The notion of grain in cooperage

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Summary : All the studies conducted on the grain or growth rings of wood have systematically underlined the narrow relationship between this notion and the quality of oak. In cooperage, the objective classification of wood coming from diverse producing regions of France puts forward the first condition which will determine the quality of barrels. The grain is defined, in the anatomy of ligneous plants, as the average size and regularity of annual growth rings. A ring is made up of spring wood (initial wood) porous and rich in large vessels and summer wood (final wood) which is dense and rich in fibre. It can be said that an oak will be tight grained when its speed of growth is slow, the size of its rings small and the amount of spring wood high. Wide grain has the opposite definition. In keeping with obtained data on a large number of samples, we have established the following classification, based on the average size of the rings (Lc) : very wide grain (GtG, large type, Lc > 5 mm), wide grain (GG, Limousin type, 4 ≤ Lc ≤ 5 mm), average grain (GmS, Vosges type, 2 ≤ Lc ≤ 4 mm), tight grain (GS, Centre France type, 1 ≤ Lc ≤ 2 mm) and very tight grain (GtS, Allier type, Lc < 1 mm). The study of the chemical composition shows that there exists a relation between the grain and the quality of the wood. In fact, we show that the wide grained woods are richer in extractable compounds and in ellagitannins whilst poorer in aromatic compounds (eugenol and whisky-lactones) than the tight grained oaks.

Key Words : Fagaceae, Quercus sp., annual growth, spring wood, summer wood, grain texture, porosity, composition

INTRODUCTION

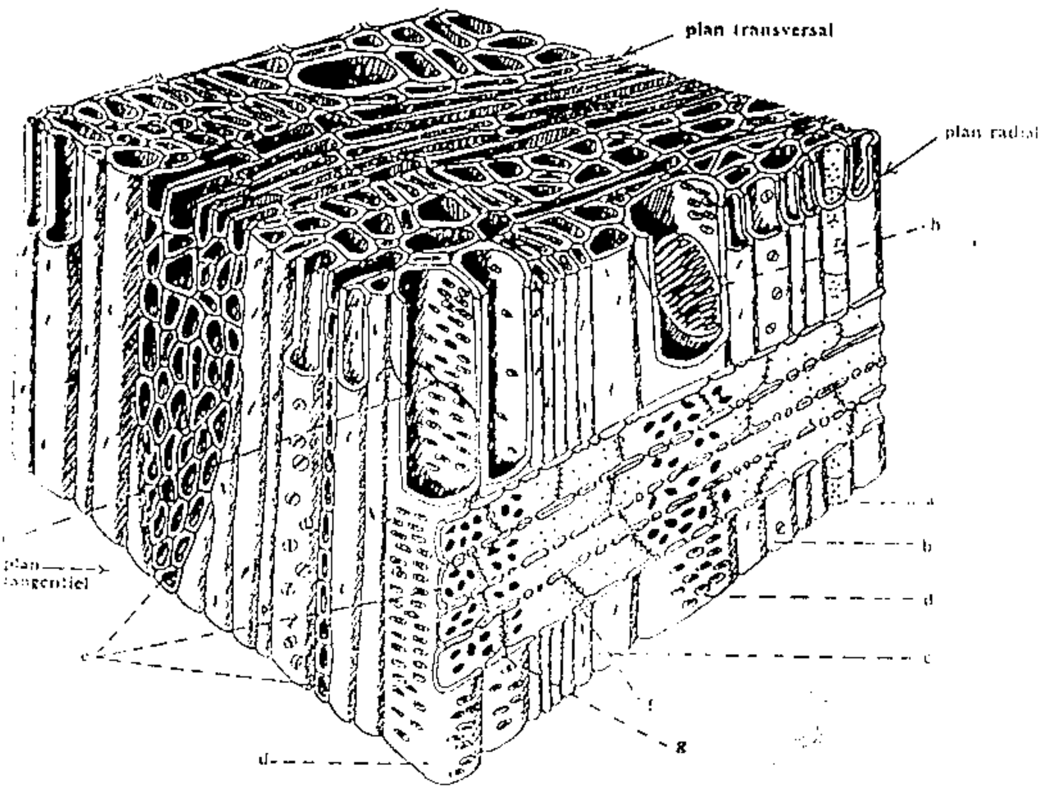
In cooperage like as in œnology, the quality of the raw material determines that of the finished product, be it barrels or wine. Thus one cannot make good barrels with bad wood.The quality criteria for oak are in keeping with the strict requirements for the ageing of wines and brandies. Firstly, the wood should be sufficiently porous to enable a slow and continuous penetration of oxygen (VIVAS and GLORIES, 1993 ; FEUILLAT and *al.*, 1993) next it should release its extractable phenol compounds (lignins, ellagitannins, phenolic acids, coumarins) and aromatic elements (whisky-lactones, eugenol and vanillin...) in moderate quantities so as not enhance the astringency and add bitterness, whilst avoiding making the nose of the wine too heavy through an excessive woody aroma (DUBOURDIEU, 1992). What is more, the wood fibres should be straight and uncut in order to assure waterproofness. Wood with burrs and knots are eliminated for the same reasons. Meanwhile, certain of these parameters are difficult to follow especially in batches of wood used for the fabrication of barrels. Coopers have thus investigated the best phenotypes criteria which will allow for a quick and accurate visual classification. Cooperage oak should be of the highest quality, straight, contain no knots or burrs, with little sapwood and regular rings, commonly known as the grain of the wood (LACROIX, 1993). The most commonly accepted criteria are those of the geographic origin of the wood and their grain. Geographic origin and type of grain are classified equally, thus the oaks from Limousin are said to be wide grain, those from Allier and Vosges are said to be tight grain. In this context, it is easier to understand the importance of the notion of grain. These classifications, by grain type and geographic origin, are important determinants in the demand and therefore the price of the wood. In recent years, the race for tight grain, of finer and finer quality, has come about for wines and brandies alike. The origins the most sought after are the Centre France, the Allier, the Bourgogne and some forests of the Seine-et-Marne and the Oise. The wood bought from these regions never ceases to increase. This venture, under the guise of a vague notion of quality, merits a complete study of the quality criteria of oak. Approaching the notion of quality by the structure and grain of the wood appears to be an obligatory starting point. It is to FEUILLAT and *al.* (1992) that we owe the first attempt to synthesise the notion of grain. Their past reviews on the evolution and definition of the grain remain full of lessons.

