

Scanning report (EIP format for practice abstracts)

***Project title (native language):** EUFRUIT: Europäisches Obst-Netzwerk

***Project title (English):** EUFRUIT: European Fruit Network

***Author/native language editor:** Dr. Angelo Zanella, Laimburg Research Centre, Laimburg 6, 39040 Post Auer, BZ-Italia, Angelo.Zanella@laimburg.it, +390471969540

Section A. Summary for EIP dissemination

***Keywords:** Thematic Network, Fruit Sector, EUFRUIT, Non-destructive technologies, fruit quality, post-harvest, multidisciplinary approaches

***Main geographical location:** ITH10 Bolzano-Bozen

Other geographical locations: ITH10 Bolzano-Bozen

***Summary (native language):**

Die Autonome Provinz Bozen (Südtirol) finanzierte das multidisziplinäre Forschungsprojekt "MONALISA- Monitoring key environmental parameters in the Alpine Environment involving science, technology and application (Monitoring der wichtigsten Umweltparameter in der alpinen Umwelt durch Wissenschaft, Technologie und Anwendungen)". In diesem Projekt arbeiteten verschiedene Forschungseinrichtungen zusammen an der Entwicklung eines Verfahrens für die Überwachung der wichtigsten Umweltparameter auf regionaler Ebene, sowie auf Ebene der Apfelanlage und der Pflanze selbst. Weiters verfolgte das Projekt das Ziel, die Produktionsprozesse zu beobachten und die Umsetzbarkeit nicht-destruktiver Methoden für die Messung der Fruchtqualität zu evaluieren.

Um die Verluste in der Nach-Ernte-Phase zu verringern arbeitete das Versuchszentrum Laimburg an nicht-destruktiven Technologien um die Qualität, die Reife, sowie die Lagerungsfähigkeit des Apfels einzuschätzen. In diesem Zusammenhang kollaborierten die Experten der Laimburg mit führenden Instituten Europas.

Die untersuchten neuen Technologien zeigten vielversprechende Resultate für verschiedene Qualitätskriterien. Die Technologien sind jedoch nicht bestens dafür geeignet, die Magness-Taylor Festigkeit einzuschätzen. Dieses Defizit zeigt, dass zukünftig Bestrebungen dahingehend gemacht werden sollten, nicht-destruktiv erhaltene Daten mit sensorischen Parametern zu verbinden. Die Resultate haben ein Potential das Vor- und Nacherntemanagement der Apfelqualität zu verbessern, da neues Wissen um die Umweltfaktoren generiert wird, die Entscheidung über den optimalen Erntezeitpunkt erleichtert wird, durch die Vorhersage des Reifeverhaltens während der Lagerung und des shelf-lifes, sowie durch das Ermöglichen der Bewertung von Obst nach der inneren Qualität und der Anfälligkeit für Unregelmäßigkeiten.

Weitere Forschung in dieser Hinsicht, in Zusammenarbeit mit Forschungsinstituten, ist erforderlich um die vielversprechenden Technologien für nicht-destruktive Messungen der Frucht zu verbessern und weiterzuentwickeln.

Summary (english):

The Autonomous Province of Bolzano (South-Tyrol) funded the multidisciplinary research project "MONALISA – Monitoring key environmental parameters in the Alpine Environment involving science, technology and application" in which different research organizations collaborated to develop multi-scale approaches for monitoring key environmental parameters at regional, orchard and plant level. Another aim of the project was monitoring the production processes and evaluating the feasibility of non-destructive assessments of fruit quality.

In order to reduce losses in the post-harvest phase, Laimburg Research Centre worked on non-destructive techniques to assess the quality, maturity and storability of the apple fruit. In this context, the experts of Laimburg collaborated with leading institutes throughout Europe.

The investigated novel techniques showed promising results if various quality criteria are concerned, but are not the most suitable for assessing Magness-Taylor firmness (MT FFF). Given the many shortcomings of the MT FFF evaluations, efforts towards relating the non-destructively obtained indices with sensory parameters should be made. The results have a potential for further improving pre- and post-harvest management of apple fruit quality by adding knowledge regarding environmental factors, by simplifying the decisions on the time of optimal harvest, by predicting the ripening behavior during storage and shelf-life, and by enabling grading of fruit based on their internal quality and their susceptibility to disorders.

Further research in this direction and collaboration with research institutes is needed in order to improve and develop the most promising technologies for non-destructive measurements of fruits.

