Sound absorption of dried brown, red, green algae

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ABSTRACT

Algae are photosynthesizing organisms found in both freshwater and marine habitats. Studies on algae applications emerged recently due to its fast-growing biomass. Algae are widely used for biofuel, wastewater treatment, and bioplastic production applications. This paper investigates dried algae for sound absorption applications. The sound absorption was measured using the impedance tube, transfer function method. Three different types of algae: red, brown, and green, and their natural mixtures, were used in this study. The algae samples were changed in density of 50; 75; 100; 125; 150 kg/m^3 to find optimal sound absorption. The results showed that average sound absorption coefficient in frequency range of 160 to 5000 Hz ($\alpha_{avg.}$) varied from 0.45 to 0.68. The highest (αavg.) was found when measuring a sample of mixture of brown and red algae (density 100 kg/m3). The frequency of the first peak of sound absorption depends on the density. The first peak frequency (500 Hz to 1250 Hz) depends on the density of algae samples. The highest peak of the sound absorption coefficient was found at 1000 Hz reached 0.98 when measuring samples of green and red algae mixture (density 75 kg/m3). The aim of this paper is to gain a significant knowledge of the sound absorption properties of macro algae and propose green materials for sound absorption applications.

Keywords: sound absorption coefficient, sound absorbing materials, natural materials, density, impedance tube.

1. INTRODUCTION

Eutrophication is the process when water ecosystems has overload of nutrients such as nitrogen or phosphorus [1]. This phenomenon usually leads to an overabundance of algae (seaweed) and plants. The biomass of algae eventually decomposes, producing a large amount of carbon dioxide that not only is greenhouse gas, but also reduces oxygen in these water ecosystems [2]. Over a long period, the fish of that environment could die due to lack of oxygen, endanger species, or cause lack of the food for the humans as well.

Natural fibres are often classified as vegetable and animal fibres. Vegetable fibers include leaf, seed, fruit, stalk, grass, wood fibers, while animal fibers include wool, silk and different hair [3]. In the classification of fibrous materials for sound absorption, algae or seaweed are usually not included, therefore the knowledge about the algae as a sound absorber is limited.

There are few studies regarding seaweed incorporation in the different composite materials. Majority of such studies concerned on mechanical properties of composite materials with seaweed [4,5]. The addition of seaweed to the composites show that it improves the thermal properties of the composites [6]. The results from previous studies suggest that there is a potential for applications for sound absorption. The aim of this paper is to evaluate the sound absorption of different algae species and mixtures found in the Azov Sea. The paper is organised as follows: In Section 2: the materials and methods described, in section 3: the main results are presented, in section 4: discussion and conclusions of the results.

2. MATERIALS AND METHODS

In this section, the materials and methods used in this study are presented. The algae used in this study is presented in Table 1. The algae was gained in the Azov sea. The algae were collected with a scoop and then dried in a room temperature. Since the algae samples were loose, they were placed in the sample holder (Fig. 1). The diameter of the

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sample holder was 29.9 mm, which inserted into the impedance tube would have no space between the holder and the tube body, while the height of the holder was 50 mm. The air flow resistivity values was gained using ISO 9053-1 standard method. The samples was put in the same sample holder.

Table 1. Algae used in the study

No.	Type of algae	Picture of the algae loose samples	Density kg/m^3	Flow resistivity, kPa/m^2
1	Brown algae		50	0,2
			75	1,0
			100	2,4
			125	5,4
			150	9,2
2	Mixture of brown and red algae		50	0,2
			75	1,2
			100	4,0
			125	7,8
			150	14,4
3	Green algae		50	0,2
			75	1,4
			100	3,4
			125	8,4
			150	14,8
4	Green algae mixture		50	1,0
			75	2,6
			100	4,4
			125	9,0
			150	15,2
5	Green algae *(Zostera angusfolia)*		50	3,4
			75	9,2
			100	20,8
			125	30,4
			150	66,2

The density of different loose algae was controlled. The mass of the algae in the sample holder of fixed volume was increased in order to increase density. The density of the samples was changed from 50 to 150 kg/m^3 in steps of 25 kg/m^3. The reason behind this decision is to obtain knowledge of how compactness of algae influences the sound absorption, and if all algae perform similarly depending on the density. To obtain the sound absorption coefficient (SAC) of the PMF, the ISO 10534-2 standard method was used [7]. Such a method was chosen due to the requirements for sample size compared with methods which can be performed in reverberant rooms. A three-microphone impedance tube measurement system was used for this study. The cross section of the tube was circular with a diameter of 30 mm. The samples were rigidly backed. The distance between mic no. 1 and no. 2 X_{12} = 120 mm; between mic no. 2 and no. 3 X_{23} = 20 mm and the distance from the nearest mic to the sample X_{3S} = 60 mm. The diameter of the tube is 30 mm. The measured frequency range is from 160 to 5000 Hz.

