Influence of pedoclimatic factors during berry ripening in Burgundy
Influence de facteurs pédoclimatiques pendant la maturation du raisin en Bourgogne

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ABSTRACT
Berry composition at ripeness can be explained by many factors. This study was carried out from 2004 through 2011 in a 60 block network in the Yonne region, Burgundy. The impact of the main components of terroir – vintage, soil, exposition, topography, varietal, rootstock, age, density and vine management- were studied simultaneously, during berry ripening. Berry composition during ripening was assessed each week by the sampling of 400 berries and the following analyses of grape-juice were carried out : sugar, total acidity, malic acid, tartaric acid, pH, and potassium. The variables total acidity, malic acid and tartaric acid were anti-correlated to sugar content. The potassium variable explained an important part of the grape composition variability in the network. Statistical analysis allowed ranking of the terroir factors in order of importance during ripening. The vintage, highly significant, was the major factor, followed by factors cultivar, exposition and soil, who all had statistically significant influence. Pinot noir reaches maturity earlier than Chardonnay. Blocks with a North exposition present a delay in maturation, especially on steep slopes. Grapes reach maturity earlier on South exposed slopes , although this does not lead to higher sugar accumulations. The shallow limestone soils on hard bead-rock, limit potassium accumulation, probably because of limited water supply. Among the colluvium soils, variability may be explained by the importance of soil depth. The wine-growers factor had also a great influence in this study.

Keywords: Ripening, variability, vintage effect, soil effect, exposition effect, typology.

1 INTRODUCTION

Berry composition at ripeness can be explained by many factors. Many authors have tried to define terroirs (1, 2, 3). Nevertheless, study terroirs stays complicated, because this notion is ambiguous, and the factors which are susceptible to have an impact on berry maturity are multiple and non-dissociable. However, it seems that climatic and pedologic factors (through vine water status), present an important role during berry ripening (4).

Terroir can be defined as an interactive ecosystem, in a given place, including climate, soil, vine and human factors (viticultural and oenological techniques). Many authors have assessed the impact of a single factor of terroir during berry ripening : climate (5), soil, cultivar (6). The effects of vine water and nitrogen status were studied (7), linked to soil type. Researchers pointed out the combined effects of soil and climate. Another study investigated the effect of soil and cultivar. The influence of climate, soil and cultivar have been examined simultaneously in Saint-Emilion, located in the Bordeaux area (8).

This study deals with the influence of many factors – vintage, soil, aspect, topography, varietal, rootstock, vine age, density and vine management, during berry ripening.

Our objectives were to assess which one of the many factors studied has the main influence during berry ripening, and to establish a scientific classification of the blocks, function of their behavior during ripening.

2 MATERIALS AND METHODS

This study analyses data from 2004 to 2011 on a 60 block network in the Chablisien and Grand Auxerrois vineyards, located in Burgundy region. Blocks were located between Epineuil and Coulanges la vineuse, 30 kilometers apart. The *Vitis Vinifera* cultivars were Chardonnay , Sauvignon Blanc, Aligoté, for the whites, and Pinot Noir and Gamay for the reds. We didn't pay attention to the clones, because we were not able to list them for each block. These varietals were grafted onto 161-49C, 3309C, 41B, SO4, 5BB or Fercal rootstocks. Vine density varied from 4808 to 10000 vines per hectare. The vines were planted between 1948 and 2000. Vines were simple-Guyot, double-Guyot or Chablis type pruned. We didn't have any information about the vine management (hedging, soil cultivation, pesticide applications…). Blocks were exposed north/north-west, south, west/south-west, east/south-east or flat. Blocks were defined as plateau, shelf or hillside.

We defined four soil types. The first was a shallow limestone with spatangoids. The second soil was a shallow limestone on hard beadrock. The third soil was shallow marls. The last soil was a colluvium soil, characterized by variance in depths.

Climatic parameters vary both spatially and within the vintage. Since we had access only to one weather station (Auxerre station) close to the blocks, climate was considered to be homogeneous among the plots in a given vintage. The effect of vintage was studied in terms of year to year variations in temperature and rainfall. Mean and low temperatures, degree-day base of 10°C (Huglin index) and Tonietto index based on

night temperatures were calculated for each vintage during the main phenological stages.

