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Assessing The Mechanical Properties And Performance Of Biocomposite And Natural Fiber Based Bulletproof Vests

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ABSTRACT

Within the munitions industry, there has been a notable emphasis on the development of cost-effective, easily wearable, and biocompatible flak armor. The rising popularity of fiber-reinforced polymer biocomposite technology, particularly employing natural fibers, stems from its eco-friendliness and cost-effectiveness, which holds particular significance in today's defense sector. As firearm technology advances rapidly, it necessitates a concurrent focus on enhancing personal protective equipment, with bulletproof vests being a commonly utilized safeguard. These vests play a critical role in mitigating the impact of ballistic threats on individuals. This study is dedicated to the investigation of natural fiber biocomposite materials for their applicability in bulletproof vests, addressing their mechanical properties and suitability for such a vital protective role.

Keywords: biocomposite, bullet-proof vest, mechanical properties, natural fiber

INTRODUCTION

Natural fibers have emerged as a promising alternative to synthetic or engineered fibers, garnering significant attention due to their inherent properties, such as being renewable and abundantly available resources. Indonesia, a country with rich resources including cotton, hemp, sisal, kenaf, and silk fibers, stands with great potential to harness these natural fibers in various applications, including the field of ballistics.

The utilization of natural fibers in ballistic applications, specifically in the creation of bulletproof vests, presents an intriguing prospect. The primary function of a bulletproof vest is to mitigate the penetration and impact energy caused by projectiles. Typically, when an impact occurs, the kinetic energy from the bullet is absorbed and dispersed across the vest's area, minimizing the energy transmitted to the body. However, the prevalent use of Kevlar-made bulletproof vests, particularly by military and police personnel in Indonesia, poses certain challenges. Kevlar vests are relatively heavy, restricting ease of movement and agility for individuals wearing them. Moreover, from an economic standpoint, the cost of Kevlar material is considerably high, necessitating importation from abroad. The import dependency, mainly due to the cost and technical complexities, limits the domestic production of such protective gear.

The aim of bulletproof vests is to safeguard vital body organs, such as the chest, abdomen, and back, by absorbing and distributing kinetic energy upon impact, thereby reducing the potential injury from ballistic loads. However, in practice, despite the protection offered, users still face physical trauma, such as bruising, swelling, and internal injuries, suggesting the need for improved materials that can better attenuate the energy transferred to the wearer.

In light of these challenges, there's a call for research into alternative materials that could match or exceed the performance of traditional bulletproof vests while being more accessible and affordable. This study focuses on exploring Indonesian natural fiber composites as potential materials for ballistic applications, particularly for crafting bulletproof vests. The goal is to examine the feasibility and potential future of utilizing indigenous natural fibers as the raw material for the development of bulletproof vests. This work aims to provide comprehensive information based on literature research and data analysis, serving as a valuable resource for further exploration and discussions in enhancing natural fiber utilization in Indonesia.

RESEARCH METHODS

This study employs a qualitative research approach, presented descriptively, which combines literature review and statistical analysis of Indonesian natural fibers. The primary objective is to assess the capabilities and potential of Indonesian natural fibers as a viable source of raw materials for the development of various bulletproof vests, integral to Indonesia's ballistic defense systems. Several key factors related to the mechanical and physical properties of natural fibers are explored, along with their practical utilization.

The research methodology initiates with an extensive literature review, which involves the systematic examination of scholarly articles, research papers, reports, and relevant documents. The literature review is conducted to gain an in-depth understanding of the existing knowledge and research on natural fibers, their mechanical properties, and their applicability in ballistic protective equipment.

1. Statistical Analysis: To assess the potential of Indonesian natural fibers, statistical analysis is performed on available data regarding fiber characteristics and their mechanical properties. This includes parameters such as tensile strength, impact resistance, and flexibility, which are vital for the performance of bulletproof vests.
2. Factors Studied:
   a. Superiority of Natural Fibers: The research explores the inherent advantages of natural fibers, including their lightweight nature, sustainability, and environmental friendliness.
   b. Potential for Cultivation of Natural Fibers: An analysis of the feasibility and scalability of cultivating natural fibers in Indonesia is conducted to determine the country's capacity for fiber production.
   c. Ability to Use Natural Fibers: The study investigates the practicality and efficacy of incorporating Indonesian natural fibers into the manufacturing process of bulletproof vests, considering factors such as cost, availability, and mechanical properties.

