Recovering and encapsulating carotenoids from the peel of Gac fruit (*Momordica cochinchinensis* Spreng)

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Food Science

School of Environmental and Life Sciences

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STATEMENT OF ORIGINALITY

I hereby certify that to the best of my knowledge and belief this thesis is my own work and contains no material previously published or written by another person except where due references and acknowledgements are made. It contains no material which has been previously submitted by me for the award of any other degree or diploma in any university or other tertiary institution.

Van Chuyen Hoang

Date..30/10/2017..

THESIS BY PUBLICATION

I hereby certify that this thesis is in the form of a series of 07 papers. I have included as part of the thesis a written statement from each co-author, endorsed in writing by the Faculty Assistant Dean (Research Training), attesting to my contribution to any jointly authored papers.

Van Chuyen Hoang

Date....30/10/2017....

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LIST OF PUBLICATIONS INCLUDED AS PARTS OF THE THESIS

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1. Paper I: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Effects of four different drying methods on the carotenoid composition and antioxidant capacity of dried Gac peel. *J Sci Food Agric*, *97*(5), 1656-1662.

2. Paper II: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Effects of pretreatments and air drying temperatures on the carotenoid composition and antioxidant capacity of dried gac peel. *Journal of Food Processing and Preservation*. DOI: 10.1111/jfpp.13226.

3. Paper III: Chuyen, H. V., Tran, X. T., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Yield of carotenoids, phenolic compounds and antioxidant capacity of extracts from Gac peel as affected by different solvents and extraction conditions. *Journal of Advanced Agricultural Technologies*, *4*(1), 87-91.

4. Paper IV: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Optimisation of extraction conditions for recovering carotenoids and antioxidant capacity from Gac peel using response surface methodology. *International Journal of Food Science & Technology*, *52*(4), 972-980.

5. Paper V: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. Microwave-assisted extraction and ultrasound-assisted extraction for recovering carotenoids from Gac peel and their effects on antioxidant capacity of the extracts. *Food Science and Nutrition*, *6*(1), 189-196.

6. Paper VI: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. Ultrasound-assisted extraction of Gac peel: An optimisation of extraction conditions for recovering carotenoids and antioxidant capacity. Submitted to *Ultrasonics Sonochemistry* (ISSN: 1350-4177).

7. Paper VII: Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. Encapsulation of carotenoid-rich oil from Gac peel: Optimisation of the encapsulating process using a spray drier and the storage stability of the encapsulated powder. Submitted to *Powder Technology* (ISSN: 0032-5910).

STATEMENT OF AUTHORS' CONTRIBUTION TO THE PAPERS

To whom it may concern,

This statement shows the contribution of Mr. Van Chuyen Hoang to the papers that have been published or submitted as parts of this PhD project. The contribution of the co-authors to the papers is also mentioned in this statement.

Regards,

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Sophie E. Parks

John B. Golding

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This study was led by Van Chuyen Hoang. He conducted all experiments and data analysis, prepared the whole manuscript and revised the manuscript to be accepted by the journal. The approximate contributions of the authors to this paper are: Van Chuyen Hoang, 75%; Minh Nguyen, 10%; Paul Roach, 5%; Sophie Parks, 5%; John Golding 5%.

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ADDITIONAL PAPER AND CONFERENCE PRESENTATIONS

Review paper:

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Conference presentations:

1. Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2014). Preliminary investigation into the postharvest characteristics of Gac fruit (*Momordica Cochinchinensis* Spreng.) grown in Australia. The 3rd Asia Pacific Symposium on Postharvest Research, Education and Extension, December 08-11, 2014, Ho Chi Minh City, Vietnam. *Poster Presentation.*

2. Chuyen, H. V., Tran, X. T., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2015). Influence of vacuum drying temperature on carotenoid content and antioxidant capacity of Gac pulp and peel. The 48th Annual Australian Institute of Food Science and Technology *(*AIFST) Convention, August 11-13, 2015, Sydney, Australia. *Poster Presentation.*

3. Chuyen, H. V., Tran, X. T., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2016). Yield of carotenoids, phenolic compounds and antioxidant capacity of extracts from Gac peel as affected by different solvents and extraction conditions. The 7th International Conference on Agriculture and Animal Science (ICAAS), October 12-14, 2016, Incheon, Republic of Korea. *Oral Presentation.*

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1. Runner Up Prize for the Poster Competition at the 48th Annual Australian Institute of Food Science and Technology (*AIFST)* Convention. August 11-13, 2015, Sydney, Australia.

2. RHD Conference Scholarship of Faculty of Science and Information Technology for attending the 7th International Conference on Agriculture and Animal Science (ICAAS). October 12-14, 2016, Incheon, Republic of Korea.

LIST OF CONTENTS

ABSTRACT

Gac fruit (*Momordica cochinchinensis* Spreng.) is a rich source of carotenoids for the manufacture of powder, oil and capsules for food, cosmetic and pharmaceutical uses. Currently, only the aril of the Gac fruit is processed and the peel, like the other components, is discarded although it contains high level of carotenoids. Thus, if these carotenoids can be extracted effectively, the peel might become a potential source of these carotenoids and add value to what is otherwise a waste product.

This research aimed at: 1) investigating the effects of different drying and treatment conditions for the preservation of carotenoids and antioxidant capacity in Gac peel; 2) determining optimal conditions for recovering carotenoids and antioxidant capacity from the dried peel; and 3) identifying optimal conditions for encapsulating the extracted carotenoids in order to increase the storage stability of the carotenoids.

The results showed that the pretreatment of Gac peel with ascorbic acid combined with hot air drying at 70^{o}C led to the highest retention of β-carotene, lycopene, lutein, total carotenoid and antioxidant capacity in the dried Gac peel. For the extraction of the dried peel, ethyl acetate was the most suitable solvent for the concurrent extraction of carotenoids and antioxidant capacity. The maximum carotenoid yield of 271 mg/100g DW was achieved by the conventional extraction carried out at 40.7^{o}C for 150 minutes with a ratio of 80:1 of solvent volume to solid weight (mL/g). The optimisation of the ultrasound-assisted extraction of Gac peel determined that 50^{o}C and 250 W were the optimal temperature and ultrasonic power for the extraction with the present sample size (0.5 gram of Gac peel with 40mL of solvent). The extraction at optimal conditions resulted in a significant higher antioxidant capacity yield (822 µM TE/100g DW), shorter extraction time (76 minutes) and a comparable carotenoid extraction yield (269 mg/100g DW) compared to the conventional extraction of Gac peel. The carotenoids recovered in oil from Gac peel were successfully encapsulated by a mixture of whey protein concentrate and gum arabic (7:3, w/w) as the wall material using a spray dryer. The encapsulated powder obtained from the emulsion containing 24.5% total solids with the ratio of 3:10 (w/w) of the carotenoid-rich oil to the wall material showed the highest retention of total carotenoid and antioxidant capacity. The optimal inlet temperature and feeding rate of the emulsion were 160^{o}C and 180mL/h, respectively. A 6-month storage study on the stability of carotenoids observed a significant higher

retention of total carotenoid in the encapsulated powder compared to that in the non-encapsulated oil containing carotenoids from Gac peel.

In conclusion, carotenoids and antioxidant capacity from Gac peel can be recovered successfully from Gac peel. The encapsulated carotenoids from Gac peel could be preserved for long storage and may be used for the carotenoid fortification of foods, cosmetic and medicines. Thus, Gac peel is suggested to be used as a natural source of carotenoids instead of being regarded as a waste from Gac processing.