

2020 Co-author_Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Q1.pdf

 Unika Soegijapranata1

Document Details

Submission ID

trn:oid::28973:123983644

Submission Date

Dec 8, 2025, 1:48 PM GMT+7

Download Date

Dec 8, 2025, 2:25 PM GMT+7

File Name

2020 Co-author_Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Q1.pdf

File Size

3.0 MB

52 Pages

15,995 Words

91,182 Characters

14% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.





Filtered from the Report

- Bibliography
- Quoted Text
- Cited Text
- Small Matches (less than 10 words)




Exclusions

- 3 Excluded Sources
- 34 Excluded Matches

Match Groups

-  **79 Not Cited or Quoted 14%**
Matches with neither in-text citation nor quotation marks
-  **0 Missing Quotations 0%**
Matches that are still very similar to source material
-  **0 Missing Citation 0%**
Matches that have quotation marks, but no in-text citation
-  **0 Cited and Quoted 0%**
Matches with in-text citation present, but no quotation marks

Top Sources

- 11%  Internet sources
- 7%  Publications
- 9%  Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

No suspicious text manipulations found.

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Match Groups

- 79 Not Cited or Quoted 14%**
Matches with neither in-text citation nor quotation marks
- 0 Missing Quotations 0%**
Matches that are still very similar to source material
- 0 Missing Citation 0%**
Matches that have quotation marks, but no in-text citation
- 0 Cited and Quoted 0%**
Matches with in-text citation present, but no quotation marks

Top Sources

- 11% Internet sources
- 7% Publications
- 9% Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Submitted works	Coventry University on 2025-11-17	3%
2	Internet	simdos.unud.ac.id	1%
3	Submitted works	University of Newcastle on 2025-06-24	<1%
4	Internet	www.firstlight.cn	<1%
5	Publication	R. A. S. N. Ranasinghe, W. L. I. Wijesekara, P. R. D. Perera, S. A. Senanayake, M. M. ...	<1%
6	Submitted works	Lovely Professional University on 2021-07-22	<1%
7	Internet	360qikan.com	<1%
8	Internet	speciation.net	<1%
9	Internet	dr.lib.sjp.ac.lk	<1%
10	Submitted works	University of Greenwich on 2022-10-10	<1%

11	Internet	www.ingentaconnect.com	<1%
12	Internet	pdf.aminer.org	<1%
13	Internet	peerj.com	<1%
14	Internet	doc-pak.undip.ac.id	<1%
15	Publication	Tanmay Sarkar, Molla Salauddin, Sarita Roy, Runu Chakraborty et al. "Underutiliz...	<1%
16	Internet	ouci.dntb.gov.ua	<1%
17	Internet	repository.poliupg.ac.id	<1%
18	Internet	www.aminer.org	<1%
19	Submitted works	Melbourne Institute of Business and Technology on 2023-08-01	<1%
20	Submitted works	School of Business and Management ITB on 2023-04-05	<1%
21	Internet	www.gmu.ac.ir	<1%
22	Publication	Siddhnath, Amit Ranjan, Bimal Prasanna Mohanty, Pooja Saklani, Krushna Chand...	<1%
23	Internet	pearl.plymouth.ac.uk	<1%
24	Internet	krishi.icar.gov.in	<1%

25	Submitted works	University of Stirling on 2022-05-18	<1%
26	Submitted works	The University of Manchester on 2025-10-10	<1%
27	Internet	www.semanticscholar.org	<1%
28	Publication	Adefisola Bola Adepeju, Temitope Omolayo Fasuan, Kunle Oni. "Implications of bl...	<1%
29	Publication	Mariel Calderón-Oliver, Luis Humberto López-Hernández. "Food Vegetable and Fr...	<1%
30	Submitted works	Higher Education Commission Pakistan on 2023-07-13	<1%
31	Internet	ia801702.us.archive.org	<1%
32	Publication	Somaye Pakseresht, Mostafa Mazaheri Tehrani. "Advances in Multi-component S...	<1%
33	Submitted works	University of Stirling on 2012-11-21	<1%
34	Internet	www.people-first.fr	<1%
35	Publication	Avtar Singh, Ajay Mittal, Sootawat Benjakul. "Full Utilization of Squid Meat and It...	<1%
36	Internet	ds.inflibnet.ac.in	<1%
37	Internet	www.passeidireto.com	<1%
38	Submitted works	Singapore Institute of Technology on 2022-03-26	<1%

39	Publication	Zeynab Fartoosi, Maryam Kolahi, Fariba Heidarizadeh, Andrea Goldson-Barnaby. ...	<1%
40	Internet	download.bibis.ir	<1%
41	Internet	mobt3ath.com	<1%
42	Internet	openknowledge.fao.org	<1%

Fakultas Teknologi Pertanian
Program Studi Teknologi Pangan
Jl. Pawiyatan Luhur IV/1 Benda Duwur Semarang 50234
Telp. (024) 8441555, 8505003(hunting) Fax. (024) 8415429 - 8445265
e-mail: unika@unika.ac.id http://www.unika.ac.id



SURAT TUGAS

Nomor : 00059/B.7.9/ST.FTP/01/2020

Dekan Fakultas Teknologi Pertanian Universitas Katolik Soegijapranata, Semarang dengan ini memberikan tugas kepada :

- Nama : **Dr. R. Probo Y. Nugrahedi STP., MSc.**
- Status : Dosen Fakultas Teknologi Pertanian, Universitas Katolik Soegijapranata, Semarang.
- Tugas : Sebagai tim Penulis (co author) dan sebagai Penulis Korespondensi Artikel .
Penelitian dengan judul: Effect of Thermal Processing on Key
Phytochemical Compounds in Green Leafy Vegetables: A Review untuk
dikirimkan di jurnal internasional.
- Waktu : Januari 2020 s.d. Semester Genap 2019/2020
- Lain-lain : Harap melaksanakan tugas dengan sebaik-baiknya dan penuh tanggung
jawab, serta memberikan laporan setelah selesai melaksanakan tugas.



Semarang, 15 Januari 2020

Dekan,

Dr. R. Probo Y. Nugrahedi, M. Sc.

NPP. : 0581 2001 244

Submission ID: 2897315898 Integrity Submission

1997

[Home](#)[All Journals](#)[Food Science & Technology](#)[Food Reviews International](#)[List of Issues](#)[Volume 38, Issue 4](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[Submit an article](#)[About this journal](#)[Browse all articles & issues](#)[Follow this journal](#)[Buy a subscription](#)[View cover image](#)

Food Reviews International, Volume 38, Issue 4 (2022)

[See all volumes and issues](#)[Share](#)[Volume 38, 2022](#)[Vol 37, 2021](#)[Vol 36, 2020](#)[Browse this journal](#)[Issue 4](#) [Issue 3](#) [Issue 2](#) [Issue 1](#)[Journal homepage](#)



Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)[Open access articles](#)[Most read articles](#)[Most cited articles](#)

2

Subscribe to updates

Stay informed when new research is published in this journal

[New content alerts](#)

Sample our Environment & Agriculture Journals
>> [Sign in here](#) to start your access to the latest two volumes for 14 days

4



Encapsulation for Improving *in Vitro* Gastrointestinal Digestion of Plant Polyphenols and Their Applications in Food Products >

Methavee Peanparkdee & Satoshi Iwamoto

Pages: 335-353

Published online: 29 Feb 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.4 MB\)](#) | [EPUB](#)

1768
Views

35
CrossRef citations

0
Altmetric



Classification, Composition, Extraction, Functional Modification and Application of Rice (*Oryza sativa*) Seed Protein: A Comprehensive Review >

Neeraj Ghanghas, Mukilan M. T. Shikha Sharma & Pramod K. Prabhakar

Pages: 354-383

Published online: 04 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.2 MB\)](#) | [EPUB](#)

2230
Views

42
CrossRef citations

0
Altmetric



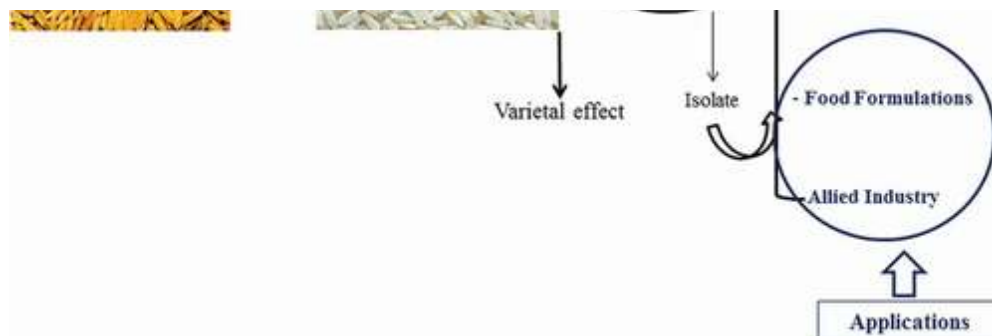
Food Reviews International



[Advanced search](#) [Citation search](#)

▼ About this journal ▼

▼ Buy a subscription



Persimmon (*Diospyros Kaki* L.): Chemical Properties, Bioactive Compounds and Potential Use in the Development of New Products – A Review >

Julia Rabelo Vaz Matheus, Cristiano José de Andrade, Roberta Fontanive Miyahira & Ana Elizabeth Cavalcante Fai

Pages: 384-401

Published online: 09 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.7 MB\)](#) | [EPUB](#)

2044
[Views](#)

55
[CrossRef citations](#)

0
[Altmetric](#)

Grape Polyphenols to Arrest *in Vitro* Proliferation of Human Leukemia Cells: A Systematic Review and Meta-analysis >

222
[Views](#)

7

[Home](#)[All Journals](#)[Food Science & Technology](#)[Food Reviews International](#)[List of Issues](#)[Volume 38, Issue 4](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)

A Systematic Review on Anti-diabetic and Cardioprotective Potential of Gallic Acid: A Widespread Dietary Phytoconstituent >

Shaikh Jamal Uddin, Mohasana Afroz, S. M. Neamul Kabir Zihad, Md. Shamim Rahman, Sanzida Akter, Ishaq N. Khan, S. M. Sabik Al-Rabbi, Razina Rouf, Muhammad Torequl Islam, Jamil A. Shilpi, Lutfun Nahar, Evelin Tiralongo & Satyajit D. Sarker

Pages: 420-439

Published online: 02 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.7 MB\)](#) | [EPUB](#)

499

Views

19

CrossRef citations

0

Altmetric



Tartary Buckwheat: An Under-utilized Edible and Medicinal Herb for Food and Nutritional Security >

Jingjun Ruan, Yuexia Zhou, Jun Yan, Meiliang Zhou, Sun-Hee Woo, Wenfeng Weng, Jianping Cheng & Kaixuan Zhang

Pages: 440-454

Published online: 04 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.5 MB\)](#) | [EPUB](#)

892

Views

62

CrossRef citations

0

Altmetric





Home

All Journals

Food Science & Technology

Food Reviews International

List of Issues

Volume 38, Issue 4

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.2 MB\)](#) | [EPUB](#)

Dates (*Phoenix Dactylifera*) and Date Vinegar: Preventive Role against Various Diseases and Related *in Vivo* Mechanisms >

Zeshan Ali, Jianke Li, Yuhuan Zhang, Naureen Naeem, Shoaib Younas & Farah Javeed

Pages: 480-507

Published online: 02 Mar 2020[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.2 MB\)](#) | [EPUB](#)

439

Views

17

CrossRef citations

1

Altmetric

Dry Fish and Its Contribution Towards Food and Nutritional Security >

Siddhnath, Amit Ranjan, Bimal Prasanna Mohanty, Pooja Saklani, Krushna Chandra Dora & Supratim Chowdhury

Pages: 508-536

Published online: 18 Mar 2020[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.2 MB\)](#) | [EPUB](#)

996

Views

31

CrossRef citations

0

Altmetric





Food Reviews International

[Advanced search](#) [Citation search](#)

Pages: 557-558

[About this journal](#)

Pages: 557-558

Published online: 09 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.6 MB\)](#) | [EPUB](#)

[Buy a subscription](#)



Electrospraying Technique and Its Recent Application Advances for Biological Macromolecule Encapsulation of Food Bioactive Substances >

Panpan Wang, Mengzhen Ding, Ting Zhang, Tingting Wu, Ruirui Qiao, Fengping Zhang,
Xichang Wang & Jian Zhong

Pages: 566-588

Published online: 19 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.3 MB\)](#) | [EPUB](#)

1033

[Views](#)

42

[CrossRef citations](#)

0

[Altmetric](#)

Current Status of 'Sanghuang' as a Group of Medicinal Mushrooms and Their Perspective in Industry Development >

Li-Wei Zhou, Masoomah Ghobad-Nejhad, Xue-Mei Tian, Yi-Fei Wang & Fang Wu

Pages: 589-607

Published online: 19 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.2 MB\)](#) | [EPUB](#)

690

[Views](#)

51

[CrossRef citations](#)

0

[Altmetric](#)



Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)

Published online: 21 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.9 MB\)](#) | [EPUB](#)

0
Altmetric

Food Vegetable and Fruit Waste Used in Meat Products >

Mariel Calderón-Oliver & Luis Humberto López-Hernández

Pages: 628-654

Published online: 27 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.5 MB\)](#) | [EPUB](#)

1645
Views

26
[CrossRef citations](#)

0
Altmetric

Nanomaterial-based Optical Biosensors for the Detection of Foodborne Bacteria >

Han Du, Zhaojie Li, Yi Wang, Qingli Yang & Wei Wu

Pages: 655-684

Published online: 30 Mar 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(3.1 MB\)](#) | [EPUB](#)

1656
Views

40
[CrossRef citations](#)

0
Altmetric

[Home](#)[All Journals](#)[Food Science & Technology](#)[Food Reviews International](#)[List of Issues](#)[Volume 38, Issue 4](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)**Published online:** 08 Apr 2020[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(3.4 MB\)](#) | [EPUB](#)

Postharvest Profile, Processing and Waste Utilization of Dragon Fruit (*Hylocereus Spp.*): A Review >

Kirti Jalgaonkar, Manoj Kumar Mahawar, Bhushan Bibwe & Pankaj Kannaujia

Pages: 733-759

Published online: 10 Apr 2020[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.4 MB\)](#) | [EPUB](#)2205
Views82
CrossRef citations0
Altmetric

Advances in Multi-component Supramolecular Oleogels- a Review >

Somaye Pakseresht & Mostafa Mazaheri Tehrani

Pages: 760-782

Published online: 08 Apr 2020[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2 MB\)](#) | [EPUB](#)1353
Views29
CrossRef citations0
Altmetric

[Home](#)[All Journals](#)[Food Science & Technology](#)[Food Reviews International](#)[List of Issues](#)[Volume 38, Issue 4](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1.9 MB\)](#) | [EPUB](#)

Functional and Bioactive Properties of Gelatin Extracted from Aquatic Bioresources – A Review >

R. A. S. N. Ranasinghe, W. L. I. Wijesekara, P. R. D. Perera, S. A. Senanayake, M. M. Pathmalal & R. A. U. J. Marapana

Pages: 812-855

Published online: 14 Apr 2020

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2.9 MB\)](#) | [EPUB](#)

998

[Views](#)

41

[CrossRef citations](#)

[Altmetric](#)

Explore articles

[Latest](#)[Open access](#)[Most read](#)[Most cited](#)[Trending](#)

Explore the most recently published articles



[Home](#)[All Journals](#)[Food Science & Technology](#)[Food Reviews International](#)[List of Issues](#)[Volume 38, Issue 4](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)

Moisture Migration and Its Prevention in Multi-Domain Bakery Products: A Review >

P. Y. Nugrahedhi et al.

Review Article | Published online: 4 Oct 2025

Integrated Review of *Akebia* Fruits: Botany, Bioactive Properties, Processing Innovations, and Post-Harvest Cracking Challenges >

Mingna Li et al.

