Activity of UMR SQPOV in WP3: second year. The results were obtained as part of a Master 2 internship (6 months)

Thermal processing of fruits improves palatability, extends shelf life and destroys micro-organisms that cause spoilage. However, high temperatures also induce some changes impacting the content of health-promoting compounds such as polyphenols, the production or degradation of aroma compounds and the mechanical property leading to different levels of puree viscosity. These changes are related to the health, sensory with textural, odour and taste characteristics of food, and consequently, with the quality and acceptance of the product by consumers.

The objective of the study carried out in 2019-2020 was to evaluate on real products, i.e. apple purees, the effect of cultivar, management system and processing conditions on viscosity, color, content and composition of polysaccharides, phenolics and volatile compounds. This study also allowed to choose the best and softest processing conditions, to limit the additives but in the same time to maintain the nutritional and organoleptic qualities of the fresh fruits.

Two apple cultivars were used: Pinova and Szampion managed both under organic and conventional management systems. Two kinds of processes were used. The first was a conventional process using hot break conditions, i.e. refers to a chopping temperature of 95 °C, which causes enzyme inactivation. HB process was carried out under vacuum. Purees were refined after. The second process was innovative insofar as apples were directly microwaved (without grinding) in presence of vapour. Purees were also refined after. All fresh and processed products were characterized by a panel of methods (rapid infrared spectroscopy (NIR and MIR), color, rheology (on purees), polysaccharide contents and composition, polyphenols and volatile compounds). Processes were done in duplicate.

Near infrared spectroscopy (900-25000 nm) performed on fresh and intact fruits (non-destructively) did not allow to discriminate samples according to the cultivar but partially allowed to discriminate samples according to the management system (Figure 1 A and B).

A B

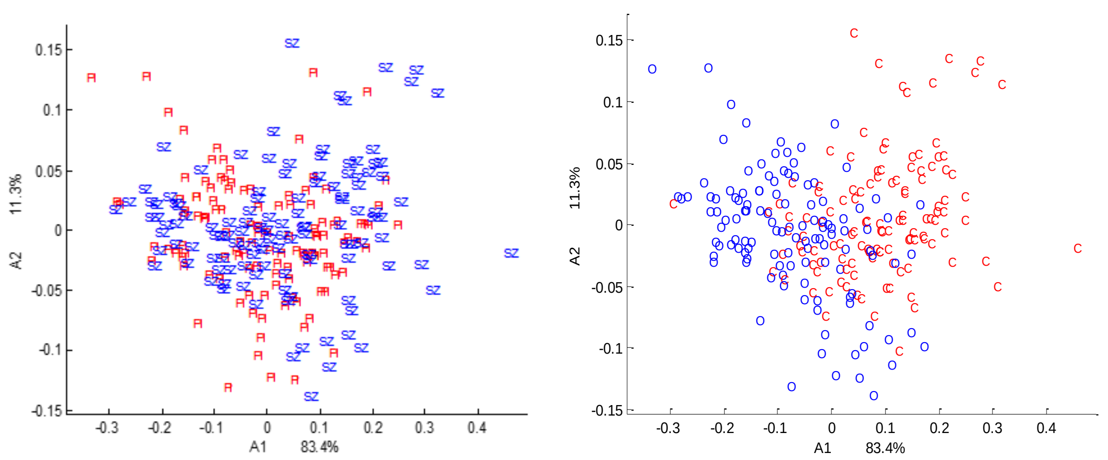
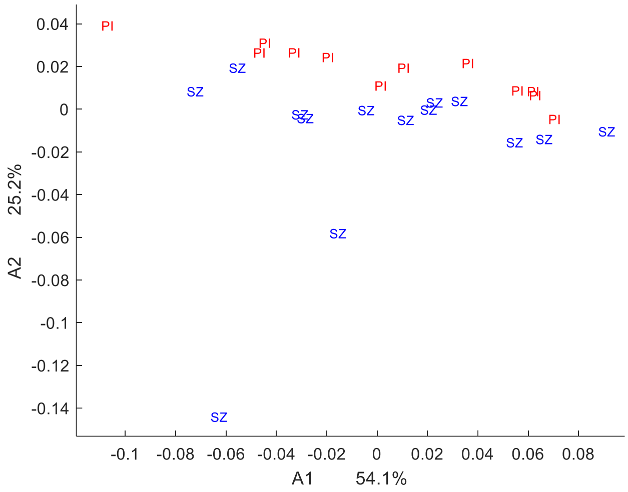


