin grows, governments and organizations may invest in research and infrastructure to support its sustainable production and commercialization. Overall, quercetin's potential as a versatile and beneficial compound positions it for continued growth and impact on human health and well-being.

Conclusion

In conclusion, quercetin emerges as a valuable bioactive compound with immense potential in the nutraceutical and functional food industries. Its rising popularity is fueled by increasing health awareness among consumers seeking natural solutions to support their well-being. The quercetin market has witnessed substantial growth, driven by the demand for plant-based nutraceuticals and functional foods.

However, this growth is not without challenges, including limited bioavailability and consumer awareness. Despite these hurdles, the isolation and production of quercetin play a crucial role in harnessing its full potential. The lab protocol for quercetin extraction provided valuable insights into its antioxidant activity, shedding light on its efficacy as a potent antioxidant. This knowledge can aid in the development of standardized products with consistent dosages, enhancing their effectiveness and overall market value. Further research and innovation are needed to address the challenges and unlock the full therapeutic potential of quercetin, paving the way for a healthier and more sustainable future in the world of nutraceuticals and functional foods.

References

1. Wianowska, Dorota and Iryna Bryshten. "New Insights into Vitamin K-From its Natural Sources through Biological Properties and Chemical Methods of Quantitative Determination." *Crit Rev Anal Chem* 54 (2024): 1502-1524.
2. David, Alexander Victor Anand, Radhakrishnan Arulmoli and Subramani Parasuraman. "Overviews of Biological Importance of Quercetin: A Bioactive Flavonoid." *Pharmacogn Rev* 10 (2016): 84.
3. Batiha, Gaber El-Saber, Amany Magdy Beshbishy, Muhammad Ikram and Zohair S. Mulla, et al. "The Pharmacological Activity, Biochemical Properties and Pharmacokinetics of the Major Natural Polyphenolic Flavonoid: Quercetin." *Foods* 9 (2020): 374.
4. Slimestad, Rune, Torgils Fossen and Ingunn Molund Vågen. "Onions: A Source of Unique Dietary Flavonoids." *J Agric Food Chem* 55 (2007): 10067-10080.
5. Wianowska, Dorota. "Application of Sea Sand Disruption Method for HPLC Determination of Quercetin in Plants." *J Liq Chromatogr Relat Technol* 38 (2015): 1037-1043.
6. Wianowska, Dorota andrzej L. Dawidowicz, Katarzyna Bernacik and Rafał Typek. "Determining the True Content of Quercetin and its Derivatives in Plants Employing SSDM and LC–MS Analysis." *Eur Food Res Technol* 243 (2017): 27-40.
7. Sharma, Kavita, Eun Young Ko, Awraris D. Assefa and Soyoung Ha, et al. "Temperature-Dependent Studies on the Total Phenolics, Flavonoids, Antioxidant Activities and Sugar Content in Six Onion Varieties." *J Food Drug Anal* 23 (2015): 243-252.
8. Liu, Jiayin, Margareta Sandahl, Per JR Sjöberg and Charlotta Turner. "Pressurised Hot Water Extraction in Continuous Flow Mode for Thermolabile Compounds: Extraction of Polyphenols in Red Onions." *Anal Bioanal Chem* 406 (2014): 441-445.
9. Wianowska, Dorota and Andrzej L. Dawidowicz. "Effect of Water Content in Extraction Mixture on the Pressurized Liquid Extraction Efficiency Stability of Quercetin 4′-Glucoside during Extraction from Onions." *J AOAC Int* 99 (2016): 744-749.
10. Wianowska, Dorota, Małgorzata Olszowy-Tomczyk and Sylwia Garbaczewska. "A Central Composite Design in Increasing the Quercetin Content in the Aqueous Onion Waste Isolates with Antifungal and Antioxidant Properties." *Eur Food Res Technol* 248 (2022): 497-505.
11. Wianowska, Dorota, Sylwia Garbaczewska, A. Cieniecka–Roslonkiewicz and R. Typek and Andrzej Lech Dawidowicz. "Chemical Composition and Antifungal Activity of *Chelidonium majus* Extracts–Antagonistic Action of Chelerythrine and Sanguinarine against *Botrytis cinerea*." *Chem Ecol* 34 (2018): 582-594.
12. Wianowska, Dorota, Sylwia Garbaczewska, Anna Cieniecka-Roslonkiewicz andrzej L. Dawidowicz, Rafal Typek and Anna Kielczewska. "Influence of the Extraction Conditions on the Antifungal Properties of Walnut Green Husk Isolates." *Anal Lett* 53 (2020): 1970-1981.
13. Muflihah, Yeni Maulidah, Ganesh Gollavelli and Yong-Chien Ling. "Correlation Study of Antioxidant Activity with Phenolic and Flavonoid Compounds in 12 Indonesian Indigenous Herbs." *Antioxidants* 10 (2021): 1530.
14. Osmic, Selma, Sabina Begic, Vladan Micic and Zoran Petrovic, et al. "Effect of Solvent and Extraction Conditions on Antioxidative Activity of Sage (*Salvia officinalis* l.) extracts obtained by maceration." *J Chem Technol* 11 (2019): 1-8.
15. Olszowy, Małgorzata. "What is Responsible for Antioxidant Properties of Polyphenolic Compounds from Plants?." *Plant Physiol Biochem* 144 (2019): 135-143.

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