sciendo

DOI: 10.2478/9788367405805-025

ICAMS The International Conference on Advanced Materials and Systems

REVIEW ON SOUNDBOARD IN REBAB-MAKING. PART I: STRUCTURE OF REBAB, SKIN, AND BOVINE PERICARDIUM

ANIL ÖZÇELİK[1], ESER EKE BAYRAMOĞLU[1], ALİ MARUF ALASKAN[2]

[1]*Ege University, Faculty of Engineering, Department of Leather Engineering, Izmir, Türkiye, ozcelikanil@gmail.com, eserekebay@gmail.com*

[2]*Ege University, State Conservatory of Turkish Music, Department of Instrument Making and Repair, Izmir, Türkiye, ali.maruf.alaskan@ege.edu.tr*

The rebab is a stringed, bowed instrument, coated in leather, with a resonance box made from calabash or wood. Leather or bovine pericardium, a skin-like material, serves as the soundboard for the instrument. The leather's structure should be homogenous, compact, and robust. The dermis layer of the skin and its fibrillar structure are significant. The angles of the fibers must be acute, and the packing density must be high. The crystalline structures of collagen provide high efficiency. When making a rebab, the strength and viscoelasticity of the materials used must be meticulously assessed. Consideration must be given to the thickness and characteristics of the leather. The bovine pericardium comprises collagen. It is a significant and distinctive tissue characterized by a heterogeneous collagen fiber structure. It demonstrates regionally varied physical limitation behavior. The predominant materials utilized in rebab fabrication are bovine pericardium and fish leather. Nevertheless, the acoustic output generated by fish leather is substantial relative to the instrument's size. The membrane's slender, robust, and flexible composition provides excellent resonance. Simultaneously, in conjunction with the calabash, it produces a distinctive sound reminiscent of leather. The production of rebabs can be standardized through leather processing, utilizing it as high-value recyclable waste. This review made assumptions by concentrating on the bovine pericardium, which has not yet been examined via an academic lens in the context of rebab-making.

Keywords: Rebab-making, skin histology, fibrillar architecture of the dermis, bovine pericardium.

INTRODUCTION

Human beings, having been perpetually enveloped by sound since their inception, have conceptualized sound as a phenomenon through their experiences and observations. Sound holds greater significance for humanity than thought. Sound serves as a mechanism for detecting threats essential for survival, constituting a fundamental instinct (Degirmenli, 2023). Individuals have constructed instruments from pole to pole utilizing the natural resources available to them (Akyol, 2017). Animal hide has been utilized for the creation of instruments since antiquity. In antiquity, the saz (rebab) was made by tautly stretching leather over a turtle shell or a calabash. The leather-covered turtle shell is exhibited at the Cairo Museum (Sonmez, 2008). Historically, individuals began producing noises by rubbing their hunting arrows against their bows (okluğ), then experimenting with bows crafted from horsehair, which were enhanced by affixing a calabash to the tip (ıklığ). Subsequently, they affixed handles to the calabash, upon which they extended thin leather. To provide a clearer sound, they extended stringer wires over the leather. Consequently, the rebab, an elongated string instrument, originated (Alaskan, 2013).

Rebab

The rebab is a traditional stringed instrument from Turkey (Ozdemir, 2020). It is a stringed instrument featuring a leather covering and a hemispherical body, played by positioning the string upon it. It is among the oldest folk instruments of the Turks that has had minimal structural alteration (Sener, 2019). The iklıg was performed by the Uyghur Turks in Central Asia during the 7th century (Acin, 1998).

The rebab comprises the following components: resonance box, neck (fingerboard), soundboard, post, threshold, pegbox, tuning pegs, string, bow, and spike. Polishing is used to achieve a smooth surface. The instrument originated with two strings, subsequently a third string was incorporated, and eventually a fourth string was added to enhance the tonal range. It is an instrument devoid of frets. The sound breadth spans 2.5 to 3 octaves. Consideration must be given to the equilibrium and proportions among the components of the instrument (Yegin, 1994; Kaya, 1998; Acin, 1998; Sezer, 2016; Altiparmak, 2007).

