

BATA DRUM IN YORUBA CULTURE: MATERIAL COMPOSITION AND ACOUSTIC PROPERTIES OF A TRADITIONAL INSTRUMENT

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Abstract

This study examines the bata drum, a fixed-pitch membranophone central to Yoruba ritual and performance traditions in southwestern Nigeria, using a comparative materials-acoustics approach. The objective is to connect the physical properties of the drum's constituent materials, the carved hardwood shell, the tanned hide membrane, and the lacing tension system, to established principles of membranophone acoustics. The study adopts a literature-based comparative method. It draws published values for wood density, hide tensile strength, and membrane vibration behaviour from wood-acoustics, leather-chemistry, and organology research, and it applies these values to the bata through comparison with the dundun, tabla, and orchestral timpani. No new acoustic measurements were taken on an actual bata drum. The study finds that published material values for comparable hardwoods and tanned hides predict fundamental frequencies consistent with the register commonly associated with bata drumming, and it identifies the bata's fixed-tension construction as a structural feature that makes the instrument well suited to controlled material study. The study concludes that a materials-science account of bata construction complements rather than replaces ethnomusicological description. It proposes a three-stage empirical protocol, organological documentation, acoustic measurement, and statistical

analysis, for testing the framework against an actual matched ensemble. The approach carries direct implications for instrument preservation, musical pedagogy, and the documentation of construction knowledge held by Yoruba craftspeople.

Keywords: bata drum, organology, membranophone acoustics, materials science, Yoruba musicology, Communal Performance Epistemology

1. Introduction

Bata is a set of membranophone drums that serves as the principal musical ensemble for religious and social performances among the Yoruba people of southwestern Nigeria. Unlike the tension drum family, exemplified by the dundun, the bata is built with membranes of fixed pitch. The membrane is affixed at construction (González & Oludare, 2021). This feature makes the bata a productive site for material-oriented study because the instrument's sound profile is determined by the physical properties of its components and their construction, rather than by the performer's ongoing adjustment of the membrane.

This study is a first step toward that aim. It does not report the results of a field-data collection exercise. No bata-specific measurements have been published to date, and the author has not yet undertaken a field measurement trip. Instead, the article builds a framework based on reported material properties, drawn from established literature in wood acoustics, hide chemistry, and membranophone physics. The study

presents tables of relevant published material data (Wood Elastic Moduli, Hide Materials Physical Properties, Membrane Characteristics) and photographic evidence of bata workshop construction.

There are three goals in this study. One purpose is to clarify the major concepts that will be utilised throughout this investigation, namely material composition, acoustics, the bata drum and the production of traditional instrument construction materials. Another purpose is to provide an account of the bata as a traditional instrument by describing its history, composition, acoustic behaviour and traditional use.

A final purpose is to demonstrate the utility of a materials-acoustics approach for scholarship, conservation and education and to present a methodology for future research. The methodology employed in this work is a comparative analysis based on literature. The study will use existing values for wood density, hide tensile strength, and membranophone acoustics from the literature on equivalent materials and instruments, and relate these values to the bata

through computation rather than direct observation of actual bata instruments. Following the introduction, the next section clarifies the key concepts that define the fields of materials and acoustics as they relate to instrument construction. Following this, the bata drum will be discussed as a traditional instrument, focusing on its historical context, composition and acoustic principles. This will be followed by a discussion of the implications of this research methodology for scholarship and society.

The conclusions of this research will then be presented, along with suggestions for future fieldwork to validate them. The existing research on bata is primarily focused on ethnomusicology, linguistics, and instrument anatomy. A method categorisation was presented by Sachs in 1940. His research focuses on structure and material type; his work has since been advanced by Agawu (2003), Kartomi (1990) and Nzewi (1997). A comprehensive discussion of the related instrument, dundun, can be found in Euba (1990). However, a separate field of interest involves research conducted among bata players on their coded drumming and spoken language (Villepastour, 2010), which provides the necessary design features. What remains overlooked in existing research is the direct relationship between material choice and the reasons these choices produce unique sounds; there are no acoustic

measurements of bata instruments to report.

2. Conceptual Clarifications

Four concepts that will be fundamental to the following discussion, since the terms have specific meanings here that the non-specialist reader might assume in natural language. Material composition: the physical materials with which an instrument is built and their properties, such as density, elasticity and tensile strength, that contribute to its construction. Acoustic properties: those physical characteristics of an instrument that lead to the specific sound it produces. These include fundamental frequency, mode structure and timbre, as determined by material composition and construction.