RESEARCH RESULTS AND DISCUSSION

Bulletproof Vest

Bulletproof vests serve as essential protective gear extensively used in military contexts to shield crucial parts of the body, specifically the chest, abdomen, and back. These specific areas provide housing and protection to vital human organs including the heart, liver, and lungs located in the chest region. The abdomen, encompassing digestive organs and kidneys, also holds significant importance. Any damage or injury to these pivotal organs could result in dire consequences, potentially leading to fatal outcomes, emphasizing the crucial role played by bulletproof vests in preserving life. The vests act as a pivotal barrier against potentially life-threatening injuries, safeguarding these organs and ensuring the well-being and survival of individuals in high-risk scenarios

Figure 1 Bulletproof Vest [1]

Bullets

A bullet, commonly discharged from a firearm, is a projectile that holds a rich history dating back to the accidental discovery of clay projectiles initially employed for hunting with catapults. The evolution of bullets spans from the 1500s to the 1800s, during which they underwent a significant transformation, adopting a more spherical shape.

One pivotal turning point in the development of bullets occurred in 1847, attributed to Claude-Etienne Minie, who introduced an ingenious design characterized by a hollow conical structure. This innovation was groundbreaking as it enabled bullets to house smokeless powder ammunition efficiently. The introduction of this design marked a crucial advancement in firearms technology, enhancing their efficiency and performance.

It's important to note that bullets are subject to significant stress and heat during their operation. The tip of a bullet can undergo melting due to the intense friction encountered as it travels through the firearm's bore, or when it comes into contact with the searing gases generated by the combustion of powder ammunition. This is a testament to the extreme conditions bullets endure while in use.

Typically, bullets are constructed from an alloy, commonly comprised of lead and tin, selected for its specific properties that make it well-suited for this purpose. To further enhance their speed, accuracy, and overall performance, bullets are often coated with various materials like copper, cupronickel, or steel. These coatings not only optimize the bullet's aerodynamics but also contribute to its longevity and effectiveness in its intended application.

In summary, bullets have a rich and transformative history, evolving from humble clay projectiles to the sophisticated and efficient designs we see today. Their development has played a crucial role in the advancement of firearms and their effectiveness in various applications, from hunting to military use.

Figure 2 Bullets[2]

Composite

A composite refers to a material formed by combining two or more substances, each with distinct mechanical characteristics. This blending of materials is done with the goal of creating a third material that exhibits superior overall mechanical properties at the macroscopic level. The mechanical attributes that can be enhanced through composite manufacturing encompass strength, stiffness, wear resistance, corrosion resistance, fatigue life, thermal resistance, and weight reduction.

In most cases, it's challenging to simultaneously enhance all these mechanical properties, often necessitating specialized treatments to achieve the desired outcomes. This is primarily due to the existence of inherent trade-offs between certain mechanical properties; for instance, improving thermal conductivity might compromise thermal insulation. The majority of composite materials consist of two primary phases: the matrix and the reinforcement. The matrix serves as the predominant component, forming a continuous structure around the reinforcement. Its role is to act as a mediator, effectively distributing and transmitting the stress applied to the composite material. On the other hand, the reinforcement is dispersed within the matrix and primarily bears the mechanical load, making it the key element responsible for withstanding stress.

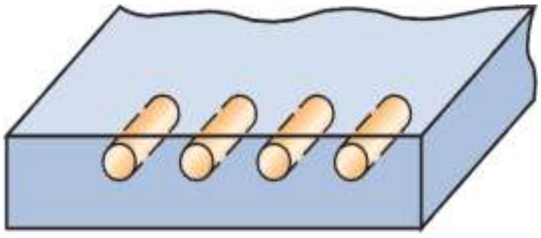

Figure 2.3 Matrix and composite images[3]

Reviews on influencing parameters of acoustical absorption coefficient

When it comes to the acoustic performance of materials, several physical parameters play a crucial role. These parameters significantly affect the material's ability to absorb sound effectively. Among these parameters, the most vital ones include fiber thickness and size, porosity, air permeability, resistivity to airflow, tortuosity, density, surface impedance, compression, position or orientation, and the overall efficiency of acoustical absorptive materials. However, this particular paper is primarily focused on examining and reviewing the impact of three specific physical factors on acoustical absorption performance.

Reviews on effect of thickness of absorptive materials

The thickness of the acoustic absorbent substances plays a important feature in increasing the AAC price regularly, due to the reality many researchers had tried many trials on impact of thickness on acoustical common performance and furthermore analytically in comparison with the Delany–Bazley version, Garai–Pompoli model and Biot–Allard version. Many literatures stated that the thicker sample suggests better acoustical houses at low-frequency variety than the higher values of frequencies.

