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Evaluation of the quality of two commercial sponges by tensile strength measurement

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The aim of this study is to investigate the possibility of using the tensile strength and the elasticity as two, among others, objective criteria for the evaluation of the quality and commercial value of two 'Elephant Ear' commercial sponges (Mediterranean and Philippine). These criteria could also provide additional taxonomic characters for the distinction of ill-defined species. The average tensile strength of the Mediterranean Elephant Ear was found equal to 2.88 ±0.19 kg cm^{-2} and that of the Philippine Elephant Ear equal to 6.88 ±0.77 kg cm^{-2} while the corresponding values for elasticity were 26.1 ±0.79% and 7.8 ±0.6%. This difference is related to the structure and arrangement of the spongin fibres as seen under the scanning electron microscope. The arrangement of the secondary fibres (very compact and regular structure) as well as the abundance and the orientation of the primary fibres (arrangement in the form of bars perpendicular to the external surface) give to the Philippine Elephant Ear a higher tensile strength value, a roughness to the touch and consequently inelasticity and stiffness. In contrast, the large number of smooth secondary fibres in the Mediterranean Elephant Ear, their loose arrangement and the limited number of primary fibres give to this sponge a higher elasticity and a smaller tensile strength value.

INTRODUCTION

Besides their recent gradually increasing value in pharmacology as providers of a huge number of new substances, sponges (Porifera) continue to be a highly demanded natural product (Sipkema et al., 2005). The commercial species belonging to the order Dictyoceratida, the 'skeleton' of which has been in use since Antiquity, still have many applications in several fields such as painting, pottery, domestic uses, etc., and their production nowadays is below the demand. The skeleton of commercial natural sponges belonging to the genera *Spongia*, *Hippospongia* and *Coscinoderma*, which is made of a dense reticulation of spongin fibres (a special kind of collagen), displays properties that have not been equally displayed by synthetic sponges obtained from cellulose material (Verdenal, 1986) or from the polymerization of vinyl and allyl derivatives (Lou et al., 1997). Their properties, such as softness, resiliency, absorptivity, durability, etc. (which are potential qualitative criteria) are significantly variable according to the species, geographical origin, ecological conditions and method of treatment by the divers and sponge dealers, with important consequences on their commercial value. The determination of the commercial quality of natural sponges, however, still relies on the expertise of a few sponge dealers, who evaluate mainly the usage of a sponge rather than its physical properties. The commercial value of the product is determined through its softness, its elasticity and its resistance, empirically evaluated by the merchants. This expertise, based on years of practice and most often transmitted through generations, is invaluable and cannot be replaced. However, it would be interesting to correlate scientifically the quality and value of the commercial product and some of the physical parameters of the sponge skeleton.

The aim of the present paper is to examine whether more quantifiable data could be obtained from physical measurements through a tensile strength meter. This method is used, among others, for the determination of the quality of fibrous materials in the textile industry, as well as that of rigid and compact materials, such as metals, ropes, chains, iron plates, etc. The measurement of the tensile strength has been also successfully applied in a series of natural products, i.e. collagen fibres, when controlling the resistance of the skin under load, which depends on the intercrossing of the collagen fibres (Dombi et al., 1993), wooden radii of *Fagus sylvatica* L. (Burget & Eckstein, 2001) and linen fibres (Baley, 2004). The same method has been used for synthetic sponges made from the polymerization of vinyl and allyl derivatives (Lou et al., 2000), which are used as biomedical materials in transplantations.

The measurements have been conducted in a preliminary investigation on two commercial sponges, Mediterranean Elephant Ear and Philippine Elephant Ear. The taxonomic distinction of these two sponges is not clear (Hooper & Wiedenmayer, 1994) and the Philippine one has generally

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Figure 1. Young non-treated individual of Mediterranean Elephant Ear.

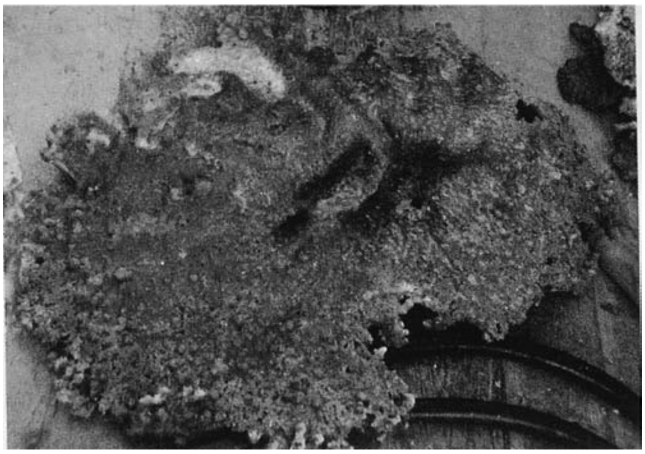

Figure 2. Adult non-treated individual of Mediterranean Elephant Ear harvested at a depth of 100 m.

