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From coastal material to relational sound: rethinking organology through the *SUKABACA* aerophone in Maluku

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ABSTRACT

This study examines the transformation of the coastal plant *papaceda* (*Scaevola taccada*) into the aerophone instrument *SUKABACA* in Maluku, Indonesia, as an organological process based on local material. While traditional organology has focused on the classification and structural aspects of musical instruments, this research proposes a relational perspective that considers the interaction between material, structure, and musical practice. This study employs a qualitative approach with a practice-based research orientation, integrating instrument-making processes with acoustic analysis and performance evaluation. Data were collected through field observation, interviews, documentation, and organological experimentation, including material selection, instrument construction, and acoustic testing using a digital tuner. The findings show that the acoustic characteristics of *SUKABACA* are not solely determined by its structural configuration but are significantly influenced by the ecological properties of papaceda material and the performer's technique. The non-homogeneous structure of the material contributes to variable pitch stability and timbral characteristics, indicating that sound production emerges from the interaction between material properties and performative practice. This study contributes to the development of organology by proposing a local material-based approach, positioning material as an active agent in shaping sound and musical innovation. This perspective expands organological studies from classification toward a relational understanding of musical instruments within ecological and cultural contexts.

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1. Introduction

Organological studies have long been grounded in the classification of musical instruments based on their sound-producing mechanisms, as established by the Hornbostel-Sachs system [1]. This framework has provided a foundational taxonomy for understanding instrument types and their structural characteristics. Early organological studies have also been shaped by historical perspectives on musical instruments, particularly in understanding their development across cultures [2]. However, such approaches tend to conceptualize musical instruments as stable objects with fixed acoustic properties, emphasizing classification and structural form rather than the processes through which sound is produced and experienced. Recent developments in ethnomusicology and organology have increasingly challenged this object-centered perspective. Scholars argue that musical instruments should be understood not merely as physical objects, but as entities embedded within social, material, and cultural processes [3]–[5]. From this perspective, instruments emerge through interactions between humans, materials, and environments, where sound is not a fixed attribute but a dynamic outcome of these relationships. Ethnomusicological approaches further conceptualize music as a cultural practice involving the interrelation of ideas, behaviors, and sound, as articulated by Merriam, and further developed by Nettl and Rice in emphasizing the contextual and performative nature of musical practice [3], [6].

In parallel, material-oriented perspectives in anthropology and sound studies highlight the active role of materials in shaping human experience. Ingold and Stobart argue that materials are not passive substances but active participants in the formation of cultural practices and sensory outcomes [7], [8]. Within music studies, this perspective is further extended through ecomusicology, which emphasizes the relationship between sound, environment, and ecological context [9], [10]. In this context, sound is not only produced by the instrument itself but is also shaped by spatial and environmental conditions, where musical experience emerges through the interaction between sound, space, and social context [11]. These approaches collectively suggest that sound production is not solely determined by instrument structure, but emerges from the interaction between material properties, environmental conditions, and embodied performance.

Despite these developments, conventional organological approaches remain largely grounded in object-based frameworks that prioritize classification, structural stability, and acoustic standardization [1]. While such frameworks are analytically useful for identifying instrument types, they are insufficient to explain how sound emerges through dynamic interactions between material, ecological context, and performative practice. Consequently, processes of transforming local materials into musical instruments, particularly those shaped by specific environmental conditions and local knowledge systems, remain under-theorized within contemporary organological discourse [3]–[5], [7]. This limitation also reflects the lack of attention to material-based musical innovation, where the emergence of new instruments is often shaped by the interaction between local materials, sensory exploration, and cultural practice, as discussed in studies on instrument innovation [12].

This study argues that conventional organology is insufficient to account for instruments whose acoustic behavior is fundamentally shaped by non-standardized natural materials. Rather than treating instrument-making as a purely technical or craft-based activity, this research conceptualizes the transformation of local materials as a relational organological process in which sound is co-produced through the interaction between material, structure, and embodied performance. Using the transformation of the coastal plant *papaceda* (*Scaevola taccada*) into the *SUKABACA* aerophone in Maluku as an empirical case, this study demonstrates how ecological material properties actively shape acoustic behavior, thereby challenging assumptions of stability and standardization in conventional instrument-making. From an acoustical perspective, variations in pitch stability and timbral response can be understood as the result of airflow behavior and resonance conditions within the material structure, as explained in foundational studies of musical acoustics [13], [14]. Accordingly, this study advances a material–relational organology as a conceptual contribution to contemporary organological studies. This framework repositions material not as a passive medium, but as an active agent that constrains and enables sonic possibilities within musical practice, in line with material-oriented perspectives in anthropology and ethnomusicology [7], [8].