Review Article | Published online: 29 Sep 2025

Unlocking Spinach Polyphenols: Novel Extraction, Impact of Processing, Value-Addition and Therapeutic Potentials >

Muhammad Faisal Manzoor et al.

Review Article | Published online: 26 Sep 2025

[View all latest articles >](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)[R&D professionals](#)[Open journals](#)[Advertising solutions](#)[Newsroom](#)[Editors](#)[Open Select](#)[Accelerated publication](#)[All journals](#)[Librarians](#)[Dove Medical Press](#)[Corporate access solutions](#)[Books](#)[Societies](#)[F1000Research](#)[Keep up to date](#)[Register to receive personalised research and resources by email](#)[Sign me up](#)

Copyright © 2025 **Informa UK Limited** [Privacy policy](#) [Cookies](#) [Terms & conditions](#) [Accessibility](#)

Registered in England & Wales No. 01072954

5 Howick Place | London | SW1P 1WG

Food Reviews International



[Advanced search](#) [Citation search](#)

[Submit an article ▼](#)

[About this journal](#)

[Browse all articles & issues ▼](#)

[Follow this journal ▼](#)

[Buy a subscription](#)

🏠 Food Reviews International


[Advanced search](#) [Citation search](#)

▼ About this journal ▼

Food Reviews International publishes state-of-the-art original reviews concerned with food science and technology, food sustainability, food chemistry, food analysis and composition, food microbiology, food safety and toxicology, functional foods, food processing and engineering, food packaging, food nanotechnology and biotechnology, sensorial science, new product development, food policy and regulation, novel foods, and food innovations (AI, food omics, future foods, smart processing).

Articles, written primarily by researchers and practitioners, should examine most recent research progresses, and emerging issues, challenges, and opportunities facing the field and the food industry, and should be of interest to the scientific community and/or the public with global impact. *Food Reviews International* publishes in-depth and comprehensive review manuscripts that go beyond simple description and summary of literature. We are not in favor of publishing manuscripts which are mainly incremental and add little new information and critical analyses. Submission of original research articles, or submissions with a focus on nutrition, pharmacology, cosmetics, and medicine (including traditional medicine), or bibliometric reviews will not be considered for publication. Authors

▼ Buy a subscription ▼

continue a
submission in
progress

**Go to
submission
site** 

**Instructions
for authors**

Sample our
Food Science & Technology
Journals



>> **Sign in here** to start your access
to the latest two volumes for 14 days

Food Reviews International

[Advanced search](#) [Citation search](#)

▼ About this journal

technologists, researchers, educators and students, food chemists, food engineers, agriculturists, microbiologists, toxicologists, nutritionists, and professionals in R&D, sales and marketing, government and governing bodies.

Peer Review Statement: All submitted manuscripts are subject to initial appraisal by the Editor, and, if found suitable for further consideration, to single-anonymous peer review by independent, expert referees. Submissions are online via ScholarOne Manuscripts.

Publication office: Taylor & Francis Group, LLC, 530 Walnut Street, Suite 965, Philadelphia, PA USA

▼ Buy a subscription

Authors can choose to publish [gold open access](#) in this journal.

Read the [Instructions for Authors](#) for information on how to submit your article.

🏠 Food Reviews International

[Advanced search](#) [Citation search](#)

▼ About this journal

downloads/views

- **6.0 (2024)** Impact Factor
- **Q1** Impact Factor Best Quartile
- **7.8 (2024)** 5 year IF
- **15.8 (2024)** CiteScore (Scopus)
- **Q1** CiteScore Best Quartile
- **1.929 (2024)** SNIP
- **1.510 (2024)** SJR
- **7** days avg. from submission to first decision
- **42** days avg. from submission to first post-review decision
- **13** days avg. from acceptance to online publication
- **11%** acceptance rate

▼ Buy a subscription

[Learn more about journal metrics and how to use them](#) ▼

Editorial board

Editor-in-Chief

Food Reviews International

[Advanced search](#) [Citation search](#)

31

▼ [About this journal](#) ▼[Chunhong Ren, Hong Ren, China](#)

Danijela Bursać Kovačević - Department of Food Engineering,
University of Zagreb, Zagreb, Croatia

International Editorial Board

Jane Mara Block - *Federal University of San Catarina, Florianopolis, Brazil*

Shiguo Chen - *Zhejiang University, Hangzhou, China*

Jae-Won Ha - *Hankyong National University, South Korea*

Zouyan He - *Guangxi Medical University, China*

Yao Li - *California State Polytechnic University, Pomona, CA, USA*

Jianhui Liu - *Nanjing University of Finance and Economics, China*

Kunlun Liu - *Henan University of Technology, China*

Przemysław Sitarek - *Medical University of Łódź, Poland*

Quancai Sun - *Florida State University, USA*

Xiaohong Sun - *Dalhousie University, Canada*

Jirayu Tanprasertsuk - *Nom Nom Now, San Francisco, CA, USA*

Diogo Thimoteo da Cunha - *State University of Campinas, Brazil*

Qingyang Wang - *Oregon State University, OR, USA*

Last updated on 22-July-2024

▼ [Buy a subscription](#)

Food Reviews International

[Advanced search](#) [Citation search](#)

▼ About this journal

Contents/Agriculture, Biology and Environmental Sciences, Division for Industrial Studies, Food Science and Technology Abstracts, Foods Adlibra, Index to Scientific Reviews, PubSCIENCE, Reference Update, Research Alert, and Science Citation Index Expanded (SCIE).

▼ Buy a subscription

Open access

Food Reviews International is a hybrid open access journal that is part of the Taylor & Francis [Open Select](#) publishing program, giving you the option to publish open access. Publishing open access means that your article will be free to access online immediately on publication, increasing the visibility, readership, and impact of your research.

Why choose open access?



Increase the discoverability and readership of your article



Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)**Rigorous peer review** for every open access article

Article Publishing Charges

If you choose to publish open access in this journal you may be asked to pay an Article Publishing Charge (APC). You may be able to publish your article at no cost to yourself or with a reduced APC if your institution or research funder has an [open access agreement or membership](#) with Taylor & Francis.

If you choose not to publish open access in this journal, there is no APC.

[Use our APC finder to calculate your article publishing charge](#) 

Publication details



Advertising information

4

1

[Aims and scope](#)[Journal metrics](#)[Editorial board](#)[Abstracting and indexing](#)[Open access](#)[Publication details](#)[Advertising information](#)

Food Reviews International

[Advanced search](#) [Citation search](#)[About this journal](#)[Buy a subscription](#)[Explore advertising solutions](#)

Taylor & Francis make every effort to ensure the accuracy of all the information (the "Content") contained in our publications. However, Taylor & Francis, our agents (including the editor, any member of the editorial team or editorial board, and any guest editors), and our licensors, make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor & Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to, or arising out of the use of the Content. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>.



Food Reviews International

[Advanced search](#) [Citation search](#)

19

[R&D professionals](#)[Open journals](#)[Advertising solutions](#)[Newsroom](#)[Editors](#) [About this journal](#)[Accelerated publication](#)[Buy a subscription](#)[Librarians](#)[Open Select](#)[Corporate access solutions](#)[All journals](#)

3

[Societies](#)[Dove Medical Press](#)[Books](#)[F1000Research](#)

Keep up to date

Register to receive personalised
research and resources by email

[Sign me up](#)

Copyright © 2025 **Informa UK Limited** [Privacy policy](#) [Cookies](#) [Terms & conditions](#) [Accessibility](#)

Registered in England & Wales No. 01072954

5 Howick Place | London | SW1P 1WG

© 2025 Informa UK Limited
All rights reserved.





Food Reviews International

ISSN: 8755-9129 (Print) 1525-6103 (Online) Journal homepage: <https://www.tandfonline.com/loi/lfri20>

Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Vegetables: A Review

Nandya Putriani, Jimmy Perdana, Meiliana & Probo Y. Nugrahedi

To cite this article: Nandya Putriani, Jimmy Perdana, Meiliana & Probo Y. Nugrahedi (2020): Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Vegetables: A Review, Food Reviews International, DOI: [10.1080/87559129.2020.1745826](https://doi.org/10.1080/87559129.2020.1745826)

To link to this article: <https://doi.org/10.1080/87559129.2020.1745826>



Published online: 16 Apr 2020.



Submit your article to this journal [↗](#)



Article views: 139



View related articles [↗](#)



View Crossmark data [↗](#)



Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Vegetables: A Review

Nandya Putriani^a, Jimmy Perdana^{a,b}, Meiliana^a, and Probo Y. Nugrahdia^a

^aDepartment of Food Technology, Soegijapranata Catholic University, Semarang, Indonesia; ^bDepartment of Science and Technology, Nestlé NPTC Food, Singen (Hohentwiel), Germany

ABSTRACT

Green leafy vegetables are widely cultivated and consumed in South East Asia. These vegetables are rich in phytochemicals, which have been associated to particular health benefits. Preparation/processing, particularly those involving heat, prior to consumption can change the level of phytochemicals in the vegetables following various mechanisms, including thermal breakdown, oxidation, leaching, and matrix degradation. Appropriate processing should minimize degradation of phytochemicals so that the optimum intake toward health promotion be achieved. Better understanding of how processing influence the retention of phytochemical compounds is therefore crucial to provide guidelines on the processing of green leafy vegetables while maximizing their nutritional values.

KEYWORDS

Green leafy vegetables; phytochemicals; thermal processing; degradation; nutritional values

Introduction

For centuries, green leafy vegetables have been staples in the diets of South East Asian people.^[1] These vegetables contribute significantly to fulfill human nutrition needs. The vegetables contain a substantial amount of protein, carbohydrate, lipids, fibers, minerals, vitamins, and particularly, phytochemical compounds.^[2,3]

Green leafy vegetables are consumed either raw or cooked/processed. Various types of processing are commonly applied to inactivate microorganism and enzymes leading to improved product safety and quality. Processings are also aimed to enhance palatability and to inactivate antinutritional compounds.^[4,5] Thermal processing methods commonly applied to green leafy vegetables are blanching, steaming, boiling, drying, microwave cooking, pressure cooking, and frying. Processing may cause significant changes in nutritional and especially phytochemical content in green leafy vegetables.^[6,7] Different methods of thermal processing can lead to various degree of changes of the phytochemical contents.

Therefore, the selection of an appropriate method to process green leafy vegetables should be critically considered. In this paper, we review the effect of processing methods on the retention of phytochemical compounds in green leafy vegetables. The retention level is calculated from previous publications reporting concentration of the phytochemicals both in the raw and the processed green leafy vegetables. The underlying mechanism leading to changes of phytochemical compounds in green leafy vegetables during processing are discussed by providing thorough information of each processing method, such as

CONTACT Probo Y. Nugrahdia ✉ probo@unika.ac.id Department of Food Technology, Soegijapranata Catholic University, Jl. Pawiyatan Luhur IV/1 Bendan Duwur, Semarang, Indonesia

© 2020 Taylor & Francis

time and temperature, pressure, and amount of water or oil, which lead to the changes via mechanisms of, e.g. cell lysis, matrix degradation, enzyme inactivation, thermal degradation, and oxidation. Previous studies have been reviewed the interaction of processing and bioavailability and bioaccessibility of phytochemicals in vegetables.^[8–11] The mechanism of absorption, distribution, metabolism, and excretion of phytochemicals have also been reviewed.^[7,8,12–15]

Phytochemicals in green leafy vegetables and their potential health benefits

Vegetable consumption has been identified to promote health, e.g. against chronic diseases such as cardiovascular disease, diabetes, obesity, alzheimer, and cancer.^[4,16] These health benefits have been associated to, for example antioxidant and anticarcinogenic activities of phytochemical compounds in vegetables. Key phytochemicals in green leafy vegetables are phenolic compounds,^[17] carotenoids,^[18] chlorophyll,^[19] ascorbic acid,^[20] flavonoids,^[21] and glucosinolates,^[22] which will be briefly discussed in the following subsection.

Polyphenols

The phenolic compound is chemically defined as a compound containing an aromatic ring, which is linked with one or more hydroxyl group.^[23] The number and position of hydroxyl groups affect its ability to scavenge free radicals and chelate metal cations, which can decrease the risk of chronic disease.^[24,25] Total polyphenol concentration in green leafy vegetables varies between 23 and 231 mg GAE/100 g fresh weight (FW) (Table 1). Most of the polyphenols in green leafy vegetables degrade during processing at 100°C or higher.^[6,26,39]

Table 1. Phytochemical compounds in green leafy vegetables.

Phytochemical compounds	Vegetables	Concentration (mg/100 g FW)	References
Total polyphenol	Spinach	23	[26]
	Water spinach	42	[27]
	Celery	35	[28]
	Coriander leaves	42	[26]
	Cassava leaves	50	[29]
	Papaya leaves	231	[30]
	Chinese mustard	63	[31]
Carotenoid	Spinach	2	[32]
	Water spinach	2	[32]
	Coriander leaves	5	[33]
	Drumstick leaves	7	[32]
	Sweet potato leaves	8	[32]
	Lettuce	3	[34]
	Chinese mustard	2	[31]
Chlorophyll	Spinach	1	[20]
	Water spinach	2	[35]
	Celery	4	[36]
	Coriander leaves	4	[36]
	Drumstick leaves	216	[37]
	Spinach	69	[20]
Ascorbic acid	Water spinach	16	[35]
	Celery	3	[38]
	Drumstick leaves	271	[37]
	Cassava leaves	48	[29]
	Papaya leaves	40	[30]
	Chinese mustard	31	[31]

The bioavailability of polyphenols depends on the matrix composition and chemical structure that could be induced by food processing.^[9,12] Food processing causes degradation and modification of cell wall composition that can increase the bioavailability of polyphenols.^[9] The bioactive metabolites could be absorbed into the circulatory system and exert antioxidant activity that gives beneficial effect on human health.^[40] Cory *et al.*^[41] have also reviewed the impact of polyphenols on human health. The antioxidant and anti-inflammatory properties of polyphenols were reported to reduce the risk of cancer, cardiovascular diseases, type 2 diabetes, obesity, and neurodegenerative diseases.