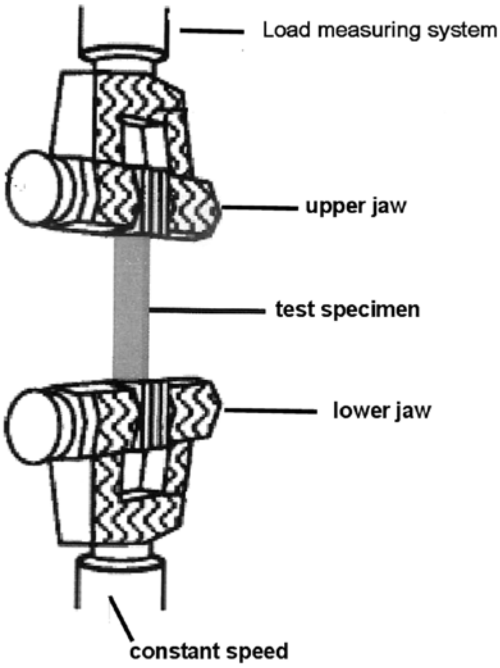

Figure 3. Tensile strength measuring device.

been considered as a subspecies of *S. agaricina* (Laubenfels, 1948; Vacelet, 1959). *Spongia agaricina* Pallas (the Elephant Ear) is generally used for Mediterranean sponges, but the name was originally given to a (similarly looking) Philippine sponge. Subsequently, Arndt changed the Philippine sponge name to *Spongia thienemanni*, an action which prevents an easy solution of the Elephant Ear nomenclature. Cook & Bergquist (2002) say '*Spongia* species are very difficult, if not impossible, to distinguish solely on skeletal morphology'.

A second aim of the paper is to examine whether some physical characteristics, such as tensile strength and elasticity, could be used as additional taxonomic characters, which could become valuable for the taxonomy of keratose sponges.

Both Mediterranean and Philippine Elephant Ears belong to the family Spongiidae, which is characterized by homogeneous skeletal fibres and dense fibre skeleton (Cook & Bergquist, 2002) and which includes all the commercial sponges. The fibres are made of a specific type of collagen, which functions as tissue support (Gross et al., 1956; Garrone & Pottu, 1973; Garrone, 1978).

Spongia agaricina (Mediterranean Elephant Ear) is probably endemic to the Mediterranean. Pallas left no specimen but, according to Laubenfels (1948), the studied species originated from the Indian Ocean.

Figure 4. Young individual of Mediterranean Elephant Ear.

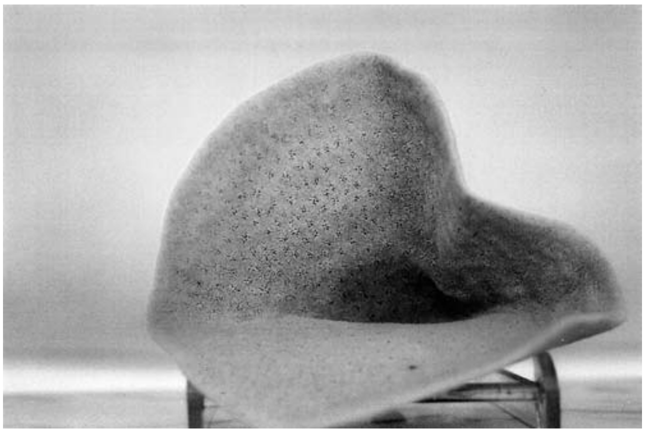

Figure 5. Young individual of Philippine Elephant Ear.

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Spongia thienemanni (Philippine Elephant Ear) was described as a new species from the Philippines by Arndt (1943). It is similar in gross morphology to *S. agaricina*. It has been considered as a subspecies of *S. agaricina* with an Indo-Pacific distribution from 10 to 35 m in depth (Vacelet, 1959). Hooper & Wiedenmayer, 1994 say that 'if segregation of Mediterranean and Australian populations is accepted, the Mediterranean subspecies would have to be renamed, and *thienemanni* would have to be replaced by the nominate subspecies, because the type locality in Pallas is Indian Ocean'.