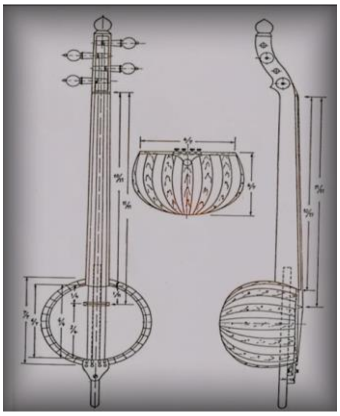

Figure 1. Cafer Acin "Equilibrium and proportionality in the rebab" (Sener, 2019)

A tree or a calabash serves as the resonance box for the rebab. The selection of wood is crucial if it is to be utilized. The kind of tree, its structural characteristics, and its geometry must be considered. The incorporation of leather and calabash in the making of the rebab imparts distinctive tonal qualities, and such a rebab is referred to as "Kabak kemane" in Turkish. The kemane family comprises four distinct variants based on size and tuning: soprano (leather diameter: 12 cm), alto (leather diameter: 15 cm), tenor (leather diameter: 24.72 cm), and bass (leather diameter: 35.63 cm). Centimeters and other dimensions. Upon the modification of the components, the instrument's body may be adorned with embroidery. The soundboard of the rebab is made from leather. The membrane is a form of leather and possesses characteristics akin to leather. A variety of raw hides and membranes, including those from horse, foal, deer, gazelle, goat, kid, sheep, catfish skin, pelican crop, and synthetic leather, were utilized in the fabrication of rebabs (Yegin, 1994; Kaya, 1998; Acin, 1998; Sezer, 2016; Akyol, 2017; Simsek, 2013; Hashas and Imik, 2016; Altiparmak, 2007). Hides or skins, after undergoing processes such as soaking, dehairing/liming, deliming, conditioning, pickling, settling, horsing, toggling, buffing, finishing, and ironing press, are subjected to sound analysis using a mechanical tensioning equipment (Alaskan, 2012; Alaskan, 2013). Historically, strings were crafted from horsetail, intestines, and silk; presently, metal is utilized (Mazlum, 2011; Sener, 2019). Broadcasting strings were primarily constructed from horsetail. Its scaly structure adheres to the string upon the bow's contact with it. Bow is covered with resin to enhance the friction between it and the strings (Berg and Strok, 1982). As animal husbandry declined in bow wire production, fishing lines became the chosen alternative (Mazlum, 2011). The rebab, made from a calabash, is the sole instrument in Turkish folk music featuring a leather covering and a string, and it is an authentic instrument. Sezer, 2016. Obtaining the pericardium to extend over the mouth of the resonance box is a hard task. Following killing, the pericardium must be incised and removed in a single, undamaged motion, subsequently smoothed by hand fleshing, and finally cleansed with soap. Rebabs with hardwood soundboards in lieu of leather have also been manufactured (Sener, 2019; Celik, 2023). A composite body constructed from glass, carbon fiber, and polyester resin has been developed, replacing the traditional handmade body with a synthetic construction (Acet & Saati, 2015). Notwithstanding these factors, the rebab continues to be crafted using traditional processes and techniques. It is an instrument that perpetuates the master-apprentice connection, with its soundboard crafted from amateur leatherwork (Majid *et al.*, 2023). When bovine pericardium serves as a soundboard, no preparation is required beyond the aforementioned procedures.

Figure 2. Rebab (Oflaz, 2008)

Below are shared photographs of rebabs, which were personally captured and utilize calf pericardium as a soundboard.

Figure 3. Rebabs at the Instrument Sales Unit of Ege University State Turkish Music Conservatory (EUSTMCIS)

To comprehend the interactions between the instrument body and the leather, it is essential to first grasp the structure of the skin and the bovine pericardium.

Histological Composition of the Skin

The skin comprises the epidermis, dermis, and hypodermis layers. The epidermis and hypodermis layers are excised throughout the process. Amorphous proteins, lipids, and other substances in the skin structure are eliminated (Harmancioglu & Dikmelik, 1993). The central region of the corium comprises a composite architecture of type I collagen and an elastin fibril network, which contributes to the leather's strength. Following all elimination processes, the dermis comprises 90-95% of the skin's mass. The upper dermis layer is referred regarded as glass, whereas the lower dermis layer is termed corium (Covington, 2009).

The dermis layer comprises tightly interlaced collagen bundles. In the central region of the dermis, the fibers increase in coarseness and strength, forming distinct angles that influence the final characteristics of the leather (Sharphouse, 1971). The dermis comprises two layers. The stratum papillary constitutes the upper layer of the dermis, whereas the stratum reticulare comprises the bottom layer (Harmancioglu & Dikmelik, 1993).