Carotenoids

Carotenoids are oil-soluble yellow-orange pigments that consist of isoprene units linked covalently in either a head-to-tail or tail-and-tail to form a symmetrical molecule.^[20,42] Carotenoids in vegetables are mostly located in chloroplasts and covered by chlorophylls. Therefore, the yellow-orange color of carotenoids becomes more evident when chlorophyll decomposes.^[42] Carotenoids commonly found in plants are in forms of lutein, zeaxanthin, lycopene, β -carotene, α -carotene, and β -cryptoxanthin.^[18] Lutein and β -carotene are the most dominant carotenoids in green vegetables.^[43]

In green leafy vegetables, the carotenoid content ranges between 2 and 8 g/100 g FW (Table 1). Carotenoids are mostly bound to proteins that may decrease their bioavailability. The absorption of carotenoids is also influenced by dietary fat. Dietary fat and bile salt could be bound with the carotenoid to form micelles that allow carotenoid absorption to the intestine. Fortunately, appropriate processing could increase carotenoid bioavailability by breaking down the cell wall and protein-carotenoid complexes. Processing combined with oils also can increase the bioavailability of carotenoids.^[40,43]

The diffusion of carotenoids from the blood circulatory system to various tissues by lipoprotein could provide beneficial effects on human health.^[43] Carotenoids could protect the cellular membranes and lipoproteins against photooxidative damage in plant and human due to their ability to scavenge reactive oxygen species, singlet molecular oxygen, and peroxy radicals. Carotenoids also contribute to macular pigment formation that could absorb harmful blue light. Thus, increased consumption of a diet rich in carotenoids could reduce the risk of diseases such as erythema, cancer, cardiovascular-linked diseases, light blindness, keratomalacia, xerophthalmia, cataract, and macular degeneration.^[44,45]

Chlorophyll

Chlorophyll structurally consists of a porphyrin ring containing a magnesium ion located at the center.^[42] Various levels of chlorophyll in green leafy vegetables were reported, ranging from 1 to 216 mg/100 g FW (Table 1). Heat treatment can lead to the formation of pheophytin because magnesium in chlorophyll can be easily displaced by two hydrogen atoms. The harsher thermal load may eventually remove the carbomethoxy group in chlorophyll to form pirochlorophyll. Further heating can release either magnesium atom in pirochlorophyll or carbomethoxy group in pheophytin to form piropheophytin.^[46]

Interestingly, the conversion of chlorophyll to pheophytin, pyropheophytin, and pheophorbide during processing can increase the bioavailability of chlorophyll. Chao *et al.*^[47] showed that pheophytin and pheophorbide are the main chlorophyll derivatives found in the

human blood, indicating chlorophyll derivatives might be easily absorbed. Chlorophyll derivatives are reported to possess antioxidant, antimutagenic, and anticancer activity.^[48]

Moreover, an in vivo and in vitro study reported chlorophyll could suppress pancreatic cancer cell viability by inhibiting heme oxygenase mRNA expression and enzymatic activity.^[49] Antioxidant activity in chlorophylls and their derivatives can prevent oxidative DNA damage and lipid peroxidation by chelating reactive ions and scavenging free radicals.^[19]

Ascorbic acid

Ascorbic acid, or commonly known as vitamin C that presents mostly in L-ascorbic acid form, is the enolic form of 3-keto-L-glucofuranolactone.^[50] Table 1 shows the broad spread of ascorbic acid content in various green leafy vegetables. Among others, drumstick leaves notably contain the highest level of ascorbic acid, while celery has the lowest.^[20,29-31,35,37,38]

L-ascorbic acid can terminate radical chain reaction, scavenge reactive species, donate an electron to a substrate, and regenerate other antioxidant compounds that may protect DNA and protein from oxidative stress.^[13] Accordingly, ascorbic acid was reported to improve the utilization of iron and prevent cardiovascular diseases, cancer, cataracts, type 2 diabetes, and inflammation due to their antioxidant and antihistamine effects.^[38,51] Unfortunately, ascorbic acid is easily degraded via oxidation reaction, especially when catalyzed by metal ions (i.e. Cu^{2+} and Fe^{3+}). Heat, light, and oxygen may accelerate oxidation.^[42] The enediol groups at carbon atom numbers 2 and 3 are prone to oxidation and can be easily altered to diketone groups. This transforms ascorbic acid to dehydroascorbic acid.^[50] Dehydroascorbic acid is unstable at physiological pH and it is easily converted to 2,3 diketogulonic acid. The alteration of ascorbic acid to dehydroascorbic acid is reversible but the products of the latter oxidation stages are irreversible.^[38] Most ascorbic acid is therefore lost during processing, cooking, and storage.

Glucosinolates

Glucosinolates are a group of secondary plant metabolites in family *Cruciferae* or *Brassicaceae*, such as broccoli, Chinese mustard, pak choi, kale, and cabbage.^[52] A glucosinolate consists of β -D-thioglucoside N-hydroxysulphate, which is a sulphur-linked β -D-glucopyranose moiety and a side chain (R).^[53] Natella, Maldini, Leoni, & Scaccini^[52] reported that glucosinolates have a weak antioxidant capacity. Two glucosinolates, i.e. sinalbin and gluconasturtiin were found to quench ABTS radical and to chelate copper that leads to low-density lipoprotein inhibition, respectively. Nevertheless, isothiocyanates, ones of the derivative products of glucosinolates were reported to play a role as cancer chemo-preventive.^[54,55] Reviews on the effect of thermal processing on glucosinolates in vegetables can be found elsewhere.^[22,56,57]

Processing methods and their impacts on phytochemical compounds in green leafy vegetables

Blanching

During blanching, vegetables are briefly exposed to hot water or steam. It is usually carried out preceding other processes (e.g. freezing, canning, or drying) to inactivate enzymes, modify the textures, and preserve color. Hot water blanching is performed at temperatures

between 70°C and 100°C for 2 to 5 min, followed by rapid cooling. Steam blanching is carried out at 100°C at a considerably shorter time than water blanching because the heat transfer of condensing steam is more efficient than hot water.^[58]

The impact of blanching on phytochemical compounds varies depending on the type of vegetables and the blanching parameters as summarized in Table 2. Hot water blanching reduced phenolic compounds, carotenoids, and flavonoids in water spinach, celery, pak choy, Chinese mustard, black night shade, and jute mallow. Decrease of phenolic compounds, flavonoids, and carotenoid are often associated with thermal degradation, leaching from vegetable tissue into the blanching water^[26,39,60], oxidation reaction, and isomerization.^[61] In contrast, various levels of increase of total phenolic content after blanching have been reported in coriander leaves (36% to 156% after water blanching and 11% to 131% after steam blanching) and nearly eight-fold in basil.^[27,59] Blanching can liberate phenolic compounds such as hydroxycinnamic acid (which is bound to cell polymer and chlorogenic acid), thus improves its extractability upon analytical measurement. Inversely, the prolonged or higher temperature of blanching decreased the retention of total polyphenolic content in coriander leaves.^[59]

Increase of flavonoids bioavailability in spinach and cassava leaves have also been reported.^[62] The underlying mechanisms involve disruption of hydrogen bonding of complex molecules, which then liberates flavonoids from leaf matrices. Blanching for a short time (30 s) increased chlorophyll content in basil and coriander leaves of 23% and 169%, respectively. This short time blanching facilitates the breakdown of organelles that contain phytochemical compounds, while the degradation can be maintained minimal.^[27]

In general, blanching decreases of phytochemical compounds due to oxidation reaction, thermal degradation, enzymatic degradation, and disruption of vegetable tissue which release water-soluble phytochemical compounds into the processing medium. However, this disruption may also lead to higher extractability of the compounds.

Boiling

Boiling is the most common method to cook green leafy vegetables. Cooking affects membrane disruption, loss of turgor, and reduction of cell adhesion strength, which will lead to loss of firmness or softening.^[63] Boiling time of green leafy vegetables may vary, depending on the type of vegetables and consumer preferences in relations to, e.g. texture, color, and taste.^[22,64] From the phytochemical retention perspective, boiling is more suitable for processing vegetables that contain fat-soluble compounds, such as carotenoid, due to less diffusion and leaching into cooking water.^[65,66]

Generally, boiling reduces phytochemicals in vegetables (Table 3), which is considered higher than that of blanching, and the magnitude is highly varied. Boiling leads leaching of water-soluble phytochemical compounds into the cooking medium.^[39] Thermal degradation of heat-sensitive compounds such as ascorbic acid^[81,85], oxidation, and degradation of, e.g. chlorophyll into their derivatives such as pheophytin further reduces the phytochemical compounds of vegetable subjected to boiling. Acidic cooking condition and longer cooking times facilitate the formation of pheophytin.^[17,79] Leaching and degradation of the phytochemical compounds are higher during boiling than blanching due to the extended time and temperature applied during boiling.^[39,61]

Table 2. The effect of blanching on the phytochemical compounds in green leafy vegetables.

Phytochemical compounds	Vegetables	Method	Temperature	Time (min)	Ratio or Mass	Phytochemical retention (%) ^a	References
Phenolic acid	Celery (<i>Apium graveolens</i>)	Hot water blanching	96–98°C	3	1:10 (vegetable: water)	80	[39]
	Water spinach (<i>Ipomoea aquatica</i>)	Hot water blanching	Boiling water	0.5	1:5 (vegetable: water)	77	[27]
	Spinach (<i>Spinacea oleracea</i>)		100°C	2	100 g	92	[26]
	Basil (<i>Ocimum basilicum</i>)		Boiling water	0.5	1:5 (vegetable: water)	893	[27]
	Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)		96–98°C	3	1:10 (vegetable: water)	65	[39]
	Coriander leaves (<i>Coriander sativum</i>)		90°C	1, 5, 7, 10	500 g	136–250	[59]
	Coriander leaves (<i>Coriander sativum</i>)		100°C	1, 5, 7, 10	500 g	97–256	[59]
	Coriander leaves (<i>Coriander sativum</i>)		Boiling water	0.5	1:5 (vegetable: water)	91	[27]
	Coriander leaves (<i>Coriander sativum</i>)		100°C	2	100 g	84	[26]
	Pak choy (<i>Brassica rapa</i> var <i>chinensis</i>)		98°C	5	1:5 (vegetable: water)	43	[60]
Carotenoid	Chinese mustard (<i>Brassica juncea</i>)		98°C	15	1:5 (vegetable: water)	18	[60]
	Green cabbage (<i>Brassica oleracea</i> var <i>capitata</i>)		98°C	5	1:5 (vegetable: water)	76	[60]
	Chinese cabbage (<i>Brassica rapa Pekinensis</i>)		98°C	15	1:5 (vegetable: water)	46	[60]
	Coriander leaves (<i>Coriander sativum</i>)		98°C	15	1:5 (vegetable: water)	80	[60]
	Water spinach (<i>Ipomoea aquatica</i>)		98°C	10	1:5 (vegetable: water)	50	[60]
	Spinach (<i>Amaranthus tricolor</i>)		98°C	15	1:5 (vegetable: water)	45	[60]
	Basil (<i>Ocimum basilicum</i>)		98°C	5	1:5 (vegetable: water)	47	[60]
	Coriander leaves (<i>Coriander sativum</i>)		98°C	10	1:5 (vegetable: water)	74	[60]
	Water spinach (<i>Ipomoea aquatica</i>)		98°C	15	1:5 (vegetable: water)	122	[60]
	Spinach (<i>Amaranthus tricolor</i>)		98°C	15	1:5 (vegetable: water)	111 – 231	[59]
	Basil (<i>Ocimum basilicum</i>)		98°C	0.5	1:5 (vegetable: water)	131	[27]
	Coriander leaves (<i>Coriander sativum</i>)		98°C	1	1:200 (vegetable: water)	69	[20]
	Water spinach (<i>Ipomoea aquatica</i>)		98°C	0.5	1:200 (vegetable: water)	140	[27]
	Spinach (<i>Amaranthus tricolor</i>)		98°C	0.5	1:5 (vegetable: water)	169	[27]
	Basil (<i>Ocimum basilicum</i>)		98°C	2	30 g	72	[61]
	Coriander leaves (<i>Coriander sativum</i>)		98°C	2	30 g	2	[61]

Flavonoid	Spinach (<i>Amaranthus viridis</i>)	Hot water blanching	Boiling water	5	2:5 (vegetable: water)	1185	[62]
	Spinach (<i>Spinacea oleracea</i>)		100°C	2	100 g	90	[26]
	Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)		96-98°C	3	1:10 (vegetable: water)	74	[39]
	Cassava leaves (<i>Manihot esculenta</i>)		Boiling water	5	2:5 (vegetable: water)	437	[62]
Chlorophyll	Coriander leaves (<i>Coriander sativum</i>)		100°C	2	100 g	68	[26]
	Water spinach (<i>Ipomoea aquatica</i>)	Hot water blanching	Boiling water	0.5	1:5 (vegetable: water)	69	[27]
	Spinach (<i>Amaranthus tricolor</i>)		Boiling water	3, 6, 9, 12, 15	250 g	48–26	[46]
	Spinach (<i>Amaranthustricolor</i>)		95 ± 3°C	1	1:200 (vegetable: water)	57	[20]
	Basil (<i>Ocimum basillicum</i>)		Boiling water	0.5	1:5 (vegetable: water)	123	[27]
Ascorbic acid	Coriander leaves (<i>Coriander sativum</i>)		Boiling water	0.5	1:5 (vegetable: water)	269	[27]
	Spinach (<i>Amaranthus tricolor</i>)	Hot water blanching	95 ± 3°C	1	1:200 (vegetable: water)	33	[20]

^aThe retention level is calculated from the concentration of the phytochemicals both in the raw and the processed green leafy vegetables.

Table 3. The effect of boiling and steaming on the phytochemical compounds in green leafy vegetables.

Phytochemical compounds	Method	Vegetables	Temperature	Time (min)	Amount of water (mL)	Mass (g)	Phytochemical retention ^a	References
Boiling								
Phenolic acid	Boiling	Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water (celery added into water at 70°C)	10	400	100	61%	[39]
Water soluble phenol		Water spinach (<i>Ipomoea aquatica</i>)	Boiling water	5	100	150	181%	[67]
Total polyphenol		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	-	200	121%	[6]
		Water spinach (<i>Ipomoea aquatica</i>)	Boiling water	Cooked until tender	150	100	160 ^b	[68]
		Spinach (<i>Spinacea oleracea</i>)	Boiling water	5	300	300	83%	[69]
		Spinach (<i>Spinacea oleracea</i>)	Boiling water	Cooked until tender	150	100	145 ^b	[68]
		Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water (celery added into water at 70°C)	10	400	100	59%	[39]
		Drumstick leaves (<i>Moringa oleifera</i>)	100°C	20–25	-	2000	290 mg/100 g ^c	[70]
		Drumstick leaves (<i>Moringa oleifera</i>)	Boiling water	5	250	50	165	[71]
		Drumstick leaves (<i>Moringa oleifera</i>)	Boiling water	10	250	50	171	[71]
		Drumstick leaves (<i>Moringa oleifera</i>)	Boiling water	20	250	50	169	[71]
		Sweet potato leaves (<i>Ipomoea batatas</i>)	100°C	2	500	100	69%	[17]
Flavonoid		Chinese mustard (<i>Brassica juncea</i>)	100°C	5	140	100	120%	[72]
		Chinese mustard (<i>Brassica juncea</i>)	100°C	13	300	200	137%	[31]
		Tatsoi (<i>Brassica narinosa</i>)	100°C	5	800	300	76%	[73]
		Bush Sorrel (<i>Hibiscus surattensis</i>)		3	50	5	25%	[74]
				5			100%	
				10			159%	[6]
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	-	200	155%	[68]
		Water spinach (<i>Ipomoea aquatica</i>)	Boiling water	Cooked until tender	150	100	125 ^b	[68]
		Spinach (<i>Spinacea oleracea</i>)	Boiling water	Cooked until tender	150	100	115 ^b	[68]
		Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water (celery added into water at 70°C)	10	400	100	54%	[39]
Carotenoid		Chinese mustard (<i>Brassica juncea</i>)	100°C	5	140	100	103%	[72]
		Galega Kale (<i>Brassica oleracea</i> var. <i>acephala</i> cv. <i>galega</i>)	100°C	20	200	20	36%	[75]
		Bush Sorrel (<i>Hibiscus surattensis</i>)		30			33%	
				3	50	5	89%	[74]
				5			114%	
				10			186%	
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	-	200	100%	[6]
		Spinach (<i>Basella alba</i>)	Boiling water	2-8	-	20	66%	[76]
		Spinach (<i>Spinacea oleracea</i>)	Boiling water	5	50	10	37% ^b	[77]
		Basil (<i>Ocimum bacillicum</i>)	100°C	1	200	10	103%	[78]
		Basil (<i>Ocimum bacillicum</i>)	Boiling water	2-8	-	20	89%	[76]