MATERIALS AND METHODS

Material

In our samplings most of the individuals of the Philippine Elephant Ear were found between 60 and 100 m in depth, on hard substrata mainly in coralligenous biocoenosis, in different shapes and sizes. Its shape varies according to the age. The young individuals are cup-shaped (Figure 1), whereas the older specimens are generally irregularly lamellar (Figure 2), with a size sometimes larger than 1 m in diameter (Castritsi-Catharios, 1998).

The sponge samples of Mediterranean Elephant Ear and Philippine Elephant Ear used for the experiments originated from the Aegean Sea and the Philippines respectively. All were approximately of the same size (Figures 4 & 5).

Twenty individuals of Mediterranean Elephant Ear were collected with the use of the fishing gear 'gagava' while ten individuals of Philippine Elephant Ear were purchased from sponge dealers in Kalymnos Island (south-eastern Aegean Sea, Greece). After harvesting, the sponges undergo a first mechanical treatment on the boat, and usually, but not mandatorily, a second chemical treatment at the warehouses of the merchants, aiming to improve the colour and the softness. Given that the chemical treatment affects the quality of the sponge, we used only sponges not chemically treated.

Most of the sponges used for the measurement were destroyed. The rest, are kept at the laboratory of Zoology and Marine Biology in the University of Athens. Two characteristic individuals from both species respectively have been deposited in the Zoological Museum of the University of Athens (ZMUA 4054 & 4055).

The classification was based on the Systema Porifera (Hooper & van Soest, 2002), the Zoological catalogue of Australia, vol. 12 Porifera (Hooper & Wiedenmayer, 1994) and Arndt (1943).

Tensile strength

The measurements were performed in the chemical laboratory of the Hellenic Navy Yard in Salamina Island, Greece. The tensile strength meter 'Zwick Material/Profung 1485—certification number 40983, certification date 08/04/04—asset no. NS DNX 0001' was used, properly connected to a computer with corresponding software. The results were automatically printed as: % maximum elongation which is a measure of the elasticity, elongation in mm and the maximum load in kg, which is a measure of the resistance of the sample. The initial distance between the jaws was 10 cm (the minimum possible). The upper jaw is stable while the other moves with a constant speed (Figure 3).

Eight individuals from each species were used in the experimental process. The sponges were washed with deionized water and were dried for 48 h at room temperature. Elongated strips were cut according to the specifications of the instrument for the 'sample preparation'.

From each species we measured 13 samples 10–12 cm long, 1.5–2.5 cm wide and 1–2 cm thick. Special care was taken for the homogeneity of the samples (avoidance of large pores, canals and foreign bodies). The results are comparable since these are expressed in kg cm^{-2} (specific maximum load).

Arrangement and dimensions of the fibres

Observation of the spongin mesh as well as measurements of the diameter of the primary and secondary fibres was performed under a scanning electron microscope (SEM), type JSM-6360. Round samples 8 mm in diameter were sputter-coated for 3 min. The fibre diameter was measured on the photographs and a short descriptive statistical analysis was performed. The measurements have been taken from six different samples of each species.

Diameter of the oscula

Photographs of the oscula were taken by using a Nikon stereoscope connected with a video camera. The measurement of the diameter was performed with the use of the image pro-image analysis (Pro Plus).The same method was used for the measurement of the secondary fibres and of the primary fibres under a light microscope.

Thickness

The thickness of the sponges was measured by using a micrometer and the measurements were performed on the wider upper part of the sponge.

RESULTS

External morphology

The specimens of both sponges were cup shaped, 10–12 cm long, and significantly different in thickness. The average thickness at the top of the sponge was 6.88 ±0.30 mm for the Mediterranean Elephant Ear and 3.20 ±0.18 mm for the Philippine Elephant Ear.

In both species, the prints of the oscula (exhalant openings) in the skeleton were located exclusively on the inner surface, as it is usual in cup-shaped sponges (Brien, 1973). Their arrangement in parallel series (mostly of five oscula each) from the base up to the upper surface of the sponge is identical in the two sponge species. There is, however, a clear difference in size and shape of the oscula prints between them. In the Mediterranean Elephant Ear the average diameter of the oscula is 1.64 ±0.08 mm while in the Philippine Elephant Ear it is only 0.69 ±0.03 mm.

