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Impact of Fermentation on the Antioxidant and Proximate Composition of Selected Cabbage (*Brassica oleracea*) Varieties

Nwandu, L.N., Marcus, A.C., & Nwoke, P.L.
Department of Chemistry, Ignatius Ajuru University of Education, Port Harcourt, Rivers State, Nigeria

***Corresponding author email**: lily.kingsleynwandu@gmail.com

Abstract
The study investigated how fermentation affects the antioxidant and proximate properties of white and red cabbage (*Brassica oleracea var. capitata f. alba* and *rubra*, respectively) and compared these effects to their unfermented counterparts. The fermentation process, carried out according to standard procedures, resulted in improved antioxidant properties, as measured by the DPPH assay. Red cabbage showed significant improvements, with antioxidant activity increasing from 43.81% at a 100 mg/L concentration to 72.45% at a 200 mg/L concentration. In contrast, white cabbage exhibited lower antioxidant activity, with values of 9.9% and 28.29% at the same concentrations. Fermentation also led to increases in protein content for both types of cabbage, with white cabbage rising from 19.77% to 20.48% and red cabbage from 19.85% to 20.55%. Similarly, moisture content increased in both varieties, from 24.06% to 27.49% in white cabbage and from 24.05% to 27.41% in red cabbage. Crude fibre content also saw an increase in both cabbages, with white cabbage increasing from 2.41% to 3.06% and red cabbage from 3.46% to 3.90%. On the other hand, carbohydrate content decreased in both types: white cabbage from 51.31% to 46.86% and red cabbage from 49.88% to 46.10%. In comparison to the unfermented samples, both fermented white and red cabbage displayed enhanced antioxidant activity and improved nutritional properties. This indicates that fermentation can significantly boost both the antioxidant and nutritional value of cabbage.

Keywords: Fermentation, Cabbage, Antioxidant, Proximate, Probiotics, Nutrition

Introduction

Fermentation is recognized as one of the safest and most effective methods for producing food that is suitable for human consumption. It is considered a simple, natural, and valuable biotechnological process for preserving food. This method offers numerous benefits, including enhancing the nutritional content, safety, and shelf life of plant-based foods, making them safer and more nutritious for consumption (Voidarou et al., 2020). Yamano et al. (2006) suggest that including fermented fruits and vegetables in the diet can improve overall nutrition by providing essential nutrients such as vitamins, minerals, and carbohydrates, thereby contributing to balanced nutrition (Pem & Jeewon, 2015; Kiczorowski et al., 2022). Furthermore, fermented fruits and vegetables have been linked to a reduced risk of conditions such as diarrhoea and liver cirrhosis due to their probiotic properties (Swain et al., 2014; Ajibola et al., 2023). Fermented foods are part of about one-third of global diets, illustrating their broad presence across various cultures, including in places like the United States. The diversity of these foods has evolved over time, shaped by regional traditions and cultural practices (Borresen et al., 2012; Dimidi et al., 2019). Fermentation plays a key role in creating unique flavours and has given rise to a wide variety of culinary traditions around the world, including popular foods such as Korean kimchi, Indian chutneys, sauerkraut, yoghurt, and cheese (Foroutan, 2012). Initially, fermentation was a home-based practice rooted in different cultures, but it has since evolved into a large-scale industrial process to meet the growing demands of the market. Fermented vegetables are particularly valued for their extended shelf life and their high content of antioxidants, including vitamins, flavonoids, phenolic compounds, carotenoids, minerals, and dietary fibres (Sun et al., 2009; Kusznierewicz et al., 2010).

Cabbage, a member of the Brassica family, is a leafy green or purple vegetable known for its tightly packed leaves. It is cultivated across temperate and tropical regions and is highly nutritious, with significant amounts of water, fibre, protein, calcium, iron, and vitamins A and C (Adeniji et al., 2010; Meena et al., 2010; Singh et al., 2010;).

