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Research article

# Investigation of kevlar application in baglama soundboard and its effects on sound properties

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**Abstract**
One of the most important problems of the baglama is the need for sound power. In order to solve the same problem in the guitar, double tops were applied and this problem was largely solved. It is thought that the application will also be a solution for the baglama. In this application, the soundboard consists of two pieces and a material called kevlar, designed in the shape of a honeycomb, is mounted between two wooden parts. Kevlar is a mounted between the soundboard, which consists of the lower cover and the upper cover in the instruments, both reducing the wooden part and creating sound chambers. It has been observed in the analyses that this structure has a positive effect on the sound in the guitar. It is thought that the use of kevlar in the baglama soundboard with the same method will have a positive effect on sound power.

**Keywords**
baglama, soundboard, music, kevlar, double tops

**Highlights**

- A new method has been developed using today's modern technology in order to produce a solution to the problem of the sound volume of the baglama, one of the ancient instruments.
- The results obtained after testing the kevlar material (carbon fiber), which is used in guitar and similar instruments in some European countries, on the soundboard of the baglama.
- Within the scope of the study, signal analysis of the sound samples of the binding designed using kevlar was performed and the prominent findings regarding the sound quality were revealed.

# Bağlama ses tahtasında kevlar uygulaması ve ses özelliklerine etkisinin araştırılması

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## Öz
Bağlamanın en önemli problemlerinden biri de ses gürlüğü ihtiyacıdır. Gitarda aynı sorunun çözümü için double tops uygulanmış ve bu sorun büyük oranda çözüme kavuşturmuştur. Uygulamanın bağlama için de çözüm olacağı düşünülmektedir. Bu uygulamada ses tablası iki parçadan oluşmakta ve iki ağaç aksam arasına bal peteği şeklinde dizaynedilmiş, 'kevlar' adlı bir malzeme monte edilmektedir. Kevlar, çalgılarda alt kapak ve üst kapaktan oluşan ses tablası arasına monte edilerek hem ağaç aksam azaltılmakta hem ses odacıkları oluşturulmaktadır. Bu yapının, yapılan analizlerde gitarda sese olumlu bir şekilde etkisi olduğu görülmüştür. Bağlama ses tablasında da aynı yöntemle kevlar kullanımının ses gürlüğüne olumlu etkisi olacağı düşünülmektedir.

**Anahtar kelimeler**
bağlama, ses tablası, müzik, kevlar, sandviç tabla

**Öne çıkanlar**

- Kadim çalgılarımızdan bağlamanın ses gürlüğü problemine çözüm üretebilmek için günümüz modern teknolojisi kullanılarak yeni bir yöntem geliştirilmiştir.
- Bazı Avrupa ülkelerinde gitar ve benzeri çalgılarda uygulanan kevlar malzemesinin (karbon fiber) bağlama ses tablasında denenmesi sonrasında elde edilen sonuçlar paylaşılmıştır.
- Çalışma kapsamında kevlar kullanılarak tasarlanan bağlamanın ses örneklerinin sinyal analizi yapılarak ses kalitesine yönelik öne çıkan bulgular ortaya konulmuştur.

## Introduction[1]

The studies carried out until today have shown that the baglama is derived from the kopuz of Asian origin from the ancient Asian cultures. Recognized as one of the oldest cultural products of Asia the kopuz has spread to a very wide area and has become the symbol of these areas (Karababa, 2005, p. 24). One of the most important problems of baglama, which has thousands of years of history, is the need for sound volume. Performers especially draw attention to this issue in the instrument. Although this problem has been solved to a great extent with the golden ratio method, studies are still ongoing to see if it is possible to increase the sound volume with other methods (Cömert, ____). To be able to produce a solution to the problem of sound volume in baglama. From this point of view, to produce a solution to the problem of sound volume by adapting the double tops (sandwich table) method, which has been tried on guitar and oud and has positive results, to the baglama.

Hence, sandwich tops (double tops) were applied to solve the same problem on the guitar and this problem was solved to a large extent. A similar application was also applied on the oud and positive results were obtained. It was thought that this application (sandwich table-double tops) would also be a solution for baglama. Sandwich tops, also known as double tops, sandwich tops and composite tops, are a new way of constructing the soundboard of a guitar. The idea of using kevlar (nomex) technology, which belonged to guitar maker Gernot Wagner, was first implemented and popularized by his friend and colleague Matthias Dammann, who built the first double tops guitar.