A summarized analysis on the impact of thickness on acoustical absorption performance of natural fibers these days completed with the aid of researchers all around the global is shown in table 1.[4] the date fibers having thickness of eight mm display 0.83 NRC. It also has a density of 11 kg/m3 that indents to enhance the absorption coefficient at low-frequency noise. on this laminate, the better dense element helped thickness parameter for enhancing the absorption stage. also, 35 mm diameter snippet suggests 0.eighty four NRC at 2587.5 Hz of frequency. This results in excessive sound absorption at mid- and high-frequency sound ranges. further, the testing of 50 mm diameter of tea leaf fiber snippet with the aid of Ersoy and oküçüok (2009) by means of an impedance take a look at tube method shows zero.7 NRC variety and 27.five kg/m3 density at mid-variety frequency of 5600 Hz. This sort of snippet may be usable for the application which include indoor ceiling insulation, acoustic barrier walls, barrier decoupler, and so on[5], Arenga pinnata indicates 0.88 NRC for 40 mm thickness at high-frequency range. it may be carried out for absorbing excessive-frequency degree applications which includes automobile cabinet, sound recording room, home theaters, and many others. Liu et al. (2015) additionally said that higher thickness indicates better sound absorption coefficient. A thickness of 20 mm shows 0.84 NRC. From the analysis of these researches, it's miles definitely said that the thicker snippet suggests better NRC than others. similarly to that, the impedance assessments tube technique for thicker and denser suggests better charge of sound coefficient degree. for that reason, it changed into found that thicker samples have been determined to be showing greater acoustical overall performance (or) high AAC than the thinner samples at low- frequency variety. but, thinner samples show off better sound absorptive residences at high-frequency variety. reviews on effect of density of absorptive substances among three factors selected on this survey, density is considered as most sizeable issue that strongly affects the acoustical absorption behavior of the cloth. The fiber's diameter is an critical microscopic parameter. In preferred, larger density of the material