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Testing Various Synthetic and Natural Fiber Materials for Soundproofing

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Summary

Noise pollution negatively impacts the health and behavioral routines of humans and other animals. Excessive sound vibrations in urbanized settings can also cause structural damage, leading to property devaluation. The increased use of electrical and mechanical appliances at home has further created a concern for noise pollution, and the production of synthetic sound-absorbing materials contributes to harmful gas emissions into the atmosphere. The goal of this study is to assess environmentally-friendly, cheap natural-fiber materials, such as jute, as an effective replacement for synthetic materials, such as gypsum and foam. The selected materials are used widely in other industries but no direct comparison has been performed to evaluate which materials are best at absorbing sound. Our results indicate that among the synthetic and fiber materials, jute fiber is the best performer: jute with a thickness of 1 cm absorbed a sound intensity of 51 dB at 400 Hz, which was 21.12% more efficient than no soundproofing and 12.57% more efficient than gypsum. These results provide a significant breakthrough in soundproofing. Low cost fiber materials can be used for reducing sounds of televisions, computers, and appliances at home, or in broadcast studios for audio recordings. Other natural fiber materials should also be investigated for their soundproofing abilities in future studies.

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Introduction

Every day humans are exposed to various types of noises that can have negative effects. Some of the consequences of noise include damage to the ears, sleep disturbance, stress, and high blood pressure [1]. Especially in large cities such as New York, noise is consistently the top reported quality-of-life issue; in 2012 local authorities received more than forty thousand noise complaints [2]. With growing urbanization comes an increase in electrical and mechanical appliance usage at home, which raises concerns for noise pollution [3]. The humming sound from home appliances may not be irritating, but over time, this can have a negative impact. Researchers claim that noises over 80 decibels (dB) can be harmful [4]. **Table 1** indicates various home appliances and their range of sound [5].

Many materials are widely used to overcome noise pollution – most of these materials are synthetic and are expensive and harmful to the environment. Fiberglass is effective at absorbing sound, but it can be hazardous to the environment and to human health [6]. It is undeniable that other synthetic materials are also used in dealing with noise pollution. Materials like foams or bubble wrap are used in a wide variety of applications, including for recording and broadcasting studios [7,8]. Common inexpensive synthetic fibers used are Styrofoam and fiberboard [9].

On the other hand, the use of natural fibers can be particularly attractive for industrial design because of the additional economic and environmental advantages [6]. Reusable and biodegradable materials prevent further stress on the environment [10]. These natural fiber materials are abundantly available in tropical regions all around the world [11]. Fibers have been used for hundreds of years and for many applications such as ropes, beds, and bags. It is also estimated that replacing synthetic materials with agricultural waste, such as coconut husk, will reduce petroleum consumption by two to four million barrels and carbon dioxide emission by 450,000 tons annually [12]. Materials such as jute, coconut husks, and sugar cane husks can be used as an alternative to synthetic materials, since they are eco-friendly, cheap, and natural. Jute has been used in a

Appliances	Loudness Range (dB)
Blender with ice	83–85
Blender with water	80–86
Dishwasher	65–78
Electric Mixer	75–80
Pop-up toaster	66–84
Vacuum Cleaner	81–94