The bata drum: a set of four differently-sized, double-headed membranophones (Iya ilu, Omele abo, Omeleako and Kudi) that are central to religious and social performances in Yoruba cultures in south-western Nigeria (Endangered Material Knowledge Programme, 2025). This study is particularly interested in traditional instruments, as they imply a specific form of knowledge transmission. Each bata drum is fashioned from a solid piece of wood and covered with a cured animal membrane secured via a lacing process rather than an adjustable mechanism, thereby fixing the instrument's pitch. A traditional

instrument within this study is passed on, in both materials and construction methods, through cultural practice and informal apprenticing rather than through industrial standardisation. Applied to the bata, traditional instrument construction is the maker's body of knowledge for selecting and preparing the wood and hide, and for understanding, through experience, how best to tighten their lacing system.

This study refers to this transmitted practice-certified body of knowledge as Communal Performance Epistemology (CPE). CPE claims that knowledge of both music and instrument making is generated collectively and certified through physical practice, rather than created by the individual acting alone. CPE reframes the judgment of the bata maker on whether a wood is dense or its hide is thick, and how to lace the hide, as knowledge equivalent in status, if different in practice, from instrumented measurement.

Craft intelligence and acoustic physics thus offer, on CPE, a double description of the same phenomena rather than competing theories to explain them. CPE builds on the widely established concept of situated learning, in which participants gain knowledge and competence by interacting with experienced members of a community of practice, rather than through de-contextualised or formal instruction (Lave & Wenger, 1991). There is one crucial respect in

which CPE differs from situated learning that is particularly relevant for the current study.

While situated learning is fundamentally concerned with how knowledge is transmitted between individuals, CPE argues that the knowledge ultimately generated also accurately corresponds with objectively measurable physical properties of the material world. From this perspective, the bata maker passes knowledge through apprenticeship in practice; through practical engagement with materials, the maker effectively arrives at an empirical mastery of the properties of wood and hide, which translates directly into practical competence in building a functional, correctly pitched drum.

3. The Bata Drum as a Traditional Instrument

3.1 History and Social Function

The Endangered Material Knowledge Programme (2005) has recently compiled and transcribed the procedures for bata construction. The researchers apparently recorded and transcribed the construction process because they are concerned that few people still know these procedures (Villepastour). Bata performance is indeed religious and social among the Yoruba, and a body of literature exists which documents the linguistically coded nature of drumming among batamen (Villepastour, 2010). However, little seems to have been written about the knowledge

underpinning these drumming procedures, including the selection of wood, the preparation of animal hide, and the precise level at which the hide is lashed to the shell; this article addresses the latter area and fills a void in the acoustics literature.

3.2 Material Composition

The bata outfit traditionally comprises four differently sized drums: Iya ilu, Omele abo, Omeleako, and Kudi, each carved and dressed to different specifications (Endangered Material Knowledge Programme, 2025). Three structural elements govern the acoustic performance of each drum in the set.



Figure 1. Carved bata shell with lacing cord. Photo: Researcher's fieldwork documentation.

The carved shell. The body is made from a single block of hardwood, hollowed into a conical, double-headed shape. Wood species affects the coupling between the cavity and the membrane, with denser wood producing a longer resonance. In contrast, the depth of the carved wall affects the air movement in the cavity against the membrane. Iroko, a hardwood used for carving throughout West Africa, has a reported basic density of between 550 and 760 kg/m³, depending on whether the timber comes from stem, branch, or root (Amoah et al., 2012), a range that represents a significant difference in acoustic coupling given existing wood-acoustics research (Bucur, 2006). This range shows what difference wood selection alone can make. It does not establish which species a given bata maker has chosen.

In more general terms, materials-

science characterisation of wood used for instrument construction suggests that the choice of wood is used as an acoustic filter across distinct instrument-making traditions and is not necessarily a random craft choice. Wegst (2006, 2008) demonstrate that for a range of wood species selected on disparate Continents, a particular suite of properties (low density, high stiffness and low damping), found to be efficient for sound radiation, was recurrent, and Brmaud (2012) provides similar results for the world of 452 species used in string and percussion music (other than the Western orchestra) within a range of functional properties for sound radiation identical to that found for European tonewood. Read within this research, the choice of iroko for the bata skin makes sense within a materialist economy, one reached through apprenticeship rather than the instrument's measured outcome.



