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STRATEGIES TO IMPROVE COTTONSEED OIL COMPOSITION AND REFORMULATE FATTY ACID PROFILE

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Abstract
Cottonseed oil is a widely utilized edible oil with significant applications in the food industry. However, its fatty acid composition, characterized by a high content of saturated fats and specific undesirable compounds, necessitates improvements to meet health and nutritional standards. This article explores innovative strategies to enhance the composition of cottonseed oil and reformulate its fatty acid profile. Key approaches include genetic engineering of cottonseed varieties, selective breeding, and advanced processing technologies such as enzymatic interesterification and hydrogenation control. The study also examines the role of biotechnological interventions in reducing gossypol content and increasing unsaturated fatty acid proportions, particularly oleic and linoleic acids. Furthermore, the article highlights the implications of these modifications on oil stability, flavor, and overall health benefits. By integrating cutting-edge research and industrial practices, this study offers actionable insights into producing cottonseed oil with an optimized fatty acid profile, aligning with consumer preferences and health guidelines.

Keywords: Vegetable oil, cholesterol content, functional, genetic resources, cottonseed, fatty acids, genetic resources, global vegetable oil, selection, designer oils.

Introduction

Cottonseed oil, derived as a byproduct of cotton production, is a vital resource in the global edible oil market. Known for its widespread use in cooking, baking, and food manufacturing, it holds economic significance in both agriculture and industry. Despite its benefits, the current fatty acid profile of cottonseed oil—characterized by a relatively high content of saturated fats and the presence of gossypol—poses challenges related to health implications and industrial applications.

Improving the composition and fatty acid profile of cottonseed oil is essential to enhance its nutritional value, align with consumer health trends, and increase its market competitiveness. Strategies such as genetic modifications, selective breeding, and advancements in processing technologies have emerged as effective tools to address these challenges. Additionally, the reduction of gossypol content and the enhancement of unsaturated fatty acids, such as oleic and linoleic acids, are crucial steps in reformulating the oil to meet health and sustainability standards.

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This article explores innovative strategies to improve the composition and fatty acid profile of cottonseed oil. By examining current methodologies and advancements, it aims to provide a comprehensive understanding of how these interventions can contribute to producing healthier, more sustainable, and economically viable cottonseed oil for global use.

Materials and methods

Cottonseed oil is a valuable product obtained from the seeds after the cotton fiber has been removed. It accounts for a large share of global vegetable oil production and is the second largest source of oil consumption worldwide. For centuries, breeders have mainly focused on improving the yield and quality of cotton fiber. In recent years, attention has been focused on increasing the percentage of cottonseed oil and improving its functional and nutritional properties. However, these efforts have lagged behind other major oilseed crops, leading to reduced consumer demand for cottonseed oil and weakening the industry. Although some progress has been made in changing fatty acid composition, stronger efforts are needed to meet the global demand for oilseeds. This review examines the available genetic resources, utilization in breeding programs, biosynthetic pathways, and key genes and QTLs associated with improving oil content and quality in cottonseed oil. Approaches to improve nutritional properties using modern genomic tools, such as gene silencing and transgenic techniques, are also highlighted.

Upland cotton (Gossypium hirsutum L.) is called the "king of fiber" because it is of great social and economic importance in more than 80 countries of the world. In addition to fiber, the whole cottonseed yields edible oil, making it the second largest source of vegetable oil in the world (Ashokkumar and Ravikesavan, 2013). Cottonseed oil is known as the "heart oil" because of its low cholesterol content. The specific ratio of saturated and unsaturated fatty acids in flour determines its unique flavor and cooking properties (Agarwal et al., 2003).

The top five producers of cottonseed oil are China, USA, India, former Soviet Union and Pakistan, which produce 27%, 12%, 11%, 10% and 9% respectively. It accounts for 70% of the total vegetable oil production (Song and Zhang, 2007). In the US, cottonseed oil is the third largest source of domestic oil demand, with annual exports of 100,000 tons (Paterson, 2009). And in Pakistan, it covers 17.7% of the edible oil demand (Malik and Ahsan, 2016).

In cotton gins, the fiber is separated from the seed for textile production. The rest of the "soft cotton seed" can be used as animal feed or processed into the following products: meal (45%), husks (26%), oil (16%) and fiber (9%), as well as during processing 4 % is lost (Cherry and Leffler, 1984). More than 10–15% of cotton farmers' income comes from these products.