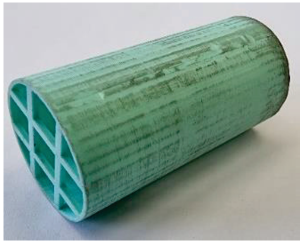

Figure 1. The sample holder used in the experimental study

The sound absorption coefficient α was obtained using an impedance tube system according to the ISO 10534-2 standard.

To easier compare samples, the average sound absorption coefficient was introduced. The average sound absorption coefficient $\alpha_{avg.}$ was calculated as the average of the sound absorption coefficient of 1/3 of the centre frequency bands (eq. 1).

$$\alpha_{avg.} = \frac{\sum \alpha_n}{n} \qquad (1)$$

Where: $\alpha_{avg.}$ – average sound absorption coefficient; α_n – sound absorption coefficient at center frequency of 1/3 frequency band, n – number of 1/3 frequency bands

The sound absorption results are presented in 1/3 octave bands for easier reading of the graphs. Each measurement was made with 3 separate samples. Each measurement was done in 100 averages. In total, 75 independent measurements were done during this study.

3. RESULTS AND DISCUSSION

In this section, the main results and discussion are presented. The results of the sound absorption coefficient are presented in Figure 2. Different types of algae are compared to each other when the sample density is the same. In this type of results representation, it is easier to compare the results and its meaning for possible future applications.

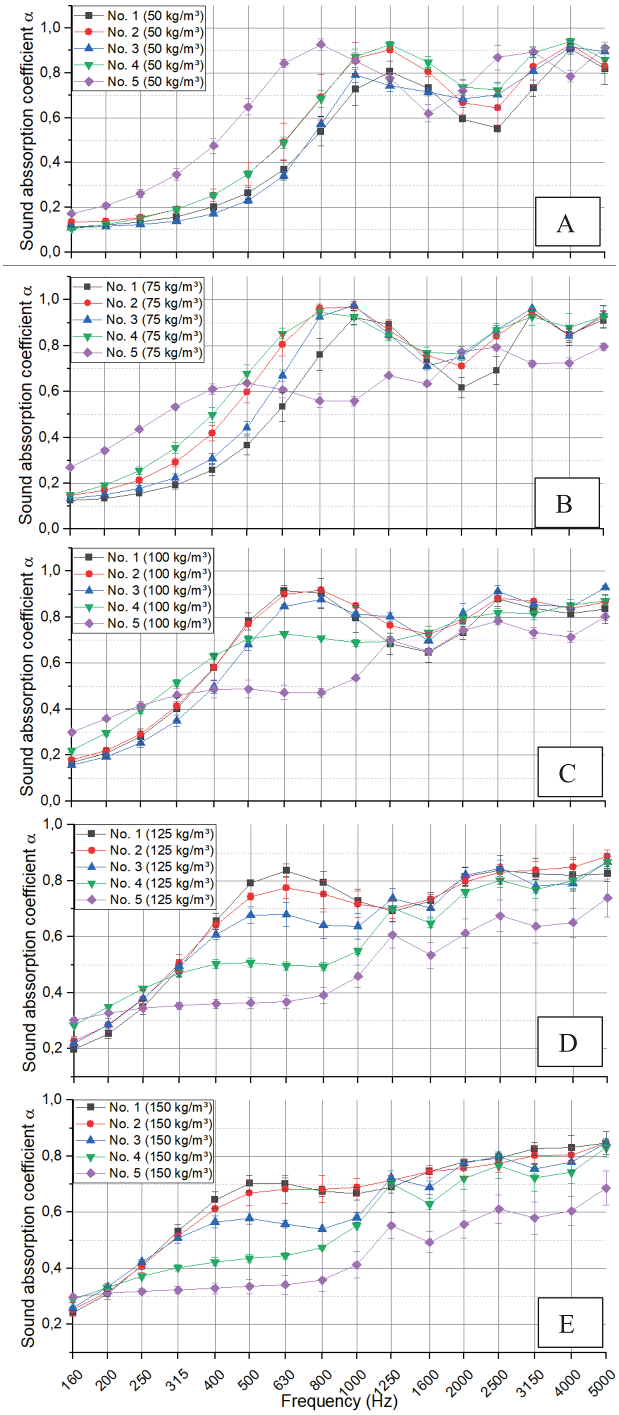

Figure 2. Sound absorption coefficient of algae samples. A – sample density 50 kg/m^3; B – 75 kg/m^3; C – 100 kg/m^3; D – 125 kg/m^3; E – 150 kg/m^3

Graphs in Figure 2 presented with density increase in each graph. In Fig. 2 (A) the results of the sound absorption coefficient of samples of 50 kg/m^3 density are presented. The results of have samples No. 1 – 4 shown that the first peak of sound absorption was found at frequency 1250 Hz, while sample No. 5 first peaked at frequency of 800 Hz. The peak sound absorption of this sample density ranged from 0.81 to 0.93. The highest peaks of sound absorption were found when measuring samples No. 4 and No. 5.

