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New progress in vine and wine research

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The scientific basis for the production of quality wines

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The principle objective in growing vines has always been the production of quality wine. Vinification, that is to say the transformation of musts by yeast fermentation, certainly constitutes the oldest of biotechnologies from time immemorial. The rules to be respected in the vineyard, and the principles of vinification, have been established empirically over the course of several centuries of rigorous and methodical observation. The production of quality wines came before all scientific knowledge. The most famous vineyards of today owe their fame to the nineteenth century. In Bordeaux, the Grands Crus du Médoc and Sauternes-Barsac were the subject, in 1855, of a hierarchical classification, which is still in use today; yet the biological mechanisms of the formation of alcohol from sugar during fermentation were demonstrated only several years later by Pasteur, in his legendary studies on beer and wine.

However, although its origins were empirical, the production of great wines has, in the last quarter of a century, been one of the forms of agricultural production which has benefited most from research developments. Vines and wines have been the subject of a considerable number of scientific and technical publications; viticulture and enology departments exist in several universities in the wine-producing countries of the world. This interest is engendered by the existence, under the generic term 'wine', of a diversity and hierarchy of quality which is quite unique among the products of the soil. Then again, there is the fundamental role played by criteria of taste, in contrast to simple nutrition. And finally, not only can wine be kept for many decades, but it also improves with aging. These are all reasons why scientists of the first rank have been able to devote many years to the study of wine, and in doing so, they have found a model which opens the way to an understanding of some of the fundamental problems of its biology and chemistry.

The subject of this introductory paper is the role of scientific and technical factors in the production of quality wine. However, the importance of natural factors must not be forgotten, either. The notions of 'terroir' and of 'cru' or growth are still of great importance; at a first glance, one is concerned with situations which are particularly favorable to the regular maturation of grapes of the *Vitis vinifera* cultivars. Moreover, economic circumstances have played a role in the creation of the vineyards of the highest reputation. For example, the port of Bordeaux facilitated the exportation of regional wines to the countries of the North; through the expansion of trade in quality products, wine producers were encouraged to perfect their growing and vinifying techniques. In order to do this, it was necessary in the various vineyards to select the most favorable terroirs and the best-adapted cultivars. One can easily imagine just how much improvement could be made through wine-tasting alone. It is certain that the creation of excellent wines implies, first of all, a certain refinement of taste and way of living, which is necessary for acquiring a precise idea of the criteria governing quality and its hierarchy. Today, one can only admire the results that have been obtained. The establishment of 'Appellations d'Origine Contrôlée' and the classification of growths have lent an official nature to the fame of quality wine.

However, these natural factors of soil and climate require certain conditions for the culture of the vine in order that its specific characteristics may be expressed. Moreover, the potential quality in the grapes can only be manifested in the wine if the many mechanisms of vinification work perfectly. The grape must is a product of the cells of the grape; it has the complex constitution of all living matter. In addition, during maturation, the grape is contaminated by numerous microbial cells (yeasts, bacteria and fungi). The juice which is the product of pressed grapes, and subsequently the wine, undergo a set of extremely complex microbiological and chemical transformations. Certain of these are useful and must be encouraged: others are harmful and must be avoided. For a long time, these processes were controlled only with empirical methods, and obtaining good wine was a chance affair.

The first achievement of science has been to optimalize these most complex natural phenomena and thus to avoid particularly serious accidents. But its impact has been much more far-reaching; by explaining the constitution and transformations of wine, scientific knowledge has revealed a concept of quality that would have been inconceivable using the old empirical methods.

The role of man was first to master the practice of vine growing: determining variety, stock, degree of fertilization, plant density per hectare, and carrying out annual trellising and pruning. A compromise must constantly be sought between quantity and quality. An important notion is that of the vigor of the plant; excessive vigor favors the development of the vegetative system, to the detriment of fruit maturation. Yields cannot be increased dramatically, without compromising quality; quality is not affected when the quantity is obtained with the conjunction of favorable natural factors; some famous wine-years were years when harvests were abundant. The improvement of culture conditions explains an increase in yields during recent years. But this tendency must not be pushed too far. It is difficult to fix a limit for this, since it depends on the particular conditions of each vineyard. While empiricism has underpinned the main rules to be respected, today's techniques are the subject of a much more rigorous approach. However, scientific data may be used only if the essential characteristics of quality are respected. It is certain that mistakes were made in the past as regards selection; these mistakes should now be kept in mind, so that they are not repeated in the future.

