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Effects of baking on the bioactive compounds in buckwheat and wheat cookies

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Abstract
This review article explores the effects of baking on the bioactive compounds in buckwheat and wheat cookies, focusing on antioxidant and anti-proliferative activities. By analyzing previous studies, reviews, and reports, this article aims to provide a comprehensive understanding of how baking influences the nutritional and health benefits of these cookies. Findings suggest that while baking can degrade some bioactive compounds, it may also enhance the bioavailability and efficacy of certain antioxidants and anti-proliferative agents.

Keywords: Baking, bioactive compounds, buckwheat cookies, wheat cookies, antioxidant activity, anti-proliferative activity

Introduction
Buckwheat (*Fagopyrum esculentum*) and wheat (*Triticum aestivum*) are staple grains widely used in the production of various food products, including cookies. Both grains are renowned for their nutritional benefits, largely due to their high content of bioactive compounds such as antioxidants and anti-proliferative agents. These bioactive compounds play a crucial role in promoting health and preventing chronic diseases by neutralizing free radicals, reducing inflammation, and inhibiting the proliferation of cancer cells.

Buckwheat is particularly rich in flavonoids, phenolic acids, and other antioxidants like rutin and quercetin. These compounds are known for their potent antioxidant activities, which help in scavenging free radicals and protecting cells from oxidative stress. Additionally, buckwheat contains D-chiro-inositol, which has shown potential in improving insulin sensitivity and managing diabetes, and fagopyrins, which possess anti-inflammatory properties.

Wheat, on the other hand, is abundant in phenolic acids, flavonoids, and carotenoids. Phenolic acids such as ferulic acid, caffeic acid, and p-coumaric acid are concentrated mainly in the bran and germ and contribute significantly to the antioxidant capacity of wheat. Flavonoids like apigenin, luteolin, and tricin also play a crucial role in providing antioxidant, anti-inflammatory, and anti-cancer benefits. Carotenoids, such as lutein and zeaxanthin, are essential for maintaining eye health and protecting against age-related macular degeneration.

Despite the well-documented health benefits of these grains, the process of baking can significantly alter the composition and efficacy of their bioactive compounds. The high temperatures involved in baking can lead to the degradation of certain antioxidants, potentially reducing their health benefits. However, baking can also induce the formation of new bioactive compounds through chemical reactions such as the Maillard reaction, which can enhance the antioxidant properties of the final product.

Understanding the impact of baking on the bioactive compounds in buckwheat and wheat cookies is essential for optimizing baking processes and developing food products that retain or even enhance their nutritional and health benefits. Previous studies have provided valuable insights into these efsfects, highlighting both the challenges and opportunities associated with baking. For instance, while rutin and phenolic acids may degrade during baking, the formation of Maillard reaction products (MRPs) can contribute additional antioxidant properties.

Objective of the paper
To evaluate and compare the effects of baking on the antioxidant activity and bioactive compounds in buckwheat and wheat cookies.

Literature Review

Buckwheat is known for its high levels of antioxidants, particularly rutin and quercetin. Zhang *et al*. (2010) [1] investigated the impact of baking on the antioxidant properties of buckwheat cookies, finding that rutin content significantly decreased during baking due to thermal degradation. However, the overall antioxidant activity did not proportionally decrease, suggesting the formation of Maillard reaction products (MRPs) during baking, which contributed additional antioxidant properties. Kim *et al*. (2012) [2] further explored this by demonstrating that baking could enhance the bioavailability of certain antioxidants in buckwheat by breaking down complex compounds into simpler, more absorbable forms. This indicates that while the quantity of some antioxidants may decrease, their effectiveness could be enhanced due to improved bioavailability. Wheat contains phenolic acids, flavonoids, and carotenoids, which contribute to its antioxidant capacity. Li *et al*. (2008) [3] reported that baking wheat cookies led to a reduction in total phenolic content by up to 30%, primarily due to thermal degradation. However, as with buckwheat, the formation of MRPs during baking could offset these losses to some extent. MRPs are known to exhibit antioxidant properties, which can help maintain the overall antioxidant activity of the cookies. Additionally, baking conditions such as temperature and time play a crucial role in determining the extent of these effects. Lower baking temperatures were found to preserve more phenolic compounds, thereby maintaining higher antioxidant activity in the final product.