On this note, we propose to clarify the biologic origin of wood grain, the evolution of its classification and definition, as well as the eventual correlation between the grain and the composition of the oak.

THE ANATOMICAL CHARACTERISTICS OF OAK AND MORE PARTICULARLY THE GROWTH RINGS

Unlike gymnosperms (resinous), the angiosperms (leafy) have a complex ligneous scheme (type and distribution of tissues), illustrated by JACQUIOT and *al.* (1973) and shown in figure 1. It is the great diversity of nature and the disposition of the generating cells of the libero-ligneous stratum (cambium), this union enable the diametric growth of the tree (figure 2), which allows the structural and anatomic diversity of the wood.

In the centrifugal direction, the cambium forms the phloem, tissue in which the elaborate sap circulates, and the suber or cork making up the tree (figure 2). In the centripetal direction, the cambium releases the xylem formed by a collection of conducting tissue (vessels) and supporting tissue (fibbers). The young xylem of 5 to 10 years old conveys the raw sap and is called sapwood or imperfect wood (figure 2). After that the hardening of the older layers form the heartwood (duramen or perfect wood) made up of a collection of dead tissue, rich in lignin and impregnated with tannins (figure 2).



a : longitudinal parenchyma - b : tracheal fibre - c : free form fibre - d: vessel with inter vascular areal punctuations - e : rays (beams, radiation) - f : simple beam fibre punctuations - g : simple vessel fibre punctuations - h : scalariform perforation - i : unique perforation

Figure 1 — The ligneous scheme of angiosperms. Applicable to broad leafed woods of heterogeneous structure and in particular to *Quercus sp.* (adapted from JACQUIOT and *al.*, 1973)

An oaks growth is essentially in a centripetal direction, therefore increasing the significance of the heartwood. Only this part of the oak is used for cooperage, the sapwood which is too porous and supple, as well as the phloem and the bark are discarded.

Each year, the development of the oak produces a layer of wood called the growth zone or the growth ring. Each ring represents one year in the life of the tree.

On plate 1 taken using a scanning electron microscope, slightly enlarged, one can see some growth rings. But one remarks at the same time that a ring is represented by a heterogeneous structure made up by a gathering of large vessels at start of the ring and the tissues appear later, dense, fibrous, slightly vascular, with vessels which are smaller in size and less numerous. The notable irregularity in annual growth corresponds to the production initial wood and spring wood at the beginning of the vegetative cycle (figure 3). When the vegetative cycle is more advanced, the final wood or summer wood appears (figure 3).