In the Philippine Elephant Ear the oscula are surrounded by projecting conules forming a kind of collar around the water outlets (Figures 12 & 13).

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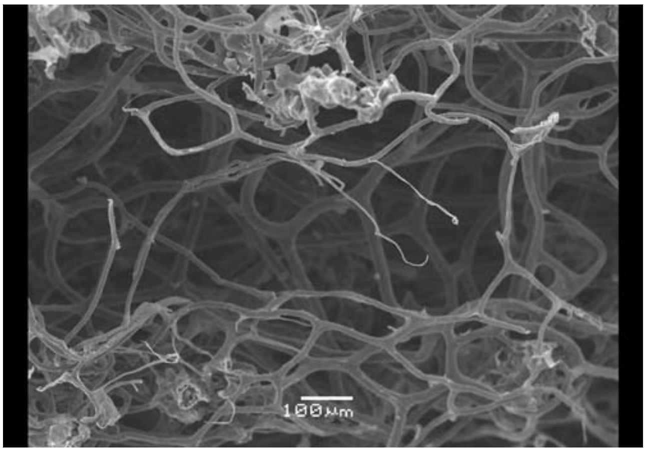

Figure 6. Mediterranean Elephant Ear, mesh of secondary fibres and fibrils (SEM).

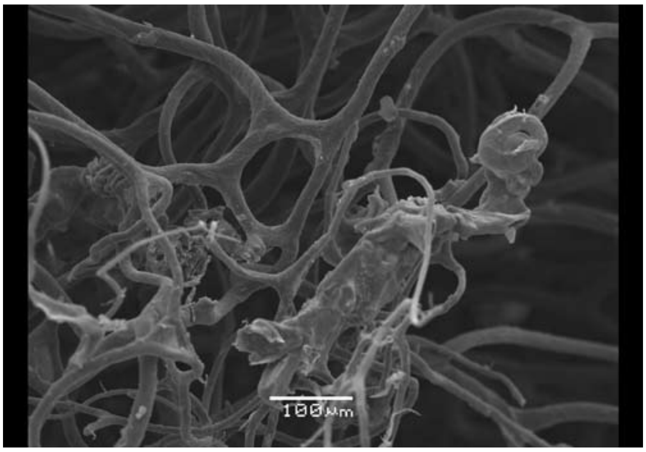

Figure 7. Mediterranean Elephant Ear, primary fibre and mesh of secondary fibres (SEM).

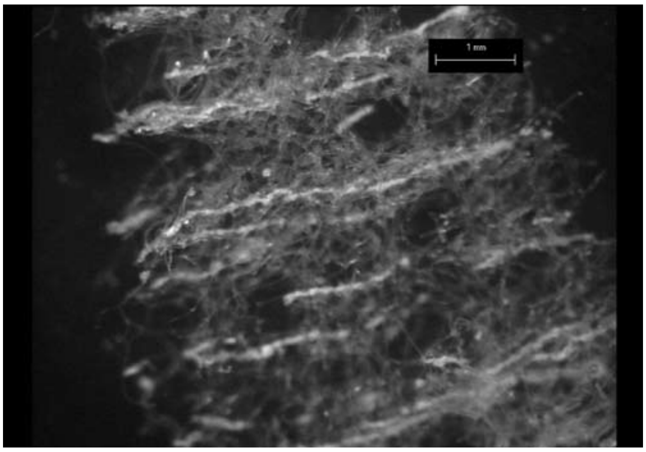

Figure 8. Mediterranean Elephant Ear, primary fibres and mesh of secondary fibres.

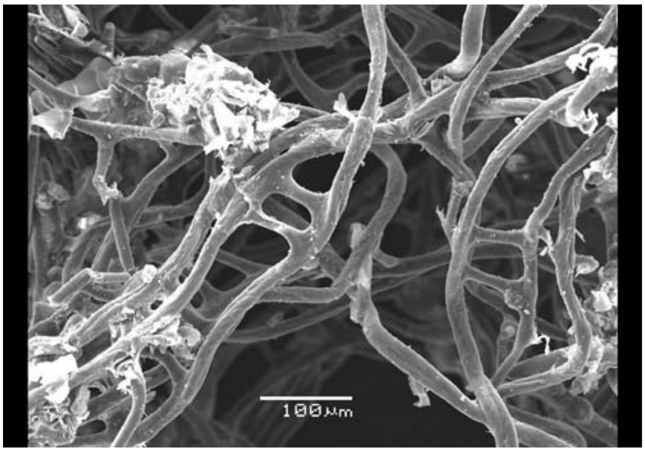

Figure 9. Philippine Elephant Ear, mesh of secondary fibres and transverse branches (SEM).

