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Improving optical fruit sorting by non-destructive determination of quality parameters affecting wine quality

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Abstract The scope of this project is finding suitable parameters correlated with grape and wine composition to be implemented as a quality criteria to sort harvested grapes. Grape quality is not only defined by sugar concentration but by a complex equilibrium of parameters depending on the type of wine to be produced. Moreover, measuring berry composition is not always linked to the amount that will finally be extracted into wine. Sorting the berry according to their density and berry size showed that measuring berry size could be another good tool to segregate groups. It was possible to relate berry color with sugar accumulation and anthocyanin accumulation until berry coloration process (veraison). However, after veraison, berry color was not a suitable parameter anymore to describe differences in maturity. It was also possible to correlate berry color with aroma precursors in Riesling white grapes, showing that VIS measurements in white grapes could indeed be a possible way to sort the berries according to quality. A multiparametric optical sensor, Multiplex® (Force A, France) showed that change in simple fluorescence ratio in green excitation was correlated to sugar concentration in white berries. Two ratios showed promising results: Firstly, the NBI_G indicating amino acid in berries and juice then secondly the ANTH_G correlating red color pigments (anthocyanin) concentration. This will have potential to determine quality parameters and in combination with user-friendly interfaces will improve grape sorting devices.

1 Introduction

In recent years, grape sorting has gained in importance and there is a growing interest in optical food evaluation technologies for grape and wine analysis [1]. This development can be observed particularly for the production of hand-picked, high-quality wines and the further processing of mechanically harvested grapes. Grape sorting provides an opportunity to actively increase the quality of the harvested grapes by sorting out green parts of plants, as well as unripe, damaged or partly rotten berries, insects such as ladybugs or earwigs and other foreign substances such as material of the trellising-system (e.g. wood, nails) (Fig. 11.1). Especially in the field of red wine production, such a selection is important because the grapes are processed with skin contact during several weeks to extract the desired substances such as anthocyanins and tannins. However, when unsorted, undesirable flavor components can be extracted. In the past, grape sorting was mainly done manually; either by selective hand-picking in the vineyard or by means of manual sorting devices such as vibrating or belt sorting tables. The growing use of mechanical harvesting leads to an increasing relevance of sorting grapes. Therefore growing interest in automatisation of the process can be observed [2].

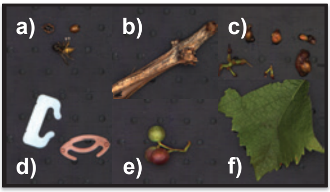

Figure 11.1: Materials Other than Grapes (MOG) to be sorted out for the harvest: insects (a), wood (b), stem pieces (c), material of the trellising-system, nails (d), unripe, smallest berries (e) and leaf pieces (f).

Nowadays, automatic sorting lines are already available, selecting the harvested grapes using mechanical or optical methods. The automatic sorting lines are positioned downstream of a destemming machine where the berries first fall onto a conveyer belt or vibration tables. During convey, juice that has accumulated as well as part of the small pieces of stems, petioles, and smallest berries are separated by means of a perforated plate imbedded in the table. By means of mechanical sorting systems, larger pieces of stems and entire rachises are separated at the end of the conveyor via different systems. The remaining berries and berry parts fall from the conveyer belt and go through an adjustable air nozzle or fall onto a perforated stainless steel roller to separate damaged berries and parts of stems. After spreading out, the berries get to a perforated sorting belt that accelerates the berries to about 2-3 m/s. At this speed, the fruit is passed alongside an optical system made up of camera, laser and/or LED technology allowing systematic selection according to colour, structure and/or form. The elements that the optical evaluation system recognizes as foreign materials or generally as negative are blown into a separate collecting system. The automatic evaluation of the harvested grapes provided by the existing systems therefore involves only a determination of foreign bodies (stem, leaves), affected berries and unripe berries [3], [4]. However, the remaining healthy berries differ largely in quality or ripeness, leading to different wine styles. The aim of this project is to determine suitable parameters correlated with grape and wine composition to be implemented as a quality criteria.