By integrating practice-based research, acoustic analysis, and performance evaluation, this study does not merely document the creation of a material-based instrument, but demonstrates the need to expand organological analysis from object classification toward relational processes of sound formation within ecological and cultural contexts. Previous studies by the author have explored material-based musical practices in Maluku, particularly in the development of stone-based instruments and ritual musical traditions, highlighting the importance of local materials in shaping musical systems [15], [16]. Based on this framework, this study aims to: (1) analyze the transformation of papaceda material into an aerophone instrument within a material-based organological perspective; (2) examine how the interaction between material properties, instrument structure, and embodied practice shapes acoustic characteristicsands; (3) articulate a conceptual contribution to organological studies, particularly in understanding musical instrument innovation based on local materials.

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2. Method

2.1. Research Design

This study employed a qualitative Practice-Based Research (PBR) approach integrating artistic practice, organological investigation, ethnographic inquiry, and practical acoustic evaluation [17]–[21]. Within the Practice-Based Research framework, artistic practice functions both as a creative process and as a means of generating research knowledge through the continuous interaction among ecological materials, instrument construction, musical performance, observation, and critical reflection [17]–[20]. Accordingly, the construction and evaluation of the *SUKABACA* aerophone constituted the principal empirical process through which new organological knowledge was generated. The study further incorporated an organological perspective to examine the relationships among natural material, structural configuration, sound production, and musical performance [1]–[5]. Rather than treating the instrument solely as a physical object, the research investigated how the natural characteristics of *papaceda* influenced construction decisions, performer interaction, and acoustic behaviour. Ethnographic inquiry complemented this perspective by documenting local ecological knowledge concerning papaceda and its traditional significance within the coastal communities of Maluku [22], [23].

2.2. Data Collection

Data were collected through four primary techniques:

- Field observation, conducted to identify the ecological characteristics of papaceda material, including growth environment, structural variation, and physical properties relevant to sound production.
- Semi-structured interviews, involving three key informants consisting of a local community member, an academic, and a music practitioner. These informants were selected purposively based on their knowledge and experience related to material use, musical practice, and cultural context. The interviews aimed to explore local knowledge, material selection criteria, and perspectives on sound production.
- Documentation, including photographs, video recordings, and process notes, systematically capturing each stage of material processing, instrument construction, and performance testing.
- Organological experimentation, consisting of material selection, instrument construction, and acoustic testing. A total of 12 papaceda stems were selected based on diameter (0.5–1 cm), density, and structural integrity, from which 5 instrument prototypes were constructed and tested.

2.3. Organological Experiment and Acoustic Testing

The organological experiment was conducted through sequential stages: (1) material selection; (2) controlled drying to reduce moisture content; (3) structural formation of the instrument body; (4) creation of embouchure and finger holes; (5) and tuning and acoustic testing. Acoustic testing was carried out using a digital tuner (A = 440 Hz standard) to measure frequency and pitch deviation in cents. Each pitch was tested through repeated measurements (minimum of three repetitions per note) to ensure consistency of results. The parameters measured included frequency (Hz), pitch deviation (cents), and response to variations in airflow. From an acoustical perspective, the analysis considers airflow behavior and resonance conditions within the material structure, following established approaches in musical acoustics [11], [13]. These measurements were used to evaluate pitch stability, timbral characteristics, and the relationship between material properties and sound production.

2.4. Performance Feasibility Testing

Performance feasibility testing was conducted to evaluate the musical functionality of the instrument. The instrument was tested by two performers: the researcher and one experienced music practitioner. Each instrument prototype was played in repeated sessions (minimum of three sessions per instrument), focusing on embouchure stability, airflow control, intonation accuracy, ergonomic handling, and timbral response. Performance observations were documented through audio-visual recordings and structured notes, allowing for comparative evaluation across different instrument prototypes and playing conditions. This stage emphasizes the embodied nature of musical knowledge, where sound emerges through interaction between the performer's body and the instrument [24], [25].