Section B. Project information

***Project coordinator:** Michelle H. Williams; Aarhus University, Department of Food, Kirstinebjergvej 10, 5792 Aarslev, Denmark; mw@food.au.dk; +45 25170049

***Project period:** 2016 - 2019

***Project status:** Ongoing

***Funded by:** Horizon 2020

***Total budget:** €1.8m

***Geographical regions:** DK011 Copenhagen, DK012 Copenhagen and its environs, DK013 North Zealand, DK014 Bornholm, DK021 East Zealand, DK022 West- and South Zealand, DK031 Funen, DK032 South Jutland, DK041 West Jutland, DK042 East Jutland, DK050 North Jutland, BE211 (Arrondissement. Antwerpen), BE212 (Mechelen), BE213 (Turnhout), BE221 (Hasselt), BE222 (Arr. Maaseik), BE223 (Tongeren), BE231 (Aalst), BE232 (Dendermonde), BE233 (Eeklo), BE234 (Gent), BE235 (Oudenaarde), BE236 (Sint-Niklaas), BE241 (Halle-Vilvoorde), BE242 (Leuven), BE251 (Brugge), BE253 (Ieper), BE254 (Kortrijk), BE255 (Arr. Oostende), BE256 (Arr. Roeselare), BE257 (Tielt), BE258 (Veurne), BE310 (Nivelles-Nijvel), BE331 (Huy-Hoei), BE332 (Liège- Luik), BE334 (Waremmе-Borgworm), BE335 (Verviers), FR8 Méditerranée; FR81 Languedoc-Roussillon, FR6 SUD-OUEST, FR512 Maine et Loire, FR611 Dordogne, FR812 Gard, DE6 (Hamburg), DE8 (Mecklenburg-Vorpommern), DE9 (Niedersachsen), DEF0 (Schleswig-Holstein), DEE0 (Sachsen-Anhalt), DEA (Nordrhein-Westfalen), DE111, DE112, DE113, DE114, DE115, DE116, DE117, DE118, DE119, E11A, DE11B, DE11C, DE11D, DE121, DE122, DE123, DE124, DE125, DE126, DE127, DE 128, DE129, DE12A, DE12B, DE12C, DE131, DE132, DE133, DE134, DE135, DE136, DE137, DE138, DE139, DE13A, DE141, DE142, DE143, DE144, DE145, DE146, DE147, DE148, DE149, DE600 Hamburg, DE932 Cuxhaven, DE933 Harburg, DE939 Stade, DEF09 Pinneberg, NL1-NL4 + NLZ Holland; NL 224 zuidwest Gelderland, NL 226 Arnhem/Nijmegen, NL230 Flevoland, NL310 Utrecht, NL321 Kop van Noord-Holland, NI322 Alkmaar en omgeving, NL338 oost Zuid-Holland, NL33A zuidoost Zuid-Holland, NL341 Zeeuws-Vlaanderen, NL342 overig Zeeland, NI411 west Noord-Brabant, NL413 noordoost Noord-Brabant, NL414 zuidoost Noord-Brabant, NL421 noord Limburg, NL422 Midden-Limburg, NL423 zuid Limburg, ES620 Murcia, UKG11 Herefordshire, UKG12, Worcestershire, UKH12 Cambridgeshire, UKH16 North and West Norfolk, UKH17 Breckland and South Norfolk, UKJ22 East Sussex, UKJ35 South Hampshire, UKJ36 Central Hampshire, UKJ37 North Hampshire, UKJ41 Medway, UKJ42 Kent, UKJ43 Kent Thames Gateway, UKJ44 East Kent, UKJ45 Mid Kent, UKJ46 West Kent, ES618 Sevilla, ES511 Barcelona, ES512 Gerona, ES513 Lérida, ES514 Tarragona, CH0 Schweiz/Suisse/Svizzera, ITH51-59 Emilia Romagna region, ITH10 Bolzano-Bozen, HU101 Budapest, HU102 Pest, RO111, RO112, RO113, RO114, RO115, RO121, RO122, RO123, RO124, RO125, RO126, RO211, RO212, RO213, RO214, RO215, RO216, RO221, RO222, RO223, RO224, RO225, RO226, RO311, RO312, RO313, RO314, RO315, RO316, RO317, RO321, RO322 RO411, RO412, RO413, RO414, RO415, RO421, RO422, RO423, RO424. HU101, HU102, LT001 Alytaus apskritis, LT002 Kauno apskritis, LT003 Klaipėdos apskritis, LT004 Marijampolės apskritis, LT005 Panevėžio apskritis, LT006 Šiaulių apskritis, LT007 Tauragės apskritis, LT008 Telšių apskritis, LT009 Utenos apskritis, LT00A Vilniaus apskritis.

