

**Structural studies of the fruit
exudate arabinogalactans and
pectin in mango (*Mangifera indica* L.)
peel and technological options for
their recovery**

Andreas Nagel



**Universität Hohenheim
Institut für Lebensmittelwissenschaft
und Biotechnologie**

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Structural studies of the fruit exudate arabinogalactans and pectin in mango (*Mangifera indica* L.) peel and technological options for their recovery

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PRELIMINARY REMARKS

The work presented in this thesis is a collection of papers published in international peer reviewed journals, which are listed below. Equivalent first authors are marked with ⁽¹⁾.

Full papers

1. NAGEL, A.; NEIDHART, S.; ANDERS, T.; ELSTNER, P.; KORHUMMEL, S.; SULZER, T.; WULFKÜHLER, S.; WINKLER, C.; QADRI, S.; RENTSCHLER, C.; PHOLPIPATTANAPONG, N.; WUTHISOMBOON, J.; ENDRESS, H.-U.; SRUAMSIRI, P.; CARLE, R. (2014). Improved processes for the conversion of mango peel into storable starting material for the recovery of functional co-products. *Industrial Crops and Products*, 61, 92–105.
2. NAGEL, A.¹; NEIDHART, S.¹; KUEBLER (NÉE WULFKUEHLER), S.; ELSTNER, P.; ANDERS, T.; KORHUMMEL, S.; SULZER, T.; KIENZLE, S.; WINKLER, C.; QADRI, S.; RENTSCHLER, C.; PHOLPIPATTANAPONG, N.; WUTHISOMBOON, J.; ENDRESS, H.-U.; SRUAMSIRI, P.; CARLE, R. (2017). Applicability of fruit blanching and intermittent microwave-convective belt drying to industrial peel waste of different mango cultivars for the recovery of functional coproducts. *Industrial Crops and Products*, 109, 923–935.
3. NAGEL, A.; SIRISAKULWAT, S.; CARLE, R.; NEIDHART, S. (2014). An acetate-hydroxide gradient for the quantitation of the neutral sugar and uronic acid profile of pectins by HPAEC-PAD without postcolumn pH adjustment. *Journal of Agricultural and Food Chemistry*, 62, 2037–2048.
4. NAGEL, A.; MIX, K.; KUEBLER (NÉE WULFKUEHLER), S.; BOGNER, H.; KIENZLE, S.; ELSTNER, P.; CARLE, R.; NEIDHART, S. (2015). The arabinogalactan of dried mango exudate and its co-extraction during pectin recovery from mango peel. *Food Hydrocolloids*, 46, 134–143.
5. NAGEL, A.¹; CONRAD, J.¹; LEITENBERGER, M.; CARLE, R.; NEIDHART, S. (2016). Structural studies of the arabinogalactans in *Mangifera indica* L. fruit exudate. *Food Hydrocolloids*, 61, 555–566.
6. NAGEL, A.; WINKLER, C.; CARLE, R.; ENDRESS, H.-U.; RENTSCHLER, C.; NEIDHART, S. (2017). Processes involving selective precipitation for the recovery of purified pectins from mango peel. *Carbohydrate Polymers*, 174, 1144–1155.

Further scientific contributions to journals, books or conferences beyond the scope of this thesis:

Full papers

1. SIRISAKULWAT, S.; NAGEL, A.; SRUAMSIRI, P.; CARLE, R.; NEIDHART, S. (2008). Yield and quality of pectins extractable from the peels of Thai mango cultivars depending on fruit ripeness. *Journal of Agricultural and Food Chemistry*, 56, 10727–10738.
2. BUCHWEITZ, M.; NAGEL, A.; CARLE, R.; KAMMERER, D. R. (2012). Characterisation of sugar beet pectin fractions providing enhanced stability of anthocyanin-based natural blue food colourants. *Food Chemistry*, 132, 1971–1979.
3. GEERKENS, C. H.; NAGEL, A.; JUST, K. M.; MILLER-ROSTEK, P.; KAMMERER, D. R.; SCHWEIGGERT, R. M.; CARLE, R. (2015). Mango pectin quality as influenced by cultivar, ripeness, peel particle size, blanching, drying, and irradiation. *Food Hydrocolloids*, 51, 241–251.

Book chapters

1. NEIDHART, S.; SIRISAKULWAT, S.; NAGEL, A.; SRUAMSIRI, P.; CARLE, R. (2009). Which mango processing residues are suitable for pectin recovery in terms of yield, molecular and techno-functional properties of extractable pectins? In H. A. Schols, R. G. F. Visser, & A. G. J. Voragen (Eds.), *Pectins and pectinases* (pp. 177–195). Wageningen: Wageningen Academic Publishers.

