Introducing Mulberry's wood (*Morus alba* L.) used in bowl shaped musical instruments of Iran

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Abstract: Morus alba L. *is the main species for making traditional bowl shaped musical instruments (Tar, Setar and Kamanche) in Iran. Its outstanding sound quality has always confirmed by professional instrument makers but never has been proved by scientific tests. Thus, this study designed to make a better perception to Morus alba's acoustical features and to find the possible relation between its anatomical structure and its sound quality. In this study mulberry's wood from different sites in Iran was chosen. A series of anatomical tests and observations were planned. The Anatomical properties were studied using both light microscopy and Environmental Scanning Electron Microscopy (ESEM). Contact analysis method & damping method were used to determine the different acoustical factors in this wood. Modulus of elasticity, damping factor, sound velocity & sound quality were the analyzed factors. Anatomical investigation showed influential factors in mulberry's structure: its semi diffused porous structure accompanied by having axial parenchyma from paratracheal type; are making Morus alba as a wood which theoretically will have a good acoustical quality. The results of acoustical tests on the mulberry's wood showed a distinct similarity between Morus alba and some other woods which are used in making guitar and violin. The importance of having lower damping (due to the increase of Q factor) and narrower growth rings (which our mulberry had) for using it in making Iranian musical instruments was observed.*

I Introduction:

Over the centuries, different kinds of woods were used in making musical instruments due to their exceptional mechanical and physical properties. The sound qualities of woods often were assessed by the procedures of trial and error by instrument makers.

For long time *Morus alba*'s wood (Mulberry) considered to be the main species which were used and still is used for making Iranian bowl shaped musical instruments (Tar, Setar & Kamanche).
Among the three instruments mentioned above, Tar is one of the most important Iranian musical instruments. The current shape of Tar is formed in the eighteenth century. The body is a double-bowl shape carved from mulberry wood, with a thin membrane of stretched lamb-skin covering the top. The long flat fingerboard has twenty-five to twenty-eight adjustable gut frets, and there are three double courses of strings (Figure 1). It is played with a small brass plectrum.

Figure 1. Tar made by Mr. Zare

For more than 200 years, traditional instrument makers used the mulberry wood for making Tar and the other bowl shaped instruments. This study started to do a comprehensive investigation on the wood and the structure of this important instrument. In this paper the micro structure and some preliminary results on the acoustical properties will be presented.

II Materials and Methods:

II.1 Sampling and Sample Preparation

From north to south of Iran concerning the weather situation; in the areas with enough water availability the Mulberry trees could grow. For this study from four areas namely (Chalous Road, Kan, Tarom and Shiraz) the wooden samples collected from the stem of the trees.
Concerning the different experiments which was planed the sample preparation was different.
For light microscopy, samples were cut with dimensions: 2cm (L) × 2cm (R) × 2cm (T) and then using the microtome micro sections were prepared. Method of sample preparation and colouring of the micro sections were done using Schweingruber et al. 2006. Small chips of woods also prepared for maceration and the method was base on Franklin

1945. For studying the samples by Environmental Scanning Electron Microscopy (ESEM), specific cuts on tiny samples were needed. Unlike the previous method (SEM), metallization were not took place on the samples. For direct contact analysis samples were taken from 2 sites (Chalous Road and Shiraz). For each site 6 samples were cut with dimensions: 2cm (L) × 2cm (R) × 2cm (T). The samples were left in the laboratory to reach the equilibrium humidity with the environment. For damping measurement (Q factor) very thin samples were taken with these dimensions: 150 mm (L), 8-12 mm (W) and thickness <2mm.