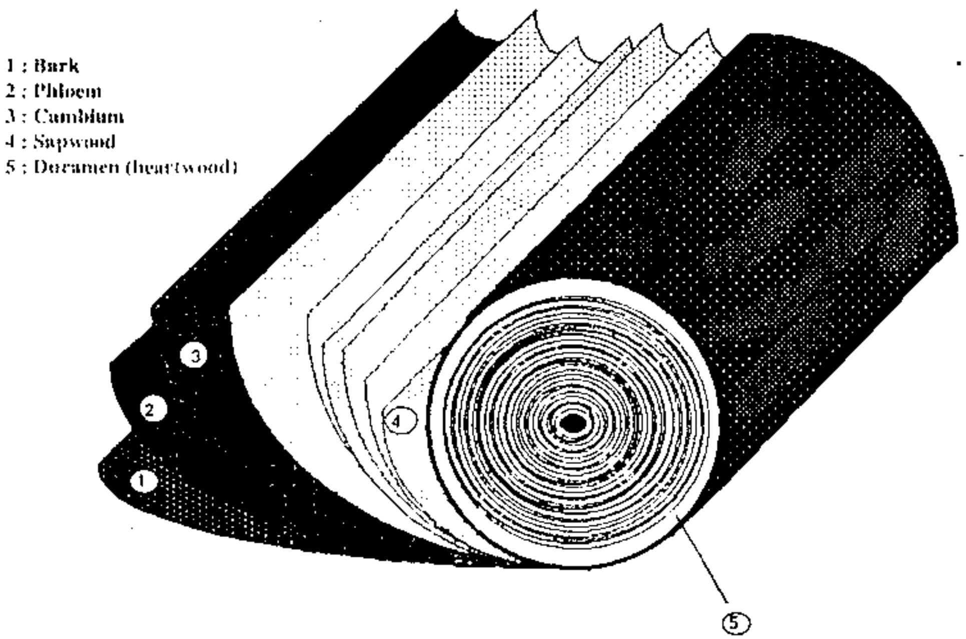


Figure 2 — Transversal section of old oak showing the different tissues

Cliché 1 — Scanning electron microscope detail of transversal section of oak wood

The increase in the growth speed favours the production of final wood, it is a function of the environment, the climate, the soil and also its genetic ability (DERET-VARCIN, 1983 ; NEPVEU, 1984)

The grain notion finds its origin in the average size and the regularity of annual growth rings (COLLARDET and BESSET, 1992). The regular growth rings give the wood a tight homogeneous grain, opposite to irregular growth which gives the wood a wide grain. Beside the grain, notion of texture completes the description of the heartwood ; it is defined as the proportion of summer wood in the total make-up of a ring (COLLARDET and BESSET, 1992).

DEVELOPMENT OF THE GRAIN NOTION AND THE CLASSIFICATION CRITERIA APPLICABLE TO OAK FOR COOPERAGE

The grain notion and its definition have changed slightly in the of course time, with only the terms characterising the nature of the grain having been modified. According to GALLOT and GAST (1878) « *nerve woods are characterised by strong growth, a thick layer of autumn wood (at present summer wood), a fibrous break [...], the fleshy wood having thin*

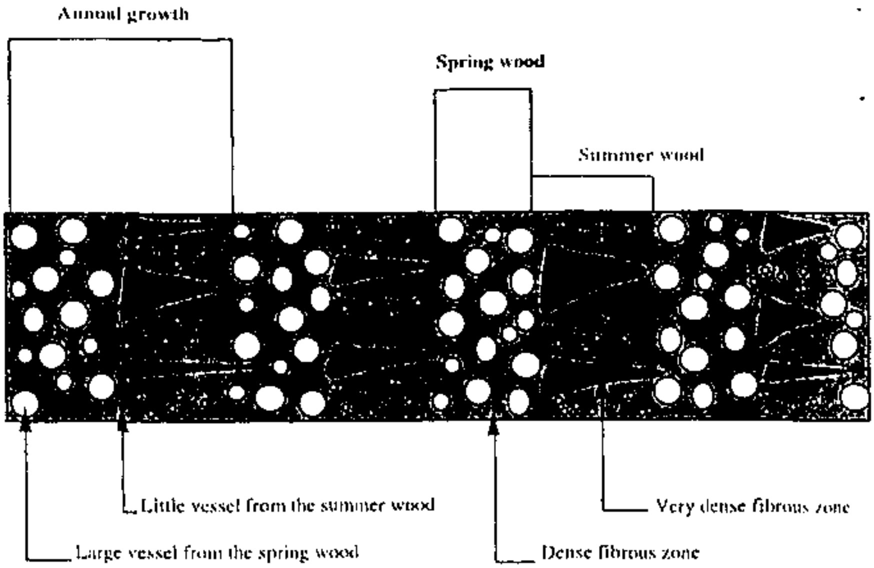


Figure 3 — Scheme of the structure of the heartwood (transversal section)