has extra fiber content consistent with unit place and it will soak up greater acoustic strength because of more frictional surfaces between the sound wave and the fiber elements. as a result it enhances the acoustical absorption coefficient of the porous materials. thinner samples exhibit higher sound absorptive houses at excessive-frequency range. opinions on impact of density of absorptive materials among three elements selected on this survey, density is taken into consideration as maximum great thing that strongly influences the acoustical absorption conduct of the fabric. The fiber's diameter is an crucial microscopic parameter. In fashionable, large density of the fabric has greater fiber content material according to unit location and it's going to soak up extra acoustic strength because of more frictional surfaces among the sound wave and the fiber elements. thus it complements the acoustical absorption coefficient of the porous substances. thinner samples show off higher sound absorptive residences at excessive-frequency range. reviews on impact of density of absorptive materials among three elements chosen on this survey, density is considered as maximum huge element that strongly influences the acoustical absorption behavior of the fabric. The fiber's diameter is an crucial microscopic parameter. 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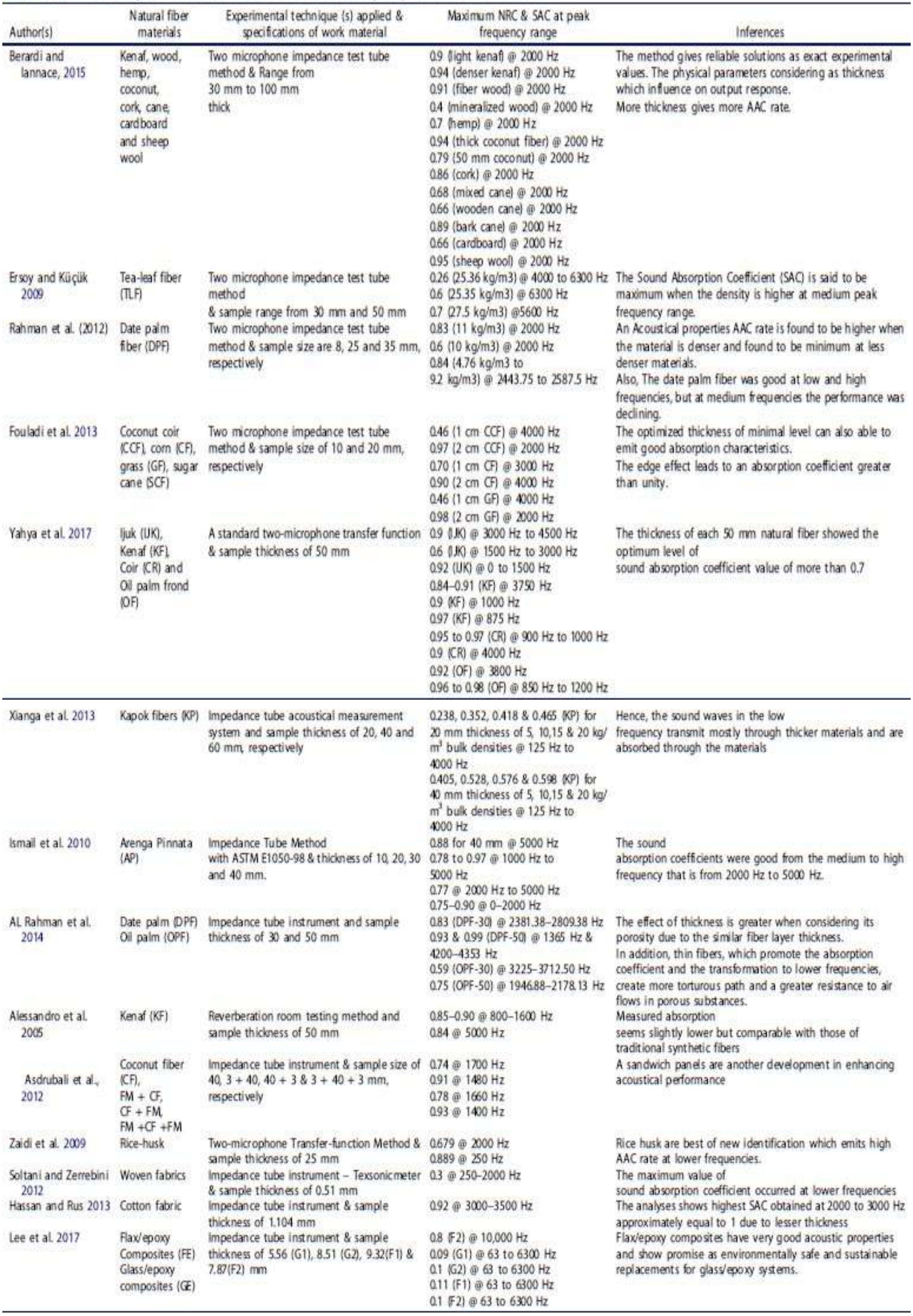
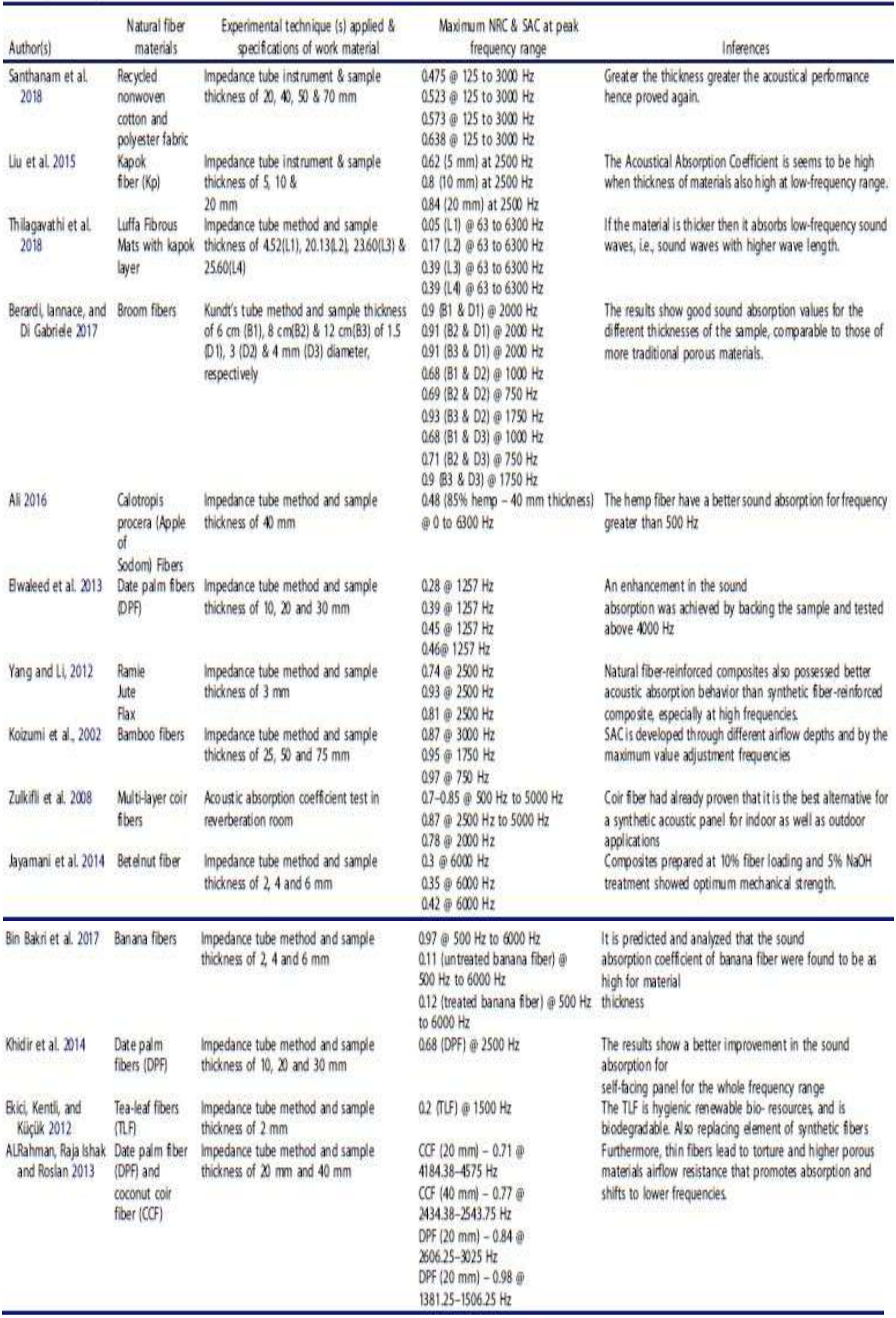
The fiber's diameter is an critical microscopic parameter. In trendy, large density of the material has more fiber content material in keeping with unit area and it will absorb greater acoustic electricity because of extra frictional surfaces between the sound wave and the fiber elements. therefore it enhances the acoustical absorption coefficient of the porous substances. Evaluation at the effect of density on acoustical absorption overall performance of natural fibers these days carried out through researchers.The impact of density is as compared with the equal literature review approximately the effect of thickness. it's miles truely validated that the higher thick and higher dense snippet shows extra NRC[4], the denser snippet of eleven kg/m3 suggests 0.83 NRC than the opposite snippets at low-frequency stage of