II.2 Measurements

Description of the micro sections was done using the IAWA (International Association of Wood Anatomists) procedures and the fibre length and width were compared between the sites.
For direct contact measurement, two sensors were attached to both reciprocal surfaces of each sample. Using them, the amount of time which sound wave took to go from one side and reach to another was accumulated (µs). Having the dimensions of the sample and the amount of time, sound velocity was concluded. At the end, by using density of the sample and the amount of sound velocity, modulus of elasticity for all three directions was measured. For damping method measurements samples were put on silk yarn. The vibration was produced by an electro magnet. Using this method, laser sensor which has a connection with oscilloscope, captures the signals in the middle of the sample and sends it to the computer. Using the logarithmic method, software accumulated the damping factor (Bremaud 2006).

III Results:

Figures 2 to 4 are the cross, tangential and radial section of the Mulberry wood respectively. The wood is ring-porous to semi ring-porous, vessels in tangential bands and in radial to diagonal pattern, vessels are mostly grouped in clusters, vessels have simple perforation plates, fibres are in the form of thin to very thick wall. Axial parenchyma are in vasicentric and in confluent form, body ray cells procumbent with one row of upright and/or square marginal cells. Rays are in 2-10 seriate in width and the ray's height in some cases reach to more than 1 mm. Tiluses were found inside the vessels.
ESEM pictures used to have a three dimensional view on wood. Figure 5 and 6 will show the 3D picture and closer look to the cross section respectively.

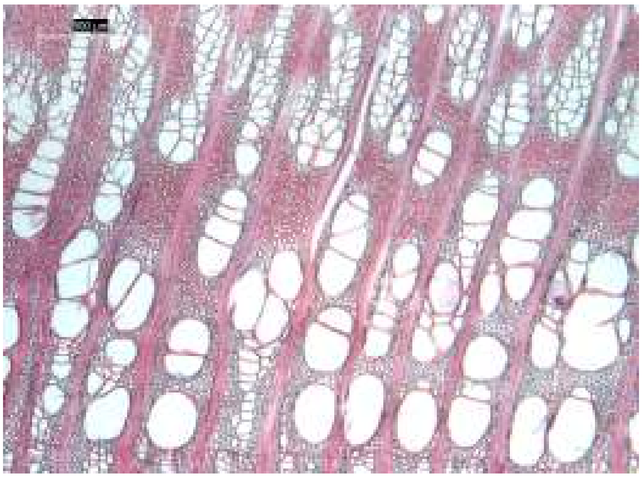

Figure 2. Cross section of Morus alba.

Figure 3. Tangential section of *Morus alba*.

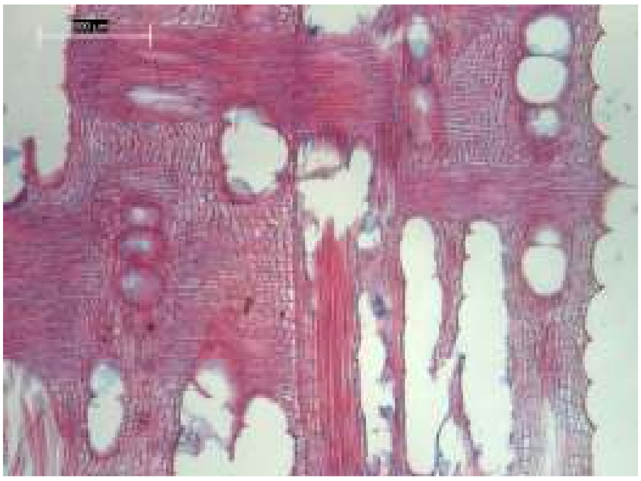

Figure 4. Cross section of *Morus alba*.

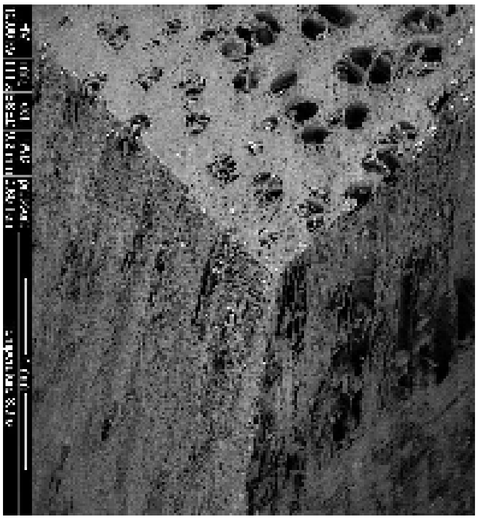

Figure 5. 3D views of *Morus alba*.