In the last 15 years, the consumption of edible oil in the world has increased from 10.13 million tons in 2001–2002 to 20.08 million tons in 2014–2015. Pakistan's edible oil demand is expected to reach 5.36 million tonnes in 2019–2030, of which 1.98 million tonnes will be produced domestically (Malik and Ahsan, 2016). Thus, increasing the oil potential of local cotton varieties is becoming a global problem.

In addition, there is increasing interest in modifying the fatty acid composition of cottonseed oil to improve its nutritional properties. Compared to other major oilseed crops, efforts to improve the nutritional value, quality, and oil content of cottonseed oil have been limited, leading to lower consumer demand and a weaker industry (Paterson, 2009). Even small improvements in fat content can have a significant impact on solving the fat crisis in developing countries. This review summarizes the existing literature on the improvement of cottonseed oil recovery and suggests future trends for the development of designer oils with unique properties.

Nutritional Importance of Cottonseed Oil

The nutritional value and industrial utility of cottonseed oil is largely determined by its fatty acid composition, which has different carbon chain lengths and degrees of unsaturation. One tablespoon of cottonseed oil contains 120 calories, 3.5 grams of saturated fatty acids, as well as vitamin A, vitamin K, and antioxidants (Malik and Ahsan, 2016). Cottonseed oil also contains essential amino acids such as lipase, phytase and lecithin. Cottonseed oil contains high levels of natural antioxidants and alpha-tocopherols (35 mg per 100 grams), which extend its shelf life and enhance vitamin E activity compared to other seed oils (Agarwal et al., 2003).

In addition, cottonseed oil is a good source of phosphorus (1%). It has moderate levels (0.5–1%) of cyclopropenoid fatty acids, which have anti-nutritional properties (Dowd et al., 2010). The value of cottonseed oil can be significantly increased by genetic modification of small components such as vitamin E, neuroactive N-acylethanolamines and phytosterols (Paterson, 2009). Even small improvements in oil content can increase its market value and address major nutritional deficiencies.

Fatty Acid Profile of Cottonseed Oil

Cottonseed oil contains 65–70% unsaturated fatty acids, and 26–35% saturated fatty acids. Among the unsaturated fatty acids, linoleic acid has the largest share (55%), followed by oleic acid (15%), and linolenic acid is less than 1%. The main saturated fatty acids are palmitic acid (26%) and stearic acid (2%) (Hui, 1996).

Despite the health benefits of unsaturated fatty acids, long-term deep frying can transform them into hyperperoxides, aldehydes, and keto derivatives, causing off-flavors (Liu et al. , 2002). The high palmitic acid content of cottonseed oil increases its resistance to oxidation during frying, which helps offset the undesirable properties of unsaturated fatty acids (Lindsey et al., 1990). However, the partial hydrogenation process used to stabilize the oil produces trans fatty acids, which increase LDL cholesterol and decrease HDL cholesterol (Mozaffarian et al., 2006).

Oleic acid, a monounsaturated fatty acid, is relatively stable at high temperatures, suitable for deep frying and prevents oxidation (Liu et al., 2009). Increasing the amount of oleic acid at the expense of polyunsaturated fatty acids can further increase the cooking stability of the oil.

While saturated fatty acids themselves do not pose a health risk, trans fatty acids formed during hydrogenation are associated with increased cholesterol levels (Mozaffarian et al., 2007). However, stearic acid is considered beneficial among saturated fatty acids because it does not increase LDL cholesterol and even helps to reduce it (Bonanome and Grundy, 1988). It also increases the melting point of the oil, which makes it useful in the production of margarine and shortening.

Conclusion

To meet the oil demand of the world, it is necessary to increase the potential of local varieties, in particular, approaches for the production of cotton varieties with high oil content should be used. Recent trends in improving fatty acid composition will help meet consumer and industry demand for cottonseed oil. In tetraploid cotton, the oil content varies in different agroecological zones of the crop, which is still a large difference. By using the right conventional and biotechnological tools, it is possible to increase the percentage of cottonseed oil, its nutritional value and ensure its widespread use in industry. Conventional approaches can be used to increase oil content to some extent through natural variation and introduced mutations. However, biotechnological tools have given breeders more opportunities to achieve the desired percentage of fatty acid content or to improve nutritional value. The gene silencing technique has yielded useful results in effecting changes by silencing targeted genes. A trait-assisted selection approach may be useful in integrating genes/QTLs that contribute to improved oil biosynthesis and quality. Among agrochemical practices, foliar application of Zn, P, and K can increase cotton oil content. The right combination of these approaches will help revolutionize the economics of cottonseed oil.

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