Kim and Lee (2014) [4] studied the addition of honey and nuts to wheat cookie dough, which significantly enhanced the antioxidant activity of the final baked product. These ingredients not only contributed their own antioxidants but also protected existing phenolic acids from degradation during baking. This finding highlights the potential of ingredient modification to improve the nutritional quality of baked goods. Comparative studies between buckwheat and wheat cookies provide further insights into how different grains respond to baking. For instance, Cho *et al*. (2013) [5] focused on the anti-cancer properties of buckwheat cookies and found that baking reduced the levels of D-chiro-inositol and fagopyrins, thereby diminishing their anti-proliferative effects. However, the study also noted that MRPs formed during baking could exhibit anti-cancer properties, suggesting a complex interaction between baking and anti-proliferative activities. Wang *et al*. (2011) [7] observed similar trends in wheat cookies enriched with blueberries. The study found that while the baking process reduced the levels of certain flavonoids with known anti-cancer properties, it also increased the concentration of some beneficial MRPs. This indicates that the health effects of baked goods are not solely dependent on the retention of original bioactive compounds but also on the formation of new compounds during baking.

Bioactive compounds in buckwheat and wheat

Buckwheat (*Fagopyrum esculentum*) and wheat (*Triticum aestivum*) are grains renowned for their rich content of bioactive compounds, which contribute to their nutritional and health benefits. Buckwheat is particularly noted for its high levels of flavonoids, phenolic acids, and other compounds that exhibit significant antioxidant and anti-inflammatory properties. One of the well-studied bioactive compounds in buckwheat is rutin, a flavonoid glycoside that has been shown to possess strong antioxidant activities. Rutin helps in scavenging free radicals, thereby protecting cells from oxidative stress and reducing the risk of chronic diseases. Quercetin, another flavonoid found in buckwheat, is known for its anti-inflammatory and anti-cancer properties. Studies have shown that quercetin can inhibit the proliferation of cancer cells and induce apoptosis, making it a potent anti-cancer agent. Additionally, buckwheat contains D-chiro-inositol, a compound that has demonstrated potential in improving insulin sensitivity and managing diabetes. Fagopyrins, found in the hulls of buckwheat, possess phototoxic properties but also exhibit anti-inflammatory and anti-cancer activities.

Wheat, a staple grain worldwide, is also rich in bioactive compounds, particularly phenolic acids, flavonoids, and carotenoids. Phenolic acids such as ferulic acid, caffeic acid, and p-coumaric acid are abundant in wheat and are primarily concentrated in the bran and germ. These compounds contribute to the antioxidant capacity of wheat by neutralizing free radicals and protecting cells from oxidative damage. Ferulic acid, in particular, has been extensively studied for its ability to enhance skin health and prevent photoaging due to its strong antioxidant properties. Flavonoids in wheat, including apigenin, luteolin, and tricin, also contribute to its antioxidant activity and have been associated with various health benefits, including anti-inflammatory, anti-cancer, and cardiovascular protective effects. Carotenoids, such as lutein and zeaxanthin, are present in wheat and are known for their role in maintaining eye health by protecting against age-related macular degeneration.

The bioactive compounds in both buckwheat and wheat play crucial roles in promoting health and preventing diseases. Several studies have highlighted the health benefits of these grains, emphasizing their antioxidant, anti-inflammatory, and anti-cancer properties. For instance, a study by Bonafaccia *et al*. (2003) [8] demonstrated that buckwheat flour has a higher antioxidant activity compared to wheat flour, primarily due to its higher rutin content. Similarly, research by Zieliński *et al*. (2007) [9] showed that wheat bran, which is rich in phenolic acids, exhibits significant antioxidant activity, contributing to the overall health benefits of whole wheat products.

Furthermore, the bioavailability and efficacy of these bioactive compounds can be influenced by processing methods such as baking. Studies have shown that while baking can degrade some bioactive compounds, it can also enhance the bioavailability of others. For example, the heat from baking can break down complex flavonoid glycosides into simpler forms that are more readily absorbed by the body. Additionally, the Maillard reaction, which occurs during baking, can produce new bioactive compounds with antioxidant properties. This reaction involves the interaction between reducing sugars and amino acids, leading to the formation of Maillard reaction products (MRPs), which can contribute to the antioxidant activity of baked goods.

Effects of baking on antioxidant activity

The process of baking has a significant impact on the antioxidant activity of both buckwheat and wheat cookies. The heat involved in baking can lead to chemical changes that either degrade or transform the antioxidant compounds present in the raw ingredients. Understanding these changes

is crucial for optimizing baking conditions to retain or enhance the health benefits of the final products.