Source [9]

Table 1. A summarized analysis on the effect of thickness on acoustical absorption performance of natural fibers.



Author(s)	Natural fiber materials	Experimental technique (s) applied & specifications of work material	Maximum NRC & SAC at peak frequency range	Inferences
Berardi and Iannace, 2015	Kenaf, wood, hemp, coconut, cork, cane, cardboard and sheep wool	Two microphone impedance test tube method & Range from 30 mm to 100 mm thick	0.9 (light kenaf) @ 2000 Hz 0.94 (denser kenaf) @ 2000 Hz 0.91 (fiber wood) @ 2000 Hz 0.4 (mineralized wood) @ 2000 Hz 0.7 (hemp) @ 2000 Hz 0.94 (thick coconut fiber) @ 2000 Hz 0.79 (50 mm coconut) @ 2000 Hz 0.86 (cork) @ 2000 Hz 0.68 (mixed cane) @ 2000 Hz 0.66 (wooden cane) @ 2000 Hz 0.89 (bark cane) @ 2000 Hz 0.66 (cardboard) @ 2000 Hz 0.95 (sheep wool) @ 2000 Hz	The method gives reliable solutions as exact experimental values. The physical parameters considering as thickness which influence on output response. More thickness gives more AAC rate.
Ersoy and Küçük 2009	Tea-leaf fiber (TLF)	Two microphone impedance test tube method & sample range from 30 mm and 50 mm	0.26 (25.36 kg/m3) @ 4000 to 6300 Hz 0.6 (25.35 kg/m3) @ 6300 Hz 0.7 (27.5 kg/m3) @5600 Hz	The Sound Absorption Coefficient (SAC) is said to be maximum when the density is higher at medium peak frequency range.
Rahman et al. (2012)	Date palm fiber (DPF)	Two microphone impedance test tube method & sample size are 8, 25 and 35 mm, respectively	0.83 (11 kg/m3) @ 2000 Hz 0.6 (10 kg/m3) @ 2000 Hz 0.84 (4.76 kg/m3 to 9.2 kg/m3) @ 2443.75 to 2587.5 Hz	An Acoustical properties AAC rate is found to be higher when the material is denser and found to be minimum at less denser materials. Also, The date palm fiber was good at low and high frequencies, but at medium frequencies the performance was declining.
Fouladi et al. 2013	Coconut coir (CCF), corn (CF), grass (GF), sugar cane (SCF)	Two microphone impedance test tube method & sample size of 10 and 20 mm, respectively	0.46 (1 cm CCF) @ 4000 Hz 0.97 (2 cm CCF) @ 2000 Hz 0.70 (1 cm CF) @ 3000 Hz 0.90 (2 cm CF) @ 4000 Hz 0.46 (1 cm GF) @ 4000 Hz 0.98 (2 cm GF) @ 2000 Hz	The optimized thickness of minimal level can also able to emit good absorption characteristics. The edge effect leads to an absorption coefficient greater than unity.
Yahya et al. 2017	Ijuk (IJK), Kenaf (KF), Coir (CR) and Oil palm frond (OF)	A standard two-microphone transfer function & sample thickness of 50 mm	0.9 (IJK) @ 3000 Hz to 4500 Hz 0.6 (IJK) @ 1500 Hz to 3000 Hz 0.92 (IJK) @ 0 to 1500 Hz 0.84–0.91 (KF) @ 3750 Hz 0.9 (KF) @ 1000 Hz 0.97 (KF) @ 875 Hz 0.95 to 0.97 (CR) @ 900 Hz to 1000 Hz 0.9 (CR) @ 4000 Hz 0.92 (OF) @ 3800 Hz 0.96 to 0.98 (OF) @ 850 Hz to 1200 Hz	The thickness of each 50 mm natural fiber showed the optimum level of sound absorption coefficient value of more than 0.7