2.5. Data Analysis and Validation

The collected data were analyzed through processes of data reduction, categorization, and interpretative analysis. Organological analysis was applied to classify the instrument within the Hornbostel–Sachs framework, while also examining its limitations in explaining the relational aspects of sound production [1]. Acoustic data were analyzed to identify patterns of pitch stability, frequency variation, and timbral response across repeated tests. Qualitative data from observations and interviews were used to interpret the role of ecological conditions and local knowledge in shaping material selection and sound production. To ensure the validity and reliability of the findings, data triangulation was conducted by comparing results from observation, interviews, documentation, and experimentation. In addition, repeated acoustic testing was employed to confirm measurement consistency, while performance testing provided empirical grounding for evaluating the instrument's musical feasibility. This approach aligns with practice-based research methodologies that emphasize knowledge production through artistic and material engagement, where making and analysis function as integrated processes. This analytical approach is also informed by broader methodological perspectives in acoustic analysis and ethnographic research [21], [26], [27].

3. Results and Discussion

3.1. Papaceda Material as an Agent of Sound Formation

Papaceda (Scaevola taccada) as the primary material used in the *SUKABACA* instrument demonstrates that sound production cannot be understood solely as the result of structural design, but rather as the outcome of interaction between material properties, ecological conditions, and practical use. This plant grows in coastal environments characterized by strong sea winds and rocky substrates, which influence its density, fiber structure, and the formation of natural cavities within the stem. These ecological conditions result in a non-homogeneous material that directly affects its acoustic response. This perspective aligns with ethnomusicological and material-oriented approaches that position materials as part of a relational system involving humans, environment, and musical practice [3]–[5], [7]. Fig. 1 presents the natural habitat and general morphological characteristics of papaceda observed during fieldwork in Ulahahan Village.

Fig 1. Natural habitat of papaceda (Scaevola taccada) in the coastal area of Ulahahan Village.

In this context, sound is not produced solely by the instrument as an object, but is also shaped by the spatial and environmental conditions in which the material develops and is used. Musical experience emerges through the interaction between sound, space, and social context, indicating that spatial and ecological dimensions play a crucial role in shaping sonic characteristics [11]. Furthermore, the relationship between material and environment can be understood within the framework of soundscape studies, where ecological conditions not only shape sonic experience but also influence how sound is perceived and contextualized within everyday life [28]. This perspective can also be linked to broader ecological approaches that examine the relationship between environment, material, and cultural practice in shaping sound [29]. Field observations indicate that papaceda stems exhibit variations in shape and size depending on their growth environment. This variation reflects the non-homogeneous nature of the material, where each stem possesses distinct acoustic potential. These differences become crucial in the material selection process, as not all stems produce similar sound qualities. In this sense, material cannot be regarded as a neutral medium, but rather as a determining factor in shaping the sonic possibilities of the instrument. As can be seen in Fig. 2.

Fig 2. Papaceda stems serve as raw material for the instrument.

Structurally, *papaceda* stems contain natural cavities formed from removable cambium, creating an air column that enables sound production similar to that of aerophones. However, these cavities are not symmetrical and exhibit variations in wall thickness across different stems. This condition causes instability in airflow within the tube, resulting in variations in frequency and distinctive timbral characteristics for each instrument produced. From an acoustical perspective, this phenomenon is related to airflow behavior and resonance conditions in non-homogeneous tubes, which directly affect pitch stability and sound quality [14], [30]. Fig. 3 presents the cross-sectional view of the selected papaceda stem after preparation. The photograph clearly shows the naturally occurring central cavity (lumen), indicating that the material already possesses an internal air passage capable of functioning as the resonating chamber of a wind instrument. The surrounding woody wall provides structural support for the subsequent stages of organological development, including embouchure formation, finger-hole drilling, and final tuning.

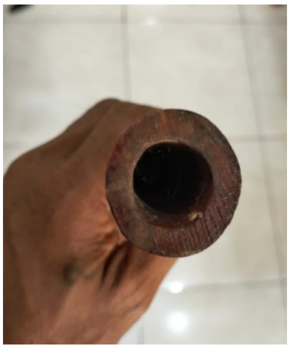

Fig 3. Cross-section of papaceda stem showing the natural cavity functioning as the air column in the *SUKABACA* aerophone.

These findings are reinforced by interviews with local community members, which reveal that papaceda is not perceived as a single-purpose material, but as part of a broader material system in everyday life. In addition to functioning as a natural barrier against coastal waves, papaceda stems are used as firewood and as raw material for accessories, such as headbands, utilizing the natural cavity of the stem. This knowledge indicates that local communities understand the internal structure of the material particularly the presence of cavities as a functional property across multiple uses. In this sense, the use of papaceda as a wind instrument does not emerge as an isolated innovation, but rather as a continuation of existing material practices within local knowledge systems [31], [32]. From an organological perspective, the presence of natural cavities in papaceda stems enables the formation of an air column as the primary source of sound production, classifying the instrument as an aerophone according to the Hornbostel–Sachs system [1]. However, the non-homogeneous nature of the material introduces variability in resonance stability that cannot be fully explained through conventional classification systems. This reveals the limitations of traditional organological approaches, which tend to emphasize structural stability, whereas in this case sound emerges from dynamic interactions between material, structure, and practice [3], [4].