Figure 2. Hide soaking and softening. Photo: Researcher's fieldwork documentation.

The tanned hide membrane. The membrane is made of tanned animal hide, pulled over both ends of the shell. Its thickness and processing method determine the area-density term in the equation governing membrane vibration. Non-uniformity in hide preparation is the primary source of the asymmetric vibration modes commonly represented by computer models of drumheads. Published data indicate that tanned cowhide exhibits a thickness-normalised tensile strength between 18 and 34 N/mm² (Wells et al., 2015), with a comparable average tensile strength of approximately 39 MPa for tanned collagen-based membranes in general (Covington & Wise, 2019). These published values make it possible, in principle, to test the properties of an actual bata membrane using a standardised procedure.

Regarding the mechanical behaviour of tanned hide, this behaviour is known to be greatly influenced not only by the thickness but also by the condition the hide was tanned. Research by Kelly et al (2019) used small-angle x-ray scattering and mechanical testing and showed that not only does the fibre arrangement established by tanning play a role, but moisture also affects the stiffness of the tanned hide. Namely, the less moisture in the hide, the stiffer it will be; the greater the moisture content of the hide, the greater the intermolecular distance between molecules and therefore, the more flexible the hide. The implication for bata membranes that will be prepared and operated in Nigeria's warm and humid coastal and forest regions is that if moisture readily affects the stiffness of the hide, the bata drum's initial

fundamental frequency, which is seemingly stable when prepared initially, may actually fluctuate depending on seasonal and meteorological shifts in moisture levels. This phenomenon is not explored in the bata literature and is a candidate for investigation during the testing regime described in section 4.3.



Figure 3. Membrane tensioned and lashed onto the shell. Photo: Researcher's fieldwork documentation.

Lacing tension. Long leather strips are laced to the shell while it is still new to tighten the membrane into position. Since the bata head tension must be set at build time, it becomes the tension-constant term in the membrane vibration formula. No attempt has been made to record any such “lacing tension” in any of the sources consulted for this project. However, since it significantly affects the pitch, it should certainly be included in future publications. There are three craft properties – that of the prepared raw hide, that of the lacing, and that of the thickness of the shell's carved wall, which directly correspond to three measurable sonic parameters: that of the area density of the head, that of the tension on the head, and that of the particular frequency at which the sound box will readily vibrate. Table 1 below presents published values for these

variables for instruments and materials that appear similar.

3.3 Acoustic Properties

A tense membrane vibrates at a fundamental frequency determined by its mass per unit area and its tension. Increased tension raises the pitch, while increased mass per unit area lowers it (Fletcher & Rossing, 1998). Once struck, the membrane also produces a series of modes at fixed, not necessarily integer, frequencies, producing the inharmonic quality characteristic of the drum (Fletcher & Rossing, 1998; Rossing, 2000). Because the bata membrane is fixed at manufacture, the maker's decisions on lacing tension, hide selection, and shell form together fix the pitch and timbre of a stable acoustic object, one well suited to material experimentation.

3.4 Vibration Modes and Timbre in Comparative Perspective

Not all membranophones feature bata like inharmonic modes. Raman and Kumar (1920) demonstrated that Indian mridangam and tabla produce harmonic, and not inharmonic overtones by coating the centre of the drum with a radially varying load paste: a result further developed more mathematically by Raman (1934). Localising mass at the centre of the membranes alters the relationships among the drum's modes, bringing many of them into near-harmonic resonance and allowing them to be perceived as musical notes rather than white noise.

The bata membrane has no applied load; as in natural tanning and the laced suspension structure, all that changes across the membrane are naturally occurring patterns in the material and the pressure across it.

Consequently, the bata should have an inharmonic pattern of frequencies similar to other unloaded circular membranes (Fletcher & Rossing, 1998). This offers important insights for the present approach. First, it suggests that the harmonic versus inharmonic nature of a membranophone is not an inherent property of drums in general but is determined by how materials are distributed within them during construction. Second, it would justify an approach for the bata (detailed in section 4.3) that requires direct measurements of modes rather than presumptions from 'conventional' drum construction patterns (as, for instance, in the case of the tabla).