Project web page: <http://www.eufrin.org/index.php?id=55>

***Project Objectives (native language):**

1. Errichtung eines europäischen Netzwerkes, welches sich auf den Obstsektor konzentriert
2. Entwicklung und Umsetzung einer systematischen Vorgehensweise zum Festhalten und Synthetisieren des bestehenden wissenschaftlichen und praktischen Wissens

3. Schaffen eines kontinuierlichen/anhaltenden Dialogs mit relevanten EU, nationalen, sowie regionalen politischen Körperschaften
4. Identifikation und Unterstützung von neuen prioritären Forschungsgebieten durch das kontinuierliche Monitoring und Analysieren von bestehender und aufkommender Forschung und Innovationsaktivitäten.

Project Objectives (English):

1. Establish a European network focused on the fruit sector.
2. Develop and implement a systematic approach for scanning and synthesizing existing scientific and practical knowledge.
3. Establish an ongoing dialogue with relevant EU, national and regional policy bodies.
4. Identify and support new priority areas of research by continually monitoring and analysing existing and upcoming research and innovation activities.

***Project partners:**

1. Aarhus University, Department of Food Science (Denmark) • AU
2. Research Station for Fruit npo (Belgium) • Pcfuit
3. Centre Technique Interprofessionnel des Fruits et Légumes (France) • CTIFL
4. Obstbauversuchsanstalt Jork (Germany) • OVA
5. Stichting Wageningen Research (Netherlands) • WR
6. ~~East Malling Research (United Kingdom) • EMR (terminated 08-02-2016)~~
7. Institut de Recerca i Tecnologia Agroalimentàries (Spain) • IRTA
8. Federal Department of Economic Affairs, Education and Research (EAER), acting through Agroscope Institute of Plant Sciences (Switzerland) • Agroscope
9. Laimburg Research Centre for Agriculture and Forestry (Italy) • Laimburg
10. University of Agronomic Sciences and Veterinary Medicine of Bucharest (Romania) • USAMV
11. National Agricultural Research and Innovation Centre Fruitculture Research Institute (Hungary) • NARIC
12. Lithuanian Research Centre for Agriculture and Forestry (Lithuania) • LRCAF
13. Assemblée des Régions Européennes Fruitières, Légumières et Horticoles (France) • AREFHL
14. Variety Innovation Consortium South Tyrol (Italy) • SKST
15. Freshfel Europe (Belgium) • FRESHFEL
16. Elbe-Obst Erzeugerorganisation r.V. (Germany) • EO
17. Fruitconsult BV (Netherlands) • FC
18. University of Greenwich (United Kingdom) • UoG
19. University of Hohenheim (Germany) • UHOH
20. Università di Bologna (Italy) • UNIBO
21. Institut National de la Recherche Agronomique (France) • INRA
22. NIAB EMR (new 09-02-2016)

Section C. Annex: Scanning report¹

Scanning report Angelo Zanella, Laimburg

Author: Dr. Angelo Zanella, Laimburg Research Centre, Angelo.Zanella@laimburg.it, +390471969540
Country: Italy
NUTS 3 region(s)²: ITH10 Bolzano-Bozen
WP no. and title: WP4, Improvement of fruit storage methods
Date: 03.04.2017

Source materials and methodology

Source materials for the best practice findings described in this report are the newest findings from the Research Centre Laimburg generated and coordinated pillar of a multidisciplinary research project “MONALISA – Monitoring key environmental parameters in the Alpine Environment involving science, technology and application” (<http://www.monalisa-project.eu/en/home/Pages/default.aspx>), funded by the Autonomous Province of Bolzano (South-Tyrol). The outcomes of the project activities, aiming at evaluating the feasibility and practicability of novel non-destructive technologies for fruit quality assessment, served also as basis for generating a public report and the publications, listed under the respective Pillar on the project’s webpage. Below a selection of articles, written in English:

Liu T, M. Bassi, N. Sadar, G. Lubes, S. Agnolet, B. Stürz, W. Guerra, P. Robatscher, A. Zanella, M. Oberhuber	The Prediction of Ascorbic Acid in Apples Using Near-Infrared (NIR) Spectroscopy together with Partial Least Squares (PLS) Regression	Oral presentation at AHC2016: 2nd Asian Horticultural Congress; Chengdu, Sichuan, 26th to 28th September 2016, China
Liu T, M. Bassi, N. Sadar, G. Lubes, S. Agnolet, B. Stürz, W. Guerra, P. Robatscher, A. Zanella, M. Oberhuber	The Prediction of Ascorbic Acid in Apples Using Near-Infrared (NIR) Spectroscopy together with Partial Least Squares (PLS) Regression	Article ISHS Acta Horticulturae
Rizzolo A, M. Vanoli, G. Bianchi, A. Zanella, M. Grassi, A. Torricelli, L. Spinelli	Relationship between texture sensory profiles and optical properties measured by time-resolved reflectance spectroscopy during post storage shelf life of 'Braeburn' apples	Oral presentation: 3rd International Conference on "Effects of Pre- and Post-harvest Factors on Health Promoting Components and Quality of Horticultural Commodities", 2014, Skierniewice, Poland
Rizzolo A, M. Vanoli, G. Bianchi, A. Zanella, M. Grassi, A. Torricelli, L. Spinelli	Relationship between texture sensory profiles and optical properties measured by time-resolved reflectance spectroscopy during post storage shelf life of 'Braeburn' apples	Article Journal of Horticultural Research, vol. 22(1); 113-121
Rizzolo A, M. Vanoli, F. Lovati, M. Grassi, M. Buccheri, N. Sadar, A. Torricelli, A. Zanella, L. Spinelli	Uso della spettroscopia di riflettanza risolta nel tempo per distinguere mele con diversa struttura	Oral presentation: 7° Simposio Italiano di Spettroscopia NIR - NIRITALIA 2016, Milano, 12-14 Ottobre 2016, Italy
Sadar N, I. Ebner, O. Rossi, G. Agati, A. Zanella	Optical, acoustic and textural attributes in cv. Braeburn and cv. Nicoter (Kanzi®) apple resulting from different pre- and post harvest conditions	Poster: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues; Cartagena, 21th to 24th June 2016, Spain

¹ Equivalent to 'final report' in EIP-AGRI format.

² Please see ec.europa.eu/eurostat/ramon/nomenclatures/ for details on NUTS regions, level 3