Celery (<i>Apium graveolens</i>)	Boiling water	2-8	-	20	81%	[76]
Drumstick leaves (<i>Moringa oleifera</i>)	100°C	3	-	2	45%	[79]
Drumstick leaves (<i>Moringa oleifera</i>)	100°C	20 – 25	-	2000	38 mg/100 g ^c	[70]
Coriander leaves (<i>Coriander sativum</i>)	100°C	1	200	10	102%	[78]
Sweet potato leaves (<i>Ipomea batatas</i>)	100°C	1	200	10	109%	[78]
Choy sum (<i>Brassica rapa</i> var <i>parachinensis</i>)	100°C	1	200	10	102%	[78]
Chinese mustard (<i>Brassica juncea</i>)	100°C	13	300	200	78%	[31]
Black nighshade (<i>Solanum scabrum</i> Mill.)	100°C	30	2000	30	33%	[61]
Jute mallow (<i>Corchorus olitorius</i> L.)	100°C	30	2000	30	0%	[61]
Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	-	200	90%	[6]
Tatsoi (<i>Brassica narinosa</i>)	100°C	5	800	300	99%	[73]
Spinach (<i>Spinacea oleracea</i>)	Boiling water	5	50	10	36% ^a	[77]
Spinach (<i>Spinacea oleracea</i>)	Boiling water	4.5	65	220	75%	[80]
Spinach (<i>Spinacea oleracea</i>)	Boiling water	8	4	1	25%	[81]
Spinach (<i>Spinacea oleracea</i>)	Boiling water	30	-	4	68%	[82]
Cassava leaves (<i>Manihot esculenta</i>)	Boiling water	-	-	20	70%	[83]
Chinese mustard (<i>Brassica juncea</i>)	100°C	13	300	200	31%	[31]
Galega Kale (<i>Brassica oleracea</i> var. <i>achepala</i> cv. <i>galega</i>)	100°C	20	200	20	20%	[75]
Tatsoi (<i>Brassica narinosa</i>)	100°C	30	800	300	18%	[73]

Steaming

Phytochemical compounds	Method	Vegetables	Temperature	Time (min)	Ratio or Mass	Phytochemical retention	References
Total polyphenol	Steaming	Spinach (<i>Amaranthus currentus</i>)	-	10	40 g	134%	[84]
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	3-5	2000 g	65 mg/100 g ^c	[70]
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	200 g	75%	[6]
		Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water	10	1:2 (vegetable: water)	98%	[39]
		Drumstick leaves (<i>Moringa oleifera</i>)	100°C	3-5	2000 g	260 mg/100 g ^c	[70]
		Sweet potato leaves (<i>Ipomea batatas</i>)	-	2	100 g	109%	[17]
		Chinese mustard (<i>Brassica juncea</i>)	Boiling water	7.5	100 g	96%	[72]
		Chinese mustard (<i>Brassica juncea</i>)	-	8	200 g	122%	[31]
		Tatsoi (<i>Brassica narinosa</i>)	Boiling water	5	3:1 (vegetable: water)	117%	[73]
Phenolic Acid		Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water	10	1:2 (vegetable: water)	93%	[39]
Flavonoid		Spinach (<i>Amaranthus currentus</i>)	-	10	40 g	125%	[84]
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	200 g	62%	[6]
		Celery (<i>Apium graveolens</i> , <i>Cryptotaenia japonica</i> Hassk)	Boiling water	10	1:2 (vegetable: water)	92%	[39]
		Chinese mustard (<i>Brassica juncea</i>)	Boiling water	7.5	100 g	66%	[72]
		Galega Kale (<i>Brassica oleracea</i> var. <i>achepala</i> cv. <i>galega</i>)	-	20	1:20 (vegetable: water)	90%	[75]
				30		89%	

(Continued)

Table 3. (Continued).

Phytochemical compounds	Method	Vegetables	Temperature	Time (min)	Amount of water (mL)	Mass (g)	Phytochemical retention ^a	References
Carotenoid		Water spinach (<i>Ipomoea aquatica</i>)	100°C	3–5	2000 g		20 mg/100 g ^c	[70]
		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	200 g		60%	[6]
		Drumstick leaves (<i>Moringa oleifera</i>)	110°C	15	2 g		93%	[79]
		Drumstick leaves (<i>Moringa oleifera</i>)	100°C	3–5	2000 g		39 mg/100 g ^c	[70]
		Chinese mustard (<i>Brassica juncea</i>)	–	8	200 g		77%	[31]
Chlorophyll		Water spinach (<i>Ipomoea aquatica</i>)	100°C	2	200 g		90%	[6]
		Spinach (<i>Spinacea oleracea</i>)	Boiling water	7.5, 15, 30, 45, 60	250 g		25 6%	[46]
		Tatsoi (<i>Brassica narinosa</i>)	Boiling water	5	3:1 (vegetable: water)		98%	[73]
Ascorbic acid		Spinach (<i>Spinacea oleracea</i>)	Boiling water	8	1 g		66%	[81]
		Spinach (<i>Amaranthus currentus</i>)	–	10	40 g		71%	[84]
		Tatsoi (<i>Brassica narinosa</i>) ⁶⁶⁶	Boiling water	5	3:1 (vegetable: water)		81%	[73]
		Galega Kale (<i>Brassica oleracea</i> var. <i>acephala</i> cv. <i>galega</i>)	–	20	1:20 (vegetable: water)		78%	[75]
				30			66%	

^aThe retention level is calculated from the concentration of the phytochemicals both in the raw and the processed green leafy vegetables.

^bNumbers are estimated from the data reported in the graphs.

^cNo data on the amount of phytochemical compounds before processing

In contrast, Ng *et al.*^[67] reported that the concentration of water-soluble polyphenol compounds in boiled water spinach was 81% higher as compared to the ones in raw spinach.^[67] Boiling notably increased total polyphenol and flavonoid contents in water spinach, drumstick leaves, and Chinese mustard.^[6,71,72] Accordingly, a slight increase of β -carotene after boiling was found in basil, coriander leaves, sweet potato leaves, and pak choi.^[78]

Similar to blanching, the increase of phytochemical compounds is likely an artifact due to the softening of the vegetable matrix due to heat, which subsequently increases extractability.^[71,74] An *in vitro* study reported that boiling could enhance the extractability of polyphenols in *Bidens pilosa* leaf matrix. Although bioaccessibility of polyphenols reduced after duodenal digestion, polyphenols still have sufficient antioxidant activity to protect cells from oxidative damage.^[66] Gehse *et al.*^[86] also reported short boiling time (less than 10 min) could increase the bioavailability of carotenoid in vegetables. This is due to disruption of the carotenoid-protein complexes, inactivation of carotenoid oxidizing enzymes,^[78] the formation of secondary plant metabolites, destruction of complex phenolics,^[6,66,69] and release of active aglycones from flavonoid conjugates.^[67]

Steaming

Steaming is probably the most appropriate cooking method to retain water-soluble phytochemical compounds in vegetables.^[75,81] This is due to the fact that during steaming vegetables are actually not in direct contact with water.^[87] Loss of nutritional contents after steaming is, however, still observed in green leafy vegetables (Table 3). Thi & Hwang^[6] reported that steaming at temperature 100°C for 2 min reduced the concentration (in dry weight basis) of polyphenol, flavonoid, carotenoid, and chlorophyll in water spinach. Minor loss of carotenoid in drumstick leaves,^[79] total polyphenol and flavonoid in celery,^[39] and ascorbic acid in tatsoi^[73] were also observed. Thermal degradation is suspected of playing a major role in the loss of phytochemical compounds during steaming.^[6,79,84]

Teng & Chen^[46] reported a slight increase in chlorophyll degradation in spinach with heating time and temperature. The formation of pheophytin (a marker of chlorophyll degradation) is higher during wet heating methods (steaming, blanching) than dry heating methods (baking, microwaving cooking). This is probably because the liberation of organic acids from the leaf matrices due to moist heat are greater than due to dry heat. Moreover, higher heating time and temperature may facilitate the removal of the carbo-methoxy group from chlorophyll.^[46]

In contrast, an increase of total polyphenol concentration in sweet potato leaves (by about 9%) and in spinach (34%) and increase of flavonoid compounds in spinach (25%) after steaming have been also reported.^[17] It is likely that the strength of the cell walls influences the amount of extracted phytochemicals after steaming.^[88] It was reported that the breakdown of cell wall due to heating might promote the release of phenolic compounds from vegetable tissue^[84] and the breakdown of complex structures, thus liberating the phenolic compounds.^[17]

Yao and Ren^[39] reported that steaming retains more polyphenol, phenolic acid, and flavonoid in celery than blanching or boiling. In steaming, direct contact between vegetables tissue and water is avoided, which significantly minimize losses of water-soluble phytochemical compounds through leaching. Steaming may also increase the bioaccessibility of

micronutrients such as lutein, β -carotene, and α -tocopherol through cell ruptures.^[79] Breakdown of cellulose structure and denaturation of carotenoid-protein complexes may be responsible for the increase of carotenoid content of vegetables after steaming.^[6]

Drying

Drying is often applied to increase shelf life by preventing the microbial growth and enzymatic reaction through the reduction of water content and water activity.^[89] Proper selection of appropriate drying methods is crucial to retain aroma, appearance, and nutritional characteristics^[90,91] while optimizing the energy (cost) efficiency.^[92–94] Various drying methods are commonly applied to green leafy vegetables, such as shade drying, sun drying, oven drying, cabinet drying, and freeze-drying.^[95]

During shade drying, significant reduction of ascorbic acid in drumstick leaves, papaya leaves, and spinach was reported. To a lesser degree, shade drying also reduced the availability of carotenoid and flavonoid content.^[20,30,96] During shade drying, despite carried out at relatively low temperatures (30–35°C), long drying time (1–3 weeks) significantly decreased phytochemical contents in vegetables.^[20,97] Shorter drying time during oven drying and the absence of thermal load during freeze-drying ensured a lower degree of thermally induced degradation of heat-sensitive chlorophylls.^[30] In contrast, the increase of available chlorophyll of 147% and carotenoid of 36% has been reported for shade drying of spinach.^[20] Raja *et al.*^[30] also reported the increase of total phenolic content in papaya leaves between 6% and 15% after shade drying. This could be due to the formation of new products from maillard reaction during heating.^[98]

Sun drying has been reported to decrease phytochemical compounds (phenolic, flavonoid, carotenoid, ascorbic acid, and chlorophyll) in green leafy vegetables ranging from 35% to 100% (Table 4). Sriwichai *et al.*^[79] reported a 63% decrease of carotenoid content in drumstick leaves upon sun drying, which is more severe than that of steaming, freezing, and sterilization. Direct light exposure is hypothesized to induce the oxidation reaction of heat-sensitive phytochemical compounds in green leafy vegetables.^[37] Moreover, grinding prior to drying can increase the contact area of vegetable and air/light, which subsequently increases the rate of autooxidation.^[79,109]

Speek *et al.*^[76] reported the decrease of carotenoid in spinach (51%) and basil (55%) after sun drying, which likely relates to decomposition and trans-cis isomerization of carotenoid. During sun drying, chlorophyll may be transformed into pheophytin via the displacement of magnesium by a hydrogen atom. Chlorophyll A is more susceptible to thermal degradation than chlorophyll B. Thus, after sun drying the decrease of chlorophyll A is usually more pronounced than chlorophyll B.^[35]

After sun drying total polyphenol, carotenoid, and chlorophyll in spinach increased by 223%,^[100] 5%^[20] and 109%,^[20] respectively. Similarly, a dramatic increase of total polyphenol in cassava leaves and chlorophyll in water spinach after drying has been reported.^[20,29,100] This may be explained by the increase of dry solid in the vegetable matrices,^[110] increase extractable carotenoid via release from matrix cell,^[18,35] and/or breakdown of the cell wall during drying, which disturbs the bond of phenolic compounds.^[97]

After oven drying, most of the phytochemical compounds (phenolic, flavonoid, carotenoid, chlorophyll, and ascorbic acid) in green leafy vegetables decreased between 4% and 100% (Table 4). Saini *et al.*^[37] reported that cabinet drying of drumstick leaves decreased

Table 4. The effect of drying on the phytochemical compounds of green leafy vegetables.

Phytochemical compounds	Method	Vegetables	Temperature or Power	Time	Mass (g)	Phytochemical retention ^a	References
Total Polyphenol	Shade drying	Drumstick leaves (<i>Moringa oleifera</i>)	Shade place	1 week	-	9535 mg/100 g ^c	[99]
		Coriander leaves (<i>Coriander sativum</i>)	Shade place (35°C)	2 days	500	78% ^b	[36]
	Sun drying	Papaya leaves (<i>Carica papaya</i>)	28°C	3 days	500	106%	[30]
		Papaya leaves (<i>Carica papaya</i>)	28°C	3 days	500	115%	[30]
		Spinach (<i>Amaranthus carentus</i>)	Sunlight	1 week	-	323%	[100]
		Drumstick leaves (<i>Moringa oleifera</i>)	Sun light	2–3 days	2000	65%	[37]
	Oven drying	Cassava leaves (<i>Manihot esculenta</i>)	35–38°C	3 days	250	520% ^b	[29]
		Spinach (<i>Spinacea oleracea</i>)	50 ± 2°C	3 days	250	70 mg/g ^c	[101]
		Celery (<i>Apium graviolens</i>)	48°C	60 minutes	-	114% ^b	[102]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	12.5 hours	2	83%	[103]
		Drumstick leaves (<i>Moringa oleifera</i>)	100°C	2.5 hours	-	96% ^b	[37]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	12 hours	2000	58%	[37]
		Coriander leaves (<i>Coriander sativum</i>)	70°C	4 hours	500	65% ^b	[36]
		Coriander leaves (<i>Coriander sativum</i>)	50 ± 2°C	-	-	22 mg/g ^c	[101]
Flavonoid	Cabinet drying	Papaya leaves (<i>Carica papaya</i>)	40°C	7 hours	-	162%	[30]
		Papaya leaves (<i>Carica papaya</i>)	40°C	7 hours	-	164%	[30]
		Spinach (<i>Spinacea oleracea</i>)	60°C	10–12 hours	100	97%	[26]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	6 hours	2000	61%	[37]
	Microwave drying	Coriander leaves (<i>Coriander sativum</i>)	60°C	10–12 hours	100	57%	[26]
		Drumstick leaves (<i>Moringa oleifera</i>)	850 W	30 seconds	2000	59%	[37]
	Freeze drying	Coriander leaves (<i>Coriander sativum</i>)	100°C	3 minutes	500	57% ^b	[36]
		Drumstick leaves (<i>Moringa oleifera</i>)	–35°C, 0.312 mbar	24 hours	2000	58%	[37]
	Shade drying	Papaya leaves (<i>Carica papaya</i>)	–100°C, 0.001 mbar	24 hours	2000	147% ^b	[30]
		Drumstick leaves (<i>Moringa oleifera</i>)	Shade place	1 week	-	6543 mg/100 g ^c	[99]
	Oven drying	Celery (<i>Apium graviolens</i>)	48°C	60 minutes	-	40%	[102]

(Continued)

Table 4. (Continued).