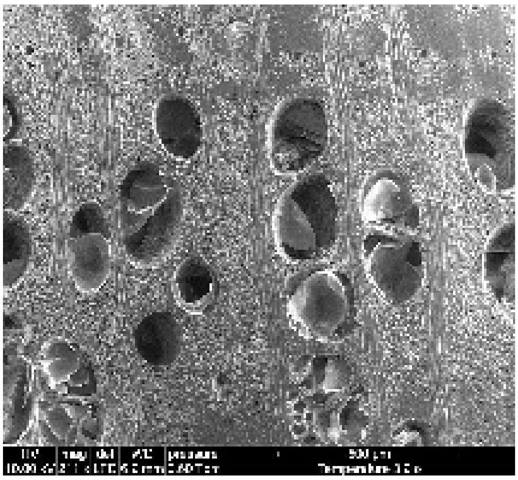

Figure 6. ESEM picture on cross section of *Morus alba*.

The fiber length of the samples from four different sites is shown in table 1. The two sites from dry area had smaller fiber length comparing to the other once from the wet sites.

Table 1. Fiber Length of *Morus alba* samples from four different sites in mm.

Chalous Road	Kan	Tarom	Shiraz	Average
1.098	0.939	1.124	0.926	1.022

Results of direct contact analysis is shown in table 2, where C stands for samples from Chalous Road and S stands for samples from Shiraz.

Table 2. *Morus alba*'s acoustic factors derived by contact analysis method.

Samples	Density	V_l	V_t	V_r	E_l	E_t	E_r	Qf
C1	599.94	4625.57	1894.74	2535.71	11980.44	2010.2	3600.33	144
C2	568.20	4613.64	1903.77	2496.36	12094.54	2059.36	3540.92	142
C3	563.71	4716.28	1815.88	2523.51	12538.87	1858.81	3589.80	145
C4	576.58	4845.24	1838.86	2519.70	13058.51	1880.87	3531.52	148
C5	557.00	5183.67	1819.01	2490.22	14966.86	1843.00	3454.06	152
C6	553.30	4821.43	1766.67	2556.11	12862.30	1726.00	3615.14	149
S1	681.26	4961.17	1965.18	2448.44	16767.12	2631.01	4084.10	133
S2	652.28	5233.50	1882.73	2419.43	17865.69	2312.11	3818.22	140
S3	613.68	5247.45	2024.46	2426.54	16898.35	2515.16	3613.45	144
S4	668.67	5151.52	1974.66	2438.10	17445.44	2607.36	3974.82	137
S5	681.84	5095.00	1940.28	2427.38	17700.15	2566.96	4017.58	135

In table 3 result of different factors which were concluded using damping method are shown; where the samples code are similar to one from table 2.

Table 3. Acoustic factors comprehended by damping method

Samples	fo	Df	Df/fo	L(moy)	R^2	Amplitude
C1	434	3.3	7.61	7.52	0.990239	506
C2	399	3.1	7.77	6.88	0.996227	560
C3	399	3.3	8.27	8.53	0.996795	543
S1	461	3.1	6.72	6.67	0.99798	380
S2	618	4	6.47	5.67	0.999093	182
S3	627	4.2	6.69	6.32	0.999527	170

IV Discussion:

IV.1 Comparing Morus alba's acoustic factors with 2 commonly used species

In table 4 the Q factor in Mulberry was compared with Q factor in Maple and Spruce (Barducci and Pasqualini, 1948) which are commonly used in making guitar and violin.

Table 4. Comparing sound quality factor of Mulberry, Maple and Spruce.