Table 1. Home Appliances and their Loudness Range

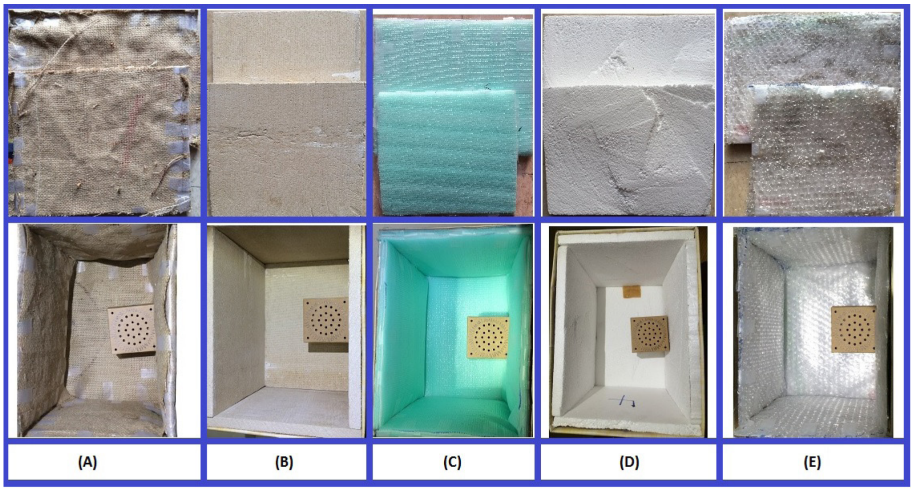

Figure 1. Soundproofing materials used for the experiment. Natural fiber such as jute was compared and contrasted with synthetic fibers such as foam and gypsum. **A**: jute, **B**: gypsum, **C**: foam, **D**: styrofoam, and **E**: bubble wrap.

variety of applications such as construction, furniture, and automotive industries, but has yet to be used widely as soundproofing material [3].

The aim of this study was to discover which materials are most appropriate for sound absorption, with an emphasis on noise produced by mechanical or home appliances. Since the synthetic materials are harmful to the environment, it may be better to replace them with a sound absorbing natural fiber. Most materials that are efficient at sound absorption are soft and fluffy. There are many air spaces in these types of materials. When sound waves hit the spaces, the waves are trapped, not absorbed, in those small spaces. If the materials are rough, the sound waves are reflected multiple times on the surface, weakening the waves [13]. There are also hard materials that are not as good at absorbing sound, but are good at reflecting it. For example, sounds from outside would not be heard as much if there is a metal wall surrounding homes or buildings. A brick is another example of a hard material that does not contain much air space in it, compared to soft materials. On the other hand, when a sound wave hits an irregular surface, such as a carpet, the waves travel along many and much smaller paths. This divides the energy of the wave, sending it in many different directions, which then depletes the wave's energy faster; this is known as diffusion. When a sound wave hits a particular surface, the kinetic energy driving it is converted into small amounts of heat energy, which then leaches its power from the sound wave and causes it to decay faster; this is known as sound absorption [13].

Our hypothesis was that natural fiber absorbs the most sound energy due to air spaces present in the material: when sound waves collide with the air spaces present, the waves become trapped. Moreover, jute has a rough surface, causing sound waves to be reflected several times on the surface and making them weaker.

Results

Five different materials with a thickness of 1 cm were used: jute, styrofoam, bubble wrap, gypsum, and foam (**Figure 1**). Bubble wrap can diffuse sound due to it having lots of bumps caused by the air pockets. On the other hand, styrofoam has several air holes in it and it is slightly uneven, properties that can diffuse and absorb the sound. Foam has small bumps and is slightly soft, which can absorb and diffuse the sound. The material gypsum is hard and rough, which will slightly diffuse the sound and reflect it multiple times, eventually weakening the sound. Jute is soft and quite rough and can absorb and diffuse the sound waves. The materials were prepared accordingly by fixing them onto boards that were used for later testing (**Figure 1**). A baseline control with no soundproofing (empty test box) was recorded at an average of 64.66 dB (**Table 2**). Jute with a thickness of 1 cm absorbed the most sound energy, with an average of 51 dB at 400 Hz, compared to the other

Materials	Intensity of Sound (dB)				The difference between no soundproofing and other test materials (%)
	Attempt 1	Attempt 2	Attempt 3	Average	
	(Raw Results)				
No sound proofing	64	65	65	64.66	0
Bubble wrap	60	61	60	60.33	6.69
Styrofoam	60	59	60	59.66	7.73
Jute	51	50	52	51	21.12
Foam	60	60	61	60.33	6.69
Gypsum	58	58	59	58.33	9.78

Table 2. Sound recorded from the test box insulated with the five soundproofing materials of 1 cm thickness. 400 Hz sound was played from inside the test box and recorded from a recorder outside the box to measure the sound absorbed by the different materials. Jute absorbed the most sound energy, with an average of 51 dB at 400 Hz, compared to the other test materials.