The sandwich tops is usually made of a material called nomex sandwiched between two thin layers of wood. Kevlar, a combustion-resistant meta-aramid material, was first designed in the 1960s by Dupont Chemical Co. as a lightweight material for use in the aerospace industry. Makers use the product's honeycomb sheet shape in instruments. Its light weight, durability and easy formability make it ideal for guitar soundboards. Although the structure of a sandwich top differs significantly from a traditional soundboard, a sandwich top guitar often looks like a traditional guitar (guitarfromspain, 2013, 2nd June).

The aim, simply put, is to make a guitar with a louder sound (Stenzel, ____). In mid-1995 Dammann wanted to take his guitars to the next level, as good as they could be, and started thinking about ways to gain more control over the weight and movement of the soundboard. His friend Wagner told him about a material called nomex, a very strong, lightweight, kevlar-based material with a honeycomb pattern. Through a long and intensive process and highly creative experimentation, Dammann found ways to insert the new nomex materials between the soundboards. In mid-1995, Dammann glued a layer of nomex between two soundboards with a special adhesive under vacuum pressure. Thus, in 1995, Dammann created the first double top with a nomex core (Kamen, 2017,

[1] This study is derived from Ph.D. dissertation entitled *Kevlar Application on Baglama Soundboard and Investigation of Its Effects on Sound Properties*, prepared by Dr. Ümit Çiçekoğlu under the supervision of Assoc. Prof. Ali Maruf Alaskan and accepted by Ege University Institute of Social Sciences on 12/12/2023.

19th May).

Today, many fine luthiers have followed in Dammann's footsteps with their own interpretations of the sandwich top guitar, including Robert Ruck, Michel Brück, Dieter Müller, Jim Redgate, Andreas Kirschner, and Jaokob Lebisch. As time has passed, many luthiers have joined the quest with this exciting aspect of the classical guitar, and each luthier adds their own ideas and concepts to the newly created sandwich tops. It is said by performers that the sandwich tops that luthiers started to make against traditional guitars brought a kind of "synergy" to the guitar, so that sandwich tops guitars can be recognized compared to traditional guitars (Kamen, 2017, 19th May).

## *Methodology*

Firstly, a standard soundboard was mounted on a mounting apparatus and audio was recorded in a studio environment and audio analysis was performed on two and three-dimensional images of the audio signals using the Wavelab 9.2 application. A new soundboard was prepared by mounting a material called nomex between the two soundboards with the same thickness as the standard soundboard. The standard soundboard was removed from the baglama, a new soundboard with nomex was mounted, sound was recorded under the same conditions and sound analysis was performed on two and three dimensional images of the sound signals using the Wavelab 9.2 application (Güdek, 2019).

The results obtained were compared and the differences in sound loudness between the two soundboards were revealed. In order to make the analysis results more reliable, the same spruce wood boards were used in the standard table and sandwich table. In the computer software used for the analysis of sound samples in the study, two-dimensional graphs were evaluated according to decibels on the vertical axis and time on the horizontal axis, and three-dimensional analyzes were made on decibels on the vertical axis and frequency parameters on the horizontal axis.

The sound samples were recorded at Ege University State Conservatory of Turkish Music Sound Recording Studio using AKG 414 B-USL microphone and Protools HD12 program. The recorded sound samples were analyzed in Wavelab Elements 9 program by cutting the first 20 ms of the initial part of the sound signals and taking 2D and 3D graphs and analyzing them according to fourier spectrum analysis. Composite materials are materials formed by combining the best properties of two or more materials together in a new and single material or by combining these materials at the macro level in order to gain a new feature. Engineering materials are required to have certain properties in different applications.

These are mechanical properties such as tensile, compression, bending, yield, friction, fatigue strength, hardness, toughness, rigidity, abrasion resistance, electrical conductivity, insulativity, thermal conductivity-insulativity, magnetic properties, density, etc. physical properties, stability, chemical properties such as corrosion resistance. The most important reasons why composite materials are preferred;

- high rigidity,
- low weight,
- excellent abrasion resistance,
- much better strength compared to materials of the same weight,
- better tensile strength compared to other materials,
- better fatigue strength,
- better impact absorption energy of composite materials compared to other materials,
- their design is more flexible and as a result, the desired features can be provided,
- virtually no risk of corrosion.

Their design is more flexible and as a result, the desired features can be provided. Meta-aramid is a resin-coated sheet called K2 (kevlar 2) paper. It is a honeycomb material produced by Dupont and is especially known for its use in fireproof clothing. It is also used in the construction of space shuttles and airplanes to both strengthen and lighten the weight. In instrument construction, it is used to protect and increase the rigidity of the soundboard and to reduce the weight of the soundboard. Since the structure used is a honeycomb, it causes the weight of the soundboard to decrease. (O'brien, 2006, 13$^{th}$ February). Superior mechanical properties provide high strength against weight. High durability under heat and humidity. Ability to withstand temperatures up to 180°C.