Berry composition

400 berries per block were sampled once a week from veraison to harvest. Sampling was carried out on the same two rows of each block, at the same hour. Sampling was not been done by a single person, but each block has been sampled by the same person (the owner). The sampling was done alternatively on the right and on the left when walking through the rows. The juices samples was analyzed for soluble solids by refractometry (in g sugar/L); total acid concentration (in g sulfuric acid/L); pH, malic and tartaric acids (in g/L), and potassium by spectrophotometry (in g/L).

Statistical analysis

Data analysis was done by ACP (Principal Components Analysis). This method is based on the reducing of the observed variables into a smaller number of principal components that will account for most of the variance in the observed variables. The observed variables observed were the sugar contents, total acidity, pH, malic acid, tartaric acid, and potassium. Then data were analyzed by ANOVA. Variables were the same as for the ACP, and the factors were vintage, soil, aspect, topography, varietal, vine age, density. Means were separated by Newman-Keuls test and percentages of variance attributable to the different factors were calculated. We also used CAH (Hierarchical Ascendant Classification), and CART (Classification Regression Tree) to make a classification of the network. Software used was Grimmersoft StatBox, R and Microsoft Excel.

3 RESULTS AND DISCUSSION

Maturity analysis started early for the 2007 and 2010 vintages, compared to the others, because of an earlier veraison. 2008 vintage was the latest. 2006 presents the highest sugar content at ripeness. However, we have to be careful interpreting these results, because we don't have the analysis at harvest, and the harvest dates can be significantly different from a winemaker to another.

In order to present these results combining the total acidity, pH, potassium, malic and lactic acid, here is an ACP of the studied vintages for each block of the network (cf. figure 1).

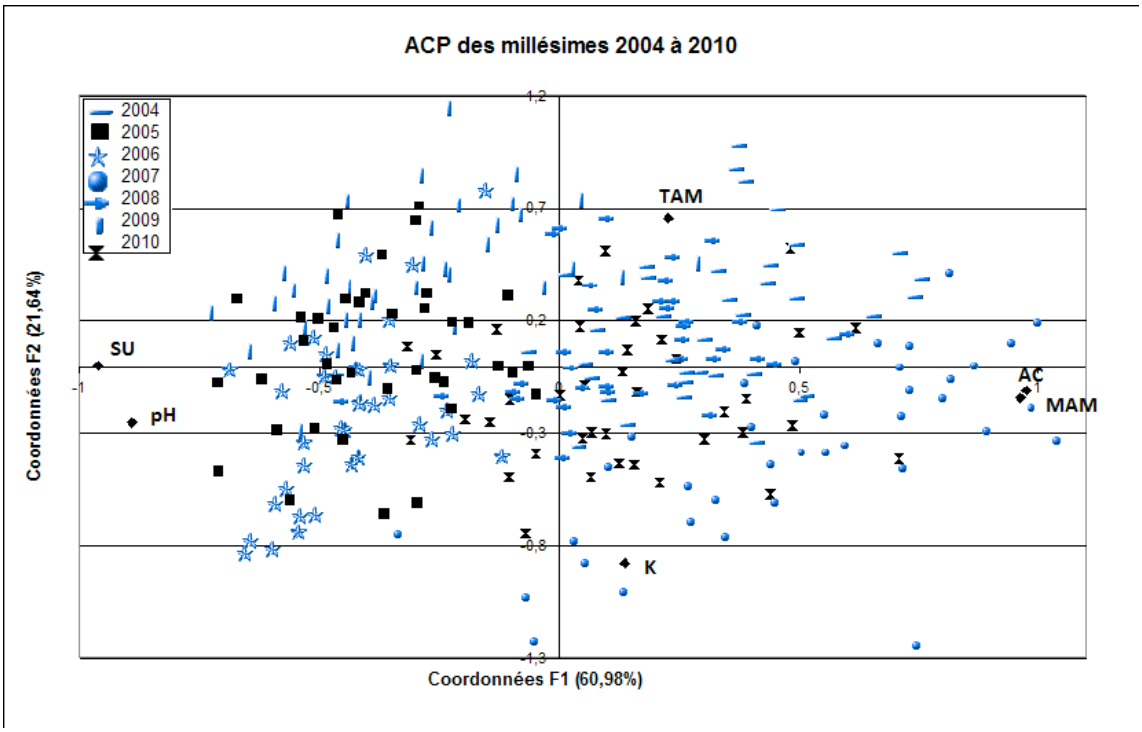

Figure 1. ACP (vintages 2004 to 2010).