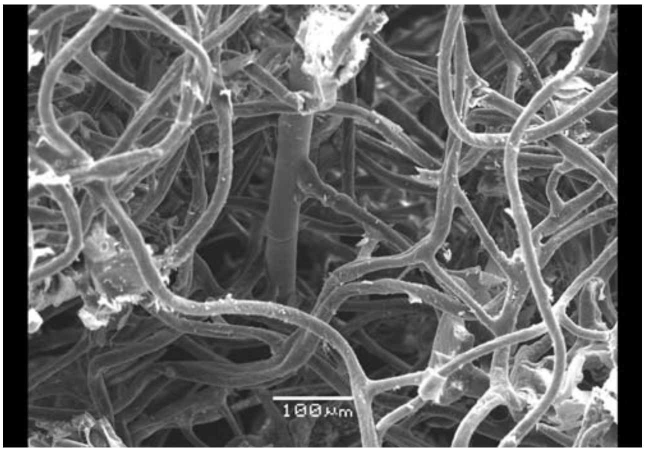

Figure 10. Philippine Elephant Ear, primary fibre and mesh of secondary fibres (SEM).

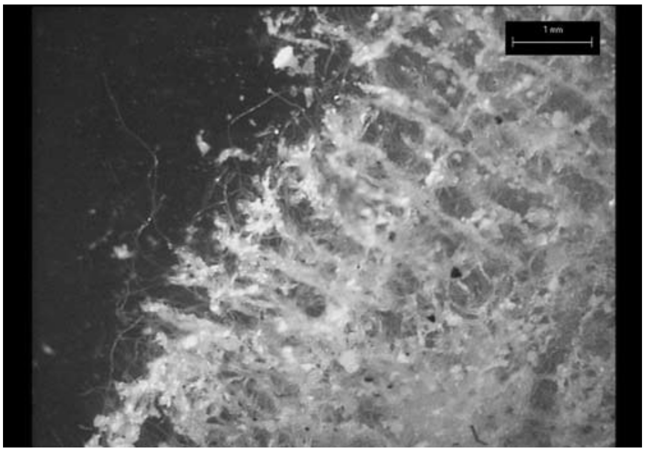

Figure 11. Philippine Elephant Ear, primary fibres with regular arrangement.

Skeleton morphology

In the Mediterranean Elephant Ear the secondary fibres are loosely arranged. They are smooth, with a diameter of 23.94 ±0.33 μm. The primary fibres are few in number and perpendicular to the surface. Their average diameter is 98.09 ±3.38 μm (Figures 6–8).

In the Philippine Elephant Ear the secondary fibres form a specially compact and regular arrangement, with an average diameter equal to 13.19 ±0.29 μm. The primary fibres are abundant, with a regular arrangement in repeated vertical bars which cross all along the body of the sponge. Their average diameter is 130.66 ±5.48 μm (Figures 9–11).

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Table 1. *Tensile strength of Mediterranean Elephant Ear.*

Sample no.	Length (cm)	Width (cm)	Thickness (cm)	Surface area (cm^2)	Maximum load (kg)	Specific maximum load (kg cm^{-2})	Maximum elasticity (%)
1	12.5	2.8	1.6	4.48	9.65	2.15	23.0
2	12.5	2.2	1.7	3.74	11.32	3.03	24.9
3	12.0	2.1	1.7	3.57	13.21	3.70	29.7
4	11.5	2.4	1.6	3.84	8.86	2.31	26.6
5	11.0	2.0	1.6	3.20	7.99	2.50	24.4
6	11.5	2.0	2.0	4.00	11.90	2.97	27.0
7	11.5	2.4	1.6	3.84	12.25	3.19	24.2
8	11.5	2.0	2.0	4.00	13.84	3.46	25.5
9	11.0	2.0	1.6	3.20	11.22	3.51	26.0
10	12.4	1.8	1.1	1.98	6.43	3.25	31.1
11	10.4	1.8	1.0	1.80	6.71	3.73	20.5
12	10.1	2.7	1.7	4.59	7.22	1.57	27.9
13	11.1	2.2	1.3	2.86	5.98	2.09	28.4
				Average	9.74	2.88	26.1
				Standard Deviation	2.72	0.69	2.8
				Standard Error	0.76	0.19	0.79
				Minimum	5.98	1.57	20.5
				Maximum	13.84	3.73	31.1