2 Quality parameters to be taken into account for wine production

Compared to many other agricultural products, grape production still holds one of the highest cash returns . Around 70% of this production is aimed for winemaking. Wine contains many different components, the majority originating from the vineyard and others produced during the winemaking process. Therefore most of the compounds responsible for wine quality depend on the quality of the grapes. Grape either produced in leaves (sugars and acids) or in berries (acids and phenolics). Grape berries contain three major types of tissue: skin, flesh, and seeds and the maturation process follows a two sigmoid curve [5]. Many of the solutes are accumulated in the grape berry during the first period of development yet their concentration is significantly reduced towards harvest due to the increase in berry volume. A grape berry is mostly composed of *water* and overall the berry approximately doubles in size and weight between veraison and harvest. Although the first growth period contributes to the final quality of the berry, the most important events occurs during the second growth period with an increase in *sugar (glucose and fructose)*, organic acids, mostly *tartaric and malic acids* that are responsible for the acidity of the wine and therefore critical to its quality. Malic acid is metabolised and used as an energy source during the ripening phase, resulting in a significant decrease of its levels relative to tartaric acid. *Nitrogen*, present in mineral or organic forms in the grapes is accumulated during ripening and metabolized by the yeast during the fermentation process. However, sugar accumulation is not well related to flavor and aroma compounds therefore phenolic and aromatic ripeness may be reached at a different time. *Phenolics* contribute to the color, color stability, structure and mouthfeel of a red wine. Tannins also decline considerably on a per-berry basis after the onset of ripening, veraison, whilst the anthocyanins accumulation begins in berry skin of red grapes. The complexity of wine *aromas* is issued from primary aromas synthesized in grapes and secondary aromas released during winemaking process. Aromatic compounds produced during the first growth period also decline on a per berry basis during fruit ripening. From a winemaking point of view, optimal grape maturity is essential for wine quality, but is difficult to assess because it is controlled by many factors, involving grapevine variety and environmental parameters such as soil, temperature, exposure to sun, and hormonal regulation.

3 Sorting berries according to berry size

Among many secondary components, phenolic components are important for red wine color (anthocyanins) and mouthfeel (tannins), therefore for the quality of a red wine. However heterogeneity of grape composition at one given date is well known and changes observed through the ripening process would be more related to berry ripeness than harvest date [6]. Phenolic compounds can be found in berry skin and seeds, however structure and accumulation differ. Therefore differences in berry size or maturity may affect their contribution to wine composition. Pinot noir berries from a vineyard at Geisenheim (Germany) were first segregated into size groups at harvest and then each group in different density subgroups as described previously [7]. As

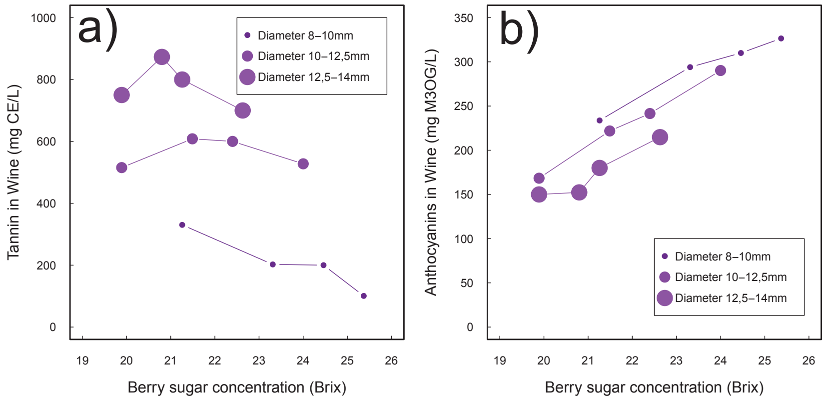

Figure 11.2: Phenolics in micro scale wines produced from berries sorted according to their density depending on 3 diameter classes. **a)** Tannin concentration in wines as mg catechin equivalent (CE) per L wine, **b)** Anthocyanin concentration in wines as malvidin 3-O Glucoside equivalent (M30G) per L wine.

grape secondary components can differ in extractability into wine, measuring berries cannot always predict the type of wine that will finally be made at the end of the process. Thus, a nanoscale winemaking technique was developed for red wine fermenting of 100 berries to be able to mimic higher scale fermentation and obtain wines from different discriminated groups. When sorting berries according to their total soluble solids (density), wine tannin concentration decreased with increasing maturity (Fig. 11.2). Flotation method has already been suggested for grape sorting method [8] and is already implemented in some systems on the market. When maturity was even, wines produced from smaller sized berries showed higher anthocyanin extraction compared to wines from bigger sized berries (Fig. 11.2b) probably a result of the greater skin to juice ratio in the fermentation process as hypothesized before [9]. On the other hand, wines produced from smaller sized berries showed lower tannin concentration compared to wines from bigger sized berries (Fig. 11.2a) [10]. Therefore segregating berries according to their size diameter would be a good tool to sort berries according to the type of wine aimed to be produced.