Fibrillar Architecture of the Dermis

Protein-based fibrous formations manifest as elongated polypeptide chains within the dermal layer. They vary from one another owing to distinctions in their peptide structures. This structure has three types of fibers: collagen fibers, elastic fibers, and reticular fibers (Harmancioglu & Dikmelik, 1993). Leather chemist Gerngross categorized unit fibrils into two classifications: crystallized and non-crystallized. Thus, power loss resulting from improper orientation can be mitigated. There exists a disparity in reactivity between crystalline and non-crystallized regions. In crystalline regions, molecular chains are interconnected by many hydrogen bonds (Phillips, 1954). The integrity of the skin's structure and surface relies on the fiber bundles remaining complete and erect. Orientation of skin fiber bundles: They may exhibit oblique angles (0°-20°), low angles (20°-45°), normal angles (45°-70°), and straight angles (70°-90°). Skin exhibiting angles of 45° or less is lax and fragile. Fiber bundles can be arranged in a dense, moderate, or sparse configuration. These characteristics influence the skin's management, mechanical attributes, and level of water absorption (Harmancioglu & Dikmelik, 1993).

Histological Composition and Mechanical Characteristics of Bovine Pericardium

The pericardium is a fibrous membrane that encases and safeguards the heart of mammals, facilitates blood circulation, and houses pericardial fluid (Oswal, 2007). The pericardium comprises three layers: serosa, fibrosa, and epipericardial connective tissue (Ishihara *et al*., 1981). The three fiber layers are oriented at an angle of roughly 60° relative to one another (Elias & Boyd, 1960). The serosa comprises a delicate glass-like covering, flattened mesothelial cells situated adjacent to the pericardial cavities, and a slender submesothelial space. The fibrosa layer contains overlapping collagen bundles that exhibit a flattened, undulating appearance and diverse orientations. Elastic fibers are present in this location as well. Elastic fibers converting to mesothelium are smaller than those in fibrosa. Findings from light microscopy, scanning electron microscopy, and transmission electron microscopy elucidate the histology of bovine pericardium (Ishihara *et al*., 1981).

The multi-directional arrangement of collagen stacks in pericardial fibrosa and the undulating collagen fibrils inside each stack substantially influence the mechanical properties of pericardial tissue. The pericardium's capacity for expansion is contingent upon the interplay of three elements, given that collagen fibrils are inextensible. 1- Orientation of collagen stacks relative to the unidirectional extension axis; 2- mobility of elastic fibers inside the tissue; 3- extent of collagen fluctuation that ceases upon tissue extension (Ishihara *et al*., 1980; Ishihara *et al*., 1981). The fibrous layer of the mature calf pericardium exhibits a collagen fiber structure that is distinctly heterogeneous. The pericardium thickness of newborn calves exhibits minimal variability internally. The mean thickness of the adult calf pericardium is 0.36 mm, while the mean thickness of the newborn calf pericardium is 0.12 mm (Sizeland *et al*., 2014).

Matrix metalloproteinases (MMP) 2 and 9 were identified in bovine and porcine pericardium via the zymography technique. The activity of MMP-9/MMP-2 in bovine pericardium is 8.5 times greater (Calero *et al*., 2002). MMP, primarily responsible for tissue rearrangement and repair, also significantly contributes to embryonic development, morphogenesis, and the management of various disorders (Bode *et al*., 1999; Bode and Maskos, 2001; Celentano and Frishman, 1997; Massova *et al*., 1998).

Prior research indicates that tensile strength and stiffness correlate with the anatomical orientation of the membrane (Zioupos & Barbenel, 1994a; Zioupos & Barbenel, 1994b). Nonetheless, it is recognized that the selection of a certain membrane region partially elucidates mechanical behavior. Regional variability in structure may exist (Hiester & Sacks, 1997b). Additionally, previous research (Simionescu *et al*., 1993) corroborates the findings that tissue structure significantly differs according to the orientation of the fibers, as verified by other research (Hiester & Sacks, 1997a). This illustrates the spatially variable physical restriction properties of the pericardium (Belenkie *et al*., 1992; Chien & Chang, 1972; Grant *et al*., 1994; Grant *et al*., 1992; Smiseth *et al*., 1994).

The skin possesses a non-linear, anisotropic, and viscoelastic structure as a result of collagen orientation. Nonetheless, there exists no correlation between these two (Wong *et al*., 2015). Skin and pericardium, both collagen-rich connective tissues, exhibit analogous characteristics.