Xianga et al. 2013	Kapok fibers (KP)	Impedance tube acoustical measurement system and sample thickness of 20, 40 and 60 mm, respectively	0.238, 0.352, 0.418 & 0.465 (KP) for 20 mm thickness of 5, 10,15 & 20 kg/m^3 bulk densities @ 125 Hz to 4000 Hz 0.405, 0.528, 0.576 & 0.598 (KP) for 40 mm thickness of 5, 10,15 & 20 kg/m^3 bulk densities @ 125 Hz to 4000 Hz	Hence, the sound waves in the low frequency transmit mostly through thicker materials and are absorbed through the materials
Ismail et al. 2010	Arenga Pinnata (AP)	Impedance Tube Method with ASTM E1050-98 & thickness of 10, 20, 30 and 40 mm.	0.88 for 40 mm @ 5000 Hz 0.78 to 0.97 @ 1000 Hz to 5000 Hz 0.77 @ 2000 Hz to 5000 Hz 0.75–0.90 @ 0–2000 Hz	The sound absorption coefficients were good from the medium to high frequency that is from 2000 Hz to 5000 Hz.
AL Rahman et al. 2014	Date palm (DPF) Oil palm (OPF)	Impedance tube instrument and sample thickness of 30 and 50 mm	0.83 (DPF-30) @ 2381.38–2809.38 Hz 0.93 & 0.99 (DPF-50) @ 1365 Hz & 4200–4353 Hz 0.59 (OPF-30) @ 3225–3712.50 Hz 0.75 (OPF-50) @ 1946.88–2178.13 Hz	The effect of thickness is greater when considering its porosity due to the similar fiber layer thickness. In addition, thin fibers, which promote the absorption coefficient and the transformation to lower frequencies, create more torturous path and a greater resistance to air flows in porous substances.
Alessandro et al. 2005	Kenaf (KF)	Reverberation room testing method and sample thickness of 50 mm	0.85–0.90 @ 800–1600 Hz 0.84 @ 5000 Hz	Measured absorption seems slightly lower but comparable with those of traditional synthetic fibers
Asdrubali et al., 2012	Coconut fiber (CF), FM + CF, CF + FM, FM +CF +FM	Impedance tube instrument & sample size of 40, 3 + 40, 40 + 3 & 3 + 40 + 3 mm, respectively	0.74 @ 1700 Hz 0.91 @ 1480 Hz 0.78 @ 1660 Hz 0.93 @ 1400 Hz	A sandwich panels are another development in enhancing acoustical performance
Zaidi et al. 2009	Rice-husk	Two-microphone Transfer-function Method & sample thickness of 25 mm	0.679 @ 2000 Hz 0.889 @ 250 Hz	Rice husk are best of new identification which emits high AAC rate at lower frequencies.
Soltani and Zerrebini 2012	Woven fabrics	Impedance tube instrument – Texsonicmeter & sample thickness of 0.51 mm	0.3 @ 250–2000 Hz	The maximum value of sound absorption coefficient occurred at lower frequencies
Hassan and Rus 2013	Cotton fabric	Impedance tube instrument & sample thickness of 1.104 mm	0.92 @ 3000–3500 Hz	The analyses shows highest SAC obtained at 2000 to 3000 Hz approximately equal to 1 due to lesser thickness
Lee et al. 2017	Flax/epoxy Composites (FE) Glass/epoxy composites (GE)	Impedance tube instrument & sample thickness of 5.56 (G1), 8.51 (G2), 9.32(F1) & 7.87(F2) mm	0.8 (F2) @ 10,000 Hz 0.09 (G1) @ 63 to 6300 Hz 0.1 (G2) @ 63 to 6300 Hz 0.11 (F1) @ 63 to 6300 Hz 0.1 (F2) @ 63 to 6300 Hz	Flax/epoxy composites have very good acoustic properties and show promise as environmentally safe and sustainable replacements for glass/epoxy systems.