4 Sorting berries according to reflection in visible part of the spectrum

4.1 Red grapes

When a red grape undergoes maturation, the color is changing from green to dark blue due to anthocyanin accumulation in berry skin (Fig. 11.3). One parameter to sort the berries would be to measure the change in color in the visible part of the spectrum. Colorimetry is an approach to evaluate grape ripeness from diffuse light reflectance which is then converted into values that represent human visual perception according to the Commission Internationale de l'Eclairage (CIE) tristimulus values (CIELab). A color index for red grapes (CIRG) was developed [11] and was already used to correlate against anthocyanins concentration (coefficient of determination 0.92) [12, 13]. Pinot noir grapes were first sorted according to their density at different time during the maturation period to obtain homogen groups in terms of sugar concentration. Single berry reflection was measured with a spectrometer in visible (VIS) part of the spectrum (Minolta 3500d, Konica Minolta, Germany). The parameters lightness (L*), red/green (a*), and yellow/blue (b*) were calculated using the D65 illuminant and a 10 degree standard observer. The berry color b* in CIELAB system (blue to yellow) was correlated with sugar accumulation and anthocyanin accumulation until berry coloration process began. However, after berry coloration, blue color (negative b*) in VIS was not anymore suitable to describe differences in maturity. Such poor estimates were also found giving maximum a 0.50 for the coefficient of determination in the correlation with anthocyanins in whole grape berries [14].

4.2 White grapes

When a white grape undergoes maturation, the color is changing from green to yellow due to loss of berry skin chlorophyll and therefore carotenoids and phenolics become responsible for the color. Carotenoids are important for grape quality as they are aroma precursors so as C13-norisoprenoids and terpenes. Grape exposition to sunlight is a critical factor for berry coloration as berry skin secondary components act as a barrier defense against UV light. Again the problem of

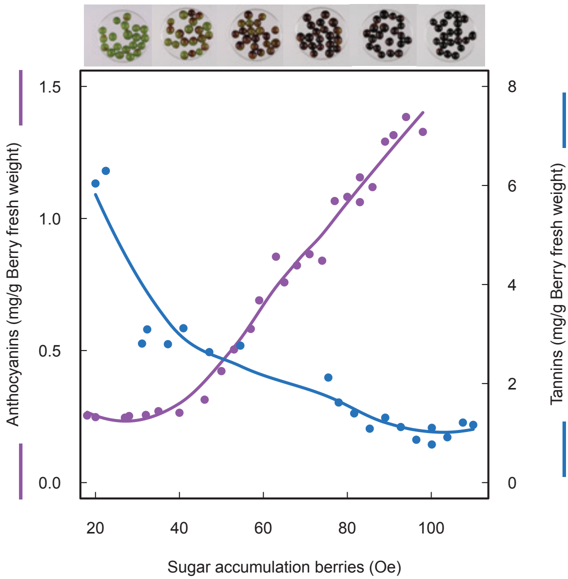

Figure 11.3: Change in berry color for Pinot noir grapes from green to blue accompanied with an increase of anthocyanins and a decrease of tannins in grapes as mg per g homogenate.

the wide range in berry color was contourned when first sorting Riesling grapes according to their red/green color (a*) [15]. It was possible to correlate the berry a* color parameter with glycosidic aroma precursors (so called Glycosyl Glucose -GG) in grapes (Fig. 11.4), showing that VIS measurements in white grapes could indeed be a possible way to sort white berries according to quality.

5 Sorting berries according other parameter than visible part

Another way for non destructive measurement would be to use berry properties in emitting specific light emission – fluorescence – under UV excitation for flavonols or visible light for anthocyanins. The tech-

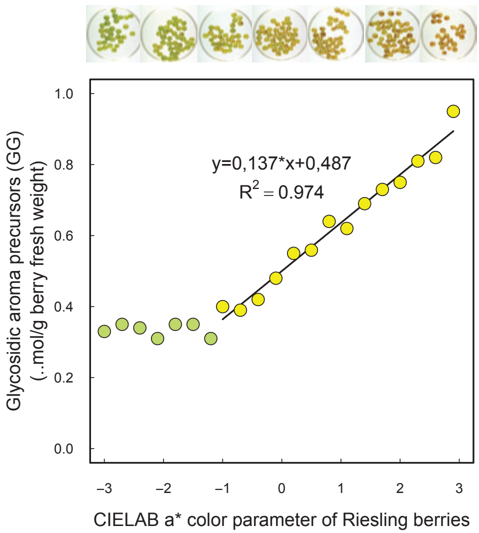

Figure 11.4: Color of Riesling berries sorted according to a* parameter measured in CIELab system as linear correlated to glycosidic aroma precursor measured as Glycosyl Glucose (GG as µmol /g berry fresh weight) in grape homogenate.

