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Experimental Sound Absorption of Several Loose Uncooked Granular Materials

Ayoub BOUBEL, Said BOUSSHINE, Mohammed GAROUM, Adil AMMAR

***Abstract**: Absorbent materials it's an acoustic solution that can be used to control the reverberation time (RT) in deferent spaces as: conference rooms, in halls, theaters, cinema.... and also, it can be used in walls or ceilings of buildings to improve the acoustic insulation Which can be used for internal separations between spaces. This study focuses on the experimental study of the acoustic absorption coefficient of several granular food materials as a function of frequency 50 to 1600 Hz. All acoustic absorption tests performed in this study are performed by an acoustic impedance tube or Kundt tube. And to the knowledge of the author it is the first time in the literature that someone studies the acoustic behavior of this kind of materials. Several parameters were studied such as the effect of thickness on the sound absorption coefficient of the materials tested, like the influence of the grain form on the acoustic absorption by the introduction of a new parameter L / D, and finally the influence of density and type of material on the sound absorption coefficient. The objective of this work is to study the influence of the grain shape on the sound absorption coefficient, and that's why we have chosen these fifteen materials each one with its own shape. The results of these experimental tests show that when the sample thickness rises, the acoustic absorption coefficient rises too with a shift from resonance frequency to low frequencies. When the L/D parameter rises, the absorption behavior increases too in all frequencies mentioned. Finally, as the density of the tested material rises, the percentage of sound absorption of the materials also rises.*

***Keywords:** Acoustic absorption coefficient, granular materials, granular pastas, impedance tube*

I. INTRODUCTION

Noise is a physical phenomenon which generates an embarrassing or unpleasant sensation. Although it is measurable, his perception remains an individual and subjective sensation.

Several statistics and surveys done on noise all over the world, but sadly not one is done in Morocco (according to the author's knowledge). This is why we are using as a reference a survey conducted in France at the request of the Ministry of Ecology, Sustainable Development and Energy in September 2014 [1], the results of which were announced at the 7th National Conference on the Quality of the Noise Environment, reveals that 82% of French people are concerned about noise (47% are "rather" and 35% are "completely", a sample of 1001 people representative of the French population aged 18 and over). As a sign that noise is an important issue in everyday life, less than one in five people interviewed do not pay particular attention to this type of inconvenience. And between the main sources of this noise according to the survey conducted we find: road traffic (37% of mentions "first", 67% in total) and the neighbourhood (respectively 38% and 65%). Home equipment, other types of transport, construction sites and other commercial activities - cited by no more than 15% of the interviewed - are clearly less identified as a source of discomfort.Transport is considered to be the main source of noise pollution (54%), followed by behavioural noise (21%) and industrial and commercial activities (9%). Among transport noise, it is road traffic that disturbs the most (59% of French people). Concerning behavioural noises, two-wheelers come in the lead with 39% of quotes, followed by conversations or yelling in the neighbourhood (9%), pets (9%), DIY or gardening (6%), the volume of TV-Hifi equipment (5%) and movements in the building (5%). Finally, among the noises related to activities, it is the worksites that disturb the French the most (31%), far ahead of garbage collection (9%), industrial or craft activities (5%), activities in bars, restaurants, theatres and discos (4%), and the operation of certain individual or collective equipment in buildings (4%).

After these statistics are completed, he begins the role of acousticians and acoustic researchers, by the introduction of new materials whatever their absorbency or insulation. And in this way and in the literature, there are several works and studies already made on deferents kind of porous materials (Fibrous or granular), as K.H. Or [2] et al who have worked on bulk fruit fibers, and they found that the fibres of the empty palm fruit cluster are a very good sound absorbent and can be an alternative to the synthetic absorber (mineral fibres). The increase in mass or density as defined by K.H. Or [2] gives a high absorption coefficient in high frequencies. For 10 mm samples with 4gram fibres, the absorption coefficient can attain 0.75 at 2500Hz. For 20 mm, the average absorption coefficient increases to 0.9. Finally, the increase in thickness and the application of the plenum caused a rise in the absorption factor. at the lowest frequencies. All sound absorption tests in K.H. Or's work [2] were done with the acoustic impedance tube or the Kundt tube. On the other hand, Garoum et al [3]