[Angelo Zanella] – Scanning report / Practice abstract

Sadar N, I. Ebner, O. Rossi, G. Agati, A. Zanella	Optical, acoustic and textural attributes in cv. Braeburn and cv. Nicoter (Kanzi®) apple resulting from different pre- and post harvest conditions	Article ISHS Acta Horticulturae
Sadar N, A. Zanella,	Image analysis of starch pattern index as an objective parameter of apple fruit maturity stage	Poster: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues; Cartagena, 21th to 24th June 2016, Spain
Sadar N, A. Zanella,	Image analysis of starch pattern index as an objective parameter of apple fruit maturity stage	ISHS Acta Horticulturae
Tijskens L.M.M., R.E. Schouten, A. Zanella, N. Sadar	Apples from MONALISA: Biological variation of firmness behaviour in storage and shelf life	Oral presentation : VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues; Cartagena, 21th to 24th June 2016, Spain
Tijskens L.M.M., R.E. Schouten, A. Zanella, N. Sadar	Apples from MONALISA: Biological variation of firmness behaviour in storage and shelf life	ISHS Acta Horticulturae
Tijskens L.M.M. , R.E. Schouten, Jongbloed G., P.J. Konopacki	Techniques to assess biological variation in destructive data	ISHS Acta Horticulturae
Van Beers R, B. Aernouts, R. Watté, A. Schenk, B. Nicolai, W. Saeys	Evolution of Vis/NIR bulk optical properties of apple skin and flesh during fruit maturation	Oral presentation : 17th International Conference on Near Infrared Spectroscopy, Foz do Iguassu, 18th to 23rd October 2015, Brazil
M. van Dael, P. Verboven, L. Van Hoorebeke, J. Sijbers, B. Nicolai	Comparison of methods for online inspection of apple internal quality	7th Conference on Industrial Computed Tomography, Leuven, Belgium (iCT 2017)
Vanoli M, M. Grassi, M. Buccheri, F. Lovati, N. Sadar, A. Zanella, A. Torricelli, A. Rizzolo, L. Spinelli	Time-resolved reflectance spectroscopy reveals different texture characteristics in 'Braeburn', 'Gala' and 'Kanzi' apples	Oral presentation: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues; Cartagena, 21th to 24th June 2016, Spain
Vanoli M, M. Grassi, M. Buccheri, F. Lovati, N. Sadar, A. Zanella, A. Torricelli, A. Rizzolo, L. Spinelli	Time-resolved reflectance spectroscopy reveals different texture characteristics in 'Braeburn', 'Gala' and 'Kanzi' apples	Article ISHS Acta Horticulturae
Vanoli M, A. Rizzolo, M. Grassi, F. Lovati, M. Buccheri, A. Zanella, N. Sadar, A. Dalla Mora, E. Martinenghi, A. Torricelli, L. Spinelli	Studio della texture di mele 'Gala': relazioni tra grado di maturazione misurato con spettroscopia di riflettanza risolta nel tempo e proprietà meccaniche, acustiche e sensoriali	Poster: XI GIORNATE SCIENTIFICHE SOI 2016, Bolzano, 14th to 16th Settembre 2016, Italy
M. Vanoli, A. Rizzolo, M. Grassi, A.Zanella, A. Torricelli, L. Spinelli	Characterizing apple texture during storage through mechanical, sensory and optical properties	Poster: V International Conference Postharvest Unlimited, 2014, Lemesos, Cyprus
M. Vanoli, A. Rizzolo, M. Grassi, A.Zanella, A. Torricelli, L. Spinelli	Characterizing apple texture during storage through mechanical, sensory and optical properties	Article Acta Hort. 1079; 383- 390
Wang Z, D. Cantre, R. Van Beers, N. Nguyen, W. Saeys, P. Verboven, B. Nicolai	Micro-CT imaging of apple tissue microstructure during shelf life	Poster: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues; Cartagena, 21th to 24th June 2016, Spain
Zanella A, N. Sadar, G. Agati, P. Robatscher, W. Saeys, R.E. Schouten, L.Tijskens, L. Spinelli, P. Verboven, M. Oberhuber	MONALISA - A collaborative multi-sensor approach for non-destructive prediction of apple fruit quality	Oral presentation: XI GIORNATE SCIENTIFICHE SOI 2016, Bolzano, 14th to 16th Settembre 2016, Italy

[Angelo Zanella] – Scanning report / Practice abstract

Zanella A	Nondestructive Technologies in post harvest quality analysis	Oral presentation at: MONALISA - Environmental Sensing for agricultural application (Interpoma Side Event)
Zanella A, F Mazzetto, D Zanotelli	MONALISA on Apple - Monitoring key environmental parameters of the alpine environment: the apple quality in the focus of science and technology	Oral presentation: Interpoma 2016, International congress "The apple in the world", Bolzano, 24 th to 26 th November 2016, Italy
Zanella A, Sadar N	Zukunftsträchtige Ansätze zur Messung und Vorhersage der Apfel-Qualität ab Ernte bis zum Konsumenten, im südtiroler Projekt MONALISA	Oral presentation: Laimburger Lagerungstagung 09.08.2016, Pfatten, Italy
A. Zanella, S Stürz, A. Panarese, O. Rossi	The Potential of Alternative Methods for Determining the Optimum Harvest Date of Apple Fruit	Article Acta Hort. 1079; 373- 382.
van Dael, M.; Verboven, P.; Zanella A.; Sijbers J.; Nicolai, B.	Combination of shape and X-ray inspection for apple internal quality control: in silico analysis of the methodology based on X-ray computed tomography	Postharvest Biology and Technology (148); 218–227.
Zanella, Angelo; Sadar, Nadja; Stürz, Stefan; Panarese, Alessia	Analisi qualitativa non distruttiva dei frutti: realtà sempre più vicina	Rivista di frutticoltura e di ortofloricoltura 81 (11), 28–32.
M. Vanoli, F. Lovati, M. Grassi, M. Buccheri, A. Zanella, T.M.P. Cattaneo, A. Rizzolo	Water spectral pattern as a marker for studying apple sensory texture	Advances in Horticultural Science 32 (3); 343-351.
Zanella Angelo, Sadar Nadja	Apfel Qualität: Definition und Verlauf nach der Ernte auf dem Weg bis zum Konsumenten	Oral presentation: Obstbauseminar, 23.01.2018, Renon, Italy
A. Rizzolo, M. Vanoli, A. Torricelli, L. Spinelli, N. Sadar, A. Zanella	Modelling optical properties of Braeburn apples during fruit maturation on the tree	Oral presentation: VI International Symposium on Applications of Modelling as an Innovative Technology in the Horticultural Supply Chain - Model-IT 2019; 09-12.06.2019; Molfetta, Italy