Author(s)	Natural fiber materials	Experimental technique (s) applied & specifications of work material	Maximum NRC & SAC at peak frequency range	Inferences
Santhanam et al. 2018	Recycled nonwoven cotton and polyester fabric	Impedance tube instrument & sample thickness of 20, 40, 50 & 70 mm	0.475 @ 125 to 3000 Hz 0.523 @ 125 to 3000 Hz 0.573 @ 125 to 3000 Hz 0.638 @ 125 to 3000 Hz	Greater the thickness greater the acoustical performance hence proved again.
Liu et al. 2015	Kapok fiber (Kp)	Impedance tube instrument & sample thickness of 5, 10 & 20 mm	0.62 (5 mm) at 2500 Hz 0.8 (10 mm) at 2500 Hz 0.84 (20 mm) at 2500 Hz	The Acoustical Absorption Coefficient is seems to be high when thickness of materials also high at low-frequency range.
Thilagavathi et al. 2018	Luffa Fibrous Mats with kapok layer	Impedance tube method and sample thickness of 4.52(L1), 20.13(L2), 23.60(L3) & 25.60(L4)	0.05 (L1) @ 63 to 6300 Hz 0.17 (L2) @ 63 to 6300 Hz 0.39 (L3) @ 63 to 6300 Hz 0.39 (L4) @ 63 to 6300 Hz	If the material is thicker then it absorbs low-frequency sound waves, i.e., sound waves with higher wave length.
Berardi, Iannace, and Di Gabriele 2017	Broom fibers	Kundt's tube method and sample thickness of 6 cm (B1), 8 cm(B2) & 12 cm(B3) of 1.5 (D1), 3 (D2) & 4 mm (D3) diameter, respectively	0.9 (B1 & D1) @ 2000 Hz 0.91 (B2 & D1) @ 2000 Hz 0.91 (B3 & D1) @ 2000 Hz 0.68 (B1 & D2) @ 1000 Hz 0.69 (B2 & D2) @ 750 Hz 0.93 (B3 & D2) @ 1750 Hz 0.68 (B1 & D3) @ 1000 Hz 0.71 (B2 & D3) @ 750 Hz 0.9 (B3 & D3) @ 1750 Hz	The results show good sound absorption values for the different thicknesses of the sample, comparable to those of more traditional porous materials.
Ali 2016	Calotropis procera (Apple of Sodom) Fibers	Impedance tube method and sample thickness of 40 mm	0.48 (85% hemp – 40 mm thickness) @ 0 to 6300 Hz	The hemp fiber have a better sound absorption for frequency greater than 500 Hz
Elwaleed et al. 2013	Date palm fibers (DPF)	Impedance tube method and sample thickness of 10, 20 and 30 mm	0.28 @ 1257 Hz 0.39 @ 1257 Hz 0.45 @ 1257 Hz 0.46@ 1257 Hz	An enhancement in the sound absorption was achieved by backing the sample and tested above 4000 Hz
Yang and Li, 2012	Ramie Jute Flax	Impedance tube method and sample thickness of 3 mm	0.74 @ 2500 Hz 0.93 @ 2500 Hz 0.81 @ 2500 Hz	Natural fiber-reinforced composites also possessed better acoustic absorption behavior than synthetic fiber-reinforced composite, especially at high frequencies.
Koizumi et al., 2002	Bamboo fibers	Impedance tube method and sample thickness of 25, 50 and 75 mm	0.87 @ 3000 Hz 0.95 @ 1750 Hz 0.97 @ 750 Hz	SAC is developed through different airflow depths and by the maximum value adjustment frequencies
Zulkifli et al. 2008	Multi-layer coir fibers	Acoustic absorption coefficient test in reverberation room	0.7–0.85 @ 500 Hz to 5000 Hz 0.87 @ 2500 Hz to 5000 Hz 0.78 @ 2000 Hz	Coir fiber had already proven that it is the best alternative for a synthetic acoustic panel for indoor as well as outdoor applications
Jayamani et al. 2014	Betelnut fiber	Impedance tube method and sample thickness of 2, 4 and 6 mm	0.3 @ 6000 Hz 0.35 @ 6000 Hz 0.42 @ 6000 Hz	Composites prepared at 10% fiber loading and 5% NaOH treatment showed optimum mechanical strength.
Bin Bakri et al. 2017	Banana fibers	Impedance tube method and sample thickness of 2, 4 and 6 mm	0.97 @ 500 Hz to 6000 Hz 0.11 (untreated banana fiber) @ 500 Hz to 6000 Hz 0.12 (treated banana fiber) @ 500 Hz to 6000 Hz	It is predicted and analyzed that the sound absorption coefficient of banana fiber were found to be as high for material thickness
Khidir et al. 2014	Date palm fibers (DPF)	Impedance tube method and sample thickness of 10, 20 and 30 mm	0.68 (DPF) @ 2500 Hz	The results show a better improvement in the sound absorption for self-facing panel for the whole frequency range
Ekici, Kentli, and Küçük 2012	Tea-leaf fibers (TLF)	Impedance tube method and sample thickness of 2 mm	0.2 (TLF) @ 1500 Hz	The TLF is hygienic renewable bio- resources, and is biodegradable. Also replacing element of synthetic fibers
ALRahman, Raja Ishak and Roslan 2013	Date palm fiber (DPF) and coconut coir fiber (CCF)	Impedance tube method and sample thickness of 20 mm and 40 mm	CCF (20 mm) – 0.71 @ 4184.38–4575 Hz CCF (40 mm) – 0.77 @ 2434.38–2543.75 Hz DPF (20 mm) – 0.84 @ 2606.25–3025 Hz DPF (20 mm) – 0.98 @ 1381.25–1506.25 Hz	Furthermore, thin fibers lead to torture and higher porous materials airflow resistance that promotes absorption and shifts to lower frequencies.