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* Correspondence Author
Ayoub BOUBEL*, Mohammed V University in Rabat, Materials, Energy and Acoustics TEAM, Morocco. boubelayoub@research.emi.ac.ma
Said BOUSSHINE, Mohammed V University in Rabat, Materials, Energy and Acoustics TEAM, Morocco.
Mohammed GAROUM, Mohammed V University in Rabat, Materials, Energy and Acoustics TEAM, Morocco.
Adil AMMAR Mohammed V University in Rabat, Materials, Energy and Acoustics TEAM, Morocco.

worked on the measurement of the acoustic absorption factor in a normal incidence and also on the estimation of the physical parameters of a granular bulk cork, for a low, medium and high granulometry. The experimental data were adjusted using the Johnson-Stinson model. A contribution to the numerical estimation of granular material parameters was studied for the Johnson-Stinson model using

Beck criteria and the Marcquardt-Levenberg non-linear data reduction algorithm. Garoum et al [3] also show from the sensitivity coefficient curves plotted that the optimal thickness for parameter estimation should be between [0.06 m and 0.08 m]. The results of the sensitivity analysis of the parameters show that the defined parameters (τ, σ, θ, β1 and β2) can be subdivided into: high sensitivity types (τ, θ), average sensitivity (β1 et β2), and low sensitivity (σ). In other sense and by integrating the effect of the propagation medium on the sound absorption behaviour, Paul T [4] and al, studied the influence of the temperature of the propagation medium on the acoustic absorption factor. The effect of the high temperature on the acoustic performance of three porous materials was studied by using a Kundt tube and adapted to high temperatures according to the methods of Sun et al [6]. It has been shown that when we use a heating belt, it is possible to maintain an approximately linear temperature tube for all tube in temperatures up to 500°C. The acoustic properties can then be found after measuring two different surface impedances [7]. The data measured by Paul T [4] Are rock and basalt wool and fibreglass, for temperatures from 20° C to 500° C. The results show that, to forecast the acoustical characteristics of a porous materials at high temperature, it is sufficient to determine these characteristics at room temperature and then adjust the temperature correction, which is appropriate for the properties of the air flow resistance of the material during the use of Bazley Delany Forms [8]. And in another work that worked on rice grains, Hasina Mamtaz and Al [9] worked on the characterization of sound absorption of a fibrous-granular composite material with cylindrical grains. This granular composite based on coconut fibres and cylindrical grains of rice and may be used as an acoustical absorbent product. The sound absorption of the composite was studied using the JCA model. Experimental studies were done using acoustic Kundt tube to confirm the analytical method. The results showed that at the frequency f <780 Hz, the acoustic absorption factor of the 30 mm of the composite was between α=0.8 and α=0.9.

The impact of sample depth, fibre/grain parameter, fibre size and binder additive were also studied. The results indicated that an increase in sample depth, grain thickness and binder quantity improved low-frequency sound absorption. A gradual shift in the maximum value of the acoustic absorption factor towards the low frequencies was observed with an increase in the thickness of the materials.

On the other hand, and still in the experimental context of measuring the acoustic absorption coefficient, Lamyaa Abd AL Rahman and Al [10], have investigated the acoustical absorption and insulation properties of fibres material and composite samples and evaluated their performance. And to the authors' knowledge, this is the first article in the literature on the acoustic characterization of luffa biomaterials. The tests showed that the acoustic absorption values of a sample of the fibres tested without a matrix is high enough for even a small sample thickness (e=12 mm). In addition, the acoustic absorption values may rise when a fabric is coated on the sample. And generally, several studies have been carried out in the direction of acoustic characterization of porous materials such as [11, 12, 13].

In this work we will work on 15 kinds of materials with different forms such a way as to control the effect of the form on the acoustic absorption factor. all materials used are food materials uncooked granular starchy foods, pastas, and cereals (Beans, wheat tongue of the bird, rice, lentils, cowpea, Maize, soybean, chickpeas, pasta grains, torti pasta vermicelli, pipe rigate, pipette rigate, Pipe doppia Rigatura). All sound absorption tests are performed using a 10 cm diameter acoustic impedance tube (Kundt tube). The objective of this study is to evaluate the acoustic absorption parameter of these several materials according to the grain size, L/D coefficient, density and thickness of the samples, using a Kundt tube.