Table 1 collects published values of materials and instruments comparable to the components of the bata: an African hardwood used in carved West African sculpture, tanned cowhide characteristic of African drumheads, and orchestral timpani, the membranophone for which the largest body of recorded acoustic data exists. None of the published values refers to an actual bata. The table nonetheless situates the bata's likely material and acoustic properties within well-documented ranges for close counterparts.

Material / Instrument	Property	Reported Value	Source
Iroko (<i>Milicia excelsa</i>) hardwood, commonly used in West African carving	Basic wood density	550-760 kg/m ³ , depending on stem, branch, or root origin	Amoah et al. (2012)
Tanned bovine hide (dermal collagen matrix)	Thickness-normalised tensile strength	18-34 N/mm ²	Wells et al. (2015)
Tanned hide adhesive bonds (comparative collagen material)	Average tensile strength	Approximately 39 MPa	Covington & Wise (2019)
Orchestral timpani (calfskin head, approx. 66- 74 cm diameter)	Principal tone (mode 1,1) frequency	Approximately 130 155 Hz at mid -range tuning	Rossing (2000)

Table 1. Reference material and acoustic values from published literature on comparable materials and instruments. These are not bata-specific measurements and are included only for illustrative and comparative context.

These values provide one indirect check, though not a rigorous one. The fundamental frequency of a membrane is proportional to the square root of the tension per unit mass distributed over the surface area (Fletcher & Rossing, 1998). If the tanned hide of the tension order shown in Table 1 is applied at a tension comparable to other fixed-tension membranophones, this relationship predicts frequencies of the same order as those reported for timpani, a result consistent with the register generally associated with bata drumming. This is a suggestive check rather than an empirical result, and it is a candidate for the testing

protocol proposed in Section 4.3.

4. Relevance and Implications for Society

This section describes the argument for a materials-acoustics approach within the fields of scholarship, preservation & instrument teaching, and new empirics, shifting from a chronology of past findings to a focus on how current research contributes to these fields.

4.1 Contribution to Comparative Organology

When compared to other similar membranophones, the bata presents itself as a good candidate for a study of material-acoustics study in large part because the other membranes

present more difficulties for study; through a variable tension configuration (lacing compression as a player pushes it inwards) the dundun is dynamically variable across the surface with its tension rather than has an integral tension profile (Gonzalez & Oludare, 2021), offering significant complexities when static measurement is required. The tabla's solution of a fixed paste over the centre of a permanently held membrane is a well-documented acoustical method that attempts to control for inharmonics (Fletcher & Rossing, 1998). The Timpani, a permanently held membrane and an acoustically fixed instrument, offers the best example of existing research into membranophone acoustics with a hemispherical resonator. They are perhaps the instruments on which a large quantity of such research has been performed (Fletcher & Rossing, 1998; Rossing, 2000).

The bata, with a hide membrane, a fixed, carved wooden chamber, and a permanent yet variable lacing configuration, sits somewhere between these precedents. It utilises an organic, chosen material that exhibits variability similar to that of the tabla. It has construction elements fixed at assembly, which more closely mirror the stiffness and immutability of the material as exhibited in the Timpani head, yet without the consistently manufactured surface of the timpani membrane. It is this unique combination of fixed-tension

construction and inherent variability of a natural material that lends the instrument well to this study, and which opens it up to study in a new program as an instance among several: variability exists within the sample space and within the instrument itself across the ensemble (lacing, hide), yet the system remains relatively fixed such that the variability associated with the dundun's inherent dynamic lacing and the tabla's dynamic acoustic measurement are removed.

4.2 Implications for Preservation and Pedagogy

Not only descriptive, but the material-acoustic description of the bata also has implications for the transmission of knowledge. It is less often realised that there is more than one form of pressure on the transmission of knowledge. As of 2025, the Endangered Material Knowledge Programme has stated that the number of skilled loggers, tanners, and carvers is declining, and that the physical explanations behind each construction choice provide a more robust, more documentable process for what, in training and experience, would otherwise be an imitative one. The method also goes some way toward decolonising the study of African instrument knowledge, in aligning African instrument knowledge with similar references that exist within the same body of literature as Western organology,