Oral communications

1. NAGEL, A.; ANDERS, T.; ELSTNER, P.; RENTSCHLER, C.; SULZER, T.; WULFKÜHLER, S.; KORHUMMEL, S.; PHOLPIPATTANAPONG, N.; WUTHISOMBOON, J.; QADRI, S.; ENDRESS, H.-U.; SRUAMSIRI, P.; CARLE, R.; NEIDHART, S. (2012). Options for integrated tropical fruit processing by recovery of food ingredients from residual mango peels. *International Scientific Conference 'Sustainable Land Use and Rural Development in Mountain Areas'*, 16–18 April 2012, Stuttgart-Hohenheim, Germany. *Book of Abstracts*, 235–236.

Poster presentation

1. CARLE, R.; NEIDHART, S.; SRUAMSIRI, P.; PHOLPIPATTANAPONG, N.; WUTHISOMBOON, J.; ENDRESS, H.-U.; RENTSCHLER, C.; NAGEL, A.; SIRISAKULWAT, S. (2009) T3 - Integrated tropical fruit processing by recovery of food ingredients from processing residues, particularly from mango peels. Application - Phase IV. *Gutachtersitzung der Deutschen Forschungsgemeinschaft (DFG) zum Sonderforschungsbereich 564 'Nachhaltige Landnutzung und ländliche Regionalentwicklung in Bergregionen Südostasiens'*, 26.–27. März 2009, Stuttgart-Hohenheim.

Co-authors' contributions to the papers presented in CHAPTERS 1–6 are specified as follows:

The work presented in this thesis was carried out under the supervision of Prof. Dr. habil. Dr. h.c. **Reinhold Carle** at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University. As the principal investigator of the SFB 564 transfer project T3, he substantially contributed to the conception of this work and the proposal. Prof. Carle gave valuable advice and proof-read all manuscripts before publication.

Dr. **Sybille Neidhart** at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University, was the instructor of this work. As the other principal investigator and the coordinator of the SFB 564 transfer project T3, Dr. Neidhart substantially contributed to the conception and the proposal of this project. She functioned as an advisor with regard to the content of this work and the publication of the results. Dr. Neidhart proof-read all manuscripts, and, as corresponding author, she was responsible for all formal aspects of the full papers displayed in CHAPTERS 1–6. As one of the two equivalent first authors of the full paper displayed in CHAPTER 2, she was primarily responsible for the part concerning microwave-convective belt drying. Furthermore, she was concerned with the analysis of the 1D NMR spectra presented in CHAPTER 5 and their comparison with literature data for the two arabinogalactan comparison samples.

As part of her diploma thesis at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University, Dr. **Sabine Kübler (née Wulfkühler)** contributed to the processing of mango peel in season 2010 at the site of the Thai industrial partner of SFB 564 transfer project T3 (Princess Foods Co., Ltd.) under guidance of the author of the present thesis. In the same context, she also performed pectin extraction from

peel, which had been dehydrated by intermittent microwave-convective belt drying, at the site of the German industrial partner of this project (Herbstreith & Fox KG) and carried out parts of the analytical work at Chiang Mai University and Hohenheim University as regards enzyme deactivation, specification of peel- and pectin therein (CHAPTERS 1–2), and quantification of methanol and acetate contents (CHAPTER 4).

As part of his diploma thesis at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University, Mr. **Tim Anders** contributed to the processing of mango peel in season 2011 at the site of the Thai industrial partner under guidance of the author of the present thesis. In the same context, he contributed to the different analyses of fresh and dried mango peel at Princess Foods Co., Ltd., Chiang Mai University, and Hohenheim University concerning the effects of the prototype processes (CHAPTER 1), the impact of fruit blanching on the skin color, and the characterization of fresh mango peel waste and peel dehydrated by direct convective drying (CHAPTER 2).

Representing the Thai industrial partner, Ms. **Niramol Pholpipattanapong** substantially contributed to the conception and implementation of the SFB 564 transfer project T3 and to the coordination of the project activities at Princess Foods Co., Ltd. She made the processing of fresh mango peel on the pilot plant scale possible and provided access to the analytical laboratory at Princess Foods Co., Ltd. Furthermore, she provided valuable advice on the storage and fruit blanching experiments and contributed to proof-reading of the manuscripts (CHAPTERS 1–2).

As contribution of the Thai industrial partner to the feasibility studies in SFB 564 transfer project T3, Mr. **Jumnong Wuthisomboon** supervised the construction and implementation of the laboratory and pilot plant for mango peel processing near to the peel waste outlet at Princess Foods Co., Ltd., Chiang Mai in season 2010 (CHAPTER 1) and 2011 (CHAPTER 2). He contributed to the conception and implementation of this transfer project and to proof-reading of the manuscripts (CHAPTERS 1–2).