II. SAMPLES PREPARATION

Fifteen granular materials are characterized with deferent forms and deferent densities. The table 1 shows the dimensions of these different materials and their density, all the values given in the table 1 are equivalent to an average of five measurements taken.

Table- I: The different granular materials sizes, their densities and their L/D ratio.

Granular Material	Grain Sizes			L/e orL/D	Density (Kg/m^3)
Pipe Doppia Rigatura	L=20,13mm	D=11,41mm		1,76	393,51
Pipette Rigate	L=17,1mm	D=6,51mm		2,63	450,32
Pipe Rigate	L=13,37mm	D=3,86mm		3,46	592,67
Vermicelli	L=21,18mm	D=0,8mm		26,48	336,12
Torti pasta	L=18.9mm	D=7.5mm		2.52	411,02
Pasta grains	L=0,42mm	e=0,256mm		1,64	929,47
chickpeas	L=1,236mm	e=0,907mm		1,36	822,33
Soybean	L=0,687mm	e=0,578mm		1,19	763,60
MAIZE	L=0,784mm	D=0,604mm	e=0,4mm	1,96	886,00
Cowpea	L=15,6mm	e=7,6mm		2,05	888,53
Lentils	e=2,17mm	D=4,1mm		1.89	881,50
Rice	L=3,01mm	e=1,01mm		2,98	876,24
tongue of the bird	L=0,838mm	D=0,298mm	e=0,22mm	2,81	853,65
wheat	L=0,755mm	e=0,326mm		2,32	740,10
Beans	L=11,88mm	D=7,22mm	e=1,08mm	1,65	797,50

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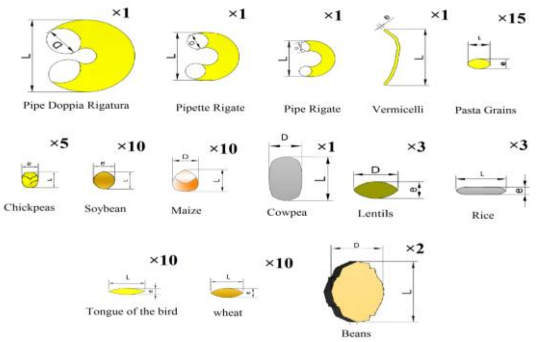

Fig. 1.Different material granulometry.

Fifteen types of materials have been examined “Fig. 2” (Beans, wheat tongue of the bird, rice, lentils, cowpea, Maize, soybean, chickpeas, pasta grains, torti pasta vermicelli, pipe rigate, pipette rigate, Pipe doppia Rigatura). A set of five cylindrical samples was tested for all materials, each one with a diameter of 10 mm. The thicknesses taken into consideration are 20mm, 40mm, 60m, 80mm and 100mm. A total of 75 samples were tested.

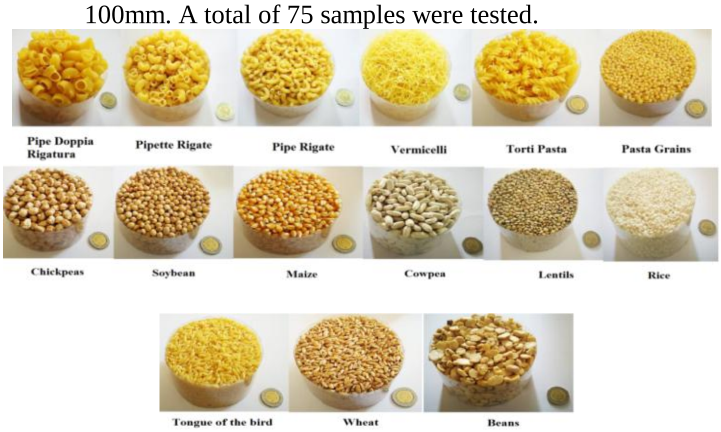

Fig. 2. Different loose granular materials.

III. METHODOLOGY AND RESULTS.

A. Methodology

The Kundt’s tube is one of the reference tools for the measurement of the acoustic properties of a sample in the normal incidence. It makes it possible to evaluate the absorption factor α of a sample over the whole range of frequencies tested. The measurement method is based on a particular frequency called clean cutoff frequency to each kind of tube according to its geometry and independently of the tested material, the propagated wave is a plane wave. Working in normal incidence with rigid walls allows you to situate yourself in a known setting, for which we know how to translate the propagation phenomenon in a theoretical way. The direction of propagation of the incident and reflected waves are the same. The purpose of placing the sample on a rigid support is to suppress the transmitted waves.