annual layers, leaving the appearance of vessel openings of small diameter on their entire surface ; their tissue is porous, their grain not very tight ». Already in those days, the grain notion was associated with the porosity of the wood ; under this classification we can recognise the Limousin type (vigorous wood, strong annual growth, a fibrous break and a thick layer of summer wood) and the Allier type (fleshy wood, not very thick annual layers). But the two definitions are sometimes contradictory, particularly for the fleshy wood which corresponds perfectly with the definition of a tight grain but whose definition ends with « *their grain is not very tight* ». MATHEY (1908) gives precision to the definition of GALLOT and GAST : « *One indicates when using the name lean wood (nerve wood), those which present a large proportion of autumn wood, in other words fibrous tissue. The section is full and smooth, often giving a corny appearance. This wood has a tight grain and takes on a good shine. Pedunculate oak, coming from a coppice under plantation in tertiary and quaternary alluviums, produces these types of lean woods* [...]. *The fleshy woods are those in which the porous spring formations predominate, in other words the vessel or conductive tissue. The section is uneven, the grain wide, and always has a brownish appearance. Rouvre oak (sessile), which have developed in rocky terrain or those providing huge tracts of continuous plantation, are the fleshy type woods* ».

But there again, the definition, even though precise, stipulates that the Limousin type is tight grained and the Allier type is wide grained. LARUE (1923) et BRUNET (1925) invert the denomination of these two categories, whilst conserving the definition of MATHEY. They attribute to the Allier type (rouvre or sissile oak) the denomination of tight grained and the Limousin type (robur or pedunculate oak) that of wide grained. This definition which was made official by the B.O.S.P. (Bulletin Officiel des Scieurs Professionnels) in 1943 (n°21.12.43) and revived by VENET in 1954, after some modifications, has led to a contrary designation to that of the authors of the last century :

Previously (1750-1920) :
lean wood = nerve wood = wide grain - fleshy wood = tight grain ;

At present (1920 - ?) :
lean wood = tight grain = tight grain - fleshy wood = wide grain.

At present the French norm « NF » has classified the all wood in two categories inspired by past findings (NF B 50-002). We distinguish between :

- tight or homogeneous grain woods, where the vessels are small in size and not easily visible with the nude eye, as in the case of beech, poplar and pear wood ;

- wide or heterogeneous grain wood, where the vessels are reasonably large in size and visible to the nude eye, as is the case of oak, chestnut, locust and ash trees.

But in the context of cooperage, the classification of wide grain wood has been subdivided, for oak, into tight, half-tight, and wide grain. It is in this sub classification that the values of each category varies in accordance with the regions and coopers. Thus there exists no objective nor common classification limit for oak wood in France nor within the European Community.

For some years, the notion of grain has been extended to include the anatomic characteristics of wood and in particular the dimension of the number and volume of vessels (FEUILLAT, 1991). This original approach lends to completing the available ways of studying the structural characteristics of oak and the evaluation of its qualities.

Thus the classing of oak necessitates nowadays combining the notions of grain, texture, as well as the application of biometrics when describing the vessels. Within two centuries an entire science consecrated to the study of wood has been established : xylology whose founding father is Philibert GUINIER (1876-1962), a forest botanist and director of the water and forests engineering school, and Marcel MONNIN (1877-1944) curator of water and forests and initiator of the physical and mechanical methods for testing wood. Work as from the end of this century was to regroup all these diverse notions in order to come up with a general classification of oak wood in relation to its quality. A first attempt was launched by the Institut National de la Recherche Agronomique (The National Agronomic Research Institute) in collaboration with the Office National des Forêts (National Forestry Bureau). The second attempt was initiated by the DEMPTOS cooperage research department and these results will be presented in the next chapter.

