# Automatic classification of peaches and nectarines according to ripeness using NIR non-destructive technology

## Summary

This Operational Group (OG) focused on the area of fruit cultivation when carrying out the project entitled "Automatic classification of peaches and nectarines according to ripeness using non-destructive NIR technology". This OG consists of BARÓ E HIJOS SL, FRUITS DE PONENT SCCL and the INSTITUTE OF AGRIFOOD RESEARCH AND TECHNOLOGY, working with MAF RODA. The aim of this OG is to obtain a tool for use in classifying fruits according to ripeness. This classification is performed using an online NIR system designed by MAF RODA. The performance of NIR models was evaluated for various instrumental parameters (firmness, sugars, acidity and chlorophyll) according to different types of sampling (species, type of fruit, variety) and the parameters with the most potential for the classification of peaches on the industrial scale. Finally, the system was put into operation at BARÓ E HIJOS and FRUITS DE PONENT.

## Objectives

The overall objective of the project was to classify peaches in line in a non-destructive way using NIR technology, in order to obtain different categories according to their ripeness in order to obtain a tool to decide on the fruit's destination (the riper fruits will go to nearby markets, and the less ripe fruits go to markets further away).

## Description of the actions carried out in the project

In the first year of the project (2019), the performance of an NIR reflectance system was evaluated to measure various instrumental peach quality parameters (firmness, soluble solids content, titratable acidity and chlorophyll content) in order to identify the parameters with the most potential to become candidates for use on an industrial scale. The NIR measurements and baseline analyses were performed at the IRTA Fruitcentre (Lleida).

An NIR transmission system was installed in the pricing line at the Fruits de Ponent plant in the second year of the project (2020). This system's performance in terms of measuring the instrumental parameters identified in the previous phase (firmness, soluble solids content, and chlorophyll content) was measured under real conditions.

In the third year of the project (2021), the same NIR transmission system as at Fruits de Ponent was installed in one of the fruit classification lines at the Baró e Hijos plant. The implementation of a procedure to create calibration and validation models to measure the chlorophyll index and Brix degrees using the NIR system installed at the plant was validated under real conditions.

## Final results and practical recommendations

Final results

**NIR transmission spectroscopy was found to be more efficient than NIR reflectance spectroscopy in measuring fruit quality parameters**. In transmission, light interacts passing through the entire fruit, which provides more accurate results of the state of the fruit as a whole. However, light interacts with a point on the surface of the fruit in reflectance measurements.

Among the instrumental quality and maturation parameters analysed (firmness, Brix degrees, acidity, chlorophyll index), the **chlorophyll index and Brix degrees were those that presented the most robust NIR calibration models for industrial use**. Measuring these two parameters provides information from two perspectives: the chlorophyll index shows the level of ripeness of the fruit, and the Brix degrees show its organoleptic quality.

The performance of the NIR calibration models varied depending on their specificity. In general, global models presented lower yields than local or specific models. However, **the chlorophyll index was less sensitive to the type of sampling than the Brix degrees**. For chlorophyll, it would be feasible to use global models for different types of fruit. In the case of Brix degrees, specific models at the level of variety and seasonality must be developed.

Chlorophyll index values enable separation into two categories: 'ripe' and 'unripe' fruits. The interpretation of the results and the tolerance thresholds may vary slightly depending on the variety or type of fruit. In general, for the same ripeness category, **round peach fruits had higher chlorophyll values than nectarines and flat peach fruits**.

In short, the **chlorophyll absorption index is the best candidate for determining the ripeness of peaches in line in a non-destructive way**. It has significant advantages (non-destructive, quick, easy measurement, correlation with the global perception of ripeness) compared to other traditional parameters such as firmness, which facilitates its implementation on an industrial scale. The adoption of this parameter by the entire chain of production has several advantages and would make its implementation in the classification lines more flexible. However, further efforts are required to obtain tolerance thresholds due to high genetic variability.

Practical recommendations

Before NIR spectroscopy can be used on an industrial scale, **robust calibration models must be developed** to ensure that the prediction results are accurate.

**Several factors may influence the robustness of the models**, i.e. the accuracy and reproducibility of the reference methods, such as the sampling method used to collect representative samples (by species, type of fruit and variety), the provenance, the size of the fruit, the pre-processing methods of the spectra and the quantitative and qualitative modelling methods.