### *Sandwich table modeling suitable for baglama and features of the analyzed baglama*

As in the guitar, kevlar will be applied to the remaining part of the soundboard of the baglama, except for the area where the strings pass up to the back of the threshold. This will both prevent the soundboard from flexing downwards and prevent a timbral change in the instrument. In our study, mahogany (swiefenia-mahagani) wood, which is among the most suitable woods in terms of sound transmission, hardness and specific gravity, was used. The binding was made according to the golden ratio and analyzed by changing the prepared soundboards.

| | | | |
|---|---|---|---|
| Soundbox | Mahagani | Form size | : 42 cm |
| Stalk | Mahagani | Depth | : 24,5 cm |
| Soundboard | Spruce | Width | : 24 cm |
| Threshold | Maple | Stalk length | : 52,5 cm |
| String threshold | Ebony | Threshold height | : 5 mm |
| Strings | Röslau | Chord | : B |
| Strings diameters | First string 0,20 | Second string 0,31 | Third string 0,22 |

Table 1. Features of the analyzed baglama

### *Preparation of the sandwich board and kevlar mounting*

The 5,5 mm thick spruce soundboard is cut for the sandwich top. In order to remove the marks from the band saw and to thin the soundboard, the soundboards are thinned with a calibrating machine on both sides to a thickness of 4,7 mm. Both surfaces are sanded smooth so that the thickness of the soundboard reaches 4,5 mm.

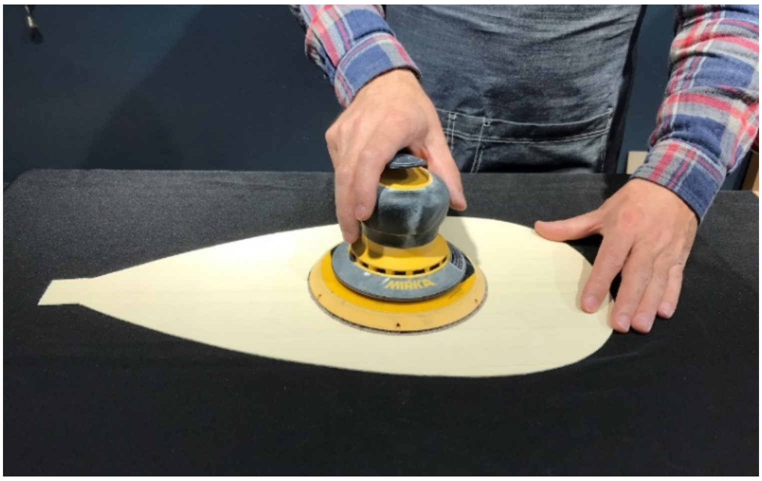

Image 1. Making the surfaces of the soundboard smooth with a vibration machine

During this process, the thickness of the soundboard should be measured frequently with the comprator. Otherwise, it may be thinned more than it should be without realizing it. After the soundboard is thinned to 4,5 mm, the area where the strings pass is left at the same thickness until 2 cm behind the threshold. The remaining areas outside this section are thinned by milling 2,8 mm. The thinned area is sanded smoothly. After the sanding process, care must be taken to ensure that the thinned area is 1,5 mm thick everywhere.

Image 2. Sanding of the soundboard after milling

Kevlar is cut according to the thinned area and mounted to the soundboard with epoxy adhesive. The most important thing to be considered here is to ensure that the epoxy is not absorbed too much on the Kevlar surface. Too much epoxy absorption will affect the result of our work as it will fill the honeycomb surface.

