Extraction of Lycopene from Tomato Peel Using Different Technologies

Divyashree M. and Ganga A.
Department of Food Processing Technology, College of Food Processing Technology and Bio-Energy, Anand Agricultural University, Anand, Gujarat-388110
Corresponding Author: divyamahantesh2001@gmail.com

Summary

Lycopene, a powerful antioxidant found abundantly in tomato peels, offers numerous health benefits and is widely extracted for use in nutraceuticals and natural colorants. Extraction techniques include conventional solvent extraction, which is simple but involves toxic solvents; supercritical fluid extraction, which yields pure extracts but requires costly equipment; and emerging green technologies such as ultrasound-assisted, enzyme-assisted, and microwave-assisted methods, which enhance yield and efficiency while reducing environmental impact. Among these, ultrasound and enzyme-assisted techniques are particularly effective in disrupting plant cell walls to release lycopene. The choice of method depends on cost, extraction yield, and application. Efficient lycopene recovery from tomato peels supports both sustainability and value addition in agro-industrial processing.

Introduction

Lycopene is a naturally occurring carotenoid pigment predominantly found in tomatoes (*Solanum lycopersicum*) and is responsible for their vibrant red color. It is a potent antioxidant with significant health benefits, including the potential to reduce the risk of chronic diseases such as cardiovascular disorders and certain types of cancer due to its free radical scavenging properties (Rao & Rao, 2007). Among various parts of the tomato, the peel contains a high concentration of lycopene, making it a valuable by-product for functional ingredient recovery.

Tomato processing industries generate large quantities of peels as waste, which not only contributes to environmental pollution but also represents a loss of valuable bioactive compounds. The valorization of tomato peel through lycopene extraction aligns with sustainable food processing and waste minimization strategies. Efficient extraction of lycopene from tomato peel can be achieved using various methods, including solvent extraction, supercritical fluid extraction, and enzyme-assisted techniques, each differing in yield, efficiency, and environmental impact (Shi et al., 2003).

Recovering lycopene from tomato peel not only adds economic value to agro-industrial by-products but also supports the development of natural colorants and nutraceuticals. This study focuses on optimizing lycopene extraction from tomato peel, aiming to enhance yield while maintaining environmental and nutritional integrity.

Extraction of Lycopene from the tomato peel

Lycopene, a natural carotenoid pigment, is one of the most discussed topics of late, acquired utmost popularity because of its potent health promoting antioxidant properties. Tomatoes and their byproducts like peels are expected to be good sources of this important compound. With extraction procedures that optimally recover lycopene from tomato peel becoming one of the most researched topics today, then possibly wasted byproduct material streams start addressing the ever-growing need for this nutrient in the human diet. The acyclic tetraterpenic hydrocarbon with 13 carbon-carbon double bonds, 11 of which are conjunct, gives the red color to tomatoes. This structure probably has an exceptional antioxidant action giving lower risk for various diseases such as cancer or cardiovascular disorders. In relation to tomato processing, a bulk of the wastes generated are the peel, with banana peel being the most generated. Thus, extraction of lycopene from this under-utilized resource has become increasingly significant (M. R. Foolad et al., 2008).

Many previous studies have attempted to assess various methods of extracting lycopene from tomato peel to optimize recovery yields. One method involves using pectinase and tri-solvent- assisted extraction methods to enhance the yield of lycopene's by 1.59 times compared to that obtained from any one solvent (M. G. Ximénez-Embún, et al., 2018).

Extraction Techniques for Lycopene

Lycopene, a very potent antioxidant with a plethora of health benefits, is mainly now extracted from the peel of tomato. The peeling waste from a tomato processing line has drawn even more interest in the extraction of lycopene from such peel because newer technologies have recently emerged as promising alternatives to the conventional techniques. Ultrasound- assisted extraction is one of such technologies that was found to increase the yield recovery of polyphenolic compounds from plant materials including pomegranate peel this technology, exposure to ultrasound waves would shorten the extraction time, lessen the consumption of the solvent, and make the process related to "green" against traditional methods. Another recently developed technique is called pressurized liquid extraction; this has successfully recovered bioactive compounds from fruit waste products, including those originating from the tomato peel (M. G. Ximénez-Embún, et al., 2018).