Figure 1 shows a **general procedure for the development and validation of an NIR calibration model**. This procedure, which has been implemented by other agrifood industries in which the use of in line NIR technology is more prevalent (milk, yoghurt, cheese, fodder, etc.), **also needs to be systematically implemented at fruit plants to ensure reliable results**.

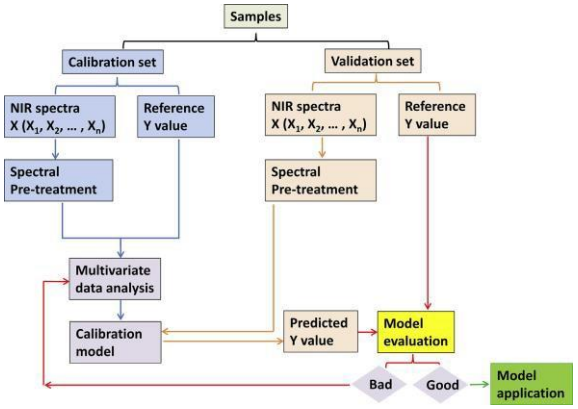


Figure 1. Development and validation of NIR calibration models [Pu, Y. Y., O'Donnell, C., Tobin, J. T., & O'Shea, N. (2020). "Review of near-infrared spectroscopy as a process analytical technology for real-time product monitoring in dairy processing". *International Dairy Journal*, 103, 104623].

**Global or local/specific models can be developed**, according to the data used in the development of the calibration. **A robust global model must be resistant to seasonal, geographical and genetic variations**. The peach is a fruit with a high degree of genetic heterogeneity. In addition, its local and seasonal variability due to different years and origins must be taken into account.

**A production plant must use historical spectroscopic data gathered over several years to obtain a robust global model**. This involves a great deal of effort during the initial years of implementation of this technology (3-5 years), entailing the collection of spectra and instrumental measurements before sufficiently robust global models can be built. Local/seasonal/specific models must be used in the meantime.

**After a calibration model has been developed, it must be validated, and it must updated periodically in global models to ensure the accuracy of the prediction of the model.** Samples from the calibration specimens are used to develop the calibration model, and then an external sample set must be used to evaluate and validate the performance of the model. According to standards for other agrifood industries (ISO 21543: 2020 [IDF 201: 2020] - Milk and milk products), **at least 120 calibration samples are required to build a robust model, and 25 samples which are independent from the calibration samples are required for validation**. In our experience, this number of samples would be sufficient to construct specific models for Brix degrees and the chlorophyll index.

Unfortunately, **a model developed in one NIR instrument cannot be used directly in another similar NIR instrument** due to variations in the instrument's components and in the detection environment. This assumption applies to any NIR application, and means that the models generated for one NIR computer cannot be used by other similar devices, whether they are installed in other plants or in the same plant. In these cases, **a spectrometry expert is required to apply calibration standardisation and transfer techniques, in order to ensure that the models can be transferred for more widespread application**.

The production plants must remember that it is **essential to identify the variables that may affect the spectra**, and that these variables must be taken into account when developing a calibration model. For example, the temperature of the samples and the operating environment may influence the repeatability of the collected spectral signals, leading to a reduction in the prediction accuracy of the calibration model.

**NIR equipment deployed in line must be able to withstand harsh operating conditions, involving high temperatures, high levels of humidity and vibrations in the process**. The NIR spectrometer must be protected to prevent this from happening. The installation of NIR probes or sensors must not affect the processing line (e.g. it must not introduce external contaminants, or disturb the flow of the process). The probes and sensors must meet an appropriate standard of hygiene to ensure a high level of food safety.

**The result from the NIR analysis must be able to be integrated into a control, monitoring and data acquisition system in order to monitor and achieve continuous control and optimisation of the process**. As a result, the cost of integration and communication between the NIR system and the quality control system for real-time industrial applications should also be considered when implementing in line NIR systems in production plants.

## Conclusions

**The in line classification of peaches according to their state of ripeness with NIR systems is achieved by measuring the chlorophyll index**. Fruits with higher values generally tend to deteriorate more quickly, and therefore have a lower conservation potential. Their interpretation or tolerance thresholds may vary depending on the type of fruit and/or the variety. **Calibration models**

**NIR for measuring the chlorophyll index are usually more robust than the models of other instrumental parameters**, such as Brix degrees or firmness. The chlorophyll index also has other advantages that facilitate its implementation in the quality processes of plants. However, as with any other application of in line NIR technology, **the implementation of systematic procedures for the development and validation of calibration models is required to ensure reliable results**.

