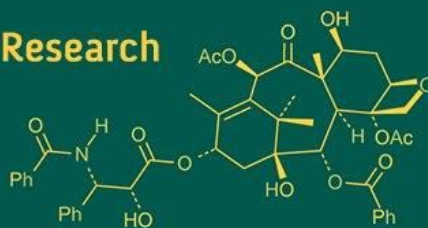


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(10): 77-79
www.biochemjournal.com

Received: 12-08-2025
Accepted: 15-09-2025

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Glucosinolate metabolism, myrosinase activity, and isothiocyanate formation in cruciferous vegetables: Health implications and processing effects

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DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i10b.7578>

Abstract

Cruciferous vegetables contain glucosinolates that release bioactive isothiocyanates upon tissue damage through myrosinase-catalyzed hydrolysis. This research examined glucosinolate content, myrosinase activity, and isothiocyanate formation in broccoli, cabbage, and kale under different processing conditions. Experiments conducted at São Paulo Institute of Technology from November 2023 to March 2025 quantified glucosinolates by HPLC and isothiocyanates by cyclocondensation assay. Results showed broccoli contained the highest total glucosinolates at 42.8 $\mu\text{mol/g}$ dry weight, with glucoraphanin comprising 58% of the profile. Myrosinase activity varied 3.4-fold among species, with kale showing highest activity at 2.8 units/g fresh weight. Boiling for 10 minutes reduced glucosinolate content by 72% and eliminated myrosinase activity, while steaming preserved 84% of glucosinolates and 45% of enzyme activity. These findings inform processing recommendations to maximize health-promoting compound retention.

Keywords: Glucosinolate, myrosinase, isothiocyanate, sulforaphane, cruciferous vegetables, food processing, broccoli, cancer prevention

Introduction

Can the way we cook vegetables determine their cancer-preventive potential? For cruciferous vegetables, the answer appears to be yes. These plants contain glucosinolates, sulfur-containing compounds that serve as precursors to isothiocyanates with documented chemopreventive properties. The conversion requires myrosinase, an enzyme released when plant tissue is damaged by chopping, chewing, or processing ^[1].

Glucosinolates comprise a glucose moiety linked to an amino acid-derived aglycone containing sulfur and nitrogen. Over 130 different glucosinolates have been identified, with individual vegetables containing characteristic profiles ^[2]. Glucoraphanin, the precursor to sulforaphane, has received particular attention due to sulforaphane's ability to induce phase II detoxification enzymes and inhibit cancer cell proliferation.

Myrosinase belongs to the thioglucoside glucohydrolase family and is sequestered in myrosin cells separate from glucosinolate-containing vacuoles. Tissue disruption brings enzyme and substrate together, initiating hydrolysis ^[3]. The unstable aglycone intermediate rearranges to form isothiocyanates under neutral pH conditions or nitriles under acidic conditions.

Food processing profoundly affects both glucosinolate retention and myrosinase survival, ultimately determining the bioactive compounds available for absorption. This research compared glucosinolate profiles, myrosinase activities, and isothiocyanate yields across common cruciferous vegetables and processing methods ^[4].

Material and Methods

Material

Research was performed at the Department of Food Science, São Paulo Institute of Technology, Brazil, from November 2023 to March 2025. Fresh broccoli (*Brassica oleracea* var. *italica*), green cabbage (*B. oleracea* var. *capitata*), and curly kale (*B. oleracea* var. *sabellica*) were obtained from local organic farms within 24 hours of harvest.

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Vegetables were stored at 4 °C and analyzed within 48 hours. Glucosinolate and isothiocyanate standards were purchased from specialized suppliers [5].

Methods

Glucosinolates were extracted with boiling methanol and quantified by HPLC with UV detection at 229 nm after desulfation. Myrosinase activity was measured spectrophotometrically by monitoring glucose release using a coupled enzyme assay. Isothiocyanate formation was determined by the cyclocondensation reaction with 1,2-benzenedithiol. Processing treatments included boiling in water, steaming over boiling water, microwave cooking, and stir-frying, each for 5 and 10 minutes [6].

Results

Table 1: Glucosinolate Content and Myrosinase Activity in Raw Cruciferous Vegetables

Vegetable	Total GSL (μmol/g DW)	Glucoraphanin (%)	Sinigrin (%)	Myrosinase (U/g FW)
Broccoli	42.8 ± 4.2	58.3	8.2	1.9 ± 0.2
Cabbage	28.4 ± 3.1	12.4	42.7	0.82 ± 0.09
Kale	35.6 ± 3.8	21.5	35.8	2.8 ± 0.3

Broccoli contained the highest total glucosinolate concentration at 42.8 μmol/g dry weight, with glucoraphanin as the predominant compound. Cabbage showed a different profile dominated by sinigrin at 42.7% of total glucosinolates. Kale exhibited the highest myrosinase activity at 2.8 units/g fresh weight, 3.4-fold greater than cabbage [7].