Table 2. *Tensile strength of Philippine Elephant Ear.*

Sample no.	Length (cm)	Width (cm)	Thickness (cm)	Surface area (cm^2)	Maximum load (kg)	Specific maximum load (kg cm^{-2})	Maximum elasticity (%)
1	11.5	2.3	0.6	1.38	8.55	6.19	13.9
2	11.9	2.3	0.6	1.38	7.47	5.41	10.9
3	10.2	1.7	0.6	1.02	7.07	6.93	6.8
4	10.4	2.3	0.6	1.38	8.33	6.04	5.7
5	10.3	1.8	0.9	1.62	6.33	3.91	6.1
6	10.3	2.1	0.5	1.05	11.45	10.90	8.4
7	10.7	1.7	0.5	0.85	12.03	14.15	7.5
8	11.0	2.0	0.7	1.40	12.88	9.20	5.0
9	11.5	2.5	0.8	2.00	15.94	7.97	6.5
10	10.0	2.5	0.8	2.00	12.34	6.17	8.6
11	10.3	2.0	0.8	1.60	9.45	5.91	6.9
12	11.0	1.4	0.7	0.98	5.53	5.64	9.7
13	10.7	2.2	0.8	1.76	7.97	4.53	5.9
14	10.9	2.2	0.8	1.76	5.94	3.37	6.6
				Average	9.38	6.88	7.8
				Standard Deviation	3.09	2.89	2.4
				Standard Error	0.83	0.77	0.6
				Minimum	5.53	3.37	5.0
				Maximum	15.94	14.15	13.9

Table 3. *Summarized results for both Elephant Ears.*

Parameter measured	Mediterranean	Philippine
Thickness of the circumference at the top of the sponges (mm)	6.88 ±0.30	3.20 ±0.18
Diameter of oscula (mm)	1.64 ±0.08	0.69 ±0.03
Diameter of secondary fibres (µm)	23.94 ±0.33	13.19 ±0.29
Diameter of primary fibres (µm)	98.09 ±3.38	130.66 ±5.48
Tensile strength as specific maximum load (kg cm^{-2})	2.88 ±0.19	6.88 ±0.77
Elasticity (%)	26.1 ±0.79	7.8 ±0.6

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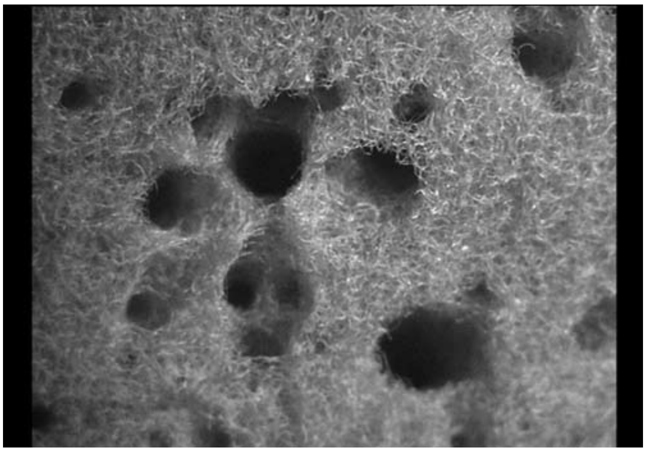

Figure 12. Oscula of Mediterranean Elephant Ear.

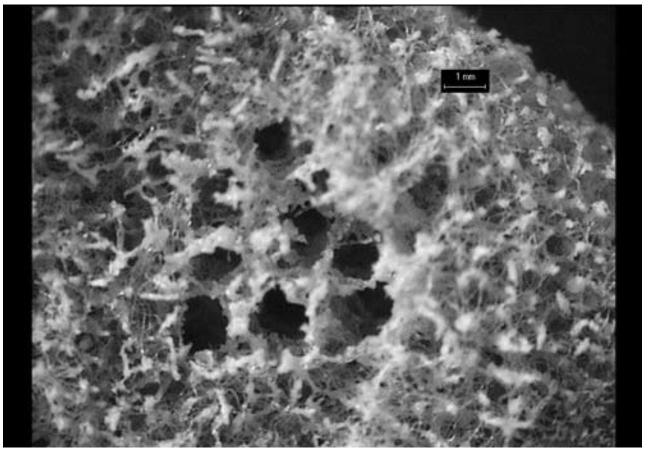

Figure 13. Oscula of Philippine Elephant Ear.