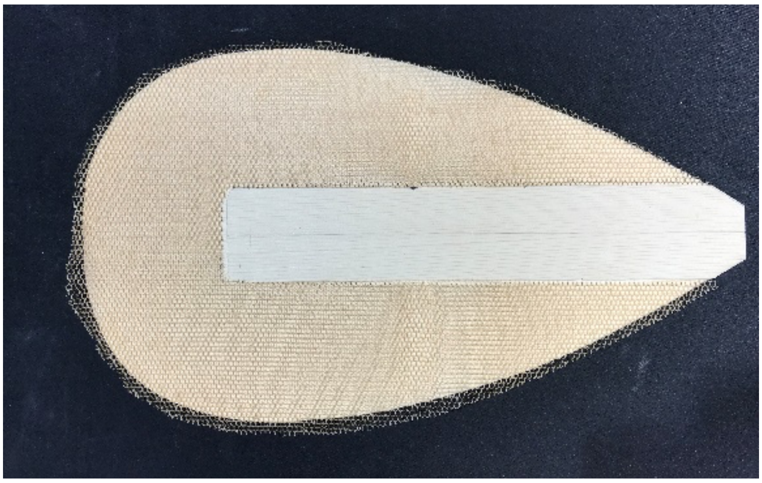

Image 3. Kevlar mounting on the soundboard

Since the drying time of the epoxy used is six hours, no further action should be taken during this period. A 2,2 mm thick soundboard is cut from the same slat. It is calibrated to a thickness of 1,7 mm by passing it through a calibrating machine and its two sides are sanded smooth like the previous soundboard. The Kevlar is cut according to the soundboard and made ready for installation. The prepared table is mounted to the soundboard with epoxy and the sandwich table is prepared.

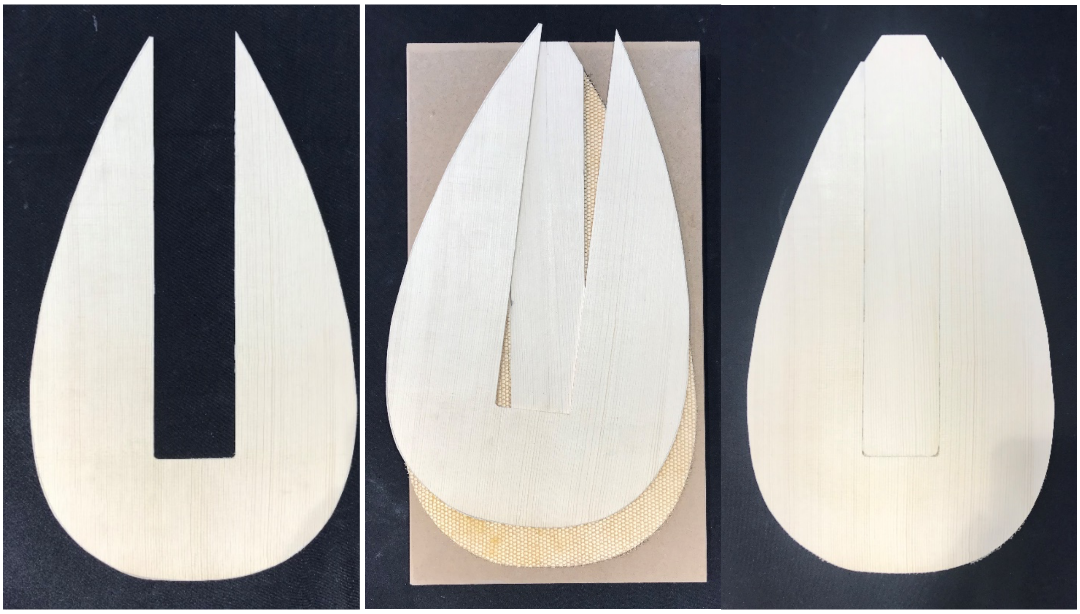

Image 4, 5, and 6. Preparations of the second soundboard for the sandwich table

It is extremely important to use a single baglama for a healthy sound analysis. Since the result will change as the variables increase, it would be more accurate to continue the analysis on a single baglama. Therefore, after recording the sound with the standard soundboard, the soundboard on the mount was dismantled and the new sandwich plate was assembled. The most important point to be considered here is to keep the threshold height constant. The analyzed normal sound table is dismounted from the baglama with the help of a milling cutter and the sandwich table is mounted.

Image 7. Mounting of the sandwich table to the baglama

In order to not to see the kevlar between the soundboards, edge laths are installed around the soundboard and thus the sandwich plate mounting to the baglama is completed. In the next step, five coats of polish applied to the sandwich soundboard, sanded and wired, and the sandwich soundboard is ready for analysis.

## Findings and discussion

### *Findings from the standard soundboard*

The main frequencies and natural frequencies were determined and evaluated in the sound recording samples taken from the baglama. According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the first wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope is -29,3 dB and the wave amplitude start time is 7 ms. The peak of the F2 envelope was -22,4 dB with a wave amplitude onset time of 17 ms, the peak of the F3 envelope was -27,4 dB with a wave amplitude onset time of 29 ms and the peak of the F4 envelope was -18,1 dB with a wave amplitude onset time of 42 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 250 ms and the decay occurs in 2,18 sec, it was determined that decay occurred. In the three-dimensional fourier spectrum analysis of the signal; it was found that the fundamental frequency n1 has a very strong signal structure, however; the subsequent n2 and n3 have lower amplitudes than the first signal and n4 has a very low amplitude. In image 8 and 9 below, 2D and 3D signal graphs of the standard table are given.