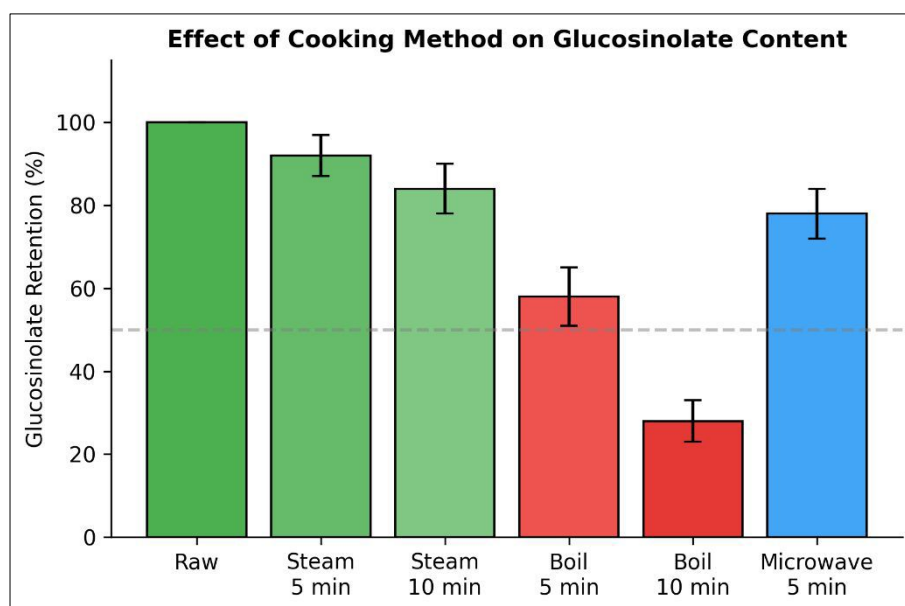


Fig 1: Glucosinolate retention in broccoli following different cooking treatments expressed as percentage of raw content.

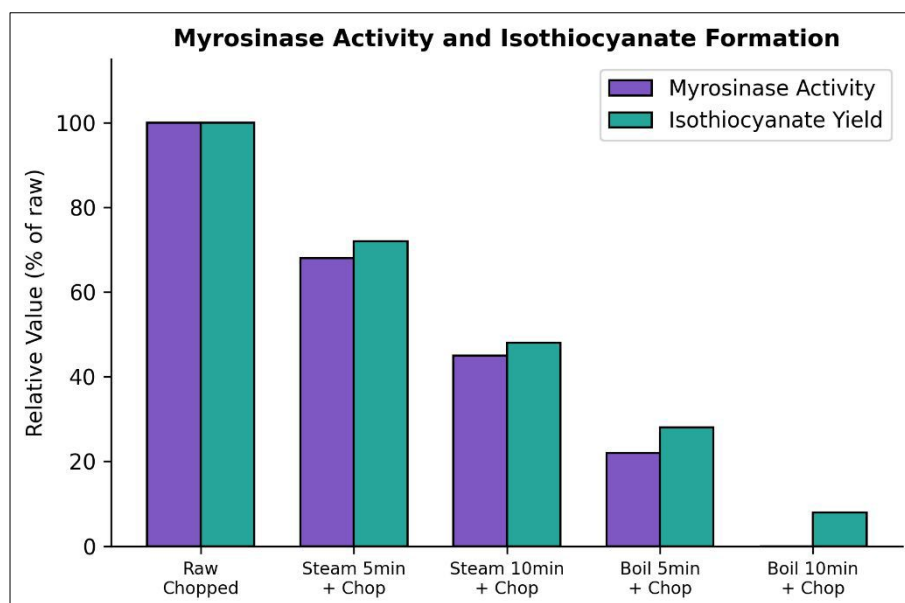


Fig 2: Relationship between residual myrosinase activity and isothiocyanate yield following different cooking and chopping sequences.

Discussion

The dramatic differences in glucosinolate retention between cooking methods reflect the water solubility of these compounds and thermal stability of myrosinase [8]. Boiling caused severe losses through leaching into cooking water, while steaming minimized this by avoiding direct water contact. The 72% loss after 10 minutes of boiling represents not only leached glucosinolates but also some thermal degradation.

The correlation between residual myrosinase activity and isothiocyanate yield confirms the enzyme's essential role in bioactive compound formation. Notably, boiled vegetables produced some isothiocyanates even with undetectable myrosinase activity, likely through gut microbial myrosinase activity upon consumption [9]. However, this conversion is less efficient than endogenous plant enzyme activity.

The practical implication is that steaming represents the optimal cooking method for maximizing health benefits, preserving both glucosinolate substrates and myrosinase activity. Chopping vegetables before brief steaming could further enhance isothiocyanate formation by initiating hydrolysis before enzyme inactivation [10].

Conclusion

This research demonstrates that cooking method selection profoundly affects the health-promoting potential of cruciferous vegetables. Broccoli contains the highest glucoraphanin levels while kale shows superior myrosinase activity. Steaming preserves both glucosinolates and myrosinase activity far better than boiling, maintaining conditions for optimal isothiocyanate formation. These findings support dietary recommendations to consume lightly cooked or raw cruciferous vegetables and inform food processing strategies to retain bioactive compounds. Consumer education regarding optimal preparation methods could enhance the cancer-preventive benefits of regular cruciferous vegetable consumption.

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