Phytochemical compounds	Method	Vegetables	Temperature or Power	Time	Mass (g)	Phytochemical retention ^a	References
Carotenoid	Cabinet drying	Kenikir leaves (<i>Cosmos caudatus</i>)	60°C	-	-	78% ^[104]	[104]
		Spinach (<i>Spinacea oleracea</i>)	60°C	10-12 hours	100	89% ^[26]	[26]
		Coriander leaves (<i>Coriander sativum</i>)	60°C	10-12 hours	100	59% ^[26]	[26]
	Shade drying	Spinach (<i>Amaranthus tricolor</i>)	-	Until the vegetables contain 7-9% moisture	-	136% ^[20]	[20]
		Drumstick leaves (<i>Moringa oleifera</i>)	Room temperature	6 days	100	183% ^[91]	[91]
		Coriander leaves (<i>Coriander sativum</i>)	Shade place (35°C)	2 days	500	52% ^b [36]	[36]
	Sun drying	Black nighshade (<i>Solanum scabrum</i> Mill.)	25.8-31.4 °C		30 g	11% ^[61]	[61]
		Jute mallow (<i>Cochorus olitorius</i> L.)	25.8-31.4 °C		30 g	2% ^[61]	[61]
		Spinach (<i>Amaranthus tricolor</i>)	Sun light	2 days	-	49% ^[76]	[76]
		Spinach (<i>Amaranthus tricolor</i>)	Sun light	Until the vegetables contain 7-9% moisture	-	105% ^[20]	[20]
		Basil (<i>Ocimum basilicum</i>)	Sun light	2 days	-	45% ^[76]	[76]
		Drumstick leaves (<i>Moringa oleifera</i>)	Sun light	2-3 days	2000	53% ^[37]	[37]
		Drumstick leaves (<i>Moringa oleifera</i>)	30°C	8 hours	2	37% ^[79]	[79]
		Drumstick leaves (<i>Moringa oleifera</i>)	Sun light	4 days	100	187% ^[91]	[91]
Oven drying		Cassava leaves (<i>Manihot esculenta</i>)	35-38°C	3 days	250	3% ^b [29]	[29]
		Drumstick leaves (<i>Moringa oleifera</i>)	60-80°C	24 hours	-	36 - 17 mg/100 g ^c [105]	[105]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	12 hours	2000	58% ^[37]	[37]
		Drumstick leaves (<i>Moringa oleifera</i>)	60°C	3 hours	2	81% ^[79]	[79]
		Drumstick leaves (<i>Moringa oleifera</i>)	60°C	4-5 hours	100	182% ^[91]	[91]
		Coriander leaves (<i>Coriander sativum</i>)	70°C	4 hours	500	34% ^b [36]	[36]
		Coriander leaves (<i>Coriander sativum</i>)	45 ± 2°C	24 hours	5-10	65% ^[106]	[106]
		Black nighshade (<i>Solanum scabrum</i> Mill.)	50 °C		30 g	7% ^[61]	[61]

Chlorophyll	Cabinet drying	Jute mallow (<i>Corchorus olitorius</i> L.)	60 °C 50 °C 60 °C 65 ± 5°C			7% 0% 0% 304%	[61] [20]
		Spinach (<i>Amaranthus tricolor</i>)		Until the vegetables contain 7-9% moisture	30 g		
	Microwave drying	Drumstick leaves (<i>Moringa oleifera</i>)	50°C	6 hours	2000	60%	[37]
		Drumstick leaves (<i>Moringa oleifera</i>)	850 W	30 seconds	2000	48%	[37]
		Coriander leaves (<i>Coriander sativum</i>)	100°C	3 minutes	500	17% ^b	[36]
		Coriander leaves (<i>Coriander sativum</i>)	180, 300, 450, 600, 850 W	30-90 seconds	5-10	135-140%	[106]
	Freeze drying	Drumstick leaves (<i>Moringa oleifera</i>)	-35°C, 0.312 mbar	24 hours	2000	61%	[37]
		Drumstick leaves (<i>Moringa oleifera</i>)	-40°C	24 hours	2	64%	[79]
		Spinach (<i>Amaranthus tricolor</i>)	-	Until vegetables contain 7-9% moisture	-	247%	[20]
		Coriander leaves (<i>Coriander sativum</i>)	35°C	2 days	500	41% ^b	[36]
	Sun drying	Water spinach (<i>Ipomoea aquatica</i>)	Sun light (27-32°C)	48 hours	1000	221% ^b	[35]
		Spinach (<i>Amaranthus tricolor</i>)	Sunlight	Until the vegetables contain 7-9% moisture	-	209%	[20]
		Drumstick leaves (<i>Moringa oleifera</i>)	Sun light	2-3 days	2000	65%	[37]
	Oven drying	Water spinach (<i>Ipomoea aquatica</i>)	65 ± 5°C	12 hours	1000	226%	[35]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	12 hours	2000	65%	[37]
		Coriander leaves (<i>Coriander sativum</i>)	70°C	4 hours	500	36% ^b	[36]
		Coriander leaves (<i>Coriander sativum</i>)	45 ± 2°C	24 hours	5-10	35% ^c	[106]
Cabinet drying	Cabinet drying	Basil (<i>Ocimum basilicum</i>)	50°C	4,5 hours	18	13%*	[107]
		Spinach (<i>Amaranthus tricolor</i>)	65 ± 5°C	Until the vegetables contain 7-9% moisture	-	144%	[20]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	6 hours	2000	70%	[37]
		Coriander leaves (<i>Coriander sativum</i>)	45, 50, 55, 60 and 65 ± 1°C	3 minutes	2000	1-3 mg/Lc	[108]

(Continued)

Table 4. (Continued).

Phytochemical compounds	Method	Vegetables	Temperature or Power	Time	Mass (g)	Phytochemical retention ^a	References
Ascorbic acid	Microwave drying	Basil (<i>Ocimum basilicum</i>)	1100 W	5 minutes	18	29% ^b	[107]
		Drumstick leaves (<i>Moringa oleifera</i>)	850 W	30 seconds	2000	56%	[37]
	Freeze drying	Coriander leaves (<i>Coriander sativum</i>)	100°C	3 minutes	500	9%	[36]
		Water spinach (<i>Ipomoea aquatica</i>)	-	72 hours	1000	272%	[35]
		Basil (<i>Ocimum basilicum</i>)	-35°C – 20°C	72 hours	18	16% ^b	[107]
		Drumstick leaves (<i>Moringa oleifera</i>)	-35°C, 0.312 mbar	24 hours	2000	74%	[37]
	Shade drying	Spinach (<i>Amaranthus tricolor</i>)	-	Until the vegetables contain 7-9% moisture	-	78%	[20]
		Papaya leaves (<i>Carica papaya</i>)	28°C	3 days	-	25-63% ^b	[30]
	Sun drying	Water spinach (<i>Ipomoea aquatica</i>)	Sunlight (27–32°C)	48 hours	1000	49%	[35]
		Spinach (<i>Amaranthus tricolor</i>)	Sunlight	Until the vegetables contain 7-9% moisture	-	46%	[20]
		Spinach (<i>Amaranthus carentus</i>)	Sunlight	1 weeks	-	63%	[100]
		Drumstick leaves (<i>Moringa oleifera</i>)	Sunlight	2-3 days	2000	38%	[37]
	Oven drying	Cassava leaves (<i>Manihot esculenta</i>)	35–38°C	3 days	250	0% ^b	[29]
		Water spinach (<i>Ipomoea aquatica</i>)	65 ± 5°C	12 hours	1000	82%	[35]
		Celery (<i>Apium graveolens</i>)	48°C	60 minutes	-	94%	[102]
		Drumstick leaves (<i>Moringa oleifera</i>)	60–80°C	24 hours	-	450 – 436 µm/100 g ^c	[105]
	Cabinet drying	Papaya leaves (<i>Carica papaya</i>)	50°C	12 hours	2000	40%	[37]
		Spinach (<i>Amaranthus tricolor</i>)	40°C	7 hours	-	72–78% ^b	[30]
			65 ± 5°C	Until the vegetables contain 7-9% moisture	-	104%	[20]
		Drumstick leaves (<i>Moringa oleifera</i>)	50°C	6 hours	2000	44%	[37]
	Microwave drying	Drumstick leaves (<i>Moringa oleifera</i>)	850 W	30 seconds	2000	64%	[37]
		Water spinach (<i>Ipomoea aquatica</i>)	-	72 hours	1000	346%	[35]
	Freeze drying	Drumstick leaves (<i>Moringa oleifera</i>)	-35°C, 0.312 mbar	24 hours	2000	98%	[37]
		Papaya leaves (<i>Carica papaya</i>)	-100°C, 0.001 mbar	24 hours	-	82% ^b	[30]

^aThe retention level is calculated from the concentration of the phytochemicals both in the raw and the processed green leafy vegetables.^bNumbers are estimated from the data reported in the graphs.^cNo data on the amount of phytochemical compounds before processing.

total polyphenol, carotenoid, chlorophyll, and ascorbic acid. Cabinet tray drying was also reported to decrease total polyphenol and flavonoid in spinach and in coriander leaves.^[26]

The retention of chlorophyll A and B is higher during cabinet drying than oven drying, thus cabinet drying produces the dark green color of the powder, which consumers prefer to choose. It is mostly due to forced convection of heated air in the cabinet dryer which can reduce the drying time.^[37]

Carotenoids retention in vegetables was higher after oven drying than after sun drying because the closed condition in oven drying mitigates the risk of photooxidation.^[18] Compared to shade drying, the decrease of total polyphenol, carotenoid, and chlorophyll in coriander leaves^[36] and β -carotene of black nightshade and jute mallow leaves^[61] after oven drying was higher, which relate to the imposed thermal load. High drying temperature needs to be avoided to mitigate trans-cis isomerization of β -carotene and lutein. The provitamin activity of the cis- form of carotenoid is lower than the trans- form.^[37,61,79]

Drying at 60°C decreased flavonoid content in *kenikir* (*Cosmos caudatus*) leaves because the increase of flavonoid degrading enzyme activity such as polyphenoloxidase enzyme.^[104] However, the enzyme activity could be reduced by drying at temperatures higher than 70°C. The content of phytochemical compounds in vegetables can also have further losses during storage.^[102] Grinding could increase the surface area of the dried product that leads to further losses through autooxidation. Therefore, dried or powdered vegetables must be protected from air and light.^[37]

Wangcharoen & Gomolmanee^[103] reported that drying of drumstick leaves at 50°C decreases total phenolic contents in vegetables. However, when drying was performed at a higher temperature (100°C), phenolic contents initially decrease then increase again in the later stage. The fluctuation of total phenolic contents could be due to the formation of new antioxidant compounds of non-enzymatic browning and due to thermal degradation of insoluble and bound phenolic compounds that occurs at high temperature. Raja *et al.*^[30] also observed the formation of maillard products formed due to heat treatment, which increased total phenolic contents in papaya leaves between 6% and 64%. Similarly, Negi & Roy^[20] reported that drying could increase carotenoid and vitamin C in spinach. This relates to the increase of solid fraction, thus concentrating the phytochemical compounds.^[26]

Table 4 shows that most of the phytochemical compounds in vegetables decreased during microwave drying ranging between 36% and 91%, which was more pronounced than that of oven-, freeze-, or cabinet drying.^[36,37,107] This might be due to the imposed higher temperature during microwave drying than the other drying methods. Dev *et al.*^[111] also reported that the color change of drumstick leaves was more severe after microwave drying than that of oven drying. Retention of chlorophyll was however higher after microwave drying than after air drying. The degradation of chlorophyll pigment to pheophytin is shown by color transformation from bright green to olive brown. The formation of pheophytin was affected by the liberation of plant acid compounds and the release of chlorophyll from protein complex.^[107] Divya *et al.*^[106] found that microwave drying increased carotenoid in coriander leaves ranging from about 35% to 40%. This is due to heating that could liberate carotenoid bound to membranes and other pigments, such as chlorophyll. This study found no trans-cis isomerization of β -carotene during microwave drying.

Lyophilization or freeze drying is a dehydration process that involves freezing then sublimation of ice. Freeze drying is slower and more energy intensive than another conventional drying.^[92,112] Freeze drying was reported to decrease total polyphenol,

carotenoid, chlorophyll, and ascorbic acid in drumstick leaves.^[37] Other studies also reported the decrease of ascorbic acid in papaya leaves and chlorophyll in basil.^[79,107] Formation of ice crystal can damage cell walls and release oxidative- and hydrolytic-enzymes, which degrade phytochemicals such as phenolic compounds.^[30]

Compared to other drying methods, freeze drying remains the best method to retain trans-lutein, trans-luteoxanthin, trans- β -carotene, total carotenoid, α -tocopherol, ascorbic acid, chlorophyll A, and chlorophyll B.^[37] Increase of total phenolic contents in papaya leaves, and chlorophyll and ascorbic acid in water spinach have also been reported.^[30,35] It is believed that the use of low temperature during freeze-drying prevents thermal degradation of these heat sensitive compounds.^[110] Furthermore, the formation of ice crystals can rupture cell walls, thus allowing the release of cellular components, which consequently improves extractability.^[97]

Microwave cooking

Water is often added during microwave cooking of vegetables. This may lead to leaching of water-soluble phytochemical compounds.^[67,69] Microwave cooking has been reported to decrease chlorophyll contents in spinach^[46] and tatsoi.^[73] Induced by heat, the removal of magnesium or carbomethoxy group from chlorophylls may occur to form pheophytins and may subsequently transform to pirochlorophylls. Microwave cooking reduced phenolic compounds in water spinach,^[67] drumstick leaves,^[113] sweet potato leaves,^[17] Chinese mustard^[72], tatsoi,^[39] and bush sorrel.^[74] Microwave cooking also reduced a significant amount of flavonoid,^[72] carotenoid,^[31] and ascorbic acid^[31] in Chinese mustard, and chlorophyll and ascorbic acid in tatsoi.^[39] Thermal breakdown, leaching (when water is added during cooking), and oxidation are the responsible mechanisms of phytochemical degradation during microwave cooking.^[31,67,69,113]

In contrast, increase of total polyphenols in Chinese mustard^[31] and drumstick leaves,^[71] ascorbic acid in spinach,^[80] and flavonoid in drumstick leaves have been reported.^[80] Breakdown of cell walls and complex phenolic compounds during heating may increase the availability of these phytochemical compounds.^[71,74,80,114]

Pressure cooking

Employing high pressure enables cooking at temperatures higher than the normal boiling point of water. Heat sensitive phytochemicals are better retained because cooking time can be considerably reduced. However, water-soluble phytochemical compounds may be leached due to the presence of added water during pressure-cooking.^[67] Veda *et al.*^[33] reported that pressure-cooking at 15 psi for 10 min decreased carotenoid in spinach, in drumstick leaves, and in coriander leaves. Pressure-cooking also decreased carotenoid and ascorbic acid content in Chinese mustard by about 13% and 69%, respectively^[31], which likely relates to leaching, oxidation, and formation of cis isomers from all trans- β -carotene.^[33]

Pressure cooking, however, has been reported to increase total phenolic concentration in Chinese mustard^[31] and in drumstick leaves.^[115] This is likely due to the softening of vegetable matrices that improve extractability, the liberation of phenolic compounds from pectin or cellulose networks, the formation of secondary plant metabolites, inactivation of

oxidative enzymes (e.g. polyphenol oxidase), and release of active aglycones from flavonoid conjugates during heating.^[67,114,115]

Frying

Frying is performed by increasing the surface temperature of food and then vaporizing a proportion of water.^[112] Based on the media for heat transfer, frying can be categorized into frying in oil (stir frying and deep frying) and frying with the addition of water such as stewing and sauteing.^[32] Frying is usually applied at high temperatures to maximize the heat transfer.

Frying generally decreased carotenoid content in basil leaves, drumstick leaves, coriander leaves, sweet potato leaves, and pak choi (Table 5). The decrease of β -carotene in vegetables was reported to be higher in deep fat frying than in shallow contact frying.^[33] This may relate to degradation or isomerization of carotenoids, the release of carotenoids to oil, and cell disruption during frying.^[65,79] Moreover, the release of carotenoid into oil is affected by the amount of oil, frying time, location, and chemical and physical structure of carotenoid.^[32]

Frying, especially stir-frying, could increase the availability of β -carotene in water spinach and spinach.^[33] The presence of oil during frying may improve the bioaccessibility of β carotene and the loosening of food matrices facilitates carotenoid absorption.^[11,32,33] Sun *et al.*^[17] found a 16% reduction of total phenolic concentration in sweet potato leaves due to the breakdown of phenolic compounds during processing. Frying also decreased phenolic compounds in spinach by 17%, bush sorrel by 29-39%, and tatsoi by 4% likely due to decomposition and liberation of phenolic compounds.^[69,73,74] On the contrary, frying has been found to increase considerably the total polyphenol and flavonoid contents in drumstick leaves, spinach, water spinach, and Chinese mustard and, to a lesser degree, increased ascorbic acid availability. Previous studies suggested that the apparent increase of these phytochemical compounds can be related to the breakdown of the cell wall and softening vegetable tissues, thus liberating the phytochemical compounds and making it more accessible. Other mechanisms include inactivation of oxidative enzymes, thus minimizing the risk of the enzyme rendering phytochemicals into, e.g. its inactive form.^[33,68,73,114,116]

Conclusion

Changes of phytochemical compounds in vegetables during cooking/processing are influenced by various factors such as characteristics of the compounds, type of vegetables, and processing methods. Loss of phytochemical compounds during blanching, boiling, microwave cooking, and pressure cooking of green leafy vegetables are often found related to leaching and thermal degradation. Significant losses during frying and drying could be due to the thermal degradation, oxidation reaction, and isomerization of phytochemical structures. Steaming can be the most suitable method to retain phytochemical compounds because of the low impact on thermal degradation, oxidation reaction, and leaching of water-soluble phytochemical compounds, such as polyphenols and ascorbic acid. Increase the bioavailability of phytochemical compounds in vegetables during processing is due to the breakdown of complex bound, cell wall disruption, and inactivation of oxidation enzymes. Processing should therefore be optimized to minimize the loss of phytochemical compounds.