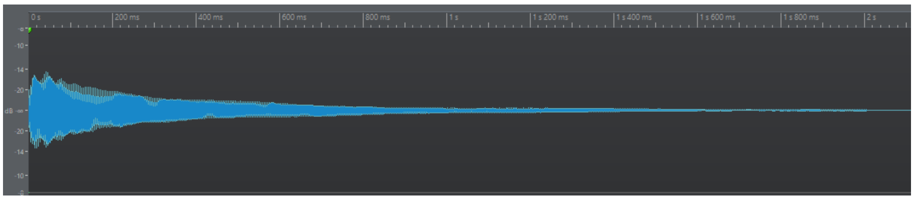

Image 8. 2D screen excerpt of the standard soundboard first wire

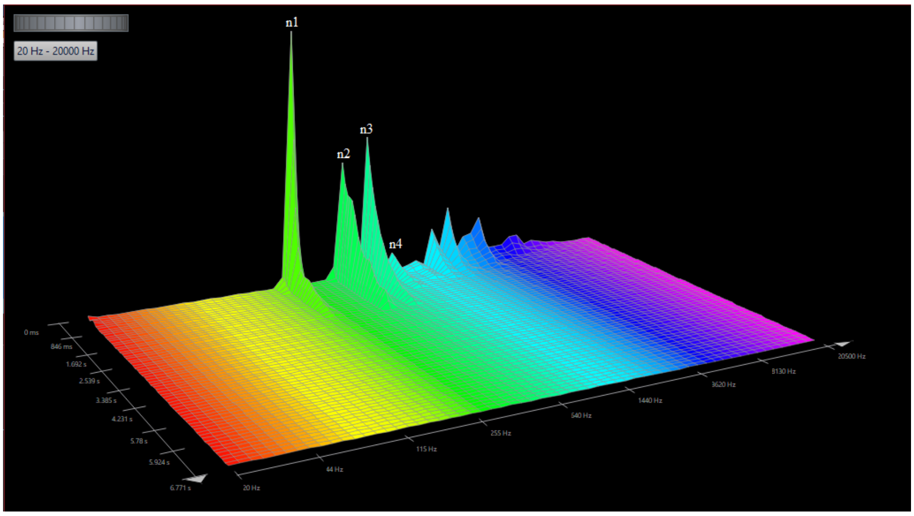


Image 9. 3D screen excerpt of the standard soundboard first wire

According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the second wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope is -22,9 dB and the wave amplitude start time is 5 ms. The peak of the F2 envelope was -29,2 dB with a wave amplitude onset time of 16 ms, the peak of the F3 envelope was -24,1 dB with a wave amplitude onset time of 25 ms and the peak of the F4 envelope was -23,2 dB with a wave amplitude onset time of 44 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 220 ms and the decay occurs in 3,30 sec, it was determined that decay occurred. In the three-dimensional fourier spectrum analysis of the signal; it was found that the fundamental frequency n1 has a weak signal structure compared to the spontaneous ones, but the subsequent spontaneous ones n2 and n3 have much higher amplitudes than the first signal, and n4 has a slightly higher amplitude than the n1 fundamental frequency. In image 10 and 11 below, 2D and 3D signal graphs of the standard table are given.