nique, based on intrinsic fruit fluorescence, called chlorophyll fluorescence screening method, has been successfully used to determine anthocyanin in berry skin [16]. An optical sensor, Multiplex® (Force A, Orsay, France), relies on such principles. The device measures the yellow fluorescence(YF-590nm), red fluorescence (RF-685nm) and far-red fluorescence (FRF-735nm) , excited by ultraviolet (_UV-375nm), blue (_B-470nm), green (_G-516nm) or red (_R-635nm) light. This fluorescence sensor would be insensitive to ambient light [17].

5.1 Red grapes

To validate the method, Pinot noir grapes were first sorted according to their density at different time during the maturation period to obtain homogen groups in terms of sugar maturity. Then population of 20 berries were measured with the Multiplex® (Force A, Orsay, France). An index called ANTH_RG, was defined as the ratio between Far-Red Fluorescence (FRF) under red excitation (FRF_R) and Far-Red Fluorescence (FRF) under green excitation (FRF_G): ANTH_RG = log(FRF_R/FRF_G). The index ANTH_RG was correlated to anthocyanin concentration proving that blue colored berries could indeed be separated in different groups when using other part of the spectrum than visible light. Similar results were found when sampling Pinot noir berries during maturation period (coefficient of determination 0.96) [16]. The Multiplex® SFR index is linked to the changes in skin chlorophyll content. This index is defined as the ratio between Far-Red Fluorescence (FRF) emitted under red excitation (FRF_R) and Red Fluorescence (RF) emitted under red excitation (RF_R): SFR_R = FRF_R/RF_R [17]. It was possible to correlate this index SFR_R with tannin concentration in berry skin, however not really for tannin concentration in berry seeds.

5.2 White grapes

Change in simple fluorescence ratio in green excitation (SFR_G) is related to berry chlorophyll content and was correlated to sugar concentration in white berries of Riesling collected at Geisenheim (Germany). Similar results were obtained for Chardonnay grapes showing the strong correlation of sugar accumulation and chlorophyll decrease [17]. However, an absolute calibration for the use as non-destructive prediction remains to be done for different varieties and seasons. Another index, NBI_G is defined as the ratio between Far Red Fluorescence emitted after UV excitation (FRF_UV) to red fluorescence emitted in red excitation (RF_R): NBI_G = FRF_UV/RF_R. The NBI_G index was correlated to amino acid concentration of the grape juice (measured as N-OPA), important substrate to assure complete fermentation of the juice.

5.3 NIR spectroscopy

Near Infrared spectroscopy (NIR) was found to be linked with berry composition and indeed, NIR spectroscopy was shown to be a good tool for acidity prediction in grapes [18]. Grape ripeness (Brix) could be predicted with NIR spectroscopy for red and white grape with however better results for red grapes. [19]. Together with sugar content (Brix) and pH, it was shown that anthocyanin content from red grapes could be predicted with spectroscopy measurements in the visible-NIR range [20]. Measurements were undertaken in 2012 to confirm the validity of assessing NIR spectroscopy to determine quality parameters in grapes of this project.

6 Summary

In the past, grape sorting was mainly done manually. With the use of mechanical harvesters, a selection is crucial for sorting out undesirable substances, i.e. material other than grapes (MOG). Automatic sorting lines are already available for negative selection of such components. However, despite the negative selection it is of major interest to sort the fruit towards quality and hence improve the final wine. The aim of this project is to find optical non-destructive parameter to assess quality of the grapes affecting wine quality. We found that measuring berry size could be a good tool to segregate groups. Moreover, berry color gives interesting hints about grape quality for white berries showing that VIS measurements could indeed be a possible way to sort the berries according to quality. The implementation of an optical sensor, Multiplex® (Force A, France) showed promising results. Further, measurements aside the visible range of the spectrum, in UV or NIR part, are tested to validate the use of such parameters for quality segregation. This work represents the basis of an on-going project implementing these techniques on a sorting machine with a user-friendly interface to improve existing systems for sorting grapes in different quality levels.

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