In addition to these methods, there is also interest in the application of other non-conventional techniques, such as microwave-assisted extraction and supercritical fluid extraction, for the recovery of high-value compounds from citrus waste, particularly carotenoids, polyphenols, and essential oils. The extraction method to be used should consider extraction yield and production cost. The mode of extraction also defines the quality of an extract; for example, food-grade solvents such as water, ethanol, or their mixtures are usually used for peel extracts (D. Naviglio, et al., 2007).

Lycopene is a lipophilic carotenoid pigment responsible for the red color of tomatoes and tomato-based products. It is a potent antioxidant with demonstrated health benefits, including protective effects against oxidative stress, cardiovascular disease, and certain types of cancer (Rao & Rao, 2007). Tomato peels, a major by-product of the tomato processing industry, are rich in lycopene and serve as a sustainable source for its recovery. Various extraction techniques have been developed to isolate lycopene from tomato peel, each differing in efficiency, purity, environmental impact, and suitability for industrial application.

Conventional Solvent Extraction

Conventional solvent extraction is the most widely used technique due to its simplicity and high extraction efficiency. In this method, non-polar solvents such as hexane, petroleum ether, or mixtures with acetone or ethanol are used to extract lycopene from dried and ground tomato peels. The process is generally performed under controlled temperature and light conditions to minimize lycopene degradation. Although effective, the major drawbacks include the use of toxic solvents, long extraction times, and environmental concerns (Fish et al., 2002). Despite these limitations, it remains a benchmark in lycopene extraction studies, especially for initial screening and small-scale applications.

Supercritical Fluid Extraction (SFE)

Supercritical fluid extraction (SFE) is an advanced and environmentally friendly technique that uses supercritical carbon dioxide (CO_2) as a solvent, often with ethanol as a co-solvent. In its supercritical state, CO_2 possesses gas-like diffusivity and liquid-like solvating power, making it ideal for extracting non-polar compounds like lycopene. SFE offers several advantages, including solvent-free extracts, higher purity, and minimal thermal degradation, making it highly suitable for food and pharmaceutical applications (Machmudah et al., 2007). However, the method is capital-intensive and requires specialized equipment and expertise, which may limit its industrial-scale application.

Ultrasound-Assisted Extraction (UAE)

Ultrasound-assisted extraction enhances lycopene yield by applying high-frequency sound waves to the tomato peel–solvent mixture. The resulting acoustic cavitation leads to the rupture of cell walls, improving solvent penetration and mass transfer of lycopene. UAE significantly reduces extraction time and solvent usage while improving efficiency (Saini et al., 2015). It is particularly effective when combined with food-grade solvents like ethanol. However, the process parameters must be carefully optimized to avoid thermal degradation, and industrial-scale adaptation of ultrasound technology remains a challenge.

Enzyme-Assisted Extraction (EAE)

Enzyme-assisted extraction involves the use of hydrolytic enzymes such as cellulase and pectinase to degrade the plant cell wall matrix, thereby releasing lycopene. This method is conducted under mild conditions, which preserves the structural and functional integrity of lycopene. Enzyme pretreatment not only improves yield but also enhances solvent penetration in subsequent steps. Studies have shown that enzymatic treatment can significantly increase lycopene recovery from tomato by-products (Anese et al., 2013). However, the high cost of enzymes and the need for careful optimization of enzymatic conditions can limit its widespread use.

Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction uses microwave energy to rapidly heat plant tissues internally, causing cell rupture and efficient release of lycopene. This method is known for its reduced extraction time, improved solvent efficiency, and potential for high yields. However, lycopene is thermolabile, and excessive heating can lead to degradation (Goula & Lazarides, 2015). Therefore, temperature and exposure time must be tightly controlled. MAE is considered a clean technology and shows great promise for sustainable lycopene extraction, especially when integrated with green solvents.

Conclusion

Each lycopene extraction technique from tomato peel offers unique advantages and limitations. Conventional solvent extraction is simple and cost-effective but involves toxic solvents. Supercritical fluid extraction produces high-purity extracts without harmful residues, though it is expensive. Ultrasound-assisted and microwave-assisted techniques offer high efficiency and shorter extraction times, with potential for scale-up. Enzyme-assisted extraction is eco-friendly and selective but may incur higher costs. The selection of an appropriate method depends on the desired extract quality, application purpose, environmental considerations, and economic feasibility. With increasing demand for natural antioxidants and clean-label ingredients, optimizing lycopene extraction from tomato peel is both a nutritional and sustainable imperative.

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