RESULTS AND CONCLUSIONS

To produce a melodious tone and ensure durability, the instrument must be constructed from suitable materials and adhere to balanced proportions and dimensions. The thickness, type, and characteristics of the leather utilized in the instrument are crucial. The selection of leather for rebab-making considers its superior strength and acoustic qualities. To achieve this, the collagen fiber bundles are complete, the weaving angles of the bundles are acute, and the bundle density is elevated, resulting in the desirable compact structure. The influence of intercellular molecules on the mechanical characteristics of leather is significant. The interfiber material, specifically globular proteins, between the bundles must be eliminated. Simultaneously, eliminating secondary forms adhered to the skin as much as feasible yields a uniform structure, hence enhancing and streamlining sound transmission within the structure. Furthermore, it is essential that the crystalline structure is maintained in collagen. Consequently, a compact structure is achieved, enhancing its strength, and the sound vibration within the leather can be standardized by diminishing its water absorption capacity. Furthermore, with advancing age, cellularity and water content diminish, fibril alignment becomes more uniform, and cross-links intensify. These advancements enhance the leather's alignment with the intended characteristics.

The calabash and leather employed in its fabrication impart a distinctive tone to the instrument. Porous materials, like leather, typically possess characteristics such as inherent sound absorption and noise attenuation. The formation of pores due to the progressive arrangement of fiber bundles diminishes the mechanical strength of the leather while enhancing its softness. The inherent composition of leather facilitates air permeability and the absorption and buffering of thermal and acoustic energy (Chen & Shan, 2022). Bovine pericardium, which reinforces the intricate arrangement of collagen fibers and elastic fibers inside its fibrosa layer, is a more appropriate option for the instrument regarding its acoustic qualities. Regional membrane selection may be conducted by considering its heterogeneous composition.

While several leathers and membranes serve as soundboards in rebab-making, calf pericardium and fish leather are the most prevalent. Capricorn leather is typically favored due to its availability. Fish leather, conversely, produces a rich and vibrant sound; yet, the instrument's volume is limited, generally inadequate for this auditory output (Altiparmak, 2007). The bovine pericardium, particularly that of calves, is the most often utilized membrane. The bovine pericardium produces a high-pitched, resonant sound due to its thin and flexible composition (Sezer, 2016).

Thick leather should be avoided. Alternatively, the instrument's sound gets muted. The utilization of thin or low-strength leather is readily compromised by environmental conditions including temperature, moisture, humidity, and inadvertent physical harm. Furthermore, as the instrument's threshold contacts the soundboard from above, it may lead to complications, particularly when utilizing membranes. Nonetheless, the membrane's elastic, robust, and slender composition generates significant resonance power (Rai *et al*., 2019). It generates a vibrant and high-decibel auditory output. Simultaneously, it is essential to note that the leather utilized for tenor and bass rebabs must be substantial in thickness to provide adequate mechanical volume due to their big dimensions. Utilizing pericardium in this instance may yield suboptimal outcomes.

The inferences drawn did not account for leather processing. Today, sustainability has gained significant importance in the leather sector (Bayramoğlu *et al*., 2024; Bayramoğlu, 2012). This phenomenon is also observed in other domains. In the context of technological and environmental considerations, high efficiency and minimizing waste by enhancing added value are crucial principles. The academic application of bovine pericardium in rebab-making can be advanced by standardization. In the context of standardizing rebab production, bovine pericardium may undergo rigorous testing and leather treatment to enhance its durability and acoustic qualities. Additionally, the characteristics of collagen, including hygroscopic qualities, uneven alkaline swelling, and swelling in response to acid and salt, must be considered (Harmancioglu & Dikmelik, 1993; Dikmelik, 2013). Consequently, durable rebabs can be developed over time, hence broadening the application scope of this material. This may foster the advancement of intercultural connections in the long run, as the instrument has disseminated throughout a broad geography.