In this study, the apparatus consists of a closed rigid tube with a circular form of 100 mm in diameter and 1200 mm in length (Fig 3). The interior walls of the tube are the most reflective possible. The clean cutoff frequency corresponds to this tube size is 1400Hz. The signal used is a pink noise. The sound pressure field is measured in two points in the tube, near to the sample under the stationary wave effect. We know the functions transfer of transmitted and reflected signals, therefore the absorption factor α of the sampels.

The tube is mounted in a vertical position for easy measurement of bulk granular materials.

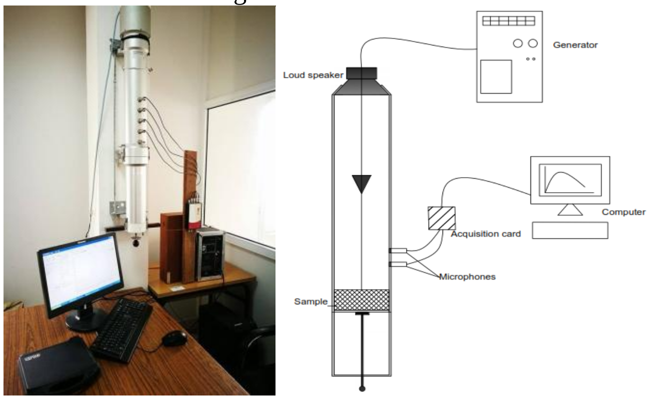

Fig. 3.Acoustic impedance tube.

The principle of calculating the absorption coefficient is related to the measurement of the transfer function H from 2 signals supplied by the 2 microphones mounted on the wall of the tube . We create a stationary plane wave system in the tube and the pressure measured on each microphone decomposed into incident and reflected pressure. The equation used to calculate the reflection coefficient is as follows

$$R = \left(\frac{H - e^{-jks}}{e^{jks} - H}\right) e^{2k(l+s)} \quad (1)$$

With k is the number of waves, s represents the spacing of the microphones and l is the spacing between the sample face and the closest microphone to the material.

The determination of the reflection coefficient makes it possible to access to the absorption coefficient α and the surface impedance characterized by the relationships:

$$\alpha = 1 - |R|^2 \quad (2)$$

With c the speed of the sound ρ the density and.

The amplitude and phase response of the 2 microphones never being exactly the same, we proceed to a calibration by performing 2 consecutive measurements of the transfer function between the 2 microphones in their initial position and then inverting them. The correction factor then corresponds to the geometric mean of these 2 transfer functions. The transfer function measured of the material will thus be corrected by this correction factor, which will make it possible to overcome differences in amplitude and phase between the 2 microphones.

B. Results and discussion

B-1: Influence of the thickness

In first we measured the sound absorption coefficient for all granular materials, for each material five thicknesses have been tested (20mm, 40mm, 60mm, 80mm and 100mm) for the purpose of determining the influence of the thickness on the sound absorption response whatever the kind of material.

"Fig. 4" illustrates the effect of the samples thickness on the acoustic absorption performance of the pasta grains.

The results show that as sample thickness grows, the acoustic absorption performance in low frequencies grows too. this increase is accompanied by a displacement of the resonance frequency to the lower frequencies. The maximum acoustic absorption value is 0.99 in 738Hz at 100mm.