The use of genetic selection to improve the vine has always been a subject of research for improving quality and developing resistance to diseases. As for the latter, it was thought during the 1930s that interspecific hybridation could work, with a view to combining the qualities of *Vitis vinifera,* with the resistance to disease of other strains of *Vitis (V. riparia; V. labrusca)*. This ended in failure, since the quality of wines from these new hybrids was never that of the wines produced from *Vitis vinifera,* which is traditionally used for the production of great wines. The corresponding wines, produced at lower cost, could not be differentiated objectively from *Vitis vinifera* wines, especially when mixed in limited proportions. Fortunately, enological research found a way round the problem by demonstrating that the red pigmentation of grapes is different according to genetic origin. The identification of an anthocyanin diglucoside proves the presence of a grape from a hybrid cultivar, even when present at a minimal percentage in wine. The test is a simple one, using paper chromatography. In the 1960s, this means of control led to the abolition of a fraudulent practice which at that time was most prejudicial to the quality and fame of Bordeaux wines. Since then, the commercial status of Bordeaux wines has improved immensely.

Another example concerns selection, within different varieties, of individual types, or clones, which are the best adapted to the production of wine. For a long time, this approach was solely concerned with yield and resistance to disease and followed the vogue that was very common at that time in agriculture. Today, we have realized the need to consider specific qualitative criteria; the results of recent work are now showing; quality and yield are now being reconciled.

Similarly, vine culture is developing all the time. As in any industrial or agricultural sector, a principal concern is to reduce production costs by reducing manual intervention. Mechanization is becoming more and more generalized, even during harvesting. On the other hand, simpler procedures are being sought, notably with the decrease in the number of plants per hectare with modifications in the trellising system or in the replacement of field labor by chemical weed killers. Of course, such practices must be controlled in order to guarantee that no qualitative changes take place. Theoretical work carried out simultaneously on the biology and physiology of the vine helps in the interpretation of possible modifications, and to pre-empt any unacceptable deviation from the norm.

The maintenance of good health represents another fundamental technological acquisition; it has contributed greatly to the improvement in quality. The vine is a plant which is sensitive to many different diseases whose agents are insects, fungi or viruses, and some which are physiological in origin. History is strewn with catastrophes befalling viticulture due to the appearance and dramatic development of plagues such as phylloxera, mildew or oidium. The consequences are great, even to the point where the very life of the plant hangs in the balance. In certain extreme conditions, a whole crop may be lost; disease may give grapes and wines very disagreeable flavors, and, finally, an outbreak of disease may lead to the grapes having to be harvested before maturation is complete. Better means of protection have progressively been developed through phytopathological studies. For phylloxera, grafts are made on resistant stocks, and in other cases specific products are used for treatment; their efficacy depends on the good tending of the plant. It is quite clear that such procedures necessitate stringent control of their effects on the evolution of the vine and the maturation of the grape, on the fermenting ability of the musts and also on the constitution and quality of wines. Today, efficient means of treatment exist. It is only the protection against rot *(Botrytis cinerea)* which still poses certain problems; there are active products, but they are costly. Their intensive use may favor the selection of strains resistant to *Botrytis.*

However, it can be said that we are now able regularly to harvest healthy, mature grapes, an indispensable precondition for producing good wine.

The study of the transformation of grapes into wine, of the constitution of wine, of its stability and of its aging process, is the field of enology. Enology, the science of wine, as it is conceived of today, dates back to the famous studies on wine by Pasteur (1860). Moreover, in this respect, it must be remembered that grape must, along with beer must, served as a study medium for the prestigious discoveries about fermentation which led to the creation of contemporary microbiology and biochemistry. Pasteur demonstrated the role of yeast, a living cell, in the fermentation which transforms grapes into wine. In addition, he discovered lactic bacteria, agents bearing disease with consequences prejudicial to quality. Moreover, he showed how it was possible to contaminate a healthy wine by inoculating it with a few drops of unhealthy wine; and it was this observation which put him on the right track for discovering the transmission of contagious diseases in humans and animals.

The work of Pasteur was an important stage in the control of vinification. With chemical analysis, the control of microbial phenomena become possible. Bacterial accidents could be better controlled; the generalization of aging and the corresponding improvement became possible. However, such discoveries were most advanced for their time and it was difficult to make them widespread in viticultural circles at the end of the nineteenth century. Particularly, the stabilization of wines by pasteurization never caught on.