## Leader of the Operational Group

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## Subject area(s) of application

| | |
|---|---|
| ☒ | Agricultural production system |
| ☐ | Agricultural practice |
| ☐ | Agricultural equipment and machinery |
| ☐ | Livestock farming and animal welfare |
| ☐ | Vegetable production and horticulture |
| ☐ | Landscape / Territorial management |
| ☐ | Pest and disease control |
| ☐ | Fertilisation and nutrient management |
| ☐ | Soil management |
| ☐ | Genetic resources |
| ☐ | Forestry |
| ☐ | Water management |
| ☐ | Climate and Climate Change |
| ☐ | Energy management |
| ☐ | Waste and by-product management |
| ☐ | Biodiversity and environmental management |
| ☒ | Food quality/processing and nutrition |
| ☒ | Supply chain, marketing and consumption |
| ☒ | Competitiveness and agricultural and forestry diversification |
| ☐ | General |

## Geographical area(s) of application

**PROVINCE(S):** Lleida

**REGION(S):** El Segrià

## Dissemination of the project: publications, seminars, multimedia, etc.

https://www.innovagri.es/actualidad/perfeccionan-la-clasificacion-comercial-de-los-melocotones-con-tecnologia-nir.html

https://www.freshplaza.es/article/9239163/como-conocer-el-punto-de-maduracion-idoneo-del-melocoton-utilizando-la-tecnologia-nir/

https://agroinformacion.com/como-conocer-el-punto-de-maduracion-idoneo-del-melocoton-utilizando-la-tecnologia-nir-en-la-clasificacion/

https://www.interempresas.net/Horticola/Articulos/311728-Tecnologia-NIR-para-conocer-el-punto-de-maduracion-idoneo-del-melocoton.html

https://www.agrodiario.com/texto-diario/mostrar/2051270/aplican-tecnologia-nir-clasificacion-comercial-conocer-punto-maduracion-adecuado-melocoton

**Speech at the XIX Post-Harvest Technical Seminar (online, 21 May 2021) "PEACHNIR: finding out the ripeness of peaches with NIR technology"**

https://www.youtube.com/watch?v=UPDpZYr-7S0

**INNOESPAI Fira Mollerussa Seminar (online, 4 June 2021) "PEACHNIR: the current situation and challenges of NIR technology in fruit cultivation"**

https://www.youtube.com/watch?v=VAHCRb6iTew

https://www.youtube.com/watch?v=ErTeMEJUyrM

**TV**

https://www.rtve.es/m/alacarta/videos/linformatiu/27062021/5959930/

https://www.rtve.es/play/videos/telediario-fin-de-semana/agricultura-tecnologia/5985123/?utm_term=Autofeed&utm_medium=Social&utm_source=Twitter#Echobox=1625950390

**Sections on corporate websites**

https://www.fruitsponent.com/node/2164

https://www.fruitsponent.com/ca/blog/fruits-de-ponent-reforca-la-seva-aposta-lid-amb-la-participacio-en-quatre-projectes

https://www.irta.cat/ca/coneixer-el-punt-de-maduracio-idoni-del-pressec-utilitzant-la-tecnologia-nir-en-la-classificacio/

## More information on the project

| PROJECT DATES | TOTAL BUDGET |
|---|---|
| Starting date: July 2019 | Total budget: €207,126.76 |
| End date: September 2021 | DARP funding: €84,648.41 |
| Current status: Executed | EU funding: €63,857.57 |
| | Own funding: €58,620.78 |

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Order ARP/133/2017 of 21 June, approving the regulatory bases for grants for cooperation for innovation by promoting the creation of European Association for Innovation operational groups in the areas of agricultural productivity and sustainability and the execution of innovative pilot projects by those groups, and Resolution ARP/1282/2018, of 8 June, announcing the call for the grant.

Generalitat de Catalunya
**Departament d'Acció Climàtica, Alimentació i Agenda Rural**

**Fons Europeu Agrícola de Desenvolupament Rural:**
Europa inverteix en les zones rurals