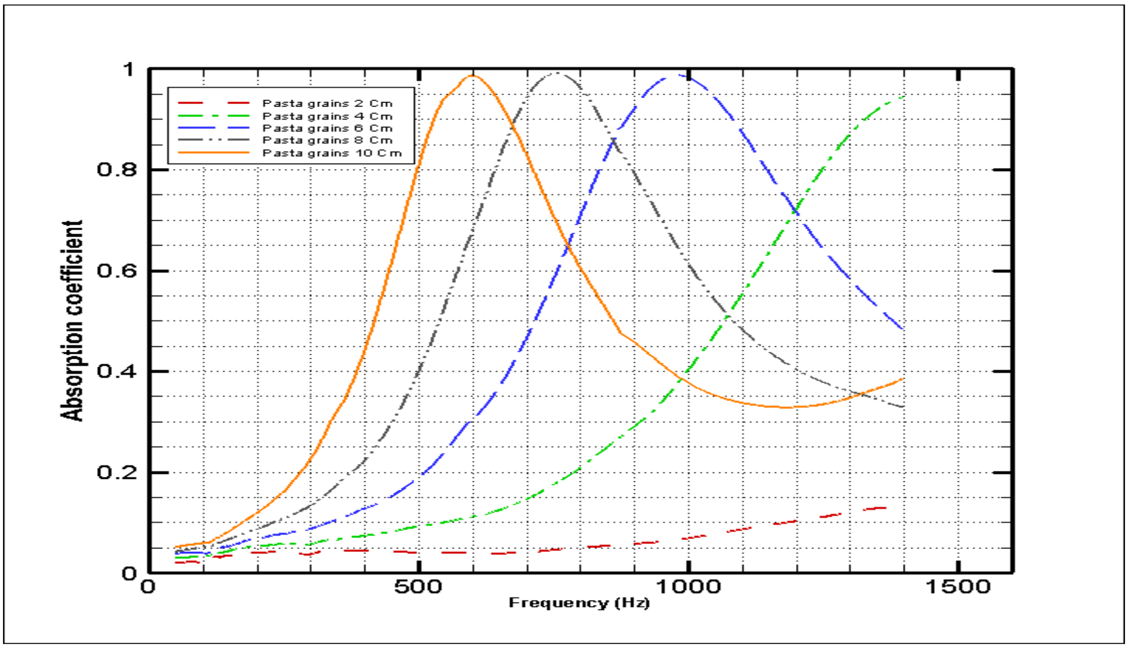

Fig. 4.Experimental absorption coefficient spectra of the grains of pasta for different Thickness

The same interpretation for all other materials, that's why we can generalize that the influence of the thickness is the same for any material whatever their nature, their form and their density (11, 12, 13).

B-2: Influence of the material

The figure 5 represents a comparison curve between the fifteen granular materials for a thickness of 60 mm as it can be compared between different materials. For comparison we selected the four octave frequencies (125Hz, 250Hz, 500Hz, 1000Hz and 1400 Hz) to plot this curve.