Figure 1. PCA results performed on near-infrared spectral data of fresh apple (900-2500 nm). A: results expressed as function of cultivar, B: results expressed as function of management system. The code corresponds to the cultivar (PI: Pinova, SZ: Szampion) and to the management system (C: Conventional, O: Organic).

A



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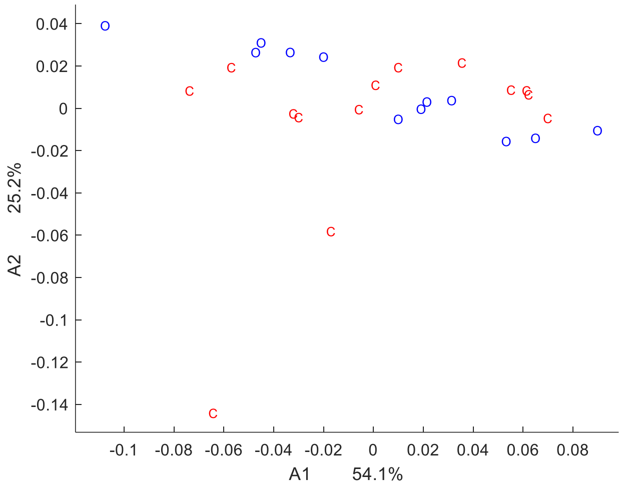

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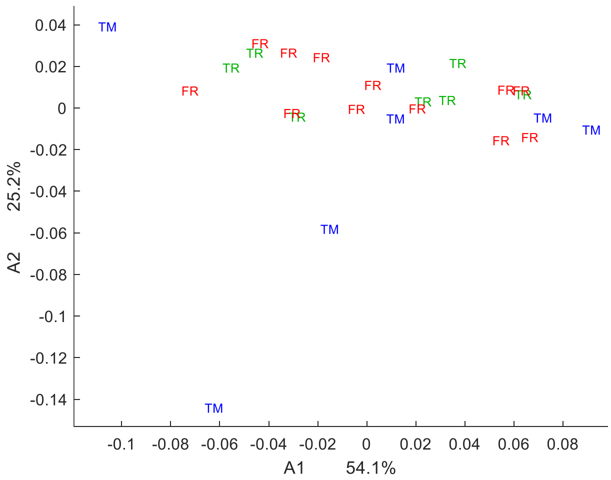

Figure 2. PCA results performed on mid-infrared spectral data of homogenates of fresh and processed apples (2000-800 cm^{-1}). A: results expressed as function of cultivar, B: results expressed as function of management system. C: results expressed as function of fresh or processed fruit. The code corresponds

to the cultivar (PI: Pinova, SZ: Szampion), to the management system (C: Conventional, O: Organic) and to the processing (FR : fresh, TM : innovative processing, TR : conventional processing).

In the region 2000 and 900 cm^{-1} the MIR spectra differ in absorbance in relation to the variability of the apple and puree composition. ANOVA performed on spectral data allowed to classify the studied factors according to their global effect. The Fisher values (F) decreased in the following order: cultivar (F = 200) > processing (F = 20) management system (F = 18) (results not shown). The effect of 'cultivar' was significantly higher than that of 'processing', itself slightly higher than the effect of 'management system'. The region 2000 and 900 cm^{-1} was used to discriminate the apple samples using principal component analyses (PCA, only the two first principal components (PC)) shown in Fig 2. The two cultivars appeared relatively well discriminated by PCA (Fig. 1A). Regarding the management system, they were partly overlapped (Fig. 2A). The processing samples were also overlapped. Whereas the variability given by cultivars was large enough to be observed in mid-infrared, differences due to the management systems and the processing were too small to discriminate the samples by their mid-infrared spectra.