The axis are explaining more than 85% of the variability, which shows that there is not a lot of information lost. The F1 axe is explained by the sugar content and the pH, anti-correlated to total acidity and malic acid. F2 is more explained by the potassium contant, whearas the tartaric acid content is not representative ($\cos^2<0,75$). The different vintages can be distinguished easily on F1 axis. Hence, 2005, 2006 and 2009 present the higest sugar content, where as the other vintages seem to have more acidity.

After these descriptions of the climatic conditions and the precocity of the different vintages, we can classify them :

- 2007 and 2010 were early vintages, but with cold and wet weather.
- 2004 and 2006 were late, with warm and dry maturation.
- 2005, 2008 and 2009 were in the middle, with roughly warm and dry maturation, and high sugar content.

Since the precocity and the climatic condition affect the results a lot, we studied each vintage separate. In order to simplify the results, we chose to show only this representative ACP of the 2010 vintage (cf. Figure 2).

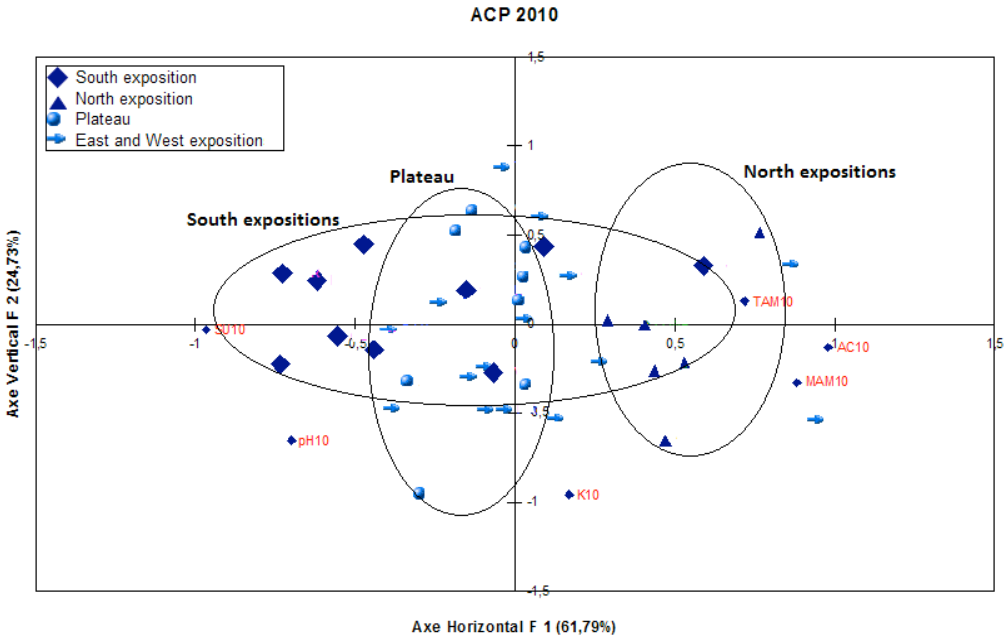

Figure 2. ACP 2010.

F1 is explained by the sugar content and the pH, anti-correlated to total acidity, malic and tartaric acid. F2 is represented by the potassium content. This means that F1 could be related to the precocity (sugar accumulation and loss of acidity), where as F2 could represent the potassium content. The different blocks labels are colored in function of the block exposition. North expositions are clearly late with their sugar content whereas south expositions have higher sugar content, which means they get to maturity before other expositions. In the flat blocks group, we can explain differences with their potassium content. The shallow colluvion soils seem to be ripening before the deep ones, because of a good draining. Marly soils show more variability because the variability in these soils is more important. Indeed, the potassium content can be related to the vine water status, function of the soil depth and type. Hence, F2 axis represents the vine water status, through the potassium content.