POSSIBLE RELATIONSHIPS BETWEEN THE WOOD GRAIN, THEIR STRUCTURE AND THEIR CHEMICAL COMPOSITION

POLGE and KELLER (1973) attempted to link quality with grain, for oak wood from the Tronçais forest and DERET-VARCIN (1983) performed a qualitative study of three types of oak (pedunculate oak, sessile, and the intermediary types) based, inter alia, on the grain of the wood. These different authors statistically linked the quality criteria to the grain oak wood, although their criteria are still a long way from the imperative cooperage requirements and are still and tend essentially toward the mechanical properties. More recently, the grain notion has been intimately associated with the porosity of the wood (FEUILLAT, 1994). In figure 4, one can observe that the spring wood possesses a low density which is due to the significance and size of its vessels. Porosity can be defined as the empty volume (vessel, tracheas, lumens) making up the total volume of the wood ; porosity is thus directly related to the structure of the wood and particularly the nature of its grain. Permeability is another characteristic which shows the ability of the material to enable a passage for fluids under normalised conditions (pressure, positioning of the sample, dimension). Although, even though oak is a porous wood (porosity = 0.5), it is reasonably impermeable.

We have attempted, on a batch of 180 wood samples (for each geographic origin) coming from the Limousin, the Vosges and the Centre France, to study the variability of their growth zones by concentrating in particular on slightly fibrous, very vascular and thus porous spring wood (figure 4).

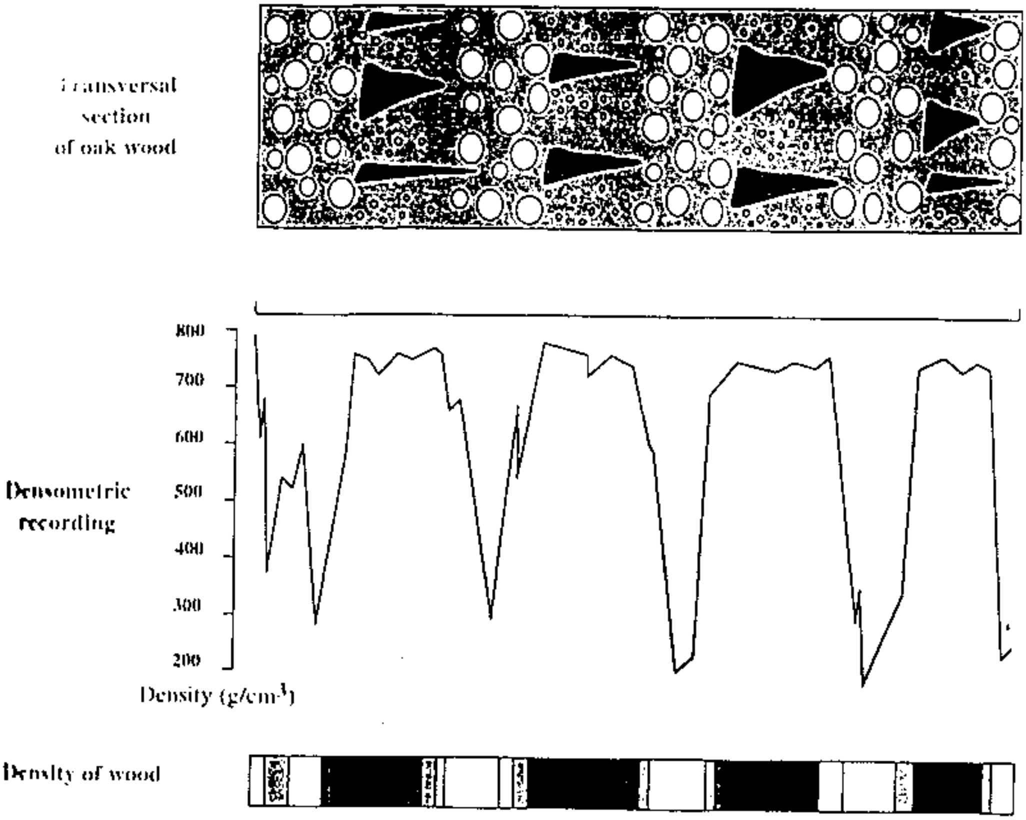


Figure 4 — Densometric measure of a transversal section the heartwood an oak (x-rays parallel to the wood fibres)

From this sampling, we only kept 30 individuals situated within the general vicinity of each geographic group, we established their dry water soluble extract, the total content of ellagitannins quantified by CLHP, the whisky-lactones content and of eugenol with coupled CG/MS. From these first results, we propose putting forward the relation between the grain (table 1) and the composition of the wood (table 2).