The color of the fruits was not modified by the management system. However, the a* CIE L*a*b* coordinate of the fruit was significantly different according to the cultivar. The color of the puree was modified by the process compared to fresh apples: L*, a* and b* CIE L*a*b* coordinates were lower after processing. However, L*, a* and b* CIE L*a*b* coordinates of the purees were not modified by both, the type of processing (conventional *vs* innovative) and the management system (conventional *vs* organic).

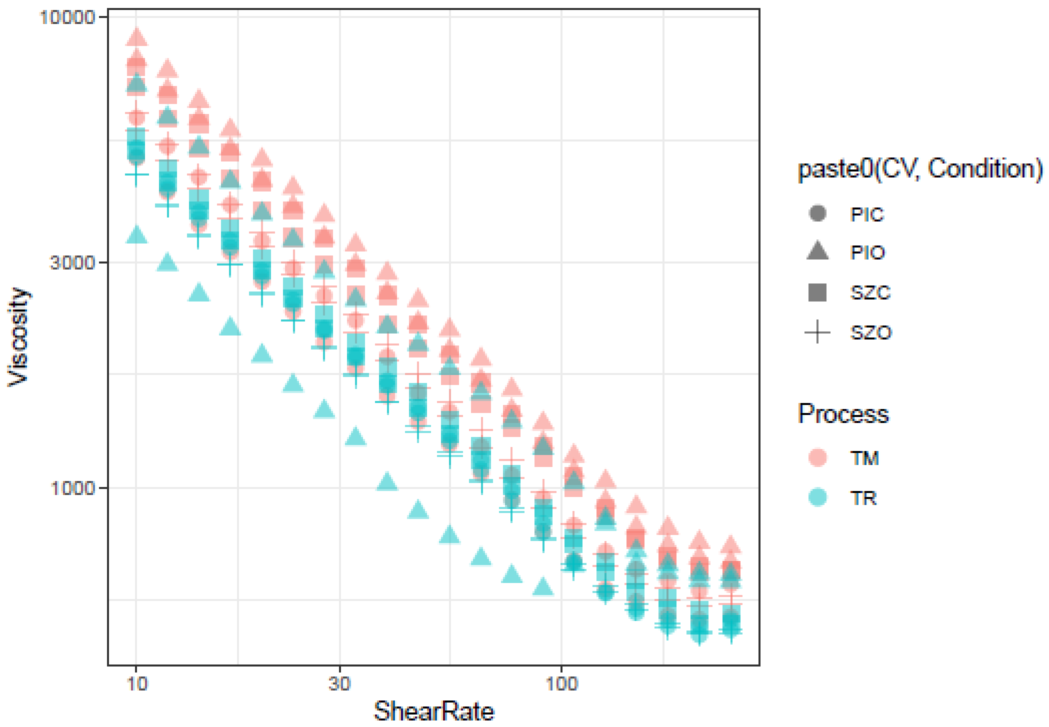

Figure 3 : Viscosity flow curves of apple purees. Dot shape corresponds to cultivar (PI : Pinova, SZ : Szampion) and management system (C : Conventional, O : Organic), and dot color corresponds to conventional (TR) and innovative (TM) processing.

Purees viscosity was mainly impacted by the type of process (conventional *vs* innovative) but it was counterbalanced by the cultivar and/or the management system (Figure 3). The innovative microwave cooking resulted in a higher viscosity, which could be due to a higher water evaporation in comparison with the conventional process.

Glucose, fructose and malic acid expressed in dry weight were significantly higher in Szampion cultivar, whereas malic acid contents were higher in organically grown fruits. Sucrose and citric acid contents were lower in purees than in fruits. Glucose and fructose contents were lower in purees processed by microwave than by conventional process.