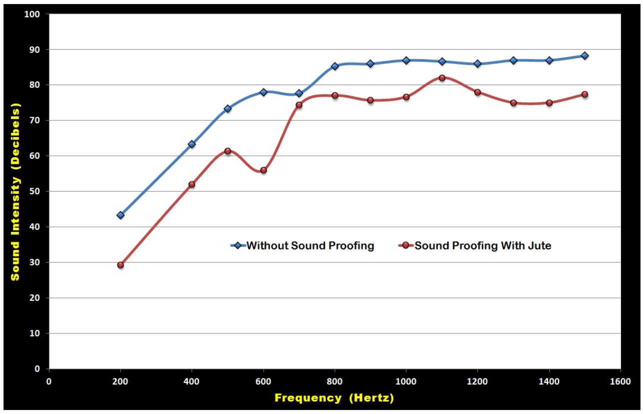

Figure 2. Frequency-dependence of jute sound absorption. Jute with a thickness of 2 cm was compared to no soundproofing at various sound frequencies. The greatest difference was recorded at 600 Hz with a difference of 22 dB.

Frequency (Hertz)	Sound Intensity (Decibels - dB)	
	Without Soundproofing	Soundproofing with Jute (2 cm)
200	43.3	29.3
300	63.3	48.7
400	63.3	50.5
500	73.3	61.3
600	78.0	56.0
700	77.7	74.3
800	85.3	77.0
900	86.0	75.7
1000	87.0	76.7
1100	86.7	82.0
1200	86.0	78.0
1300	87.0	75.0
1400	87.0	75.0
1500	88.3	77.3

Table 3. Jute with a thickness of 2 cm was compared to no soundproofing at various sound frequencies. The greatest difference was recorded at 600 Hz with a difference of 22 dB.

test materials. Materials such as bubble wrap and foam were the most inefficient in terms of soundproofing, with an average of 60.33 dB. Styrofoam and gypsum only recorded a difference of 0.67 dB and 2 dB, compared to bubble wrap and foam respectively. Jute is 21.12% more effective than no soundproofing and 12.57% more effective than gypsum.

We next asked whether thicker jute insulation would improve sound absorption. **Figure 2** indicates the resultant sound intensity when jute with 2 cm thickness is compared against no soundproofing. Jute with a thickness of 2 cm recorded an average of 50.5 dB at 400 Hz. This shows that there is only a 1% difference between jute with 1 cm and 2 cm thickness at 400 Hz. Moreover, when jute with a thickness of 2 cm was compared with no soundproofing, the greatest difference was recorded at 600 Hz with a difference of 22 dB (**Table 3**). The average reduction in sound intensity at 200–600 Hz was 24% using jute, while the average reduction at 700–1100 Hz was 8.7%, and at 1200–1500 Hz was 12.3%.

Discussion

This investigation aimed to find out which material absorbs the most sound energy. Jute was the most efficient at absorbing sound, both at 1 cm and 2 cm thickness. Jute was predicted to absorb the most sound energy because it has a large quantity of air spaces in it. Moreover, jute had a rougher surface than most of the tested materials. For example, bubble wrap has air pockets, but its surface is not as rough as jute. This is the same case with other materials such as foam, which has small bumps but its surface is slightly soft. Judging from the tests conducted, fiber materials with rough surfaces are good at absorbing sound energy. The results also supported the hypothesis when jute with two thicknesses was measured against other parameters. This may be explained by the surface of jute: jute has a rough surface, causing sound waves to be reflected multiple times on the surface and diminishing the waves' energy.