Best practice findings

In the post-harvest supply chain, entire batches of apples are wasted due to the presence of internal disorders or inferior eating quality, even when only a minor part of the fruit within a batch is affected. This causes significant losses to the fruit industry and is spurring research towards the development of effective ways for the assessment and the prediction of apple fruit quality and storage potential. Aiming to increase the competitiveness of the region's apple production sector, the Autonomous Province of Bolzano (South-Tyrol) funded the multidisciplinary research project "MONALISA – Monitoring key environmental parameters in the Alpine Environment involving science, technology and application" in which different research organizations (EURAC, Free University Bolzano, Laimburg, IDM) collaborated to develop multi-scale approaches for monitoring key environmental parameters at regional, orchard and plant level. Another aim of the project was monitoring the production processes and evaluating the feasibility of non-destructive assessment of fruit quality. Given its complex and multifaceted nature, the project was divided into seven Pillars (www.monalisa-project.eu). Moreover, the fruit industry was involved in the project from the start.

The main focus of the Pillar (no. 4), coordinated by Laimburg, was to test, improve and assess the practicability of various innovative techniques for quick and non-invasive assessment of fruit quality, and to develop models for predicting maturity and storability of apple fruit. To this aim, but from different perspectives, six groups from different European institutes (Laimburg, WUR-HPC, BIOSYST-MeBioS, CNR-IFN) collaborated, applying a multidisciplinary approach combining: i) optimizing non-destructive methods for assessing fruit quality and physiological disorders ii) identifying the role of environmental, pre- and post-harvest factors on fruit quality development and iii) applying process-oriented kinetic modeling.

Apple cultivars from different altitudes and European production regions (Italy, Belgium), as well as from different agronomic and storage conditions, were analyzed by the selected cutting-edge technologies.

Fruit maturity and texture were modeled by non-invasive sensors based on VIS interactance, chlorophyll fluorescence, acoustic impact response, and by semi-non-invasive, limited distance compression. The results revealed a high intra- and inter-batch variability of fruit, as well as a pronounced effect of cultivar, growing season, environment, cultivation practices, and post-harvest conditions on temporal development of the measured indices after harvest. After applying probelation and quantile regression, and assuming a logistic behavior, process-oriented kinetic models linking the biological shift factor of non-destructive measurements with destructively assessed texture, for predicting texture evolution after harvest, were successfully calibrated and validated. In another approach, spatially-resolved and time-resolved NIR spectroscopy, which provide information on both absorption and scattering properties, helped to understand the complex relationship between optically measured reflectance spectra and apple texture. Clear differences between genotypes, and production regions, including altitudes in the same region, were revealed. For evaluating the potential of non-destructive assessment of internal disorders by X-ray technology, different settings for 2D X-ray and 3D X-ray computer tomography (CT) were tested. While simple radiography revealed limited success, 3D X-ray settings, combined with appropriate image analysis protocols, enabled spatio-temporal monitoring of internal defects development in intact fruit. The last approach dealt with alternative ways of predicting fruit quality: the feasibility and potential of NIR spectroscopy for non-destructive assessment of nutraceutical and bio-active compounds in apple peel. From NIRS data, prediction models for nutraceutical compounds L-ascorbic acid, total polyphenol content, total antioxidant capacity and for bio-active precursors of superficial scald, were successfully developed.

The investigated novel techniques showed promising results with respect to various quality criteria, but are not the most suitable for assessing Magness-Taylor firmness (MT FFF). Given the many shortcomings of the MT FFF evaluations, efforts towards relating the non-destructively obtained indices with sensory parameters should be made. The results, briefly described above, have a potential for further improving pre- and post-harvest management of apple fruit quality by adding knowledge regarding environmental factors, by simplifying the decisions on the time of optimal harvest, by predicting the ripening behavior during storage and shelf-life, and by enabling grading of fruit based on their internal quality and their susceptibility to disorders.

Further research in this direction and collaboration with research institutes is needed in order to improve and develop the most promising technologies for non-destructive quality measurements of fruits.