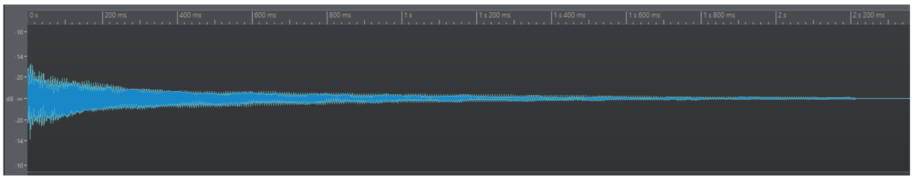

Image 10. 2D screen excerpt of the standard soundboard second wire

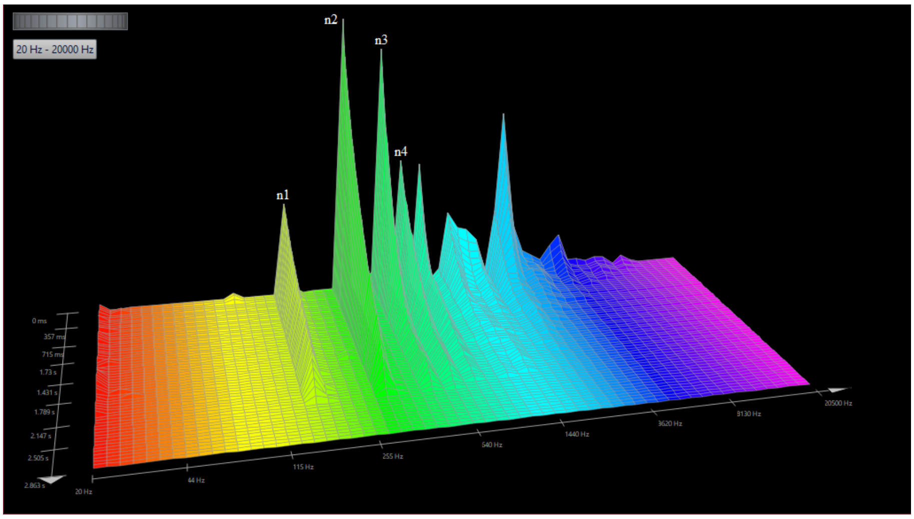


Image 11. 3D screen excerpt of the standard soundboard second wire

According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the third wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope is -27,6 dB and the wave amplitude start time was 9 ms. The peak of the F2 envelope was -30,8 dB with a wave amplitude onset time of 23 ms, the peak of the F3 envelope was -19,6 dB with a wave amplitude onset time of 38 ms and the peak of the F4 envelope was -28,3 dB with a wave amplitude onset time of 51 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 240 ms and the decay occurs in 2,21 sec, it was determined that decay occurred. In the three-dimensional fourier spectrum analysis of the signal; it was found that the fundamental frequency n1 has a very strong signal structure, however; the following n2 and n4 have higher amplitudes than the first signal, while n3 has a very low amplitude. In image 12 and 13 below, 2D and 3D graphs of the standard table are given.

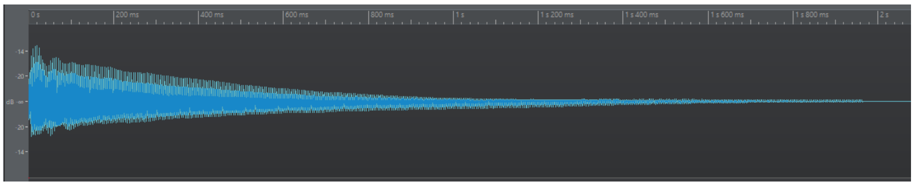

Image 12. 2D screen excerpt of the standard soundboard third wire

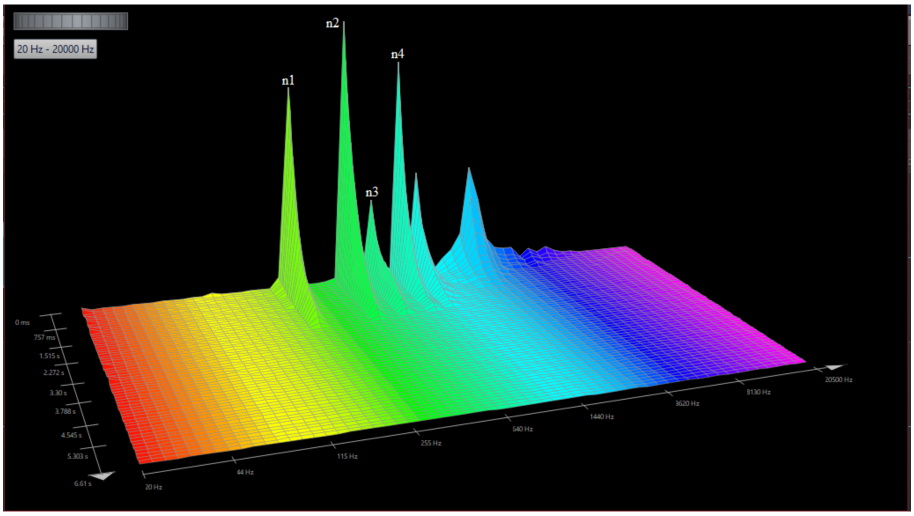


Image 13. 3D screen excerpt of the standard soundboard third wire

### *Sandwich table*

According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the first wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope is -36,7 dB and the wave amplitude start time is 6 ms. The peak of the F2 envelope was -25,2 dB with a wave amplitude onset time of 16 ms, the peak of the F3 envelope was -29,7 dB with a wave amplitude onset time of 33 ms and the peak of the F4 envelope was -31,3 dB with a wave amplitude onset time of 68 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 420 ms and the decay occurs in 4,42 sec, it was determined that decay occurred. Three-dimensional fourier spectrum analysis of the signal shows that the fundamental frequency n1 has a very strong signal structure, but the subsequent n2, n3 and n4 components have much lower amplitudes than the first signal. In image 14 and 15 below, 2D and 3D signal graphs of the sandwich table are given.