In buckwheat cookies, one of the primary antioxidants is rutin, a flavonoid glycoside known for its strong free radical scavenging abilities. Studies have shown that rutin content can decrease significantly during the baking process. Zhang *et al.* (2010) [1] reported that baking at high temperatures can lead to the thermal degradation of rutin, thereby reducing its concentration in the final product. However, this loss does not necessarily translate to a reduction in overall antioxidant activity. This is because the heat from baking can induce the Maillard reaction, which produces Maillard reaction products (MRPs) with notable antioxidant properties. The MRPs are formed from the reaction between amino acids and reducing sugars, leading to compounds that can compensate for the loss of rutin and other native antioxidants. Additionally, baking can increase the bioavailability of certain antioxidants in buckwheat. Kim *et al.* (2012) [2] found that the baking process can break down complex flavonoids into simpler, more absorbable forms. This transformation can enhance the antioxidant activity by making these compounds more accessible for absorption in the human body. Therefore, while the quantity of some antioxidants may decrease, their effectiveness could be enhanced due to improved bioavailability. In the case of wheat cookies, phenolic acids such as ferulic acid are the major contributors to antioxidant activity. Baking can cause a reduction in the total phenolic content, as observed by Li *et al.* (2008) [3], who noted that up to 30% of phenolic compounds can be lost during baking. The decline in phenolic acids is partly due to thermal degradation, which reduces their presence in the final product. However, similar to buckwheat, the Maillard reaction can produce MRPs that possess antioxidant properties, partially compensating for the loss of phenolic acids. The impact of baking on the antioxidant activity of wheat cookies can also be influenced by the baking conditions. Lower baking temperatures can help preserve more phenolic compounds, thereby maintaining higher antioxidant activity. Li *et al.* (2008) [3] suggested that optimizing baking temperatures and times can minimize the degradation of phenolic acids, ensuring that more of these beneficial compounds are retained in the cookies. Moreover, the addition of other antioxidant-rich ingredients during the baking process can enhance the overall antioxidant activity of wheat cookies. Kim and Lee (2014) [4] demonstrated that adding honey or nuts to wheat cookie dough before baking can result in a final product with higher antioxidant activity. These ingredients not only contribute their own antioxidants but also protect existing phenolic acids from degradation during baking. The formation of MRPs during baking is a crucial factor that adds complexity to the overall antioxidant activity of baked goods. While MRPs can enhance antioxidant properties, their health effects are not fully understood and can vary depending on the specific compounds formed. Further research is needed to fully elucidate the health implications of MRPs and their contribution to the antioxidant activity of baked products.

In summary, the process of baking significantly impacts the antioxidant activity of both buckwheat and wheat cookies. While some native antioxidants are degraded by the heat, the formation of MRPs and the potential increase in bioavailability can compensate for these losses. Optimizing baking conditions and incorporating antioxidant-rich ingredients can help maximize the health benefits of these cookies. Understanding these dynamics is essential for developing baked goods that retain or even enhance their nutritional value through careful control of the baking process. Further studies are necessary to explore the long-term health effects of consuming MRPs and to identify the best practices for preserving antioxidant activity in baked products.

Conclusion

This study highlights the complex effects of baking on the antioxidant activity of buckwheat and wheat cookies. Baking can lead to the degradation of certain bioactive compounds such as rutin in buckwheat and phenolic acids in wheat due to thermal exposure. However, this process also induces the formation of Maillard reaction products (MRPs), which possess antioxidant properties that can partially offset the loss of native antioxidants. Additionally, baking can enhance the bioavailability of some antioxidants, making them more effective in the human body. The antioxidant activity of buckwheat and wheat cookies can be influenced by various factors, including baking temperature, time, and the addition of antioxidant-rich ingredients such as honey or nuts. Optimizing these conditions is crucial for maximizing the retention and efficacy of antioxidant compounds in the final baked products. The findings underscore the importance of understanding the thermal dynamics and chemical reactions that occur during baking. This knowledge can guide the development of baking processes and recipes that preserve or enhance the health benefits of cookies made from buckwheat and wheat. Future research should continue to explore the health implications of MRPs and the long-term effects of consuming baked products with enhanced antioxidant properties. In conclusion, while baking poses challenges to maintaining antioxidant activity, it also offers opportunities for improving the nutritional profile of baked goods through careful process optimization and ingredient selection. These insights can help in creating healthier baked products that leverage the full potential of their bioactive compounds.

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