In table 1, the measures of the wood growth are grouped ; the heterogeneity between the maxima and minima of each group gives the average ratings (0.4 < heterogeneity < 0.65) to be in the order of those established by DERET-VARCIN (1983) and FEUILLAT and *al.* (1993). We notice, on average, that the grain (evaluated by the number of rings/cm) is a function of the geographic and botanical origin of the wood.

Table 1 — Variability in the growth of wood samples from the Limousin, the Vosges and the Centre France. (n = 180 ; V.C. : variation coefficent)

Origin of the wood	Variability of the sample	Number of growth rings/cm	Size of the zone of spring wood (mm)
	Average (x)	2.22	1
	Minimum value (x-)	1.53	0.54
Limousin	Maximum value (x+)	3.67	1.36
	Heterogeneity (x-/x+)	0.41	0.39
	V.C. %	28	21
	Average (x)	3.44	0.77
	Minimum value (x-)	2.42	0.45
Vosges	Maximum value (x+)	5.75	1.17
	Heterogeneity (x-/x+)	0.42	0.38
	V.C. %	29	29
	Average (x)	5.56	0.39
	Minimum value (x-)	5.56	0.27
Centre France	Maximum value (x+)	8.55	0.57
	Heterogeneity (x-/x+)	0.65	0.47
	V.C. %	14	18

Wood from the Limousin (*Quercus robur*, syn *Q. pedonculata*) has a wider grain whilst those from the Vosges and the Centre France (*Quercus petraea*, syn. *Q. sessiliflora*) have average grain and a tight grain respectively (plate 1). It equally appears that the size of the zone of spring wood decreases when the grain becomes denser, along with a drop in the growth speed. On initial classification of the grain, from these results, we point out (figure 5) that the Limousin type (wide grain, GG) have ring sizes of 4 to 5 mm, the Vosges (average grain, GmS) sizes of 2 to 4 mm and the Centre France (tight grain, GS) sizes of 1 to 2 mm.

The archetype of the wood with very tight grain (GtS) are generally the Allier, we therefore reserve the Allier type for wood with ring sizes strictly inferior than 1 mm and which represent only 7 % of the sampling of the Centre France type, but bringing about an undeniable quality argument.

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Table 2 — Variability in the composition of the oak wood samples from the Limousin, the Vosges and the Centre France

Origin of wood of the sample	Variability	Dry extract (mg/g)	Total ellagitannins (mg/g)	Eugenol (µg/g)	Whisky lactones (µg/g)
Limousin	Average (x)	109	62.5	1.1	5.5
	Minimum value (x-)	99.7	30.5	0	2
	Maximum value (x+)	118	87.6	2.4	13
	Heterogeneity (x-/x+)	0.84	0.34	—	0.15
	V.C. %	5.4	24	52	56
Vosges	Average (x)	97	72	0.66	58
	Minimum value (x-)	56.8	19	0	28
	Maximum value (x+)	161	118.8	1.6	77
	Heterogeneity (x-/x+)	0.35	0.15	—	0.36
	V.C. %	25	34.5	64	25
Centre France	Average (x)	77.8	37.2	11.5	80
	Minimum value (x-)	66.7	20.1	4	64
	Maximum value(x+)	109.7	55.7	16	121
	Heterogeneity (x-/x+)	0.6	0.36	0.25	0.52
	V.C. %	13.5	36	29.5	15

These groups represent the different geographic origins, selected from the results of table 1
(n = 30 ; V.C. : variation coefficient)