Based on our results, we find that jute can absorb sounds across a range of frequencies, shown in **Table 3**, reducing the sound intensity by 4.4% (at 700 Hz) to 32.3% (at 200 Hz). Sound reduction using jute was more effective at lower frequencies compared to higher frequencies. Thus, we expect if applied to noise reduction within the home, jute would absorb much of the low frequency sounds as well as some of the high frequency sounds produced by the household appliances in **Table 1**.

Therefore, our results support further investigation of jute and other natural fibers as a sound proofing materials. Jute was the only type of natural fiber material used in this study to compare to common synthetic materials including bubble wrap, Styrofoam, foam and gypsum. Future studies would try a wider range of fibers, such as sugar cane husks, coconut husks, and oil palm tree husks. These other natural materials would be compared with jute at different frequencies, and with other common synthetic materials, like fiberglass. Fiberglass is good at absorbing sound, but due to its hazardous nature, the material was not included in testing. If the appropriate protective gear and supervision were available, fiberglass would have been included. The relative safety and ease of use of jute, as compared to fiberglass, are important practical advantages.

The final choice of sound absorption material will depend on many factors, such as cost, safety, durability, fire resistance, sound attenuation, and ease of use. For natural materials, resistance to pests and fungi may be a significant issue. For larger commercial design, the environmental and economic effects of growing and maintaining jute as sound proofing material should be studied. This will help us understand the advantages and possible disadvantages of using eco-friendly fiber materials in daily life.

Materials and Methods

Materials

Different types of synthetic materials were used along with a natural fiber material (**Figure 1**). Jute was the only natural fiber material employed due to material limitations.

Experimental parameters

For a fair investigation, the controlled variables were kept the same; the thickness of the materials used to cover the test box was 1 cm. Since jute outperformed the other materials, jute was further tested by comparing the thickness of the existing 1 cm sheet to approximately 2 cm. The test box used throughout the experiment was comprised of cardboard material with the following dimensions: height, 22.5 cm; length, 30.5 cm; and width, 21.5 cm. **Figure 3** depicts the experimental setup.

The distance between the decibel meter and the test box was 30 cm; this distance was maintained for every test. A battery-powered speaker was turned on to the maximum volume. Numerous sound frequencies (ranging from 200 to 1500 Hz) were tested, and the volume of it was kept exactly the same throughout the experiment. Different sound frequencies were tested in order to find the sound penetration among the different frequencies. The speaker was then connected to a laptop using a stereo jack (**Figure 3**). The speaker was placed in a test box covered with the test materials (bubble wrap, foam, Styrofoam, gypsum and jute). The Online Tone Generator software [14] from a laptop was used to play a constant sound. A Sound Meter app [15] was used to measure and record the sound intensity (dB) of the experiment. The test was performed three times in total to obtain an average. The test procedure was repeated using different materials with the same thickness of 1 cm (except for jute).

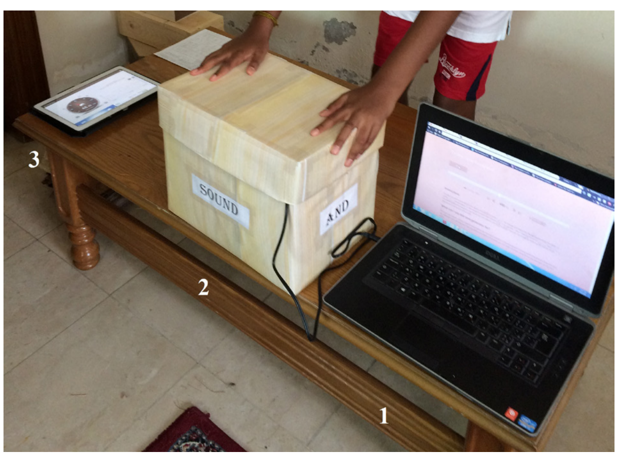

Figure 3. Experimental Setup. 1: Laptop (application to create sound). 2: Test box (contains speaker and covered with the test materials). 3: iPad (sound meter).

During testing, all safety precautions were observed: earplugs were worn due to the loud noise, and masks were worn to avoid inhalation of dust from materials, in particular jute and gypsum.

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