REFERENCES

Acet, R.C. & Saati, F. (2015). Sound Performance Investigation of Composite Materials for the Soundbox of a Membrane Musical Instrument. The 22nd International Congress on Sound and Vibration (ICSV22), Florence. https://doi.org/10.13140/RG.2.1.4293.1044

Acin, S.Y. (1998). Latest Construction Techniques of Baglama and Rebab, Two Turkish Folk Music Instruments. Proficiency Thesis in Art, Istanbul Technical University, Institute of Social Sciences, Istanbul

Akyol, A. (2017). Rebab's Yesterday, Today and Tomorrow. *Inonu University Journal of Culture and Art*, *3*(1), 163-181. https://doi.org/10.22252/ijca.337011

Alaskan, A.M. (2012). Research on Musical Sound and Its Features, Depending on Structural Properties of Hides Investigation. Ph.D. Thesis, Ege University Science Institute, Izmir, 110

Alaskan, A.M. (2013). Instrument Making Education in Universities and the Traditional Master-Apprentice Relationship. *Journal of Cankiri Karatekin University Social Sciences Institute*, *4*(1), 175-180

Alaskan, A.M. (2013). Research on Musical Sound and Its Features, Depending on Structural Properties of Heads. *Ege University State Turkish Music Conservatory Journal*, (3), 65-77

Altiparmak, C. (2007). Rebab in Turkish Music and Standardization in Its Structure. Master's Thesis, Istanbul Technical University, Social Sciences Institute, Istanbul, 115

Bayramoglu, E.E. (2012). Environmental Problems in Leather Tannery and Sustainable Production, Tannery and Environment. In: G.T. Yamamoto (Ed.), *Tannery and Environment*. Kriter Publishing, Istanbul, 31-54, ISBN: 978-605-4613-56-4

Bayramoglu, E.E., Ozcelik, A., Civi, S., Eke, G. & Bayramoglu, B. (2024). Keratin Hydrolysis from Tannery Unhairing Process Wastes Structural Property Determination and Keratin Molecular Size Investigation Reducing by Electrospinning Method. *Journal of the American Leather Chemists Association*, *119*(7), 314-322

Belenkie, I., Dani, R., Smith, E.R. & Tyberg, J.V. (1992). The Importance of Pericardial Constraint in Experimental Pulmonary Embolism and Volume Loading. *American Heart Journal*, *123*(3), 733-742. https://doi.org/10.1016/0002-8703(92)90514-V

Berg, E.R. & Stork, G.D. (1982). *The Physics of Sound*. Prentice-Hall Inc., Englewood Cliffs, 07632, ISBN: 0-13-674283-1

Bode, W. & Maskos, K. (2001). Structural Studies on MMPs and TIMPs. *Methods in Molecular Biology*, *151*, 45-77

Bode, W., Catalan, C.F., Tschesche, H., Grams, F., Nagase, H. & Maskos, K. (1999). Structural Properties of Matrix Metalloproteinases. *Cellular and Molecular Life Sciences*, *55*, 639–652. https://doi.org/10.1007/s000180050320

Calero, P., Herrero, E.J., Turnay, J., Olmo, N., Silanes, I.L., Lizarbe, M.A., Maestro, M.M., Arenaz, B. & Castillo-Olivarez, J.L. (2002). Gelatinases in Soft Tissue Biomaterials. Analysis of Different Crosslinking Agents. *Biomaterials*, *23*(16), 3473-3478. https://doi.org/10.1016/S0142-9612(02)00054-6

Celentano, D.C. & Frishman, W.H. (1997). Matrix Metalloproteinases and Coronary Artery Disease: A Novel Therapeutic Target. *The Journal of Clinical Pharmacology*, *37*(11), 991-1000. https://doi.org/10.1002/j.1552-4604.1997.tb04278.x

Celik, O. (2023). *Three-Stringed Instrument in the Turkish World: Kılkopuz, Kemanche and Rebab*. 2nd Edition, Ege University Publishing, Izmir. ISBN: 978-975-483-878-7

Chen, J.Z.H. & Shan, Z. (2022). A Sound-Absorbing and Heat-Insulating Collagen Fiber Composite Material. *Cellular Polymers*, *42*(1), 3-24. https://doi.org/10.1177/02624893221130154

Chien, J.C.W. & Chang, E.P. (1972). Small-Angle Light Scattering of Reconstituted Collagen. *Macromolecules*, *5*(5), 610–617. https://doi.org/10.1021/ma60029a016

Covington, A.D. (2009). *Tanning Chemistry: The Science of Leather*. R.S.C. Publishing, London. ISBN: 978-0-85404-170-1

Degirmenli, E. (2023). Musical. In: Acigoz, S. (Ed.), *A Journey from Vibration to Sound: Instrument Acoustics*. Bogazici University Publishing, Istanbul, *15*, 42-57. Retrieved from: http://butmk.boun.edu.tr