Tensile strength and elasticity

For the Mediterranean Elephant Ear, the specific maximum load was 2.88 ±0.19 kg cm^{-2} while maximum elasticity was 26.1 ±0.79 % (Table 1).

For the Philippine Elephant Ear, the values were 6.88 ±0.77 kg cm^{-2} for the specific maximum load, and 7.8 ±0.6% for the maximum elasticity (Table 2).

The summarized results in Table 3 show a clear differentiation between the two Elephant Ears as far as the measured characteristics are concerned.

DISCUSSION

The quality of the commercial sponges is a really complex matter, affected by several parameters (species, fishing area, fishing ground, method of harvesting, physical and chemical treatment) and physical characteristics. There is no doubt that physical characteristics such as softness, absorbance, durability, etc. determine the quality of a natural sponge and, consequently, its commercial value. At the moment, neither a quality control system has been developed (protocol concerning sampling, standard methods of measurement, expression of the results, etc.) nor has a quality assurance system been applied.

The most significant result of this paper is that the tensile strength measurement which has been applied in a considerable number of natural and synthetic materials as one of the quality parameters, can be successfully applied in natural sponges. Specific care must be taken so that the sponge specimens should be as homogenous as possible and free of other organisms, such as *Acasta spongites*, or foreign materials, such as sand. It is also important that the test specimens should be of the same dimensions and cut towards one direction while the size of the oscula should be as uniform as possible.

The results of our measurements with the application of this technique, show that it can become an additional classification tool, specifically for ill-defined species. It is the first time, to our knowledge, that the tensile strength has been examined as a potential criterion (not exclusive) for the quality determination and taxonomy of the natural commercial sponges.

The selection of the two Elephant Ears was made basically for two reasons. The first is that the individuals were massive and almost compact, without large oscula, the latter being regularly arranged, so that the measurements were more representative and reliable.

The second is that the Mediterranean sponges are considered to exhibit better quality, but fraudulent trading frequently occurs. According to Verdenal & Verdenal (1987) 'the Cuban species, whose qualities are only mediocre, do not diminish the Mediterranean's reputation and business'. Of course, *Spongia agaricina* is not mainly used as a bath sponge but for decorative purposes. Our data obtained from the Kalymnian sponge fishing fleet in 1996 (Castritsi-Catharios, 1996) show that *S. agaricina* constitutes 3.09% of the total product (0.17% in *Posidonia* beds and 2.92% on hard substrata) against 4.36% (1.25% and 3.11% respectively) for *S. zimocca*, 15.28% (1.47% and 13.81) for *S. off. mollissima*, 37.29% (4.81% and 32.48%) for *S. off. adriatica* and 39.98% (13.35% and 26.53%) for *Hippospongia communis* (Castritsi-Catharios, 1996). Due to its relatively limited abundance in the Aegean Sea and its superior quality, the commercial value of the Mediterranean Elephant Ear is high and the sponge is currently 'substituted and or mixed' in the stock by the imported and cheaper Philippines' 'Elephant Ear'. It is a common commercial trick for compromising the quality. The two species have significant morphological similarities and we presumed that the differences in the tensile strength values would not be statistically significant. However, the findings were quite opposite to this consideration and the results show that the measurement of the tensile strength can distinguish these two Elephant Ears. These differences are corroborated by the examination of the mesh, the arrangement and the diameter of primary and secondary fibres.

Differences in tensile strength and elasticity measured are due to the structure of the mesh of the secondary fibres and to their thickness as well as to the number, arrangement and thickness of the primary fibres. It appears that the Mediterranean Elephant Ear, which has a much higher commercial value than the Philippine Elephant Ear, has a lower tensile strength and a higher elasticity, although its secondary fibres are thicker (Table 3).

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These preliminary results obtained by measuring a relatively small number of sponges appear to be promising, and warrant future comparative studies on other species, and on sponges growing in various ecological conditions or having been subjected to various commercial treatments.

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