One had to wait until the 1930s for a renewed interest in enological research, this time with the association of concepts from physical chemistry, which at this time were quite new, such as pH values, oxidoreduction and colloids. Enological research tended to concentrate essentially on chemistry, looking particularly at problems of clarification and stabilization. The problem then was to acquire the knowledge which would allow limpid vines to be conditioned and for this limpidity to be maintained during aging. This work led to the description of various chemical phenomena (iron, copper or protein casses) which were liable, under some conditions, to give rise to turbidity or the formation of deposits, which constitute serious accidents if the wine is already bottled. Procedures for predicting and preventing such accidents were developed.

In brief, research developed in a way which was the inverse of the process of production. That is to say, it looked first at problems of conditioning before looking at vinification. It may be easily understood that there was no point in improving quality if it was impossible to maintain this quality during conservation, processing and aging. In effect, the rational study of different forms of vinification goes back only to the 1960s. A review of successive publications in enological literature bears witness to this evolution.

In the recent past, enological research, which used to be based essentially on chemistry, has turned more and more to microbiology and biochemistry. In particular, our microbiological knowledge of wine has been completely revised.

First of all, the notion of malolactic fermentation has become definitely established in the last 25 years or so. The first observations showing that this reaction is indispensable for the development of quality in red wines were in fact made more than 30 years earlier. But such ideas went against the theories of Pasteur, who considered lactic bacteria as causes of disease. In fact, when they degrade malic acid they are favorable to quality, but when they attack sugars, they form volatile acids and this constitutes a serious accident. Today, one of the roles of the enologist is precisely to create the conditions in which these bacteria intervene only when all the sugar present has been fermented by the yeast. Malolactic fermentation is a bacterial transformation of malic acid, with a reduction of acidity lending suppleness to wines and improving them, at least in the case of red wines. The fermentation also gives bottled wines greater stability; in wines which do not contain sugar, malic acid is the molecule which is the most easily biodegraded. Malolactic fermentation has become the rule in Champagne, and this is essentially for reasons of stability; it is essential to be sure that it cannot occur in the bottle.

The use of paper chromatography provides a simple test for the presence or absence of malic acid. Using this technique, the existence and the importance of this secondary fermentation have been definitively established. Earlier, only chemical assay methods were available and these were complicated and not very accurate.

Similarly, the alcoholic fermentation of grape must has been the object of important recent research which has completely modified basic concepts. First, it must be noted that it is impossible to transpose the classic ideas of general microbiology to vinification, which has its own particular characteristics. Grape must is a medium rich in sugar, and is inoculated by indigenous yeasts to a significant extent. The cessation of the growth of the yeast population is not controlled by the exhaustion of the sugar substrate. The fermentation of the last grams of sugar is brought about by cells in a survival situation. In order to accelerate this fermentation, it is not enough to increase the maximum population; it is still more important to increase the fermentation capacity of the cells in the decline phase. These discoveries have led to the notion of survival factors, which complements the earlier notions about growth factors.

All these research developments have contributed to a better mastery of the phenomena of vinification. By avoiding deviations and accidents, such knowledge has regularly led to the expression, in the quality of wine, of all the potential of different grapes.

In enology, important technological progress has been made in the recent past concerning the materials and equipment available to the professional. It is true that this development has been slowed down by the seasonal nature of wine production. But nowadays, work carried out on the vine, on the one hand, and the processes of vinification and conservation, on the other, both have at their disposal mechanical means for simplifying and improving the work. For example, vinification cellars are now systematically equipped with temperature controlling devices, which have contributed greatly to the mastery of fermentation.

Yet this development of equipment and work conditions has sometimes led to an exaggerated simplification of operations, particularly with the reduction in personnel. Serious mistakes have been made in the past in not respecting enological imperatives. Some significant examples, involving white wines, date back about 50 years; at that time a simplification in the vinification process consisted in replacing, for the process of fermentation, low capacity casks with large volume tanks. Since fermentation produces calories, the problem of overheating arose. Yet nowadays it is common knowledge that yeast fermenting at a low temperature forms more esters, therefore more aroma, than yeast fermentating at a higher temperature. Without it being realized, the consequence was a decrease in quality. Cooling systems should have been planned simultaneously, but they were introduced only much more recently.

Another example concerns the treatment of the grape (crushing, draining and pressing) which is necessary in juice extraction. Today, it is possible with powerful machines to process rapidly large quantities of harvested grapes. However, such machines exert a brutal force on the grape and thus give musts which are more turbid than

those obtained with the manual processes used in the past. Moreover, in this case, it is now known that the fermentation of a clear must is necessary for obtaining aromatic white wine. The conclusion was therefore drawn that the use of such machines, necessary for economic reasons, requires clarification of the must before fermentation.