Dikmelik, Y. (2013). *Leather Technology*. Sepici Culture Service Publishing, Izmir. ISBN: 978-605-85630-0-1

Ege University State Turkish Music Conservatory Instrument Sales Unit (EUSTMCIS), Bornova, Izmir

Elias, H. & Boyd, L.J. (1960). Notes on the Anatomy, Embryology and the Histology of the Pericardium. *New York Medical College News and Notes*, *2*, 50–75

Grant, D.A., Kondo, C.S., Maloney, J.E. & Tyberg, J.V. (1994). Pulmonary and Pericardial Limitations to Diastolic Filling of the Left Ventricle of the Lamb. *American Journal of Physiology*, *266*(6), 2327–2333. https://doi.org/10.1152/ajpheart.1994.266.6.H2327

Grant, D.A., Kondo, C.S., Maloney, J.E., Walker, A. & Tyberg, J.V. (1992). Changes in Pericardial Pressure During the Perinatal Period. *Circulation*, *86*(5), 1615-1621. https://doi.org/10.1161/01.CIR.86.5.1615

Harmancioglu, M. & Dikmelik, Y. (1993). *Rawhide Structure Composition and Properties*. Ozen Offset, Izmir

Hashas, S. & Imik, U. (2016). Innovative Experiments in Turkish Folk Instrument Making; Cumba, Bowed Baglama, Bass Rebab, Cura with Squash Box. *Inonu University Journal of Culture and Art*, *2*(1), 93-106

Hiester, E.D. & Sacks, M.S. (1998a). Optimal Bovine Pericardial Tissue Selection Sites. I. Fiber Architecture and Tissue Thickness Measurements. *Journal of Biomedical Materials Research*, *39*(2), 207-214. https://doi.org/10.1002/(SICI)1097-4636(199802)39:2%3C207::AID-JBM6%3E3.0.CO;2-T

Hiester, E.D. & Sacks, M.S. (1998b). Optimal Bovine Pericardial Tissue Selection Sites. II. Cartographic Analysis. *Journal of Biomedical Materials Research*, *39*(2), 215-221. https://doi.org/10.1002/(SICI)1097-4636(199802)39:2%3C215::AID-JBM7%3E3.0.CO;2-S

Ishihara, T., Ferrans, V.J., Jones, M., Boyce, S.W. & Roberts, W. (1981). Structure of Bovine Parietal Pericardium and of Unimplanted Ionescu-Shiley Pericardial Valvular Bioprostheses. *The Journal of Thoracic and Cardiovascular Surgery*, *81*(5), 747-757, PMID: 7218840. https://doi.org/10.1016/S0022-5223(19)39457-7

Ishihara, T., Ferrans, V.J., Jones, M., Boyce, S.W., Kawanami, O. and Roberts, W.C. (1980). Histologic and Ultrastructural Features of Normal Human Parietal Pericardium. *The American Journal of Cardiology*, *46*(5), 744-753. https://doi.org/10.1016/0002-9149(80)90424-5

Kaya, M.R. (1998). Rebab from Past to Today and Its Reconsideration. Proficiency in Art Thesis, Istanbul Technical University, Institute of Social Sciences, Istanbul, 168

Majid, A.Z.A., Suhaily, S.S., Mutti, M.A.I., Rizal, R. & Aizal, M. (2023). Sound Analysis of an Innovative Development for a Traditional Music Instrument. *Journal of Pharmaceutical Negative Results*, *14*(2), 266-273. https://doi.org/10.47750/pnr.2023.14.02.33

Massova, I., Kotra, L.P., Fridman, R. & Mobashery, S. (1998). Matrix Metalloproteinases: Structures, Evolution, and Diversification. *The FASEB Journal*, *12*(12), 1075-1095. https://doi.org/10.1096/fasebj.12.12.1075

Mazlum, H. (2011). Examining the Timbral Characteristics of Turkish Music Instruments and Miking Techniques. Master's Thesis, Istanbul Technical University, Social Science Institute, Istanbul, 216

Naffa, R., Maidment, C., Ahn, M., Ingham, B., Hinkley, S. & Norris, G. (2019). Molecular and Structural Insights into Skin Collagen Reveals Several Factors that Influence Its Architecture. *International Journal of Biological Macromolecules*, *128*, 509-520. https://doi.org/10.1016/j.ijbiomac.2019.01.151