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Notably, cabbage is recognized for its antioxidant properties, which help regulate blood flow, temperature, and pressure, contributing to overall health and reducing the risk of cardiovascular issues (Watanabe et al., 2011). In addition to vitamin C and soluble fibre, cabbage contains various nutrients and phytochemicals, including polyphenols and flavonoids, which contribute to its numerous health benefits (Chauhan et al., 2016). Fermented cabbage, such as sauerkraut, further enhances these benefits by increasing its antioxidant potential due to compounds like vitamin C and ABG, as well as providing probiotics and anticarcinogenic properties (Wagner et al., 2008; Kusznierewicz et al., 2010). Fermentation also offers significant benefits for grains, improving protein content, digestibility, and the availability of micronutrients like calcium and iron, while producing antimicrobial compounds that protect against harmful microorganisms (Iyang & Zakari, 2008; Xiang et al., 2019). During the fermentation process, notable biochemical changes occur that not only enhance the nutritional profile but also reduce antinutritional factors, thereby increasing the bioavailability of essential nutrients (Gupta et al., 2015). This study aims to explore how fermentation influences the antioxidant and nutritional properties of both white and red cabbage.

Materials and Methods

Two varieties of cabbage—white and red—were selected for this study. These cabbages were purchased from the Igbo-Etche local market in Port Harcourt, Rivers State, Nigeria, with each type bought in triplicate to ensure accuracy and minimize variation. The cabbages were washed, weighed, dried at room temperature, and ground into fine powder. A portion of the fresh cabbages was fermented by soaking in a 1.5% salt solution for 14 days, then dried and ground into powder. Both unfermented and fermented samples were labelled and taken to the laboratory for analysis of antioxidant and proximate properties. The antioxidant activity was evaluated through the DPPH free radical scavenging assay, based on the method (Koleva et al., 2002). The ascorbic acid content was assessed through a titrimetric method utilizing 2,6-dichlorophenolindophenol. A 5-gram portion of the homogenized sample was mixed with 25 ml of 6% oxalic acid, filtered, and then titrated with the 2,6-dichlorophenolindophenol solution. The moisture content, ash percentage, carbohydrate, protein, and lipid levels were carefully analyzed using the standard procedures recommended by the Association of Official Analytical Chemists (AOAC, 2005; AOAC, 2006).

Results

The result of the antioxidant analysis is presented in Table 1.

Table 1: Result of antioxidant analysis of white and red cabbage species

	100mg/L concentration		200mg/L concentration	
Sample	**Absorbance**	**%Antioxidant activity**	**Absorbance**	**%Antioxidant Activity**
White Cabbage	1.089	9.90±0.13	0.866	28.37±0.25
Red Cabbage	0.679	43.81±0.29	0.333	72.45±0.50
Ascorbic acid	0.559	53.74±1.93	0.301	75.13±0.71

LEGEND: Absorbance is at 517nm. Aqueous extractions were used. Control absorbance = 1.209nm. Control was test tube blank without plant extract or sample.
Values are represented as mean±SD.

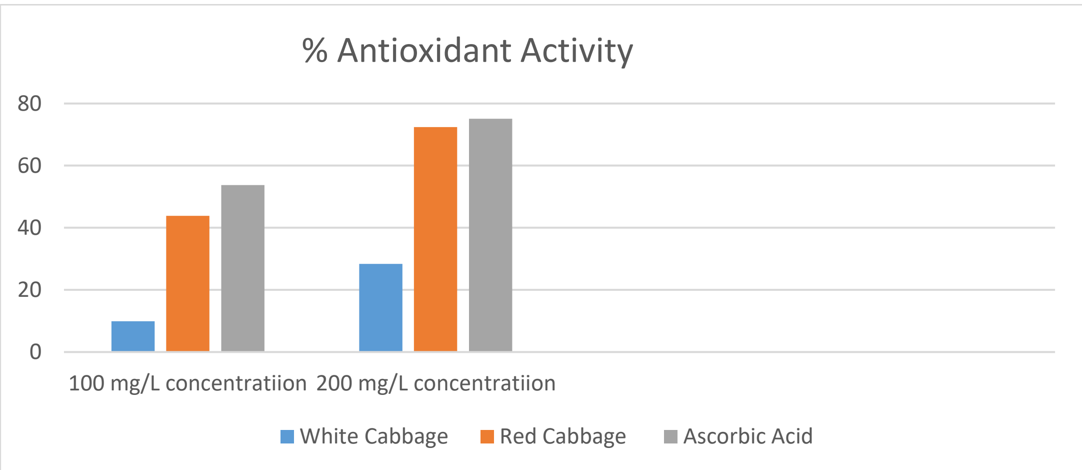

Fig. 1. Bar chart showing the Antioxidant activity of white cabbage, red cabbage and ascorbic acid.