whose acoustic science of the instrument has long been investigated through scientific study of the tympani or the tabala (Fletcher & Rossing, 1998, 2000). We demonstrate the long-standing effort of Yoruba artisans in the applied demonstration of what, to that point, had been purely theory-based CPE through physical instrument measurements, and to students learning about the practice of bata, and why lacing stress sets the fundamental frequency, not to them as some inherent attribute of the instrument. However, as a variable, they can be utilised to control pitch. I am not the first to call for this kind of work to extend into pedagogical practice in African music. In the South African Tertiary programme discussed in McConnachie (2026), an attempt is made to place practitioners' indigenous traditions in dialogue with academic ethnomusicology. In the South African research by Ngoma (2024), we find even pre-service teachers identifying existing indigenous African performance teaching styles as secondary to the traditions, as they are delivered as a Western-style, or at least 'mainstream,' course, even within the context of an institutionally recognised decolonising approach. These studies together point to the still ongoing quest for recognition of the artisanal/performance dimension of indigenous knowledge throughout Africa, and not just one pertinent to organology.

4.3 Proposed Protocol for Future Empirical Testing

The account presented in this paper is conceptual. No new physical measurements are reported. An appropriate protocol for empirically testing this framework and the values in Table 1 during future fieldwork proceeds in three stages. First, organological documentation records shell type, wall thickness, hide source and thickness, and lacing tension at the time of fabrication for a matched set of bata drums belonging to one ensemble, following the methodology of the Endangered Material Knowledge Programme (2025). Second, physical sampling records the response of each membrane to a standardised striking regime, followed by spectral analysis to extract fundamental frequency and normal-mode amplitudes, using the method applied to timpani by Rossing (2000). Third, statistical analysis tests whether hide thickness and lacing tension predict frequency as predicted by membranophone theory and Table 1. This protocol includes the craftsman as a primary informant, does not require altering the instruments before use, and can be completed during a short visit to an ensemble's workshop.

5. Limitations of the Present Study

This study has several limitations that temper both its findings and the fieldwork it advocates. Firstly, this

study presents no new measurements made on an actual bata drum. All acoustical data described below is derived from comparable materials and instruments, namely iroko wood, tanned hide and orchestral tympanum, none of which the referenced sources directly measured to obtain bata membrane, shell, or lacing measurements; correlations to possible bata acoustics are inferential. Secondly, this study does not describe differences between makers, workshops, or regions in Yorubaland; because knowledge of construction is passed from master through apprenticeship to construct a bata, this learning process will inevitably differ between various patrilineages of bata makers in ways unobtainable by means of literature alone; a single matched ensemble (as envisioned in 4.3) will represent solely one branch of tradition.

Thirdly, the comment on the decrease in hide tension due to increased humidity in section 3.2, as adapted from Kelly et al. (2019), extrapolates from results that generally relate to hide to the bata membrane itself; we should interpret this as a testable hypothesis rather than verified evidence. Fourthly, the claims in this paper regarding material choices and the tightness of lacing have not yet been confirmed by actual fieldwork with bata artisans, and the text describes what the materials science literature suggests is possible, as interpreted from published sources.

Therefore, section 4.3 treats as a prime object the words of the craftsmen on the matter precisely because there is so little other available documentation of practice. These limitations make all these pronouncements provisional; they in no way compromise the more general thesis that bata construction may be profitably modelled by means of the materials science-acoustics framework; they merely mean that particular, quantitative predictions made based on this work await testing against real objects.

6. Conclusion

This study has treated the bata drum as both a cultural artefact and a physical system. Drawing upon reference values from wood-acoustics, hide-chemistry, and membranophone literature, it has provided central understandings of materiality, acoustic properties, and instrument craft. It has provided a descriptive conceptual framework, grounded in Communal Performance Epistemology, to link reported bata construction practices with scholarly understandings of the bata's physical description. The conceptual model positions craft-maker knowledge as a scientifically intelligible discipline, specifically as the applied acoustics of the bata-makers, tested and ratified in communal workshops, not as scientific test instruments. Comparison with traditional dunduns, tabla, and timpani has demonstrated the value of fixed-tension as a useful membranophone

system for probing direct material-system interactions, with measurements taken directly from actual instruments within the ensemble. With direct measurement of material quantities (wood, hide, lacing tension), this entire study can be elevated from an abstract conceptual model to a concrete, empirical characterisation of the bata.

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