Table 5. The effect of microwave cooking, pressure cooking, and frying on the phytochemical compounds of green leafy vegetables.

Phytochemical compounds	Method	Vegetables	Power (W)	Times (minutes)	Amount of water (mL)	Mass (g)	Phytochemical retention (%) ^a	References
Total polyphenol	Microwave cooking	Drumstick leaves (<i>Moringa oleifera</i>)	-	5	60	100	88	[113]
		Drumstick leaves (<i>Moringa oleifera</i>)	1000	5	250	50	165	[71]
		Drumstick leaves (<i>Moringa oleifera</i>)	1000	10	250	50	153	[71]
		Drumstick leaves (<i>Moringa oleifera</i>)	1000	20	250	50	166	[71]
		Sweet potato leaves (<i>Ipomea batatas</i>)	1000	2	-	100	74	[17]
		Chinese mustard (<i>Brassica juncea</i>)	550	5	150	100	81	[72]
		Chinese mustard (<i>Brassica juncea</i>)	-	5	10	200	107	[31]
		Bush Sorrel (<i>Hibiscus surattensis</i>)	300	3	50	5	116	[74]
				5			70	
				10			112	
Water soluble phenolic Flavonoid		Tatsoi (<i>Brassica narinosa</i>)	450	5	10	300	96	[73]
		Water spinach (<i>Ipomoea aquatica</i>)	1000	5	100	150	87	[67]
		Spinach (<i>Spinacea oleracea</i>)	500	5	12	200	110	[69]
		Drumstick leaves (<i>Moringa oleifera</i>)	-	5	60	100	105	[113]
		Chinese mustard (<i>Brassica juncea</i>)	550	5	150	100	90	[72]
		Bush Sorrel (<i>Hibiscus surattensis</i>)	300	3	50	5	127	[74]
				5			102	
				10			106	
Carotenoid Chlorophyll		Chinese mustard (<i>Brassica juncea</i>)	-	5	10	200	70	[31]
		Spinach (<i>Spinacea oleracea</i>)	700	1	-	50	82	[46]
				9			39	
		Tatsoi (<i>Brassica narinosa</i>)	450	5	10	300	70	[73]
		Spinach (<i>Spinacea oleracea</i>)	750	2.5	-	240	106	[80]
		Chinese mustard (<i>Brassica juncea</i>)	-	5	10	200	27	[31]
Phytochemical compounds Water soluble phenolic Total polyphenol Flavonoid	Pressure cooking	Tatsoi (<i>Brassica narinosa</i>)	450	5	10	300	78	[73]
		Water spinach (<i>Ipomoea aquatica</i>)	121°C, 2 mPa	20	100	150	101	[67]
		Drumstick leaves (<i>Moringa oleifera</i>)	-	-	1000	-	128	[115]
		Chinese mustard (<i>Brassica juncea</i>)	-	4	150	200	135	[31]
		Drumstick leaves (<i>Moringa oleifera</i>)	-	7	80	100	120	[113]
		Drumstick leaves (<i>Moringa oleifera</i>)	-	-	1000	-	92	[115]

(Continued)

Table 5. (Continued).

Phytochemical compounds	Method	Vegetables	Power (W)	Times (minutes)	Amount of water (mL)	Mass (g)	Phytochemical retention (%) ^a	References
Chlorophyll Ascorbic acid		Basil (<i>Ocimum basilicum</i>)	190	1	-	10	51	[78]
		Drumstick leaves (<i>Moringa oleifera</i>)	100	10	185 mg groundnut oil	2	58	[33]
		Drumstick leaves (<i>Moringa oleifera</i>)	180	3	-	2	21	[79]
		Coriander leaves (<i>Coriander sativum</i>)	100	10	185 mg groundnut oil	2	61	[33]
		Coriander leaves (<i>Coriander sativum</i>)	190	1	-	10	53	[78]
		Sweet potato leaves (<i>Ipomea batatas</i>)	190	1	-	10	42	[78]
		Pak choi (<i>Brassica rapa</i> var <i>parachinensis</i>)	190	1	-	10	48	[78]
		Tatsoi (<i>Brassica narinosa</i>)	130	5	10 mL blend oil	300	63	[73]
		Tatsoi (<i>Brassica narinosa</i>)	130	5	10 mL blend oil	300	75	[73]

^aThe retention level is calculated from the concentration of the phytochemicals both in the raw and the processed green leafy vegetables.

^bNumbers are estimated from the data reported in the graphs.

Declarations of Interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- [1] Ebert, A. W.; Promotion of Indigenous Vegetables in Asia: Conservation and Use of Selected Crops in Indonesia, the Philippines, and Taiwan. *Acta Hortic.* **2011**, 918(918), 397–403. DOI: [10.17660/ActaHortic.2011.918.51](https://doi.org/10.17660/ActaHortic.2011.918.51).
- [2] Olayinka, O. O.; Antioxidant Contents (Vitamin C) of Raw and Blanched Different Fresh Vegetable Samples. *Food Nutr. Sci.* **2012**, 3(1), 18–21. DOI: [10.4236/fns.2012.31004](https://doi.org/10.4236/fns.2012.31004).
- [3] Duma, M.; Alsina, I.; Zeipina, S.; Lepse, L.; Dubova, L. Leaf Vegetables as Source of Phytochemicals. In *Foodbalt 2014: 9th Baltic conference on food science and technology "Food for consumer well-being"*; LLU: Jelgava, **2014**; pp 262–265.
- [4] Williams, D. J.; Edwards, D.; Hamernig, I.; Jian, L.; James, A. P.; Johnson, S. K.; Tapsell, L. C. Vegetables Containing Phytochemicals with Potential Anti-Obesity Properties: A Review. *Food Res. Int.* **2013**, 52(1), 323–333. DOI: [10.1016/j.foodres.2013.03.015](https://doi.org/10.1016/j.foodres.2013.03.015).
- [5] Perdana, J.; den Besten, H. M. W.; Aryani, D. C.; Kutahya, O.; Fox, M. B.; Kleerebezem, M.; Boom, R. M.; Schutyser, M. A. I. Inactivation of *Lactobacillus plantarum* WCFS1 during Spray Drying and Storage Assessed with Complementary Viability Determination Methods. *Food Res. Int.* **2014**, 64, 212–217. DOI: [10.1016/j.foodres.2014.06.029](https://doi.org/10.1016/j.foodres.2014.06.029).
- [6] Do, T. N.; Hwang, E. Effects of Different Cooking Methods on Bioactive Compound Content and Antioxidant Activity of Water Spinach (*Ipomoea aquatica*). *Food Sci. Biotechnol.* **2015**, 24(3), 799–806. DOI: [10.1007/s10068-015-0104-1](https://doi.org/10.1007/s10068-015-0104-1).
- [7] Zhao, C.; Liu, Y.; Lai, S.; Cao, H.; Guan, Y.; San Cheang, W.; Liu, B.; Zhao, K.; Miao, S.; Riviere, C.; et al. Effects of Domestic Cooking Process on the Chemical and Biological Properties of Dietary Phytochemicals. *Trends Food Sci. Technol.* **2019**, 85(2017), 55–66. DOI: [10.1016/j.tifs.2019.01.004](https://doi.org/10.1016/j.tifs.2019.01.004).
- [8] Sivakumar, D.; Chen, L.; Sultanbawa, Y. A Comprehensive Review on Beneficial Dietary Phytochemicals in Common Traditional Southern African Leafy Vegetables. *Food Sci. Nutr.* **2018**, 6(4), 714–727. DOI: [10.1002/fsn3.643](https://doi.org/10.1002/fsn3.643).
- [9] Ribas-Agustí, A.; Martín-Belloso, O.; Soliva-Fortuny, R.; Elez-Martínez, P. Food Processing Strategies to Enhance Phenolic Compounds Bioaccessibility and Bioavailability in Plant-Based Foods. *Crit. Rev. Food Sci. Nutr.* **2018**, 58(15), 2531–2548. DOI: [10.1080/10408398.2017.1331200](https://doi.org/10.1080/10408398.2017.1331200).
- [10] Sensoy, I.; Mahalleli, U.; Bulvari, D. A Review on the Relationship between Food Structure, Processing, and Bioavailability. *Crit. Rev. Food Sci. Nutr.* **2013**, 54(7), 37–41. DOI: [10.1080/10408398.2011.619016](https://doi.org/10.1080/10408398.2011.619016).
- [11] Barba, F. J.; Mariutti, L. R. B.; Bragagnolo, N.; Mercadante, A. Z.; Barbosa-Cánovas, G. V.; Orlén, V. Bioaccessibility of Bioactive Compounds from Fruits and Vegetables after Thermal and Nonthermal Processing. *Trends Food Sci. Technol.* **2017**, 67, 195–206. DOI: [10.1016/j.tifs.2017.07.006](https://doi.org/10.1016/j.tifs.2017.07.006).
- [12] Shahidi, F.; Peng, H. Bioaccessibility and Bioavailability of Phenolic Compounds. *J. Food Bioact.* **2018**, 4, 11–68. DOI: [10.31665/JFB.2018.4162](https://doi.org/10.31665/JFB.2018.4162).
- [13] Davey, M. W.; Montagu, M. V.; Inze, D.; Sanmartin, M.; Kanellis, A.; Smirnoff, N.; Benzie, I. J.; Strain, J. J.; Favell, D.; Fletcher, J. Review Plant L-Ascorbic Acid: Chemistry, Function, Metabolism, Bioavailability and Effects of Processing. *J. Sci. Food Agric.* **2000**, 80, 825–860. DOI: [10.1002/\(SICI\)1097-0010\(20000515\)80:7<825::AID-JSFA598>3.0.CO;2-6](https://doi.org/10.1002/(SICI)1097-0010(20000515)80:7<825::AID-JSFA598>3.0.CO;2-6).
- [14] Thilakarathna, S. H.; Rupasinghe, H. P. V. Flavonoid Bioavailability and Attempts for Bioavailability Enhancement. *Nutrients.* **2013**, 5, 3367–3387. DOI: [10.3390/nu5093367](https://doi.org/10.3390/nu5093367).

- [15] Corte-Real, J.; Bohn, T. Interaction of Divalent Minerals with Liposoluble Nutrients and Phytochemicals during Digestion and Influences on Their Bioavailability – A Review. *Food Chem.* **2018**, 252, 285–293. DOI: [10.1016/j.foodchem.2018.01.113](https://doi.org/10.1016/j.foodchem.2018.01.113).
- [16] Zhang, Y.; Gan, R.; Li, S.; Zhou, Y.; Li, A.; Xu, D. Antioxidant Phytochemicals for the Prevention and Treatment of Chronic Diseases. *Molecules.* **2015**, 20, 21138–21156. DOI: [10.3390/molecules201219753](https://doi.org/10.3390/molecules201219753).
- [17] Sun, H.; Mu, T.; Xi, L.; Song, Z. Effects of Domestic Cooking Methods on Polyphenols and Antioxidant Activity of Sweet Potato Leaves. *J. Agric. Food Chem.* **2014**, 62, 8982–8989. DOI: [10.1021/jf502328d](https://doi.org/10.1021/jf502328d).
- [18] Djuikwo, V. N.; Ejoh, R. A.; Gouado, I.; Mbofung, C. M.; Tanumihardjo, S. A. Determination of Major Carotenoids in Processed Tropical Leafy Vegetables Indigenous to Africa. *Food Nutr. Sci.* **2011**, 2, 793–802. DOI: [10.4236/fns.2011.28109](https://doi.org/10.4236/fns.2011.28109).
- [19] Hsu, C.; Chao, P.; Hu, S.; Yang, C. The Antioxidant and Free Radical Scavenging Activities of Chlorophylls and Pheophytins. *Food Nutr. Sci.* **2013**, 4, 1–8. DOI: [10.4236/fns.2013.48A001](https://doi.org/10.4236/fns.2013.48A001).
- [20] Negi, P. S.; Roy, S. K. Effect of Blanching and Drying Methods on β -carotene, Ascorbic Acid and Chlorophyll Retention of Leafy Vegetables. *Food Sci. Technol.* **2000**, 33(4), 295–298. DOI: [10.1006/fstl.2000.0659](https://doi.org/10.1006/fstl.2000.0659).
- [21] Shashank, K.; Abhay, K. Chemistry and Biological Activities of Flavonoids: An Overview. *Sci. World J.* **2013**, 4(2), 32–48.
- [22] Nugraheni, P. Y.; Verkerk, R.; Widianarko, B.; Dekker, M. A Mechanistic Perspective on Process-Induced Changes in Glucosinolate Content in Brassica Vegetables: A Review. *Crit. Rev. Food Sci. Nutr.* **2015**, 55(6), 823–838. DOI: [10.1080/10408398.2012.688076](https://doi.org/10.1080/10408398.2012.688076).
- [23] Durazzo, A.; Lucarini, M.; Souto, E. B.; Cicala, C.; Caiazza, E.; Izzo, A. A.; Novellino, E.; Santini, A. Polyphenols: A Concise Overview on the Chemistry, Occurrence, and Human Health. *Phyther. Res.* **2019**, 33(9), 2221–2243. DOI: [10.1002/ptr.6419](https://doi.org/10.1002/ptr.6419).
- [24] Balasundram, N.; Sundram, K.; Samman, S. Phenolic Compounds in Plants and Agri-Industrial by-Products: Antioxidant Activity, Occurrence, and Potential Uses. *Food Chem.* **2006**, 99(1), 191–203. DOI: [10.1016/j.foodchem.2005.07.042](https://doi.org/10.1016/j.foodchem.2005.07.042).
- [25] Liu, R. H.; Health Benefits of Fruit and Vegetables are from Additive and Synergistic Combinations of Phytochemicals. *Am. J. Clin. Nutr.* **2003**, 78, 517–520. DOI: [10.1093/ajcn/78.3.517S](https://doi.org/10.1093/ajcn/78.3.517S).
- [26] Meena, S.; Agrawal, M.; Agrawal, K. Effect of Blanching and Drying on Antioxidants and Antioxidant Activity of Selected Green Leafy Vegetables. *Int. J. Sci. Res.* **2016**, 5(10), 1811–1814.
- [27] Nartnampong, A.; Kittiwongsunthon, W.; Porasuphatana, S. Blanching Process Increases Health Promoting Phytochemicals in Green Leafy Thai Vegetables. *Int. Food Res. J.* **2016**, 23 (6), 2426–2435.
- [28] Yao, Y.; Sang, W.; Zhou, M.; Ren, G. Phenolic Composition and Antioxidant Activities of 11 Celery Cultivars. *J. Food Sci.* **2010**, 75(1), 9–13. DOI: [10.1111/j.1750-3841.2009.01392.x](https://doi.org/10.1111/j.1750-3841.2009.01392.x).
- [29] Zoro, A. F.; Zoué, L. T.; Adom, N. J.; Niamké, S. L.; Effect of Sun Drying on Nutritive and Antioxidant Properties of Leafy Vegetables Consumed in Western Côte D'Ivoire. *African J. Sci. Res.* **2015**, 54, 24–31. DOI: [10.11648/j.jfns.20150301.14](https://doi.org/10.11648/j.jfns.20150301.14).
- [30] Raja, K. S.; Taip, F. S.; Azmi, M. M. Z.; Shishir, M. R. I. Effect of Pre-Treatment and Different Drying Methods on the Physicochemical Properties of *Carica papaya* L. Leaf Powder. *J. Saudi Soc. Agric. Sci.* **2017**. DOI: [10.1016/j.jssas.2017.04.001](https://doi.org/10.1016/j.jssas.2017.04.001).
- [31] Bembem, K.; Sadana, B.; Bains, K. Effect of Domestic Cooking Methods on the Nutritive and Antioxidative Components of Mustard Leaves (*Brassica juncea*). *Int. J. Food, Agric. Vet. Sci.* **2014**, 4(1), 24–31.
- [32] Kidmose, U.; Yang, R. Y.; Thilsted, S. H.; Christensen, L. P.; Brandt, K. Content of Carotenoids in Commonly Consumed Asian Vegetables and Stability and Extractability during Frying. *J. Food Compos. Anal.* **2006**, 19(6–7), 562–571. DOI: [10.1016/j.jfca.2006.01.011](https://doi.org/10.1016/j.jfca.2006.01.011).
- [33] Veda, S.; Platel, K.; Srinivasan, K. Enhanced Bioaccessibility of β -Carotene from Yellow-Orange Vegetables and Green Leafy Vegetables by Domestic Heat Processing. *Int. J. Food Sci. Technol.* **2010**, 45(10), 2201–2207. DOI: [10.1111/j.1365-2621.2010.02385.x](https://doi.org/10.1111/j.1365-2621.2010.02385.x).