Image 14. 2D screen excerpt of sandwich table first wire

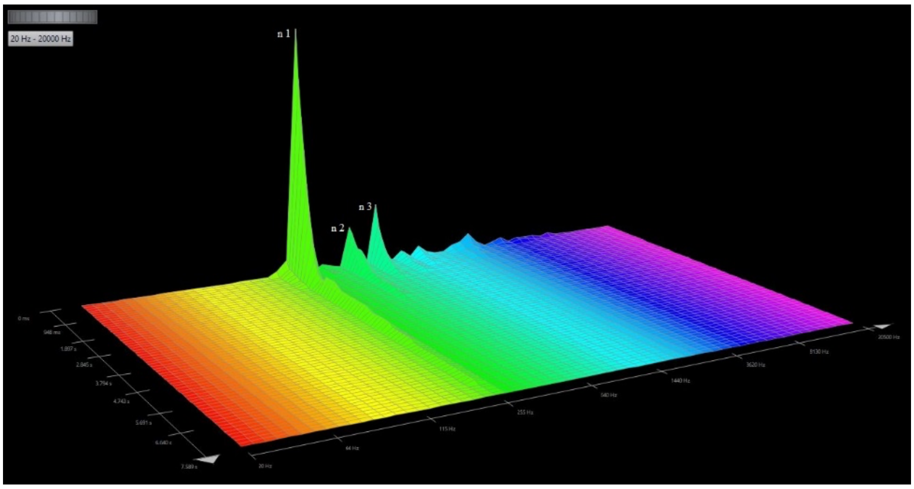


Image 15. 3D screen excerpt of sandwich table first wire

According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the second wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope -34,0 dB and the wave amplitude start time is 9 ms. The peak of the F2 envelope was -27,2 dB with a wave amplitude onset time of 24 ms, the peak of the F3 envelope was -30,6 dB with a wave amplitude onset time of 36 ms and the peak of the F4 envelope was -33,2 dB with a wave amplitude onset time of 54 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 455 ms and the decay occurs in 4,35 sec, it was determined that decay occurred. In the three-dimensional fourier spectrum analysis of the signal; it was found that the fundamental frequency n1 has a very strong signal structure, however; the following n2 and n4 have much lower amplitudes than the first signal, and n3 has a slightly higher amplitude than n2 and n4. In photos 17 and 18 below, 2D and 3D signal graphs of the sandwich table are given.

Image 16. 2D screen excerpt of sandwich table second wire

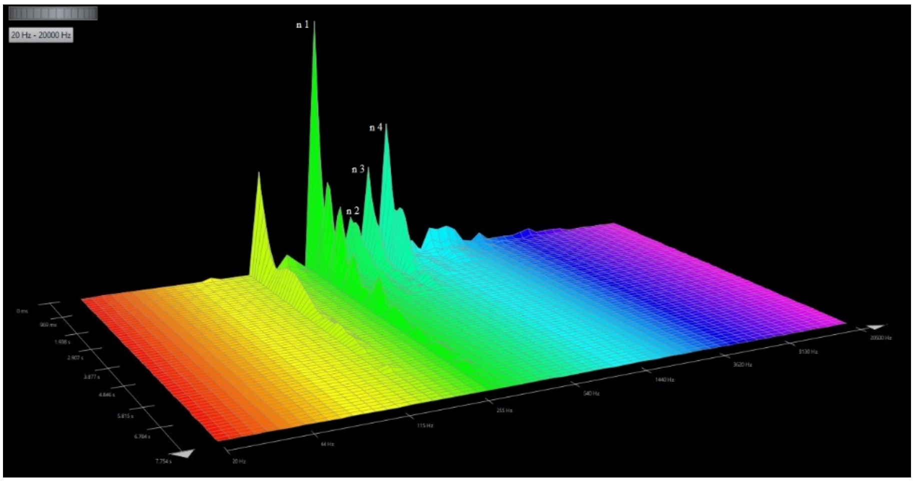


Image 17. 3D screen excerpt of sandwich table second wire

According to the sound recording sample taken from the standard soundboard of the baglama; when the waveform graph at the attack moment (20-100 ms) when the third wire is strummed on the open wire is analyzed in two dimensions; it is observed that the peak of the F1 envelope -32,5 dB and the wave amplitude start time is 5 ms. The peak of the F2 envelope was -25,5 dB with a wave amplitude onset time of 14 ms, the peak of the F3 envelope was -27,6 dB with a wave amplitude onset time of 40 ms and the peak of the F4 envelope was -28,8 dB with a wave amplitude onset time of 54 ms. It can be said that there is a regular decrease in the audio signal after the F4 envelope, which is important in terms of audio signal quality.