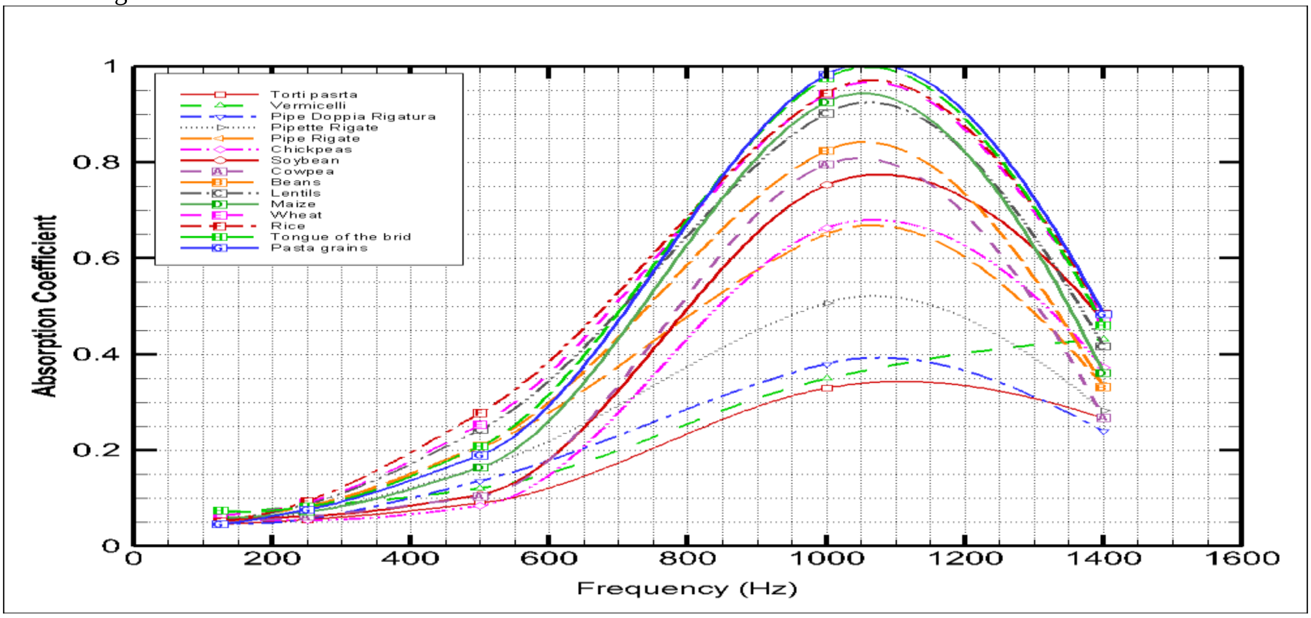

Fig. 5. Comparison of the normal acoustic absorption factor of the fifteen kinds loose granular materials

At 125 Hz the curves seem the same with a deference of 0.04 between the maximum and the minimum values of the sound absorption coefficient, in this case we can not make a comparison between the materials.

The same thing for the frequency 250Hz with a deference of 0.041 between the maximum and the minimum values of the acoustic absorption factor this deference is not enough to interpret the results, in this case we can say that, at low frequencies all the materials tested are characterized by a low sound absorption value.

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From the frequency 500Hz we start to observe a slight distribution of the curves with a deference of 0.2 between the maximum and the minimum values of the sound absorption coefficient but it's still insufficient to compare between the materials.

At 1000 Hz it's the ideal frequency to compare between the fifteen curves because the distribution of values is maximum. The table-2 indicates the acoustic absorption values coefficient at 1000 Hz for the deferent materials tested in increasing order.

Table- II: The values of sound absorption coefficient at 1000 Hz for the deferent materials

Materials	α at 1000Hz
Torti pasta	0,3294
Vermicelli	0,3491
Pipe Doppia Rigatura	0,3802
Pipette Rigate	0,5072
Pipe Rigate	0,6504
Chickpeas	0,6640
Soybean	0,7529
Cowpea	0,7959
Beans	0,8245
Lentils	0,9021
Maize	0,9259
Wheat	0,9420
Rice	0,9441
Tongue of the bird	0,9757
Pasta grains	0,9827

We observe that the 5 materials will have an irregular shape (Torti pasta, Vermicelli, Pipe Doppia Rigatura, Pipette Rigate and Pipe Rigate) are the less absorbent compared to other materials. The Pasta grains are the most absorbing material with an absorption coefficient of about 0.9827 at 1000 Hz. The grains of Lentils, maize, wheat, rice, and the tongue of the brid characterizing with an absorption value greater than 0.9 because of the approximation of their forms

According to this comparison, it can be seen that the value of the sound absorption coefficient does not depend to the nature of the materials used, but it depends to other parameters like the form, the size, the density and the physical parameters of materials as: tortuosity, porosity and the air flow resistivity.

B-3: L/D Influence

The Torti pasta, Pipe Doppia Rigatura and the Pipette Rigate are the three of the 15 materials that have the same shape with deferents values of L and D, therefore they are the ideal choice for determining the effect of the L / D parameter on the acoustic absorption factor of the materials.

The L/D parameter has a strong impact on the acoustic absorption. The "Figure 6" shows this effect for three kinds of materials, the frequencies concerned are 125Hz, 250Hz, 500 Hz and 1000 Hz. The tests showed that when the L/D parameter increases the absorption coefficient also increases in all the frequencies mentioned.

The same as the influence of the material it's difficult to observe the influence of the L / D ratio at the low frequencies (125Hz-250Hz) because all absorption coefficient values in this area are almost equal.