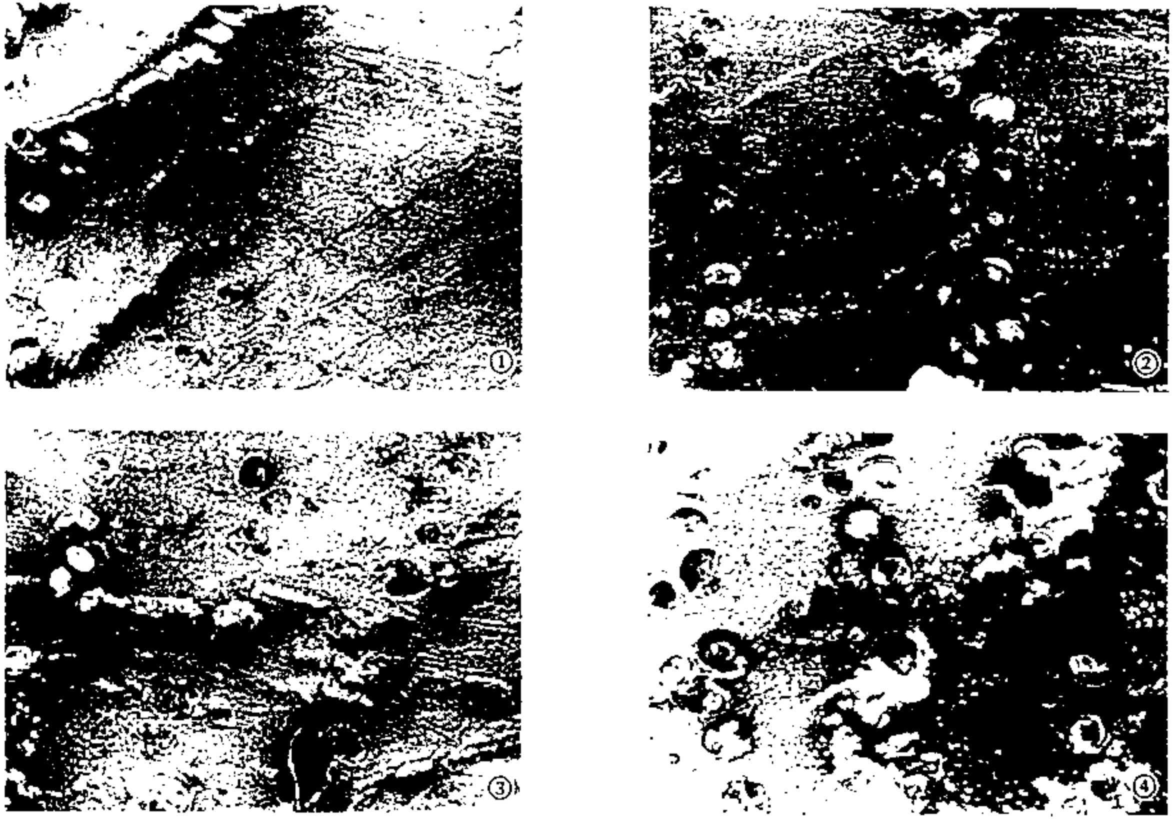

Plate 1 — Scanning electron microscope detail of transversal sections of different heartwood from oaks typical to the regions of Limousin (1), Vosges (2), Centre France (3) and Allier (4) (x 25.4)

We observe that the decrease in the speed of growth (from 1 to 4) is expressed by a reduction of the final wood zone to the benefit of the initial wood, which is greatly vascularised

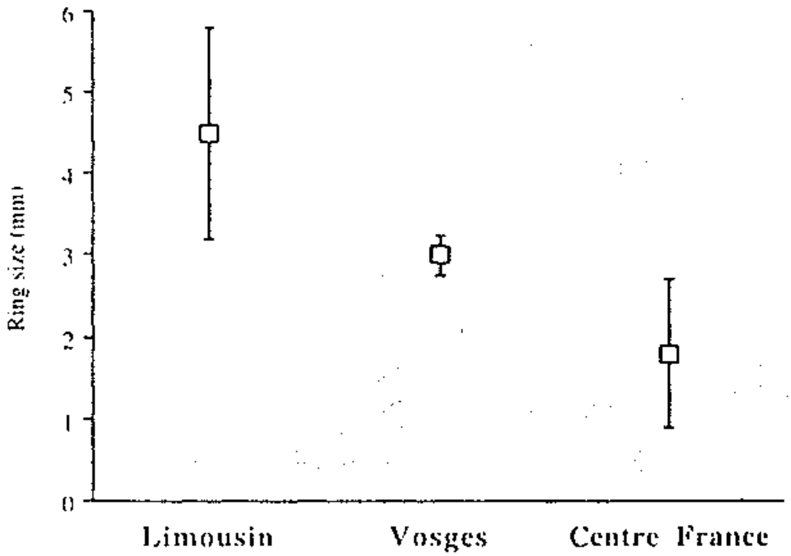

Figure 5 — Influence of the geographic origin of oak on the ring size of the wood (n = 180/origin)