- [34] Ahamad, M. N.; Saleemullah, M.; Shah, H. U. Determination of Beta Carotene Content in Fresh Vegetables Using High Performance Liquid Chromatography. *Sarhad J. Agric.* **2007**, 23(3), 767–770.
- [35] Shin, L. E. R.; Zzaman, W.; Kuang, Y. T.; Bhat, R. Influence of Dehydration Techniques on Physicochemical, Antioxidant and Microbial Qualities of *Ipomoea aquatica* Forsk: An Underutilized Green Leafy Vegetable. *J. Food Process. Preserv.* **2015**, 39(6), 1118–1124. DOI: [10.1111/jfpp.12326](https://doi.org/10.1111/jfpp.12326).
- [36] Kamel, S. M.; Thabet, H. A.; Algadi, E. A. Influence of Drying Process on the Functional Properties of Some Plants. *Chem. Mater. Res.* **2013**, 3(7), 1–9.
- [37] Saini, R. K.; Shetty, N. P.; Prakash, M.; Giridhar, P. Effect of Dehydration Methods on Retention of Carotenoids, Tocopherols, Ascorbic Acid and Antioxidant Activity in *Moringa oleifera* Leaves and Preparation of a RTE Product. *J. Food Sci. Technol.* **2014**, 51(9), 2176–2182. DOI: [10.1007/s13197-014-1264-3](https://doi.org/10.1007/s13197-014-1264-3).
- [38] Combs, G. F.; McClung, P.; Vitamin, J. C. Chapter 10 - *In the Vitamins Fundamental Aspects in Nutrition and Health*. London: Academic Press, **2017**; pp 267–295. doi: [10.1016/B978-0-12-802965-7.00010-1](https://doi.org/10.1016/B978-0-12-802965-7.00010-1).
- [39] Yao, Y.; Ren, G. Effect of Thermal Treatment on Phenolic Composition and Antioxidant Activities of Two Celery Cultivars. *Food Sci. Technol.* **2011**, 44(1), 181–185. DOI: [10.1016/j.lwt.2010.07.001](https://doi.org/10.1016/j.lwt.2010.07.001).
- [40] Palafox-Carlos, H.; Ayala-Zavala, J. F.; González-Aguilar, G. A. The Role of Dietary Fiber in the Bioaccessibility and Bioavailability of Fruit and Vegetable Antioxidants. *J. Food Sci.* **2011**, 76(1), 6–15. DOI: [10.1111/j.1750-3841.2010.01957.x](https://doi.org/10.1111/j.1750-3841.2010.01957.x).
- [41] Cory, H.; Passarelli, S.; Szeto, J.; Tamez, M.; Mattei, J. The Role of Polyphenols in Human Health and Food Systems: A Mini-Review. *Front. Nutr.* **2018**, 5, 1–9. DOI: [10.3389/fnut.2018.00087](https://doi.org/10.3389/fnut.2018.00087).
- [42] Schwartz, S. J.; Elbe, J. H. V.; Giusti, M. M. Colorants. In *Fennema's Food Chemistry*; Damodaran, S., Parkin, K.L., Fennema, O.R., Eds.; CRC Press: New York, **2008**; pp 571–638.
- [43] Yahia, E. M.; Ornelas-Paz, J. Chemistry, Stability, and Biological Actions of Carotenoids. In *Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value, and Stability*. Rosa, L. A. de la, Alvarez-Parrilla, E., Gustavo A. Gonzalez-Aguilar, Eds.; Wiley-Blackwell: Oxford, **2009**; pp 177–222. <https://doi.org/10.1002/9780813809397>.
- [44] Stahl, W.; Sies, H. Antioxidant Activity of Carotenoids. *Mol. Aspects Med.* **2003**, 24(6), 345–351. DOI: [10.1016/S0098-2997\(03\)00030-X](https://doi.org/10.1016/S0098-2997(03)00030-X).
- [45] Khalid, M.; Rahman, S.; Bilal, M.; Iqbal, H. M. N.; Huang, D. Biosynthesis and Biomedical of Carotenoids with Special Reference to Human-Related Applications. *Biocatal. Agric. Biotechnol.* **2019**, 17, 399–407. DOI: [10.1016/j.bcab.2018.11.027](https://doi.org/10.1016/j.bcab.2018.11.027).
- [46] Teng, S. S.; Chen, B. H. Formation of Pyrochlorophylls and Their Derivatives in Spinach Leaves during Heating. *Food Chem.* **1999**, 65(3), 367–373. DOI: [10.1016/S0308-8146\(98\)00237-4](https://doi.org/10.1016/S0308-8146(98)00237-4).
- [47] Chao, P. Y.; Huang, M. Y.; Huang, W. D.; Lin, K. H.; Chen, S. Y.; Yang, C. M.; Study of Chlorophyll-Related Compounds from Dietary Spinach in Human Blood. *Not. Bot. Horti Agrobot. Cluj-Napoca.* **2018**, 462, 309–316. DOI: [10.15835/nbha46210918](https://doi.org/10.15835/nbha46210918).
- [48] Khalid, M.; Saeed-ur-Rahman,; Bilal, M.; Iqbal, H. M. N.; Huang, D. Biosynthesis and Biomedical Perspectives of Carotenoids with Special Reference to Human Health-Related Applications. *Biocatal. Agric. Biotechnol.* **2019**, 17, 399–407. DOI: [10.1016/j.bcab.2018.11.027](https://doi.org/10.1016/j.bcab.2018.11.027).
- [49] Vaňková, K.; Marková, I.; Jašprová, J.; Dvořák, A.; Subhanová, I.; Zelenka, J.; Novosádová, I.; Rasl, J.; Vomastek, T.; Sobotka, R.; et al. Chlorophyll-Mediated Changes in the Redox Status of Pancreatic Cancer Cells are Associated with Its Anticancer Effects. *Oxid. Med. Cell. Longev.* **2018**. DOI: [10.1155/2018/4069167](https://doi.org/10.1155/2018/4069167).
- [50] Ottaway, P. B.; Fortification of Beverages with Vitamins and Minerals. In *Functional and Speciality Beverage Technology*; Paquin, P., Ed.; Woodhead Publishing Limited: Cambridge, **2009**; pp 71–90.

- [51] Chambial, S.; Dwivedi, S.; Shukla, K. K.; John, P. J.; Sharma, P. Vitamin C in Disease Prevention and Cure: An Overview. *Indian J. Clin. Biochem.* **2013**, 28(4), 314–328. DOI: [10.1007/s12291-013-0375-3](https://doi.org/10.1007/s12291-013-0375-3).
- [52] Natella, F.; Maldini, M.; Leoni, G.; Scaccini, C. Glucosinolates Redox Activities: Can They Act as Antioxidants? *Food Chem.* **2014**, 149, 226–232. DOI: [10.1016/j.foodchem.2013.10.134](https://doi.org/10.1016/j.foodchem.2013.10.134).
- [53] Vig, A. P.; Rampal, G.; Thind, T. S.; Arora, S. Bio-Protective Effects of Glucosinolates - A Review. *Food Sci. Technol.* **2009**, 42(10), 1561–1572. DOI: [10.1016/j.lwt.2009.05.023](https://doi.org/10.1016/j.lwt.2009.05.023).
- [54] Mitsiogianni, M.; Koutsidis, G.; Mavroudis, N.; Trafalis, D. T.; Botaitis, S.; Franco, R.; Zoumpourlis, V.; Amery, T.; Galanis, A.; Pappa, A.; et al. The Role of Isothiocyanates as Cancer Anti-Melanoma Agents. *Antioxidants*. **2019**, 8(106), 1–35.
- [55] Vanduchova, A.; Anzenbacher, P.; Anzenbacherova, E. Isothiocyanate from Broccoli, Sulforaphane, and Its Properties. *J. Med. Food.* **2018**, 22(2), 1–6. DOI: [10.1089/jmf.2018.0024](https://doi.org/10.1089/jmf.2018.0024).
- [56] Lafarga, T.; Bobo, G.; Viñas, I.; Collazo, C.; Aguiló-Aguayo, I. Effects of Thermal and Non-Thermal Processing of Cruciferous Vegetables on Glucosinolates and Its Derived Forms. *J. Food Sci. Technol.* **2018**, 55(6), 1973–1981. DOI: [10.1007/s13197-018-3153-7](https://doi.org/10.1007/s13197-018-3153-7).
- [57] Oliviero, T.; Verkerk, R.; Dekker, M. Isothiocyanates from Brassica Vegetables—effects of Processing, Cooking, Mastication, and Digestion. *Mol. Nutr. Food Res.* **2018**, 62(18), 1–30. DOI: [10.1002/mnfr.201701069](https://doi.org/10.1002/mnfr.201701069).
- [58] Corcuera, J. I. R.; Cavalieri, R. P.; Powers, J. R. Blanching of Foods. In *Encyclopedia of Agricultural, Food, and Biological Engineering*; Heldman, D.R., Moraru, C.I., Eds.; Marcel Dekker, Inc.: New York, **2004**; pp 1–5. DOI: [10.1081/E-EAFE-120030417](https://doi.org/10.1081/E-EAFE-120030417).
- [59] Kaiser, A.; Kammerer, D. R.; Carle, R. Impact of Blanching on Polyphenol Stability and Antioxidant Capacity of Innovative Coriander (*Coriandrum sativum* L.) Pastes. *Food Chem.* **2013**, 140(2013), 332–339. DOI: [10.1016/j.foodchem.2013.02.077](https://doi.org/10.1016/j.foodchem.2013.02.077).
- [60] Amin, I.; Wee, Y. L. Effect of Different Blanching Times on Antioxidant Properties in Selected Cruciferous Vegetables. *J. Sci. Food Agric.* **2005**, 85(13), 2314–2320. DOI: [10.1002/jsfa.2261](https://doi.org/10.1002/jsfa.2261).
- [61] Traoré, K.; Parkouda, C.; Savadogo, A.; Ba, F.; Kamga, R.; Traore, Y. Effect of Processing Methods on the Nutritional Content of Three Traditional Vegetables Leaves: *Amaranth*, *Black Nightshade*, and *Jute Mallow*. *Food Sci. Nutr.* **2017**, 5(6), 1139–1144. DOI: [10.1002/fsn3.504](https://doi.org/10.1002/fsn3.504).
- [62] Salau, B.; Odufuwa, K.; Adeosun, C.; Atunnise, A.; Blanching and Juicing Effect on Flavonoids Contents in Commonly Consumed Leafy Vegetables in South West Nigeria. *Int. J. Biochem. Res. Rev.* **2015**, 53, 207–213. DOI: [10.9734/IJBCRR/2015/14230](https://doi.org/10.9734/IJBCRR/2015/14230).
- [63] Waldron, K. W.; Smith, A. C.; Parr, A. J.; Ng, A.; Parker, M. L. New Approaches to Understanding and Controlling Cell Separation in Relation to Fruit and Vegetable Texture. *Trends Food Sci. Technol.* **1997**, 8(7), 213–221. DOI: [10.1016/S0924-2244\(97\)01052-2](https://doi.org/10.1016/S0924-2244(97)01052-2).
- [64] Miglio, C. C.; Chiavaro, E.; Visconti, A.; Fodliano, V.; Pellegrini, N.; Fogliano, V.; Pellegrini, N. Effects of Different Cooking Methods on Nutritional and Physiochemical Characteristics of Selected Vegetables. *J. Agric. Food Chem.* **2008**, 56(1), 139–147. DOI: [10.1021/jf072304b](https://doi.org/10.1021/jf072304b).
- [65] Kao, F. J.; Chiu, Y. S.; Chiang, W. D. Effect of Water Cooking on Antioxidant Capacity of Carotenoid-Rich Vegetables in Taiwan. *J. Food Drug Anal.* **2014**, 22(2), 202–209. DOI: [10.1016/j.jfda.2013.09.010](https://doi.org/10.1016/j.jfda.2013.09.010).
- [66] Moyo, S. M.; Serem, J. C.; Bester, M. J.; Mavumengwana, V.; Kayitesi, E. Influence of Boiling and Subsequent Phases of Digestion on the Phenolic Content, Bioaccessibility, and Bioactivity of *Bidens pilosa* (Blackjack) Leafy Vegetable. *Food Chem.* **2020**, 311. DOI: [10.1016/j.foodchem.2019.126023](https://doi.org/10.1016/j.foodchem.2019.126023).
- [67] Ng, Z. X.; Chai, J. W.; Kuppusamy, U. R. Customized Cooking Method Improves Total Antioxidant Activity in Selected Vegetables. *Int. J. Food Sci. Nutr.* **2011**, 62(2), 158–163. DOI: [10.3109/09637486.2010.526931](https://doi.org/10.3109/09637486.2010.526931).
- [68] Hossain, A.; Khatun, M. A.; Islam, M.; Huque, R. Enhancement of Antioxidant Quality of Green Leafy Vegetables upon Different Cooking Method. *Prev. Nutr. Food Sci.* **2017**, 22(3), 216–222. DOI: [10.3746/pnf.2017.22.3.216](https://doi.org/10.3746/pnf.2017.22.3.216).