The cell wall contents of the fruits, expressed in dry weight, were only significantly affected by the cultivar. However, puree cell wall contents (expressed dry weight) were significantly lower after processing, without any effect of the type of process (conventional *vs* innovative). Among neutral sugars (rhamnose, fucose, arabinose, xylose, mannose, galactose, non-cellulosic and cellulosic glucose) and galacturonic acid that are constitutive of the apple cell wall, only arabinose and galactose were significantly lower in Szampion cultivar whereas non-cellulosic glucose was significantly lower in Pinova cultivar. This could be related to differences in pectin side chains and hemicelluloses. However, it could not be exclude the factthat this effect may be due to a difference in the ripening stage, known to affect their contents. The degree of methylation of pectins was lower in Szampion cultivar. Management system was only significant for galactose and methanol contents (methylation of pectins), with lower contents in conventional grown fruits. Cell wall composition was not modified after processing, except for non-cellulosic glucose and methanol which were higher after processing. The composition of the cell wall was not modified by the type of process except for fucose and non-cellulosic glucose, with higher fucose contents in innovative process and higher non-cellulosic glucose in conventional process.

Among polyphenols quantified (expressed in dry weight) in fresh fruits, cultivar had only a significant impact on dihydrochalcone (phloretine xyloglucoside and phloridzine), hydroxycinnamic acid (5-caffeoylquinic and para-coumaroylquinic acids) and anthocyanin contents. Flavan-3-ols both, monomers and polymers were not different between the cultivars. The effect of the management system on fresh fruits was limited to minor compounds, i.e. (+)-catechin and flavonols with lower contents in organically grown fruits. The DPn of the procyanidins was also lower in organically grown fruits. The effect of processing was significant on polyphenol contents such as procyanidins and 5-caffeoylquinic acid, i.e. polyphenols that are direct or indirect substrates of polyphenol oxidase and on anthocyanins known to be sensitive compounds. In the case of the microwave innovative process, the cooking is very fast, i.e. 8 min, compared to the conventional one, i.e. 24 min, giving in purees a lower content of compounds present in peel and pips such as quercetin derivatives, dihydrochalcones and anthocyanins. This may be due to a lower diffusion of polyphenols from the peel and the pips to the flesh. Moreover, (-)-epicatechin, procyanidins and 5-cafffeoylquinic acid were lower in purees obtained by the innovative process.

Our study revealed a large variability in volatile compounds, and the cultivar is one of the main factor on fresh fruit. Szampion cultivar was more aromatic than Pinova cultivar (Figure 4). On puree, the cultivar effect was also observed but it was not possible to detect a process effect or a management system effect (Figure 5).