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Proximate content analysis
The result of the proximate analysis is presented in Table 2

Table 2: Result of the proximate analysis (%) of white and red cabbage

	Unfermented		Fermented	
Proximate%	**White Cabbage**	**Red Cabbage**	**White Cabbage**	**Red Cabbage**
Moisture	24.06±0.07	24.05±0.03	27.49±0.02	27.41±0.02
Ash	1.34±0.06	1.71±0.04	1.14±0.02	1.05±0.01
Crude Fiber	2.41±0.02	3.46±0.02	3.06±0.04	3.90±0.02
Crude Lipid	1.11±0.02	1.05±0.01	0.97±0.02	0.99±0.01
Crude Protein	19.77±0.09	19.85±0.05	20.48±0.04	20.55±0.05
Carbohydrate	51.31±0.03	49.88±0.02	46.86±0.05	46.10±0.04

Values are represented as mean±SD.

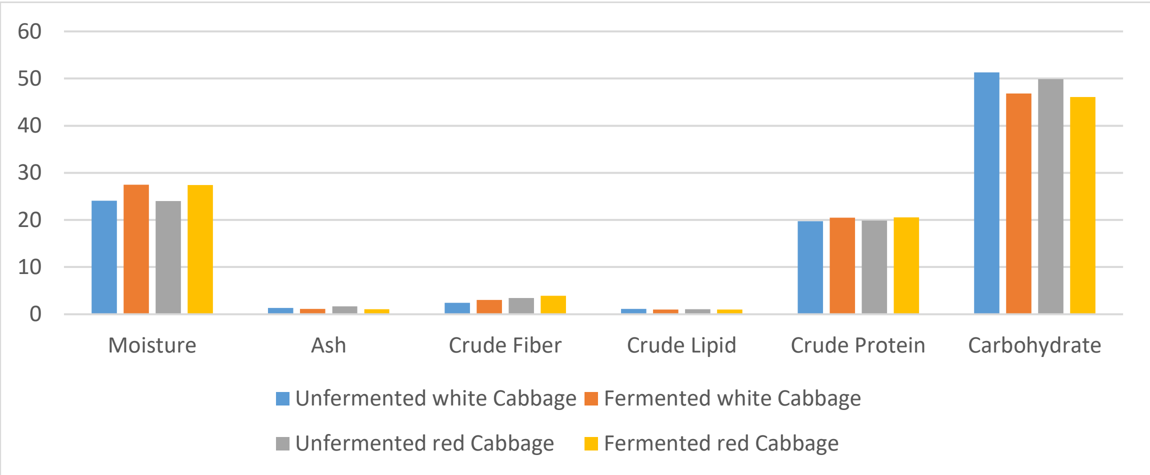

Fig. 2. Clustered column showing the Proximate properties of white cabbage and red cabbage

Discussion

Effects of Fermentation on the Antioxidant Properties of White and Red Cabbage

The effect of fermentation on the antioxidant properties of white and red cabbage was clearly demonstrated in this study, showing significant enhancements in both varieties. Red cabbage exhibited a marked increase in antioxidant activity, from 43.81% at a 100 mg/L concentration to 72.45% at a 200 mg/L concentration. In contrast, white cabbage showed lower antioxidant activities of 9.9% and 28.29% at the same respective concentrations. The increased antioxidant activity, as measured using the DPPH method, can be attributed to the modification of bioactive compounds by lactic acid bacteria during the fermentation process. This finding aligns with previous research by Dordevic et al. (2010), which suggests that fermentation induces structural breakdowns in plant cell walls, leading to the release of phenolic compounds through enzymatic processes, thereby boosting antioxidant activity. The findings are also consistent with Parada et al. (2023), who observed similar antioxidant capacity enhancements in Brassica vegetables using controlled fermentation. However, these results contrast with those of Kusznierewicz et al. (2008), who reported that fermentation increased the antioxidant activity in white cabbage but did not significantly affect red cabbage. This variability highlights the influence of specific fermentation conditions and cabbage varieties on the outcomes.