Within contemporary organological frameworks, these findings demonstrate that material should not be positioned as a passive medium in sound production. Instead, material functions as an active agent that shapes acoustic characteristics and determines the boundaries of musical possibility. In this context, papaceda not only provides the physical form of the *SUKABACA* instrument but also constructs its sonic properties through ecological conditions and internal structure. This perspective aligns with material-oriented approaches in cultural and ethnomusicological studies, which emphasize the active role of material in shaping sonic experience [7], [8]. Therefore, *papaceda* as a material demonstrates that sound production in *SUKABACA* is a relational phenomenon that cannot be reduced to a single factor. Sound emerges from the dynamic interaction between material properties, ecological conditions, and practical engagement, collectively shaping the sonic character of the instrument. This finding reinforces the argument that within a material relational organology framework, material plays an active role in shaping sound, not merely as a container, but as a determining element in the formation of musical possibilities.

3.2. Instrument Structure and Embodied Performance

The structural configuration of the *SUKABACA* instrument demonstrates that sound production cannot be understood solely as a result of physical design, but must be examined as an outcome of interaction between structural properties and embodied musical practice. The instrument is typically constructed from papaceda stems measuring approximately 25–30 cm in length, with a diameter ranging between 0.5–1 cm, and features six finger holes and one embouchure hole arranged linearly along the body. This configuration enables pitch variation through combinations of finger positioning and airflow control. Fig. 4 illustrates the preparation of the embouchure opening after the *papaceda* stem had been cleaned and shaped.

Fig 4. Structural configuration of the *SUKABACA* instrument showing the linear arrangement of finger holes and embouchure for sound production.

Within conventional organological frameworks, instrument structure is often assumed to determine acoustic output in a stable and predictable manner [1]. However, the findings of this study indicate that the structure of *SUKABACA* does not automatically produce stable sound without active performative engagement. Instead, sound production depends significantly on the player's ability to regulate embouchure, airflow pressure, and finger coordination. This suggests that the structure functions not as a fixed determinant of sound, but as a framework that requires activation through bodily technique. From a performative perspective, this condition reflects the embodied nature of musical practice, where sound emerges through interaction between the instrument and the performer's body [24], [25]. The embouchure, as the point of contact between the player and the instrument, plays a crucial role in controlling airflow direction, pressure, and resonance. Minor variations in lip positioning and breath intensity result in measurable changes in frequency and timbre, indicating that sound is dynamically produced rather than mechanically fixed. This reinforces the view that musical knowledge emerges through embodied practice, where physical engagement with the instrument plays a central role in shaping sound production [19]. Musical performance also

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involves sensory and experiential dimensions that contribute to the formation of musical meaning and identity [33], [34]. Fig. 5 presents the formation and positioning of the six finger holes according to the dimensional proportions of the traditional Malukan bamboo flute.

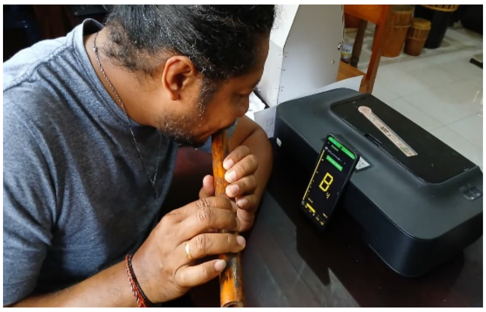

Fig 5. Drilling and positioning of the six finger holes based on the dimensional configuration of the traditional Malukan bamboo flute.

These observations are supported by acoustic testing, which shows that variations in blowing technique directly influence pitch output. Changes in airflow pressure and embouchure positioning result in fluctuations in frequency, reflecting the sensitivity of the instrument's internal air column. From an acoustical perspective, this phenomenon is consistent with airflow behavior and resonance conditions in wind instruments, where sound production depends on the interaction between air pressure, tube structure, and material properties [14], [30]. The experiential dimension of performance is further reinforced by insights from music practitioners, who describe the timbral quality of *SUKABACA* as soft, "calm," and emotionally expressive, differing from conventional bamboo flutes. While the instrument is perceived as relatively stable in performance, this stability is understood as the result of adaptive technique rather than inherent structural precision. The similarity in blowing technique to bamboo flute performance indicates that *SUKABACA* operates within a familiar performative framework, yet produces distinct sonic characteristics due to differences in material. Fig. 6 shows the completed *SUKABACA* aerophone following the final tuning adjustments.