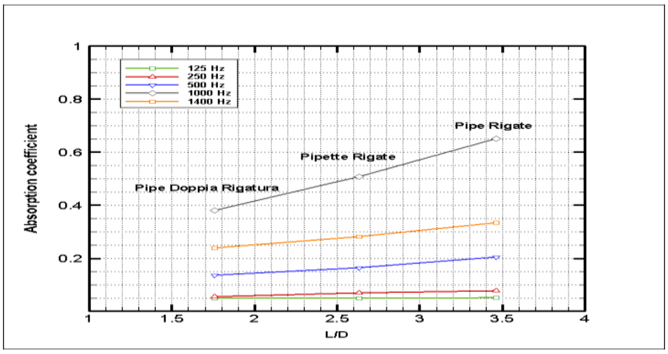

Fig. 6. the effect of the L / D parameter on the acoustic absorption cactor for the three materials (Pipe Doppia Rigatura-Pipette Rigate-Pipe Rigate)

B-4: Influence of density

We have chosen five materials from the pasta family (Vermicelli, Pipe Doppia Rigatura, Pipette Rigate, Pipe Rigate and Pasta grains) to deduce the influence of density on the sound absorption coefficient. Each material among these five is characterized by its own density, the vermicelli is the least dense material (336,12 Kg/m^3) and the Pasta grains are the densest material (929,47 Kg/m3). The figure 7 represents the relation between the density and the sound absorption coefficient at the three frequencies (500Hz, 800Hz and 1000Hz).

For the three frequencies we have the same interpretation, when the density of the material increases (336,12Kg/m3->393,51Kg/m3->450,32Kg/m3->592,67 Kg/m^3-> 929,46 Kg/m^3) the acoustic absorption rate of the samples also increases: at 500Hz (0.12->0.13->0.16->0.2=0.19) ,at 800Hz (0.25->0.39->0.51->0.59->0.7),at 1000Hz (0.34-> 0.38-> 0.5-> 0.65-> 0.98).

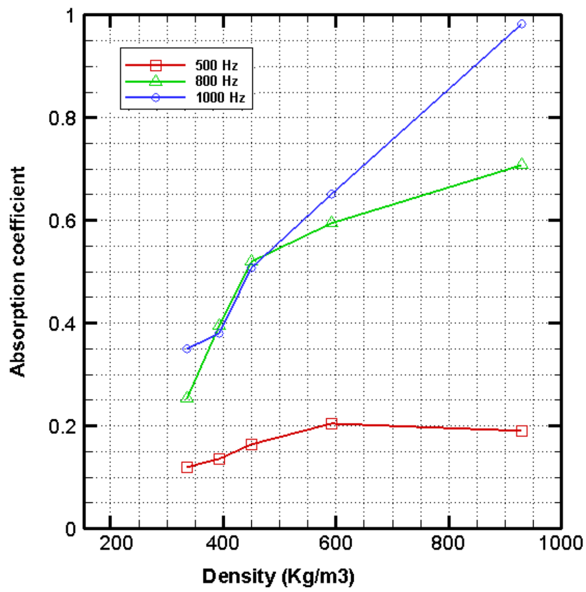

Fig. 7. Influence of density on the acustic absorption coefficient

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IV. CONCLUSION

In this study, we have measured the acoustic absorption factor of fifteen types of granular materials of different shapes and thicknesses (0.02m, 0.04m, 0.06m, 0.08m,and 0.1m) divided in two groups, the first one is the pasta group containing six different materials (vermicelli, Torti pasta, Pipe Rigate, vermicelli, Pipette Rigate, grains pasta and the Pipe Doppia Rigatura,), The other group contains nine deferent materials (Rice, Chickpeas, Soybean, Cowpea, Beans, Lentils, Tongue of the bird, Wheat and Maize). The results show that as sample thickness is increased, the acoustic absorption performance in low frequencies rises too. The increasing thickness is combined with a shifting of the resonance frequency to the low frequencies. The comparison between the fifteen deferent materials shows that the 5 materials will have an irregular shape (Torti pasta, Vermicelli, Pipe Doppia Rigatura, Pipette Rigate and Pipe Rigate) are the less absorbent compared to other materials, and The Pasta grains are the most absorbing material with an absorption value of about 0.9827 at 1KHz. another factor has been introduced, is L/D ratio, the results prove that the L/D parameter has a strong effect on the acoustic absorption. As the L/D parameter rises, the absorption factor also rises. Finally, the influence of density also considered, the results of the density effect show that when the density of the material rises the acoustic absorption rate of the material rises too. And this increase sound absorption is logical because of the viscous and thermal dissipation of sound waves caused to the variations in physical properties (porosity, tortuosity, air flow resistivity...). And as arguments for all the results found in our study comes the role of acoustic modelling which links the acoustic absorption coefficient by the physical parameters related to the shape of porous materials.