Considering these snippet whilst recollect for thickness it suggests more Acoustic Absorption for 35 mm diameter. it's miles sincerely verified that both thick and dense snippet continually enhances the sound proofing quality at both mid- and excessive-range frequencies. it is able to be relevant for low-frequency absorbing walls. in keeping with Ersoy and küçüokay (2009), 27.five kg/m3 suggests better NRC of zero.7 at 5600 Hz. these snippets are implemented in the application where the mid- and excessive-frequency range is to be managed. in addition, Xiang et al. (2013) and Liu et al. (2015) indicates better NRC of zero.627 and 0.93 for densities of 58 kg/m3 and one hundred fifty kg/m3, respectively. It shows that denser materials generally tend to soak up extra acoustic energy in comparison to much less dense substances. but, in some increase, materials with higher density will take in much less acoustic electricity because of non-fibrous nature of the substances. materials which might be greater compact and dense are low in porosity which significantly impacts its sound absorption performance (Gokulkumar et al., 2020).

CONCLUSIONS AND RECOMMENDATIONS

This study delves deeply into the exploration of natural fibers as potential substitutes for conventional materials in the creation of bulletproof vests. Specifically, the utilization of fillers derived from agricultural waste displays promising capabilities in composite manufacturing due to their superior characteristics and material properties. The research findings underscore the significance of the type of polymer and natural fiber used, particularly in determining key mechanical properties such as modulus of elasticity, flexibility, hardness, and tensile strength. Variations in these properties, including reductions in elongation at break, flexural strain, flexural strength, and impact resistance, are observed based on the specific combination of polymer and natural fiber. The pivotal outcome of this study is its potential impact on industrial munitions. The study suggests that the fabrication process involved is both efficient and cost-effective, offering a favorable method for creating bulletproof materials. The insights gleaned from this research could be invaluable for future advancements in armor development. Notably, the study proposes that developing bulletproof plates using thin biocomposites could significantly enhance the quality of future armor. This approach might offer a viable solution for enhancing the effectiveness of bulletproof materials, subsequently benefitting the field of industrial munitions.

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