A B

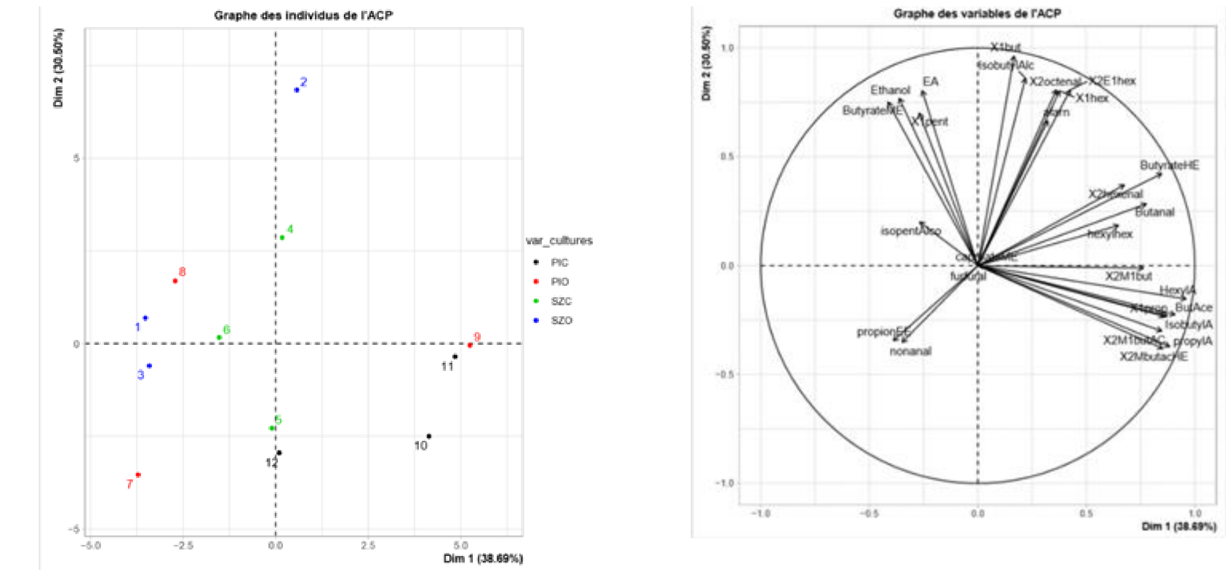

Figure 4 : PCA results performed on volatile compounds of fresh fruits. A: Sample map of scores on PC1 and PC2 as function of the cultivar and the management system. B: Correlation circle of volatile compounds loadings on PC1and PC2.

A B C

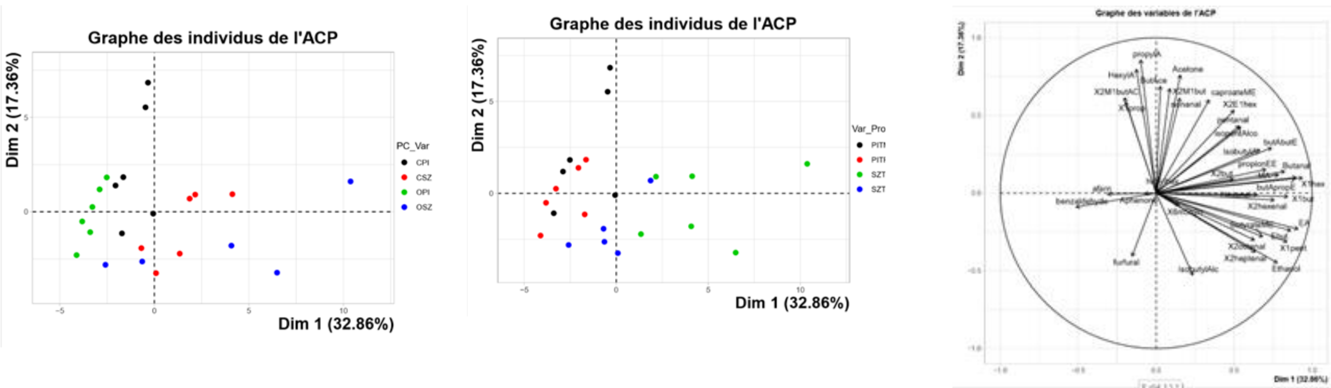

Figure 5 : PCA results performed on volatile compounds performed of puree sample. A: Sample map of scores on PC1 and PC2 as function of the cultivar and the management system. B: Sample map of scores on PC1 and PC2 as function of the cultivar and the processing. C: Correlation circle of volatile compounds loadings on PC1and PC2.

Regards to our results, the main factor of variation in determining the quantitative primary and secondary metabolites composition of fresh apples, was the cultivar while the management system (organic or conventional) had little influence on fruit. Fast innovative microwave process allowed producing purees with a lower polyphenol contents but with a higher viscosity than the conventional process. Another year of experimentation (2020-2021) is necessary to validate or not the results obtained. However, sensorial analysis is needed in order to define the consumer acceptability of this kind of product, with in the same time an economical/environmental/technical evaluation of the innovative microwave process to transfer it to the industry.