REFERENCES

1. The French and noise pollution - Ifop survey for the Ministry of Ecology, Sustainable Development and Energy - September 2014
2. K.H. Or, and Al "OIL PALM EMPTY FRUIT BUNCH FIBERS AS SUSTAINABLE ACOUSTIC MATERIAL" Proceedings of Mechanical Engineering Research Day 2015, pp. 99-100, March 2015
3. Mohammed.G, and Al "CHARACTERISATION OF NON-CONSOLIDATED CORK CRUMBS AS A BASIC SOUND ABSORBER RAW MATERIAL", Proceedings of the Twelfth International Congress on Sound and Vibration Lisbon, Portugal, 11-15 July, (2005).
4. Williams Paul T., and Al "MEASUREMENT OF THE BULK ACOUSTIC PROPERTIES OF ﬁBROUS MATERIALS AT HIGH TEMPERATURES" Applied Acoustics 77 (2014) 29–36
5. European Standard EN ISO 10534-2:2001, Determination of acoustic absorption factor and in impedance tubes. Transfer function method.
6. Utsuno H, and Al. Transfer function method for measuring characteristic impedance and propagation constant of porous materials. J Acoust Soc Am 1989;86:637–43.
7. F. Sun, and Al. Sound absorbing characteristics of fibrous metal materials at high temperatures. Appl Acoust 2010;71:221–35.
8. Delany ME, Bazley EN. Acoustical properties of fibrous materials. Appl Acoust 1970;3:105–16.
9. Hasina Mamtaz, and Al "ACOUSTIC ABSORPTION OF ﬁBRO-GRANULAR COMPOSITE WITH CYLINDRICAL GRAINS" Applied Acoustics 126 (2017) 58–67.
10. Abd ALRahman Lamyaa, and Al "EXPERIMENTAL STUDY ON NATURAL FIBERS FOR GREEN ACOUSTIC ABSORPTION MATERIALS" American Journal of Applied Sciences 10 (10): 1307-1314, 2013.
11. Bousshine Said, and Al "EXPERIMENTAL INVESTIGATION OF SOUND ABSORPTION OF LOOSE BIO-SOURCED ALFA FIBERS" Proceedings of the Twenty fourth International Congress on Sound and Vibration, London, UK, 23-27 July,(2017).
12. Ayoub BOUBEL, and Al" SOUND ABSORPTION MEASUREMENTS OF SOME POROUS LOOSE GRANULAR MATERIALS", Proceedings of the 45th Inter.Noise HAMBOURG, Germany, 21-24 August, (2016).
13. Ayoub BOUBEL and Al "EXPERIMENTAL INVESTIGATION OF SOUND ABSORPTION OF SOME LOOSE UNCOOKED GRANULAR PASTAS, STARCHY FOODS AND CEREALS". Proceeding of the 24th International Congress on Sound and Vibration, London, UK, 23-27 July,(2017).

AUTHORS PROFILE

Ayoub BOUBEL has a Master's Degree in civil engineering in 2015 from abdelmalek essaadi University, Tangier. His fields of interest are granular materials, Acoustic characterization of materials and acoustic simulation.

Said BOUSSHINE has a DESS Degree in automatic in 2000 from Hassan II Ain chock University, Casablanca. His fields of interest are fibrous materials and Acoustic characterization of materials.

Mohammed GAROUM is now a professor at the School of Technology of Salé (ESTS), Mohammed V University in Rabat, Morocco from 1995 to the present. In 1991 he obtained his first PH.D in acoustics from the Ecole Central de Lyon France. In 1997 he obtained his second state PHD in Photoconductivity of semiconductor from the Institute of Sciences of Engineering and Scientific Development at Claude Bernard University Lyon I and Faculty of Sciences of Cadi Ayyad University, Marrakech. He is an author and co-author of more than 50 scientific publications Journals and communications mainly related to: experimental characterization of materials, building energy efficiency, simulation of thermophysical and acoustical properties of materials, numerical inverse estimation of thermal and acoustical parameters based gradient and global algorithms.

Adil AAMAR has his PH D in Acoustics in 2019 from Mohammed V university in Rabat, His fields of interest are the road traffic and the environmental noises.