As contribution of the Thai industrial partner to the feasibility studies in SFB 564 transfer project T3, Ms. **Saiko Qadri** coordinated the project activities at Princess Foods Co., Ltd., provided access to fresh mango fruits for the blanching studies (CHAPTER 2), and synchronized industrial mango fruit processing and the respective byproduct streams with the mango peel processing on the pilot plant scale in the seasons 2010 (CHAPTER 1) and 2011 (CHAPTER 2). She contributed to

the conception and implementation of the SFB 564 transfer project T3 and to proof-reading of the manuscripts (CHAPTERS 1–2).

As the Thai project partner, Assoc. Prof. Dr. **Pittaya Srumsiri**, Department of Crop Science and Natural Resources, Chiang Mai University, substantially contributed to the conception and implementation of the SFB 564 transfer project T3. He provided valuable advice on the conception of the feasibility studies, supervised the analytical work carried out at Chiang Mai University, and contributed to proof-reading of the manuscripts (CHAPTERS 1–2).

As contribution of the German industrial partner to the feasibility studies in SFB 564 transfer project T3, Ms. **Tanja Sulzer** performed analyses of the dried mango peel (as regards the contents of sugars and dietary fiber) and the pectin derived thereof at Herbstreith & Fox KG, Germany (CHAPTERS 1 and 2).

In the scope of the feasibility studies of the SFB transfer project T3, Ms. **Sabine Rieger (née Korhummel)** carried out the β -carotene analyses and determined the antioxidant capacity of dried mango peel at the Hohenheim University (CHAPTERS 1–2).

In the scope of the feasibility studies of the SFB transfer project T3, Mr. **Peter Elstner** contributed to mango peel processing, performed investigations on fresh and dried mango peel at Princess Foods Co., Ltd. and at Chiang Mai University, and provided organizational support in the seasons 2010 and 2011 and throughout the storage experiment (CHAPTERS 1–2). Furthermore, he contributed to the characterization of the wet mango exudate at Chiang Mai University (CHAPTER 4).

Representing the German industrial partner, Prof. Dr. **Hans-Ulrich Endress**, Herbstreith & Fox KG, Neuenbürg, Germany, substantially contributed to the conception and implementation of the SFB 564 transfer project T3 and provided valuable advice on the experimental design of the feasibility studies concerning peel processing and pectin recovery. He supervised the experiments performed at Herbstreith & Fox KG and contributed to data interpretation and proof-reading of the manuscripts (CHAPTERS 1, 2 and 6).

As contribution of the German industrial partner to the feasibility studies in SFB 564 transfer project T3, Ms. **Christine Rentschler** advised the experiments on the recovery of mango pectin and the analyses of peel and pectin at Herbstreith & Fox KG, Germany (CHAPTERS 1–2). Additionally, she substantially contributed to the experiments on enzymatic treatments of mango

pectin for the removal of starch (CHAPTER 6). She contributed to proof-reading of the manuscripts (CHAPTERS 1, 2 and 6).

Ms. **Suparat Sirisakulwat** was involved in the pectin analyses described in CHAPTER 3, by determining the moisture and ash contents of the apple and citrus pectins and their degrees of acetylation and methylation at Hohenheim University. This also included the titrimetric quantitation of their uronic-acid contents.

Dr. **Stefanie Kienzle** was responsible for the determination of alk(en)ylresorcinols in mango fruit exudate (CHAPTER 4) and dried mango peel (CHAPTER 2) at Hohenheim University.

Mr. **Klaus Mix** assisted in the experiments concerning semi-preparative fractionation of mango pectin (CHAPTER 4) at Hohenheim University and in the development of this procedure.

Ms. **Hanna Bogner** determined the amino acid composition of pectins, mango exudate, and arabinogalactans (CHAPTER 4) in the scope of her bachelor thesis at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University.

Dr. **Jürgen Conrad** performed and interpreted the NMR spectroscopic experiments of the arabinogalactans at Hohenheim University. As one of the two equivalent first authors of the respective full paper, he substantially contributed to the discussion of the NMR spectroscopic results (CHAPTER 5).

Mr. **Martin Leitenberger** carried out the FTIR analyses of the arabinogalactans and contributed to the interpretation of the data obtained (CHAPTER 5).

As part of her diploma thesis at the Institute of Food Science and Biotechnology, Section Plant Foodstuff Technology and Analysis, Hohenheim University, Ms. **Carina Winkler** performed experiments on the extraction of pectins from peel, which resulted from the prototype processes (CHAPTER 1) and from convective air drying (CHAPTER 2), determined the galacturonic acid contents of these pectin samples at the site of the German industrial partner (Herbstreith & Fox KG) (CHAPTERS 1–2), and conducted experiments concerning the purification of mango pectin (CHAPTER 6) at Hohenheim University. In the same context, she was involved in the investigations into the composition and macromolecular characteristics of the pectins and polysaccharide fractions (CHAPTER 6).