Fig 6. Embouchure technique in *SUKABACA* performance showing the role of lip position and airflow control in sound production.

These findings demonstrate that the relationship between structure and performance in *SUKABACA* is inherently relational. The structural configuration provides the physical conditions for sound production but does not fully determine the acoustic outcome. Instead, sound emerges through continuous negotiation between material properties, structural design, and embodied practice. This reinforces the argument that musical instruments should be understood not as static objects, but as dynamic systems activated through performance [3], [4]. Furthermore, the structure of *SUKABACA* reflects an orientation toward performative interaction rather than structural standardization. The placement of finger holes, the dimensions of the air column, and the size of the embouchure are not determined solely by acoustic calculation, but are shaped through practical experimentation and bodily engagement. This indicates that instrument-making is closely tied to performative considerations, where structural design evolves in response to embodied musical practice. In this context, *SUKABACA* exemplifies an organological system in which structure and performance are inseparable. The instrument cannot be fully understood through its physical form alone, as its sonic

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characteristics emerge only through interaction with the performer's body. This perspective aligns with the framework of material–relational organology, where sound is conceptualized as the outcome of interaction between material, structure, body, and practice.

3.3. Acoustic Evaluation of the *SUKABACA* Aerophone

The findings of this study indicate that *SUKABACA* cannot be understood merely as an aerophone classified by its sound-producing mechanism, but as an empirical case that reveals the limitations of conventional organological approaches in explaining the relationship between material, structure, and musical practice. Within the Hornbostel–Sachs classification system, *SUKABACA* is categorized as an aerophone because its sound is produced through the vibration of an air column [1]. However, such classification only explains the type of instrument, without adequately addressing how sound is formed through the interaction of material properties, ecological conditions, and embodied performance. Acoustic testing results show that *SUKABACA* produces pitch deviations ranging from approximately ±1 to ±30 cents. Greater stability is observed in the middle register, while larger fluctuations occur in the extreme registers. These variations are not merely technical imperfections, but reflect the non-homogeneous nature of papaceda material, which directly influences resonance behavior within the air column. From an acoustical perspective, this phenomenon is related to the interaction between airflow, resonance length, and irregular material density, which collectively shape pitch stability and timbral response [14], [30]. In conventional organological frameworks, pitch stability is often considered a primary indicator of instrument quality, achieved through structural standardization and precision. However, in the case of *SUKABACA*, pitch variability reveals an alternative organological logic, where sound is not treated as a fixed and stable entity, but as the result of continuous negotiation between material properties and performative practice. In this context, what is technically perceived as "instability" becomes an inherent characteristic of the instrument's sonic identity. This interpretation aligns with ethnomusicological perspectives that conceptualize sound as a product of performance rather than a fixed property of an object [18], [19]. The tonal system of *SUKABACA* is therefore not entirely embedded within the instrument itself, but emerges through interaction between the instrument and the performer's body. Embouchure control, airflow pressure, and finger positioning play essential roles in shaping pitch and timbre, reinforcing the idea that sound is dynamically produced. To further illustrate the acoustic characteristics of SUKABACA, the following table presents the measured pitch, frequency, and deviation across its tonal range. Table 1 summarises the frequencies and pitch deviations produced by the *SUKABACA* aerophone.

Tabel 1. Frequency and pitch deviation (cents) of the *SUKABACA* aerophone obtained through repeated pitch verification using the DaTuner mobile application.