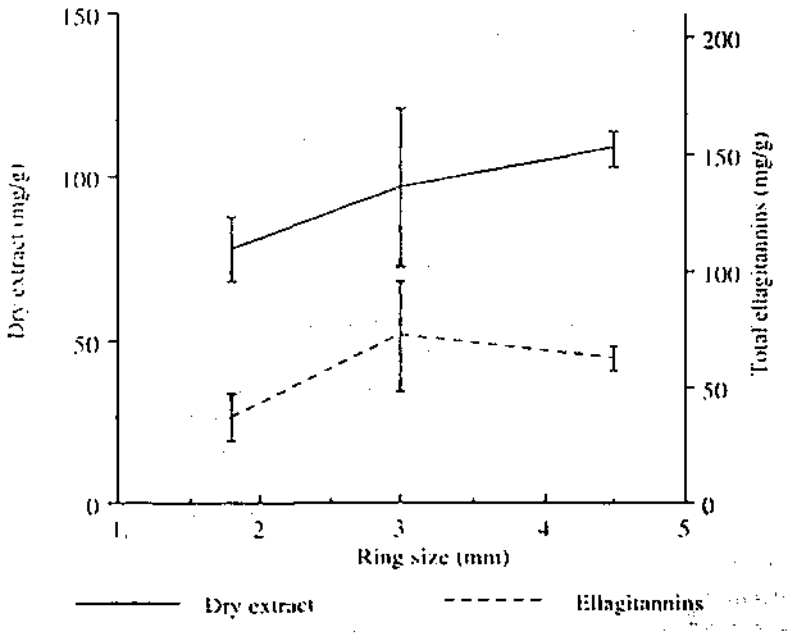

Figure 6 - Relation between the dry extract, total ellagitannins and the size of the growth rings (n = 90)

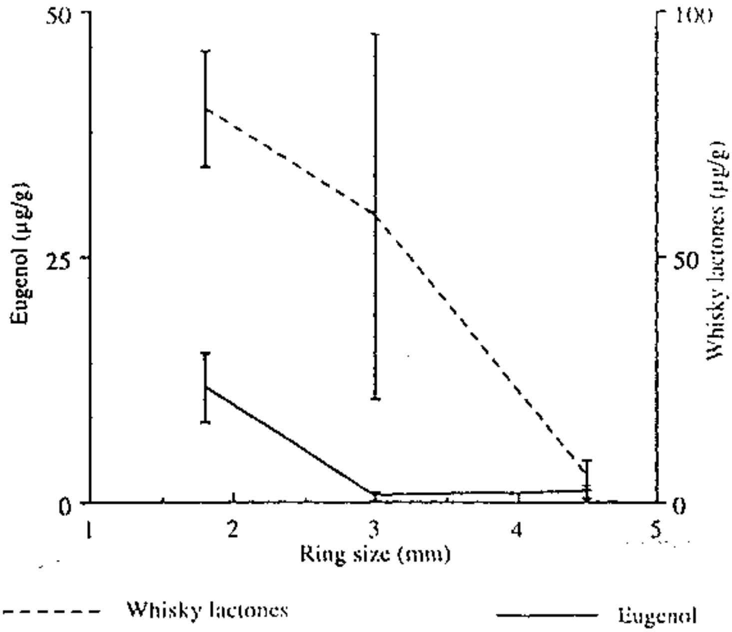

Figure 7 — Relation between the content of aromatic compounds and the ring size of the wood (n = 90)

Finally we reserve for wood with ring sizes strictly larger than 5mm the denomination of large type (very wide grain GtG),this class allows one to differentiate the Limousin type into grain wideness, particularly large grain coming from wood which has grow very quickly. This is to prevent a « scrap » category from coming about, for wood considered insufficiently noble.

The variability in the growth of oak within the same region is high (± 30 %) and facilitates the explanation, for example, as to why portion of the wood from Limousin should rather fall into the Vosges category. On the other hand, the wide grained woods are richer in dry extract and in ellagitannins than the tight grained woods (table 2 and figure 6) and containing less whishy-lactone and eugenol (table 2 and figure 7). There thus exists a relation between the grain and the composition of the wood. According to certain authors (PONTALLIER and *al.*, 1982), they propound that wide grained woods yield barrels which provide little in the way of aromatic compounds and give a lot of phenol compounds in the wine. Inversely, barrels made from tight grained wood give the wine more aroma and less polyphenols.

CONCLUSION

The grouping together of the most significant works relating to the notion of grain in cooperage enables the subject to be tackled from a more synthetic point of view. Past and present studies enable the confirmation of a relational existence, more or less direct, between the growth of oak and some of its physical (ring size) and chemical properties (aromatic and phenol compounds).

The primary established connections should be seen in a generalised sense concerning the processes which lead to on the one hand, the objective classification of cooperage wood and the establishment of methods of quality control and on the other hand, a precise definition of the composition and structure of the wood, in general terms, in the long run, the adaption of wood with wine leads to the adaptation of heating when pairing wood/wine. This qualitative ambition represents the new challenge of the XXIth century for French cooperage as a whole.

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