- [69] Sultana, B.; Anwar, F.; Iqbal, S. Effect of Different Cooking Methods on the Antioxidant Activity of Some Vegetables from Pakistan. *Int. J. Food Sci. Technol.* **2008**, 43(3), 560–567. DOI: [10.1111/j.1365-2621.2006.01504.x](https://doi.org/10.1111/j.1365-2621.2006.01504.x).
- [70] Lako, J.; Trenerry, V. C.; Wahlqvist, M.; Wattanapenpaiboon, N.; Sotheeswaran, S.; Premier, R. Phytochemical Flavonols, Carotenoids and the Antioxidant Properties of a Wide Selection of Fijian Fruit, Vegetables and Other Readily Available Foods. *Food Chem.* **2007**, 101(4), 1727–1741. DOI: [10.1016/j.foodchem.2006.01.031](https://doi.org/10.1016/j.foodchem.2006.01.031).
- [71] Subramaniam, S.; Rosdi, M. H. B.; Kuppusamy, U. R. Customized Cooking Methods Enhance Antioxidant, Antiglycemic, and Insulin-Like Properties of *Momordica charantia* and *Moringa oleifera*. *J. Food Qual.* **2017**, 2017, 1–9. DOI: [10.1155/2017/9561325](https://doi.org/10.1155/2017/9561325).
- [72] Subudhi, B. B.; Bhoi, A. Antioxidative Effects of *Brassica juncea* and *Moringa oleifera* Prepared by Different Processing Methods. *J. Food Sci. Technol.* **2014**, 51(4), 790–794. DOI: [10.1007/s13197-011-0542-6](https://doi.org/10.1007/s13197-011-0542-6).
- [73] Yang, W.; Lu, X.; Zhang, Y.; Qiao, Y. Effect of Cooking Methods on the Health-Promoting Compounds, Antioxidant Activity, and Nitrate of Tatsoi (*Brassica rapa* L. Ssp. *Narinosa*). *J. Food Process. Preserv.* **2019**, 43(8), 1–8. DOI: [10.1111/jfpp.14008](https://doi.org/10.1111/jfpp.14008).
- [74] Moorthy, P.; Rajan, M.; Sathyanarayanan, S.; Muniyandi, K.; Sivaraj, D.; Sasidharan, S. P.; Thangaraj, P.; Effect of Different Cooking Methods of *Hibiscus surratensis* L. Leaf Vegetable on Nutritional, Anti-Nutritional Composition, and Antioxidant Activities. *J. Culin. Sci. Technol.* **2018**, 181, 13–28. DOI: [10.1080/15428052.2018.1502110](https://doi.org/10.1080/15428052.2018.1502110).
- [75] Armesto, J.; Gómez-Limia, L.; Carballo, J.; Martínez, S. Effects of Different Cooking Methods on the Antioxidant Capacity and Flavonoid, Organic Acid and Mineral Contents of Galega Kale (*Brassica oleracea* Var. *Acephala* Cv. *Galega*). *Int. J. Food Sci. Nutr.* **2018**, 70(2), 136–149. DOI: [10.1080/09637486.2018.1482530](https://doi.org/10.1080/09637486.2018.1482530).
- [76] Speek, A. J.; Saichua, S. S.; Schreurs, W. H. P. Total Carotenoid and β -Carotene Contents of Thai Vegetables and the Effect of Processing. *Food Chem.* **1988**, 27, 245–257. DOI: [10.1016/0308-8146\(88\)90010-6](https://doi.org/10.1016/0308-8146(88)90010-6).
- [77] Miti, V.; Stankov, V.; Dimitrijevi, M.; Cvetkovi, J.; Stojanovi, G. Chemometric Analysis of Chlorophyll A, B and Carotenoid Content in Green Leafy Vegetables. *Biol. Nyssana.* **2013**, 4, 49–55.
- [78] Kao, F. J.; Chiu, Y. S.; Tsou, M. J.; Chiang, W. D. Effects of Chinese Domestic Cooking Methods on the Carotenoid Composition of Vegetables in Taiwan. *Food Sci. Technol.* **2012**, 46(2), 485–492. DOI: [10.1016/j.lwt.2011.11.019](https://doi.org/10.1016/j.lwt.2011.11.019).
- [79] Sriwichai, W.; Collin, M.; Tranbarger, T. J.; Berger, J.; Avallone, S. Improvement of the Content in Bioaccessible Lipophilic Micronutrients in Raw and Processed Drumstick Leaves (*Moringa oleifera* Lam.). *Food Sci. Technol.* **2017**, 75, 279–285. DOI: [10.1016/j.lwt.2016.09.001](https://doi.org/10.1016/j.lwt.2016.09.001).
- [80] Hunter, K. J.; Fletcher, J. M. The Antioxidant Activity and Composition of Fresh, Frozen, Jarred and Canned Vegetables. *Innov. Food Sci. Emerg. Technol.* **2002**, 3(4), 399–406. DOI: [10.1016/S1466-8564\(02\)00048-6](https://doi.org/10.1016/S1466-8564(02)00048-6).
- [81] Delchier, N.; Reich, M.; Renard, C. M. G. C. Impact of Cooking Methods on Foliates, Ascorbic Acid and Lutein in Green Beans (*Phaseolus vulgaris*) and Spinach (*Spinacea oleracea*). *Food Sci. Technol.* **2012**, 49(2), 197–201. DOI: [10.1016/j.lwt.2012.06.017](https://doi.org/10.1016/j.lwt.2012.06.017).
- [82] Zaman, W. U.; Akram, M.; Rehman, R. Effect of Temperature Variations during Cooking and Storage on Ascorbic Acid Contents of Vegetables: A Comparative Study. *J. Chem. Soc. Pakistan.* **2013**, 35(1), 1–4.
- [83] Fafunso, M.; Bassir, O. Effect of Cooking on the Vitamin C Content of Fresh Leaves and Wilted Leaves. *J. Agric. Food Chem.* **1976**, 24(2), 354–355. DOI: [10.1002/jctb.5000592602](https://doi.org/10.1002/jctb.5000592602).
- [84] Adefegha, S. A.; Obboh, G. Enhancement of Total Phenolics and Antioxidant Properties of Some Tropical Green Leafy Vegetables by Steam Cooking. *J. Food Process. Preserv.* **2011**, 35(5), 615–622. DOI: [10.1111/j.1745-4549.2010.00509](https://doi.org/10.1111/j.1745-4549.2010.00509).
- [85] Igwemmar, N. C.; Kolawole, S. A.; Imran, I. A. Effect of Heating on Vitamin C Content of Some Selected Vegetables. *Int. J. Sci. Technol. Res.* **2013**, 2(11), 209–212.
- [86] Gehse, S.; Knorr, F.; Patzelt, A.; Zastrow, L.; Meinke, M. C.; Lademann, J.; Darvin, M. E. Determination of the Effect of Boiling on the Bioavailability of Carotenoids in Vegetables

- Using Resonance Raman Spectroscopy. *Laser Phys.* **2018**, 28, 10. DOI: [10.1088/1555-6611/aad1b4](https://doi.org/10.1088/1555-6611/aad1b4).
- [87] Zeng, C.; Effect of Different Cooking Methods on the Vitamin C Content of Selected Vegetables. *Nutr. Food Sci.* **2013**, 43(5), 438–443. DOI: [10.1108/NFS-11-2012-0123](https://doi.org/10.1108/NFS-11-2012-0123).
 - [88] Le, G. H.; Philippe, F.; Domon, J.; Gillet, F.; Pelloux, J.; Rayon, C. Cell Wall Metabolism in Response to Abiotic Stress. *Plants.* **2015**, 4(1), 112–166. DOI: [10.3390/plants4010112](https://doi.org/10.3390/plants4010112).
 - [89] Chen, X. D.; Putranto, A. *Modeling Drying Processes: A Reaction Engineering Approach*; Cambridge University Press: Cambridge, **2013**. DOI: [10.1017/CBO9780511997846](https://doi.org/10.1017/CBO9780511997846).
 - [90] Boateng, E. D.; Effect of Drying Methods on Nutrient Quality of Basil (*Ocimum viride*) Leaves Cultivated in Ghana. *Int. Food Res. J.* **2013**, 20(4), 1569–1573.
 - [91] Joshi, P.; Mehta, D.; Effect of Dehydration on the Nutritive Value of Drumstick Leaves. *J. Metabolomics Syst. Biol.* **2010**, 11, 5–9. DOI: [10.1016/S0031-9422\(02\)00549-6](https://doi.org/10.1016/S0031-9422(02)00549-6).
 - [92] Schutyser, M. A. I.; Perdana, J.; Boom, R. M. Single Droplet Drying for Optimal Spray Drying of Enzymes and Probiotics. *Trends Food Sci. Technol.* **2012**, 27(2), 73–82. DOI: [10.1016/j.tifs.2012.05.006](https://doi.org/10.1016/j.tifs.2012.05.006).
 - [93] Perdana, J.; Van der Sman, R. G. M.; Fox, M. B.; Boom, R. M.; Schutyser, M. A. I. Measuring and Modelling of Diffusivities in Carbohydrate-Rich Matrices during Thin Film Drying. *J. Food Eng.* **2014**, 122(1), 38–47. DOI: [10.1016/j.jfoodeng.2013.08.033](https://doi.org/10.1016/j.jfoodeng.2013.08.033).
 - [94] Thirunathan, P.; Arnz, P.; Husny, J.; Gianfrancesco, A.; Perdana, J. Thermogravimetric Analysis for Rapid Assessment of Moisture Diffusivity in Polydisperse Powder and Thin Film Matrices. *Food Chem.* **2018**, 242, 519–526. DOI: [10.1016/j.foodchem.2017.09.089](https://doi.org/10.1016/j.foodchem.2017.09.089).
 - [95] Jin, X.; Van Boxstel, A. J. B.; Gerkema, E.; Vergeldt, F. J.; Van As, H.; Van Straten, G.; Boom, R. M.; Van Der Sman, R. G. M. Anomalies in Moisture Transport during Broccoli Drying Monitored by MRI? *Faraday Discuss.* **2012**, 158, 65–75. DOI: [10.1039/c2fd20049j](https://doi.org/10.1039/c2fd20049j).
 - [96] Alakali, J. S.; Kucha, C. T.; Rabi, I. A. Effect of Drying Temperature on the Nutritional Quality of *Moringa oleifera* Leaves. *African J. Food Sci.* **2015**, 9(7), 395–399. DOI: [10.5897/AJFS2014.1145](https://doi.org/10.5897/AJFS2014.1145).
 - [97] Chan, E. W. C.; Lim, Y. Y.; Wong, S. K.; Lim, K. K.; Tan, S. P.; Lianto, F. S.; Yong, M. Y. Effects of Different Drying Methods on the Antioxidant Properties of Leaves and Tea of Ginger Species. *Food Chem.* **2009**, 113(1), 166–172. DOI: [10.1016/j.foodchem.2008.07.090](https://doi.org/10.1016/j.foodchem.2008.07.090).
 - [98] Nicoli, M. C.; Anese, M.; Parpinel, M. Influence of Processing on the Antioxidant Properties of Fruit and Vegetables. *Trends Food Sci. Technol.* **1999**, 10(3), 94–100. DOI: [10.1016/S0924-2244\(99\)00023-0](https://doi.org/10.1016/S0924-2244(99)00023-0).
 - [99] Ilyas, M.; Arshad, M. U.; Saeed, F.; Iqbal, M. Antioxidant Potential and Nutritional Comparison of Moringa Leaf and Seed Powders and Their Tea Infusions. *J. Anim. Plant Sci.* **2015**, 25(1), 226–233.
 - [100] Oboh, G.; Akindahunsi, A. A. Change in the Ascorbic Acid, Total Phenol and Antioxidant Activity of Sun-Dried Commonly Consumed Green Leafy Vegetables in Nigeria. *Nutr. Health.* **2004**, 18(1), 29–36. DOI: [10.1177/026010600401800103](https://doi.org/10.1177/026010600401800103).
 - [101] Shyamala, B. N.; Gupta, S.; Lakshmi, A. J.; Prakash, J. Leafy Vegetable Extracts - Antioxidant Activity and Effect on Storage Stability of Heated Oils. *Innov. Food Sci. Emerg. Technol.* **2005**, 6(2), 239–245. DOI: [10.1016/j.ifset.2004.12.002](https://doi.org/10.1016/j.ifset.2004.12.002).
 - [102] Viña, S. Z.; Chaves, A. R. Effect of Heat Treatment and Refrigerated Storage on Antioxidant Properties of Pre-Cut Celery (*Apium graveolens* L.). *Int. J. Food Sci. Technol.* **2008**, 43(1), 44–51. DOI: [10.1111/j.1365-2621.2006.01380.x](https://doi.org/10.1111/j.1365-2621.2006.01380.x).
 - [103] Wangcharoen, W.; Gomolmanee, S. Antioxidant Activity Changes during Hot-Air Drying of *Moringa oleifera* Leaves. *Maejo Int. J. Sci. Technol.* **2013**, 7(3), 353–363. DOI: [10.14456/mijst.2013.29](https://doi.org/10.14456/mijst.2013.29).
 - [104] Sukrasno, I.; Anggadiredja, K.; Handayani, W. A.; Anam, K. Influence of Drying Method on Flavonoid Content of *Cosmos caudatus* Leaves. *Res. J. Med. Plant.* **2011**, 5(2), 189–195. DOI: [10.3923/rjmp.2011.189.195](https://doi.org/10.3923/rjmp.2011.189.195).
 - [105] Olabode, Z.; Akanbi, C. T.; Olunlade, B.; Adeola, A. A. Effects of Drying Temperature on the Nutrients of Moringa (*Moringa oleifera*). *Direct Res. J. Agric. Food Sci.* **2015**, 3(5), 117–122.

- [106] Divya, P.; Puthusseri, B.; Neelwarne, B. Carotenoid Content, Its Stability during Drying and the Antioxidant Activity of Commercial Coriander (*Coriandrum sativum* L.) Varieties. *Food Res. Int.* **2012**, 45(1), 342–350. DOI: [10.1016/j.foodres.2011.09.021](https://doi.org/10.1016/j.foodres.2011.09.021).
- [107] Cesare, D.; Forni, E.; Viscardi, D.; Nani, R. C. Changes in the Chemical Composition of Basil Caused by Different Drying Procedures. *J. Agric. Food Chem.* **2003**, 51, 3575–3581. DOI: [10.1021/jf021080a](https://doi.org/10.1021/jf021080a).
- [108] Ahmed, J.; Shivhare, U. S.; Singh, G.; Gupta, P. Drying Characteristics and Product Quality of Coriander Leaves. *Food Bioprod. Process.* **2001**, 79(2), 103–106. DOI: [10.1205/096030801750286258](https://doi.org/10.1205/096030801750286258).
- [109] Yang, J.; Jin, X.; Chen, X. D. Investigation of the Effects of Mechanical Treatments on Cellular Structure Integrity and Vitamin C Extractability of Broccoli (*Brassica oleracea* L. Var. *Italica*) by LF-NMR. *Food Funct.* **2018**, 9(5), 2942–2950. DOI: [10.1039/c8fo00140e](https://doi.org/10.1039/c8fo00140e).
- [110] Perdana, J.; Zubia, A. A.; Kutahya, O.; Schutyser, M.; Fox, M. Spray Drying of *Lactobacillus plantarum* WCFS1 Guided by Predictive Modeling. *Dry. Technol.* **2015**, 33(15–16), 1789–1797. DOI: [10.1080/07373937.2015.1026975](https://doi.org/10.1080/07373937.2015.1026975).
- [111] Dev, S. R. S.; Geetha, P.; Orsat, V.; Gariépy, Y.; Raghavan, G. S. V. Effects of Microwave-Assisted Hot Air Drying and Conventional Hot Air Drying on the Drying Kinetics, Color, Rehydration, and Volatiles of *Moringa oleifera*. *Dry. Technol.* **2011**, 29(12), 1452–1458. DOI: [10.1080/07373937.2011.587926](https://doi.org/10.1080/07373937.2011.587926).
- [112] Fellows, P.; *Food Processing Technology Principles and Practice*; Woodhead Publishing Limited: Cambridge, **2000**.
- [113] Padmini, T.; Karpagavalli, B.; Vijayalakshmi, R.; Jesupriya, P. S. Changes in Antioxidants during Heat Processing of Green Leafy Vegetables. *Int. J. Agric. Food Sci.* **2015**, 5(4), 115–120.
- [114] Jiménez-Monreal, A. M.; García-Diz, L.; Martínez-Tomé, M.; Mariscal, M.; Murcia, M. A. Influence of Cooking Methods on Antioxidant Activity of Vegetables. *J. Food Sci.* **2009**, 74(3), 97–103. DOI: [10.1111/j.1750-3841.2009.01091.x](https://doi.org/10.1111/j.1750-3841.2009.01091.x).
- [115] Thummakomma, K.; Prashanthi, M.; Rajeswari, K. Effect of Cooking Methods on Bioactive Compounds in Vegetables. *Int. J. Chem. Stud.* **2018**, 6(4), 3310–3315. DOI: [10.13140/RG.2.2.35490.27844](https://doi.org/10.13140/RG.2.2.35490.27844).
- [116] Pérez-burillo, S.; Rufián-henares, J. Á.; Pastoriza, S. Effect of Home Cooking on the Antioxidant Capacity of Vegetables: Relationship with Maillard Reaction Indicators. *Food Res. Int.* **2018**. DOI: [10.1016/j.foodres.2018.12.007](https://doi.org/10.1016/j.foodres.2018.12.007).