Oflaz, D. (2008). Sound Recording Techniques Today and Used in Turkish Music Recordings Methods. Master's Thesis, Istanbul Technical University, Social Science Institute, 210

Oswal, D., Korossis, S., Mirsadraee, S., Wilcox, H., Watterson, K., Fisher, C. & Ingham, E. (2007). Biomechanical Characterization of Decellularized and Cross-Linked Bovine Pericardium. *The Journal of Heart Valve Disease*, *16*(2), 165-74, PMID: 17484467

Ozcan, A.G. (2008). Iklığ, Rebab, Kemancha, Violin: String Instrument Evolution and Music. Master Thesis, Mersin University, Social Sciense Institute, 66

Ozdemir, M.A. (2020). Iklığ (Iklık) Family as an Advanced Instrument and Teaching-Education Practices. *ASOS Journal*, *8*(107), 1-31. https://doi.org/10.29228/ASOS.43824

Phillips, H. (1954). The Chemistry of Leather. *Journal of the Royal Society of Arts*, *102*(4934), 824-875. Retrieved from: https://www.jstor.org/stable/41365795

Rai, I.W., Sadguna, I.G.A.J. & Sadguna, I.G.M.I. (2019). Rebab: A Musical Instrument in Balinese Performing Art. *Journal of Arts and Humanities (JAH), 8*(5), 75-87. https://doi.org/10.18533/journal.v8i5.1644

Sener, G. (2019). Rebab's Historical Process and Present. *Journal of World of Turks*, *11*(1), 227-246. ISSN 1869-2338, 81

Sezer, S. (2016). Comparison of Rebab and Azerbaijani Kemancha in Terms of Performance Technique. Master's Thesis, Firat University, Social Science Institute, Elazig, 68

Sharphouse, J.H. (1971). *Leather Technician's Handbook*. Northampton, ISBN: 0-950-2285-1-6

Simionescu, D., Simionescu, A. & Deac, R. (1993). Mapping of Glutaraldehyde-Treated Bovine Pericardium and Tissue Selection for Bioprosthetic Heart Valves. *Journal of Biomedical Materials Research*, *27*(6), 697-704. https://doi.org/10.1002/jbm.820270602

Simsek, M. (2013). Regional Rebab Playing Techniques of Teke Region Burdur Province Local Rebab Players. Master's Thesis, Halic University, Social Science Institute, Istanbul, 93

Sizeland, K.H., Wells, H.C., Higgins, J., Cunanan, C.M., Kirby, N., Hawley, A., Mudie, S.T. & Haverkamp, R.G. (2014). Age Dependent Differences in Collagen Alignment of Glutaraldehyde Fixed Bovine Pericardium. *BioMed Research International*, *2014*(1), 1-10. https://doi.org/10.1155/2014/189197

Smiseth, O.A., Scott-Douglas, N.W., Thomson, C.R., Smith, E.R. & Tyberg, J.V. (1987). Nonuniformity of Pericardial Surface Pressure in Dogs. *Circulation*, *75*(6), 1229-1236. https://doi.org/10.1161/01.CIR.75.6.1229

Sonmez, D. (2008). In Anatolia in Ancient Period Music and Musical Instruments. Master's Thesis, Selcuk University, Institute of Social Sciences, Konya, 178

Wong, W.L.E., Joyce, T.J. & Goh, K.L. (2016). Resolving the Viscoelasticity and Anisotropy Dependence of the Mechanical Properties of Skin from a Porcine Model. *Biomechanics and Modeling in Mechanobiology*, *15*, 433–446. https://doi.org/10.1007/s10237-015-0700-2

Yegin, V. (1994). New Construction Techniques in Rebab. Master's Thesis, Istanbul Technical University, Institute of Social Sciences, Istanbul, 55

Zioupos, P. & Barbenel, J.C. (1994a). Mechanics of Native Bovine Pericardium: I. The Multiangular Behavior of Strength and Stiffness of the Tissue. *Biomaterials*, *15*(5), 366-373. https://doi.org/10.1016/0142-9612(94)90249-6

Zioupos, P. & Barbenel, J.C. (1994b). Mechanics of Native Bovine Pericardium: II. A Structure Based Model for the Anisotropic Mechanical Behaviour of the Tissue. *Biomaterials*, *15*(5), 374-382. https://doi.org/10.1016/0142-9612(94)90250-X