A sudden rise and fall in the audio signal while the prolongation-dampening process continues normally disrupts the normal course of the signal and is considered as a negative in terms of sound quality in terms of hearing in the audio signal, the sustain area starts after 155 ms and the decay occurs in 3,10 sec, it was determined that decay occurred. In the three-dimensional fourier spectrum analysis of the signal; it was found that the fundamental frequency nl has a very strong signal structure, however; the following n2 and n4 have much lower amplitudes than the first signal, and n3 has a slightly higher amplitude than n2 and n4. In image 18 and 19 below, 2D and 3D signal graphs of the sandwich table are given.

Image 18. 2D screen excerpt of sandwich table third wire

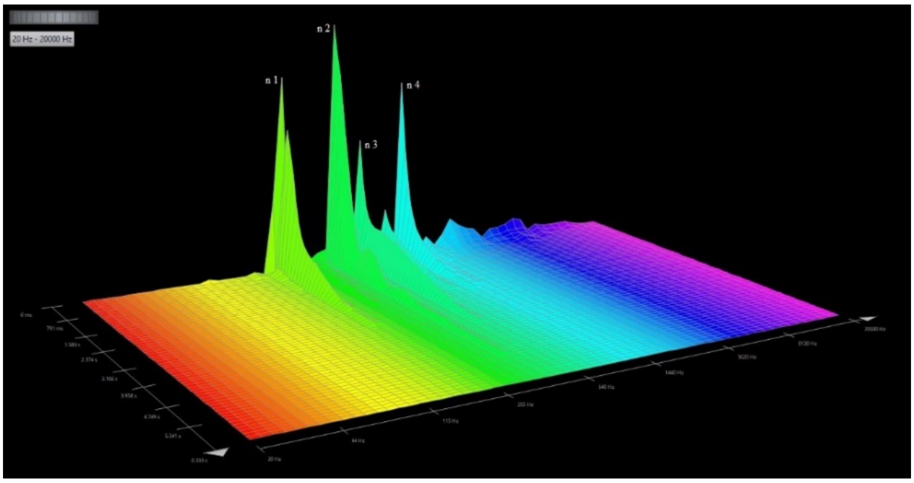


Image 19. 3D screen excerpt of sandwich table third wire

| | First wire | Second wire | Third wire |
|---|---|---|---|
| **Standard soundboard** | 2s 18 ms | 3s 30ms | 2s 21ms |
| **Sandwich board** | 4s 42ms | 4s 35ms | 3s 10ms |

Table 2. Sound signal dampening times of the standard soundboard and the sandwich table

| | First wire | Second wire | Third wire |
|---|---|---|---|
| **Standard soundboard** | -29,3 dB | -22,9 dB | -27,6 dB |
| **Sandwich board** | -36,7 dB | -34,0 dB | -32,5 dB |

Table 3. Envelope amplitudes of the standard soundboard and the sandwich table

## Conclusion

In his study, Ali Maruf Alaskan (2012) determined that the difference between the signal samples obtained in the method he used while investigating the sound properties of natural leathers used in percussion instruments depends on the structural, chemical and surface properties of the material. In this study, a similar method was used to determine the differences between the sound signal samples. When the sound signal samples obtained from the baglama standard soundboard and the sandwich soundboard were analyzed and compared;

- Sound signal fading times were 2,24 sec longer on the lower string, 1 sec 05ms longer on the middle string and 89ms longer on the upper string on the sandwich table than on the standard sound table,

- The envelope amplitudes at the first peaks of the audio signal were 7,4 dB higher on the bottom string, 11,1 dB higher on the middle string and 4,9 dB higher on the top string of the sandwich table, so the sound volume was higher on the sandwich table,
- On the sandwich table, the fundamental frequencies are stronger and harmonics weaker on the lower and middle strings, while the fundamental is slightly weaker than the harmonics on the upper string,
- In the standard soundboard, the harmonics are stronger than the basic frequency, has been observed. The method tested in this study is the first time it has been tried on a baglama soundboard and we hope that it will provide ideas for future work.

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