No	Pitch	Frequency (Hz)	Deviation (cents)
1	B4	493.88	±15–25
2	C#5	554.37	±15–20
3	D#5	622.25	±10–15
4	E5	659.25	±1–5
5	F#5	739.99	±1–5
6	G#5	830.61	±10–20
7	A#5	932.33	±15–25
8	B5	987.77	±20–30

The data show that pitch stability is relatively higher in the middle register (E5–F#5), where deviation is minimal, while greater variability is observed in both lower and higher registers. This pattern confirms that pitch stability in *SUKABACA* is uneven and is strongly influenced by the interaction between material properties, airflow control, and structural irregularities of the instrument. Based on these findings, this study advances a material–relational organology framework as a conceptual contribution to contemporary organological studies. This framework conceptualizes musical instruments as relational systems formed through the interaction of four interdependent elements: material, structure, body, and sound. Material provides ecological and physical conditions; structure organizes these conditions into an instrument form; the performer's body activates and negotiates the instrument; and sound emerges as the outcome of this dynamic interaction. This perspective extends recent

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developments in organology that emphasize the social and material dimensions of musical instruments [3]–[5]. These relationships can be conceptually illustrated through a relational model linking material, structure, body, and sound. The acoustic findings presented in this section provide the empirical basis for the conceptual framework proposed in Fig. 7.

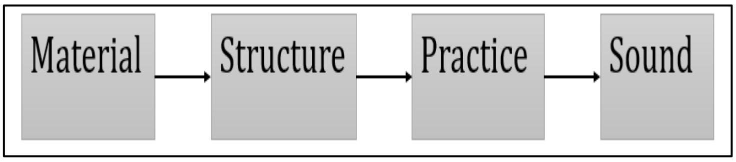

Fig 7. Conceptual model of material-based organology illustrating the dynamic relationship between material, structure, practice, and sound.

Within this framework, *SUKABACA* represents not merely the creation of a new instrument, but a demonstration of how local materials generate alternative organological possibilities. Rather than eliminating material irregularity, the instrument embraces it as a source of sonic variation and expressive potential. This finding aligns with studies on musical instrument innovation, which emphasize that innovation can emerge from engagement with material properties and local knowledge rather than from strict standardization [12]. Furthermore, *SUKABACA* illustrates that the boundary between instrument-making and musical practice is inherently fluid. The tonal system cannot be separated from performative interaction, and sound cannot be fully understood without considering the role of the body in shaping acoustic outcomes. This reinforces the view that musical instruments function as dynamic systems embedded within cultural and performative contexts [3], [4]. Therefore, the tonal system and acoustic characteristics of *SUKABACA* demonstrate that sound is a relational phenomenon that cannot be reduced to structural or material factors alone. Instead, sound emerges from the dynamic interaction between material properties, structural configuration, embodied practice, and environmental context. This finding expands organological understanding beyond classification-based approaches toward a relational framework that emphasizes processes of sound formation within ecological and cultural contexts.

4. Conclusion

This study demonstrates that the transformation of *papaceda (Scaevola taccada)* into the *SUKABACA* aerophone cannot be adequately understood through conventional organological approaches that emphasize classification, structural stability, and acoustic standardization. While such frameworks remain useful for identifying instrument types, they are insufficient to explain how sound emerges through the interaction of material properties, ecological conditions, and embodied musical practice. The findings show that the acoustic characteristics of *SUKABACA* are not determined solely by its structural configuration, but are significantly shaped by the non-homogeneous properties of *papaceda* material and the performer's interaction with the instrument. Variations in density, internal cavity formation, and ecological growth conditions directly influence pitch stability, resonance behavior, and timbral qualities. At the same time, sound production is not fixed within the instrument itself, but emerges through continuous negotiation between material structure and embodied performance, where embouchure control, airflow pressure, and bodily technique play essential roles. Based on these findings, this study advances a material–relational organology as a conceptual contribution to contemporary organological studies. This framework shifts the analytical focus from object-based classification toward relational processes of sound formation, conceptualizing musical instruments as systems formed through the interaction of material, structure, body, and sound. In this perspective, material is not a passive medium, but an active agent that constrains and enables sonic possibilities, while performance functions as the process through which these possibilities are realized. The significance of this study lies not merely in documenting the creation of a new instrument, but in demonstrating how local ecological materials can generate alternative organological logics. In the case of *SUKABACA*, material irregularity and acoustic variability are not treated as technical limitations, but as integral components of the instrument's sonic identity. This challenges dominant assumptions in organology that prioritize standardization and stability as primary indicators of instrument quality. Furthermore, this study contributes to ethnomusicological discourse by reinforcing the understanding of musical instruments as performative and culturally embedded systems. The findings highlight that instrument-making, material engagement, and musical practice are inseparable processes, where sound emerges through the dynamic interaction between environment, material, and human action. Future research may expand this framework through comparative studies across different ecological contexts, more detailed acoustic measurement, and broader investigation of performance practices. Such developments would further strengthen the theoretical and empirical foundations of material-based approaches in organology and ethnomusicology.

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Declarations

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Additional information	:	No additional information is available for this paper.

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