At the present moment, the extent of enological knowledge is much greater; the conditions for good vinification are much better defined and such processing problems are now no longer possible. This could be clearly seen at the time when the harvesting machine came into general use. The process was a progressive one, and the problems arising were also solved progressively. The performance of the machines was improved, skill in using them was developed and the vine itself was better prepared for this kind of harvesting. At the some time, people looked for ways of profiting from some of its advantages, especially its flexibility in use. Mechanical harvesting will certainly continue to develop and, in a few years, only certain special vineyards will still be harvested by hand.

Thus, an eminently traditional activity, the production of great wines, has profited enormously, in the relatively recent past, from the development of scientific knowledge and from technical progress. The consequence has been a certain improvement, and sometimes a considerable one, in quality, and the Bordeaux vineyards provide a good example of this. Moreover, the current prosperity of these vineyards, which is exceptional in their history, bears witness to the reputation of these wines with wine-lovers; they are sometimes ready to pay high prices because they appreciate quality and recognize that it is consistent.

The analysis of old wines which still exist today provides a good insight into what wine-tasting in the past must have been like. A large number of analytical factors may provide evidence of technological defects whose consequences for the taste would no longer be accepted today. Among old wines, some have always had a better taste, and today's methods of analysis have shown that these wines were technically the most modern in their structure; it was only by chance that such results were formerly obtained.

It is not only by eliminating defects that quality has improved, but also by perfecting types and characters. This improvement has had results simultaneously on maximum quality and average quality; it has led to the elimination of mediocre wines. Present-day wines are without doubt more smooth and supple, but they also retain for a longer time the aromatic freshness of the fruit, which is the expression of the character of the 'terroir' concerned. Vinification and conservation must indeed be conducted perfectly and with the greatest rigor, in order to allow the expression in the wine of the natural character of the grape, which must not be hidden by the disastrous consequences of microbial or chemical accidents.

It would certainly be erroneous to believe that everything is now known as regards the culture of the vine, vinification and conservation of wines; nor must it be thought that progress today is only a question of popularizing definitively established ideas. The enduring technical revolution, which has been the hallmark of the last 20 years, shows that this is not at all the case. The process is far from being finished and it continues today. New discoveries are still leading to new progress.

The improvement of the vine with regard to the quality of production and the resistance to disease should benefit from the development of genetic engineering. It may be supposed that the technique of in vitro culture will be applied to the vine in as fruitful a manner as for other cultivated plants. Similarly, research is under way on developing robots capable of pruning the vine, taking into consideration not only the shape of the plant but also the type of pruning, which is a factor dictating the volume of the crop.

With regard to the production of wine, we know today how to realize fully the potential of the grapes through the mastery of vinification. Consequently, new progress will involve the improvement of the grapes. Enological research must thus turn more and more to looking at the criteria of harvest quality; the incidence of varieties, culture conditions and possible diseases must be specified. Significant progress in this area necessitates new knowledge of the chemistry and the biochemistry of the grape.

Technical refinements are also necessary for defining the conditions for maturing wines in oak casks and for aging in bottles. The conditions used at present are almost entirely the result of empirical observation, and are the heritage of a tradition lacking scientific grounding. One is concerned here with organic chemical reactions of a most complex nature, the study of which is made even more difficult by the fact that the changes are very slow. These reactions intervene particularly in the well-known evolution of color in red wines during long aging, the theoretical interpretation of which remains most imprecise.

Finally, enology stands to benefit from the modern biotechnologies which could permit the creation of new microbial strains (yeasts or bacteria), which are better adapted to the production of quality wines and which might eventually lead to the production from grapes of completely new beverages which would be different from wine.

In any case, a major preoccupation during the development of new techniques must always be to respect the permanent criteria of quality, the result of natural factors. It is clear that today the conditions of work in the vineyards, the wineries and the cellars are no longer what they used to be. Other changes will also take place. As with all human enterprise, the role of the human hand will diminish in the quest for increasing productivity, and working conditions must therefore be modified. Yet these changes should take place without compromising the characteristics and typicalness of wines. It is absolutely essential to avoid the errors of the past which were due to technical modifications having little compatibility with quality. Fortunately today we are, thanks to enological developments, no longer at the mercy of such shortcomings in quality and we may therefore be optimistic, since we may be sure that the quality of great wines will be guaranteed in the future.

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