In Fig. 2 (B) results of the sound absorption coefficient of samples of 75 kg/m^3 density are presented. In this graph it is clearly seen that with increase of density sample No. 5 sound absorption decreases drastically (first peak reaching 0.64 at 500 Hz). Other samples did not change sound absorption in similar matter. The first peak sound absorption of samples No. 1–4 reached 0.92 – 0.97 at frequencies of 800 and 1000 Hz.

In Fig. 2 (C) results of the sound absorption coefficient of samples of 100 kg/m^3 density are presented. These results indicate that this density is the point where sound absorption coefficient starts to decrease compared to lower density samples. The first peak values varied between 0,70 and 0,92, the lowest peak value was found at 1250 Hz (sample No. 5), the highest peak value was at 630 Hz (sample No. 1) and 800 Hz (sample No. 2).

In Fig. 2 (D) the results of the sound absorption coefficient of samples of 125 kg/m^3 density are presented. Compared to the figures mentioned above, the peak sound absorption coefficient is lower. The first peak of sound absorption varied between 0.61 (Sample No. 5 in frequency band 1250 Hz) – 0.84 (Sample No. 1 at frequency band 630 Hz).

In Fig. 2 (E) the results of the sound absorption coefficient of samples of highest density samples (150 kg/m^3) are presented. In this case, of sample density, the peak of sound absorption is not clear. The first peak of sound absorption varied from 0,55 (Sample No. 5 at frequency band of 1250 Hz) to 0,75 (Sample No. 1 at frequency of 630 Hz).

All of the results could be justified by the flow resistivity of the samples. The sample No. 5 showed higher flow resistivity values which resulted in lower frequency peak sound absorption and lower sound absorption values in general when density of the samples was increased.

In Table 2 the results of the average sound absorption coefficient are presented. The results presented in this matter allow for easier comparison of samples between one another. The average results of sound absorption show that optimum density for sound absorption is 100 kg/m^3. In most cases, samples of this density showed the highest average sound absorption coefficient. The average sound absorption coefficient of samples of this density ranged from 0.57 to 0.68. The highest average sound absorption coefficient was gained with Samples No. 2 where the mixture of brown and red algae was tested.

Table 2. The average sound absorption coefficients of algae samples

Density, kg/m^3	No.1	No.2	No.3	No.4	No.5
50	0.49	0.55	0.50	0.57	0.64
75	0.57	0.65	0.62	0.68	0.60
100	0.65	0.68	0.66	0.65	0.57
125	0.66	0.67	0.64	0.59	0.48
150	0.65	0.64	0.61	0.55	0.44

Several studies have also been focused on the influence of sample density on sound absorption as well. The other authors gained a similar trend in which density influences sound absorption or noise reduction coefficients [8–10]. These studies show that the change in a change in density results in flow resistivity and, ultimately, sound absorption properties. In this paper, we got similar tendencies compared with other studies.

4. CONCLUSIONS

In this paper, we investigated the sound absorption properties of different loose algae and its mixtures. The results are promising for sound absorption applications in the future.

The experimental study showed that the first peak of sound absorption decreases and shifts toward a lower frequency range when the density of the samples increases. The peak sound absorption of 50 kg/m^3 samples reached up to 0.93 at 1250 Hz, while 150 kg/m^3 peaked at 0.75 at frequency of 630 Hz.

To analyse and compare samples in broadband sound absorption, the average sound absorption coefficient was used. The results showed that in most cases, optimum broadband sound absorption could be reached when sample density is 100 kg/m^3. The average sound absorption coefficient reached 0.68 (mixture of brown and red algae).

The algae mixtures used in the study are made naturally. The different algae content in the samples is hard to define. Therefore, the sound absorption results of the algae mixtures might vary depending on the season when algae is harvested in the sea.

Future studies will be more focused on methods of defining the content of algae species in natural mixtures. Regarding the work of sound absorption application, studies on binding the algae to form panels is planned in the near future.

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