This graph can also show the influence of the varietal on the maturity. Pinot Noir blocks get to maturity before chardonnay (higher sugar content and less acidity). But this can be explained by the good south exposition of all the Pinot blocks.

With different climate conditions

Late vintages

Concerning the ripening axis, more variability is observed in the network. North exposition are more scattered, plateau have a later ripening. Furthermore, we can hardly see a difference of earliness between varieties. Regarding the potassium axis, high slopes are less supplied, because of their thin soil.

Intermediary vintages conditions

The ripening axis shows that north expositions have later ripening, as do the blocks at the bottom of the slopes. Colluvions have early ripening, because of good water draining. Steep slope ripe earlier than when the climate conditions are rainy. Concerning the potassium axis, plateaux do not have high concentrations, and we show that north exposition scatterings are not related to this axis anymore.

The ANOVA tests enable us to classify the studied factors. Hence the vintage is the most important factor influencing the berry ripening. Then comes the variety, the topography, the exposition and the soil. The rootstock comes after, as the vineyard management and the density, with the age of the vines.

We showed that the vineyard management as an importance too. Indeed, some blocks, where the only difference is the owner, do not show the same behavior.

We also studied the stability of the blocks behavior facing the ripening. It appeared that the oldest vineyards (planted in 1948) are the most stable, whereas the youngest one (planted in 2000) is the most scattered. This may means that when the vines are getting older, their behavior would be more stable in the time, whatever the vintage climatic conditions.

After these analyses, we tried to create a typology of the network. It appeared 3 groups:

- North exposition, presenting a late ripening, but with high potassium content;
- Steep slopes, plateau, blocks at the bottom of slopes, presenting a late ripening, and low potassium content;
- Chablisien blocks, with a general early ripening.

It is not possible to find an explanation for all these formed groups, but it seems to be repeatable because it works with 2011 vintage.
Also, we tried another type of classification, called CART, which is based on regression trees. This one considers only variety and exposition factors, and forms 3 groups:
- Pinots noirs on one side,
- White varieties on the other side. This group is then divided in two: North exposition, and East, west and south exposition.
Even if this typology considers two factors, the explanation of the group is easier for vineyard managers.

CONCLUSIONS
This study allowed us to show in Burgundy that north expositions and plateau have, in general, a late ripening period (sugar accumulation), contrary to south exposition and pinot noir. Concerning the potassium accumulation during ripening, steep slopes and thin soil on hard limestone present low content, whereas bottom slopes in general present high content, regarding their water status. Furthermore, we achieved to establish to types of classification, which seem stable in time, working with at least 2011 vintage. Hence, vintage has the more impact on the earliness of ripening. Then the variety, the exposition and the topography are important, and make a difference during berry ripening.

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Relationships between berry quality and climatic variability in grapevine cultivars from Piedmont (Italy)

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ABSTRACT
A major topic in viticultural research is the analysis of the relationships between climate on one side, and grape and wine quality on the other. It is well known that climatic conditions have a high impact on growth and development of grapevine and consequently on yield and quality. In particular, wine quality is correlated with bioclimatic indexes, which are based on air temperature and cumulated rainfall during the growing season.
This study was aimed at creating and analyzing a dataset containing berry quality data collected on 13 grapevine cultivars of Piedmont, and climatic and geomorphological data of the vineyards where berry samples were taken. Berry quality and meteorological data were collected from 1999 to 2010 and bioclimatic indexes were calculated over the vegetative growing period.
In a preliminary analysis, for each cultivar an ANOVA was performed, and significant differences among years as concerns total soluble solids (TSS), titratable acidity and pH were detected.
Pearson's correlation analysis was applied separately for each cultivar, in order to perform a first evaluation of the relationships between climatic, geomorphological and berry quality data. As expected, significant relationships between berry quality and climatic data were detected. Such relationships changed from one cultivar to another. PCA was carried out to examine TSS distribution among the different areas, based on some climatic and geomorphological parameters. In particular, Huglin index, cumulated precipitation, number of thermal units, cumulated radiation, altitude, slope and aspect were chosen.
A multiple regression analysis was also performed and the regression coefficients were used to build synthesis maps, using digital layers for each cultivar, and applying basic GIS techniques.

Keywords: not specified