Effect of Fermentation on the Proximate Constituents of White and Red Cabbage

Fermentation noticeably influenced the proximate composition of both white and red cabbage, altering their moisture, ash, crude fibre, crude lipid, crude protein, and carbohydrate levels. Moisture content, which is crucial for product development and sensory quality, increased in both varieties post-fermentation. The moisture content rose from 24.06% to 27.49% in white cabbage and from 24.05% to 27.41% in red cabbage. These findings are consistent with those of Oladunmoye (2007), suggesting that fermentation can enhance moisture retention. Ash content, which indicates the mineral composition of food, decreased in both cabbage varieties, with red cabbage

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showing a more significant reduction (from 1.71% to 1.05%) than white cabbage (from 1.34% to 1.14%). This reduction may be due to the leaching of soluble minerals into the fermentation medium or the action of fermenting microorganisms. The results align with Oladunmoye (2007) but contrast with Amare et al. (2016) and Kiczorowski et al. (2022), who observed an increase in ash content post-fermentation. The crude fibre content, which is important for digestive health, increased significantly after fermentation. The crude fibre content rose from 2.41% to 3.06% in white cabbage and from 3.46% to 3.90% in red cabbage. These results are in line with the findings of Oulai et al. (2014) and Ohaegbulam et al. (2021), who reported similar increases in fibre content after fermentation. However, other studies, such as those by Oladunmoye (2007) and Oboh et al. (2012), reported a decrease in fibre content, highlighting that fibre content changes can vary significantly depending on fermentation conditions and cabbage variety. Regarding lipid content, the study observed a decrease in crude lipid content, with white cabbage declining from 1.11% to 0.97% and red cabbage from 1.05% to 0.99% post-fermentation. This reduction is likely due to lipid metabolism by microorganisms during fermentation, which use lipids as an energy source. This finding is consistent with Oladunmoye (2007) but diverges from studies by Kiczorowski et al. (2022) and Adegoke et al. (2023), which noted an increase in lipid content.

One of the most significant findings of this study is the increase in crude protein content due to fermentation. In white cabbage, crude protein increased from 19.77% to 20.48%, and in red cabbage, it increased from 19.85% to 20.55%. This increase is attributed to the concentration effect, where microorganisms consume carbohydrates during fermentation, leading to an apparent increase in protein concentration. Similar results were reported by Oladunmoye (2007), Amare et al. (2016) and Adegoke et al. (2023). The increase in protein content underscores the potential of fermented cabbage as a protein supplement, particularly in diets based on cereals and legumes. Finally, the carbohydrate content decreased after fermentation, consistent with the findings of Ogodo et al. (2017) and Adegoke et al. (2023). This reduction is likely due to the utilisation of carbohydrates by fermenting microorganisms as a source of energy.

Conclusion

This study highlights the positive impact of fermentation on the nutritional and antioxidant properties of white and red cabbages. Fermentation not only enhances antioxidant activity but also improves the protein content, making fermented cabbage a valuable dietary component for promoting human health. The increased fibre content and decreased lipid content further contribute to the health benefits of fermented cabbage. These findings suggest that incorporating fermented cabbage into the diet could offer substantial nutritional and health benefits, including probiotic properties that support gut health. Therefore, it is recommended that cabbage be consumed in its fermented form to maximize its health-promoting properties.

Recommendations

1. Fermentation could be considered as one of the best methods in preserving and improving the antioxidant activity of both white and red cabbages thereby contributing immensely to the promotion of human health.
2. Fermentation of cabbage creates an environment for the development of lactic acid bacteria which have probiotic properties, and hence can be recommended in nutrition.
3. The research work revealed that unfermented samples have a high value of protein which was enhanced significantly as a result of fermentation and so could also be a good source of protein as a supplement for cereal and legumes.

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