Species	no	density	Qf	Place of growth
Spruce	1	460	125	Italy
	2	410	125	Italy
	3	415	135	Italy
	4	440	130	Tyrol
	5	450	115	Tyrol
	6	450	95	Italy
Maple	1	720	80	Italy
	2	665	105	Italy
	3	785	80	France
Mulberry	1	600	144	Iran

	2	568	142	Iran
	3	564	145	Iran
	4	577	148	Iran
	5	557	152	Iran
	6	553.30	149	Iran

Regarding the damping factor, generally two factors would be used to represent sound damping in a wood: damping coefficient from Logarithmic decrement and damping factor.
It has been proved that the more the damping factor is, the less wave damping the wood has. Considering this fact and by comparing the damping coefficient which we acquired in Mulberry with different species commonly used in making violin sound box (Haines, 1979), the resemblance was undoubted (Table 5). Regarding to the narrow growth rings along with higher Q factor, *Morus alba* has a low damping and this point works as an influential factor for making mulberry the leading species in making Iranian bowl shaped musical instruments.

Table 5. Comparing tan(δ) in different *Acers* and *Morus alba*

name	tan(δ)
Acer platanoide	6.1
Acer saccharinum	6.7
Acer pseudoplatanus	7
Morus alba	6.56

IV.2 Anatomical features of Morus alba and their relation with sound quality:

Many authors like (Brancheriau et al, 2006) mentioned in their results that vessel elements will not help the sound qualities of the wood. But here we have seen the Mulberry wood is consisting of many vessels. The key point in this structure is the existing of vasicentric axial parenchyma cells which surrounded the vessel systems to keep them in a closed structure. This is in agreement with Brancheriau et al, 2006 which mentioned axial parenchyma cells play an important role in improving the sound quality of the woods. It has to be mentioned that the axial parenchyma cells coincide with the vessels will have much more positive effects comparing to the apotracheal axial parenchyma.
High percentage of fiber in the structure, in addition to the high fiber length along with appropriate cell wall thickness indicates a really good ability for sound transition in this wood.

V Conclusion:

The main purpose of this paper was only focused on introducing of Mulberry wood as an important wood in Iranian musical instruments. All the results of acoustical properties are in the preliminary situation.
Looking back to the figure 1 will show us the very unique shape of this instrument and the beautiful appearance of the mulberry wood. In fact in this picture the mixture of sap and heartwood made by a professional instrument maker (my dear friend; Mr. Zare) is designed for decorative purposes and never will be done for a high quality Tar which is going to make a good sound! This is just an example to show the professional instrument makers without knowing in details about the structure and acoustical properties of sap and heartwood will avoid using the sapwood for high quality instruments. But nowadays it is our task to exchange information between scientists and instrument makers. In this exchange the both sides will receive new achievements!
This study will be continued and in the near future the results and discussion will be improved.

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Bibliography

[1] Barducci, I, et al., « Misura dell'attrito interno e delle costanti elastiche del legno », *Nuovo Vimento*, vol. I(5), 1948, p. 416-466.
[2] Brancheriau, Loic, et al., « Key signal and wood anatomy parameters related to the acoustic quality of wood for xylophone-type percussion instruments », *JOURNAL OF WOOD SCIENCE*, vol. 52, 2006, p. 270-273.
[3] Franklin, G.L, « Preparation of Thin Sections of Synthetic Resins and Wood-Resin Composites, and a New Macerating Method for Wood », *Nature journal*, vol. 155:51, 1945, p. 51.

[4] Haines, D., « On Musical instrument wood I », *Catqut Acoust. Soc. Newslett.*, no. 31, 1979, p. 23-32.
[5] Schweingruber, Fritz H., Börner, Annett., Schulze, Ernst-Detlef, *Atlas of Woody Plant Stems: Evolution, Structure, and Environmental Modifications*, 1st ed, Springer, 2006.

Photographs owns