ACOUSTIC PROPERTIES OF DOLPHIN MELON STRUCTURES

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ABSTRACT

Local measurements of the acoustic characteristics of the dolphin melon preparation were performed. The measurements resulted in the topography of the sound velocity distribution and tissue density over all local melon structures. Anisotropy of morphology is reflected in anisotropy of the acoustic properties of the melon. The local velocity of sound was shown to vary in a wide range 1244-1504 m/s. Topography of variation of the sound velocity in melon structures allows us to presume that the velocity gradually changes from the centre to periphery. Such changes in the sound velocity create prerequisites for sound refraction. The tissue density varies in the range 0.74-1.34 kg/m^2.

1. INTRODUCTION

On the basis of research into the biochemical composition of the melon's lipid structures it was shown that the accumulated experimental data allow to proceed with construction of a three-dimensional model realizing the function of the bioacoustic antenna [1]. The refractor model can be realized for the known spatial distribution of the sound velocity. In melon structures, this velocity depends on the molecular composition of lipid structures responsible for focusing. Many samples of melon tissues were tested and heterogeneity in the composition of melon's lipid structures was demonstrated with a smooth transition of the structure from the central part with short carbon bonds and low molecular weight to tissues in the periphery region acoustically coordinated with aquatic medium [2, 3]. In spite of the fact that spatial characteristics of the dolphin's irradiation field as a whole have been studied relatively well, only little is known about acoustic properties of the melon and its influence on formation of spatial characteristics of the field. In literature, there are no data available on changes in the acoustic field of the melon caused by spatial displacement of the acoustic transmitter.

In this work we present results of our studies on acoustic properties of preparations of the melon and structures affecting formation of spatial acoustic characteristics of the irradiation field.

2. METHODS

The measurements are conducted according to the procedure described in [4]. The difference consists in the position of guide tubes, which in this case were placed across the bath (Gt - guide tubes).

Before measurements of the amplitude – space distribution of the sound field formed by the melon, the optimal position for the transmitter was determined. The term «optimal» suggests that the transmitter is placed so that the sound is concentrated most efficiently. The transmitter was placed 1 cm behind the melon preparation in the zone of premaxilar and tubular pouches. The receiving hydrophone was placed at the same height, as the transducers. The distance between the converters was 100 cm. Measurements of the directional pattern were conducted for frequencies 30, 40, 66, 80 and 130 kHz in the sector of angles ±20°.

To measure the propagation velocity of ultrasonic sound in melon structures, the melon preparation was cut by means of macrotome into equal sections 20±2 mm thick .The total number of obtained sections was 8 (fig. 1-A). Each section was fixed in the vertical position on a special reference graticule with nylon strands (fig.1-B).

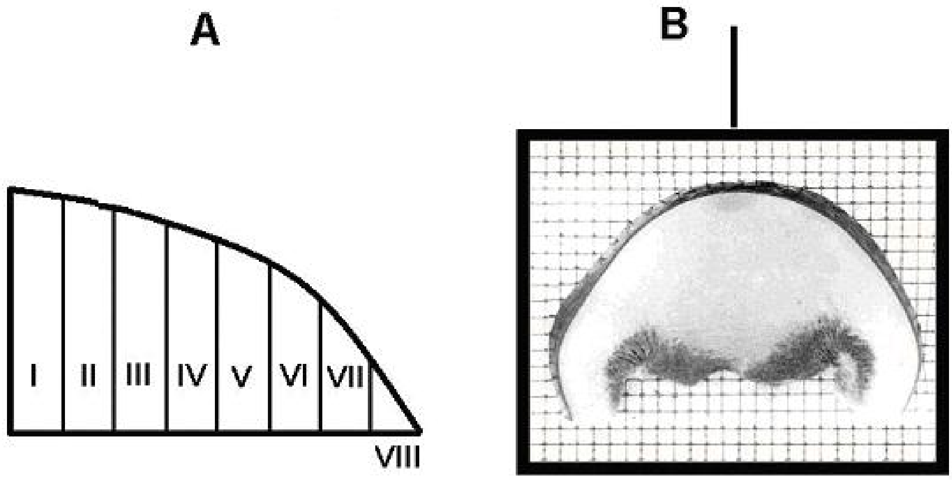

Fig. 1. A – topography of frontal sections of the dolphin melon; B - system for fixing sections on the reference graticule

The sound velocity was calculated from the measurements of the recorded time delay of sounding signals for known sample's thickness. The signal formed by piezoelectric sonic transducer (∅ 7 mm), with excitation by video impulse of 2 ms duration, was used as a sounding impulse. The spectral maximum of the radiated signal was located at the frequency of 180 kHz. During the measurements the transmitter and receiver were adjacent to the sample. The measurements were taken with a 2 cm step both in the vertical and horizontal direction. The error in measuring the sound velocity did not exceed 40 m/s.

The density of lipids structures was determined from the measurements of the volume and weight of the particular melon fragment.

3. RESULTS AND DISCUSSION

Measurements of the amplitude – spatial characteristics of the sound field formed by the dolphin's melon in the horizontal plane allowed us to determine the width of the directional pattern for a level 0.7 of sound pressure, The obtained values were 23°, 12°, 16°, 12°, 5° for frequencies 30 kHz, 40 kHz, 66 kHz, 80 kHz, 130 kHz, respectively.

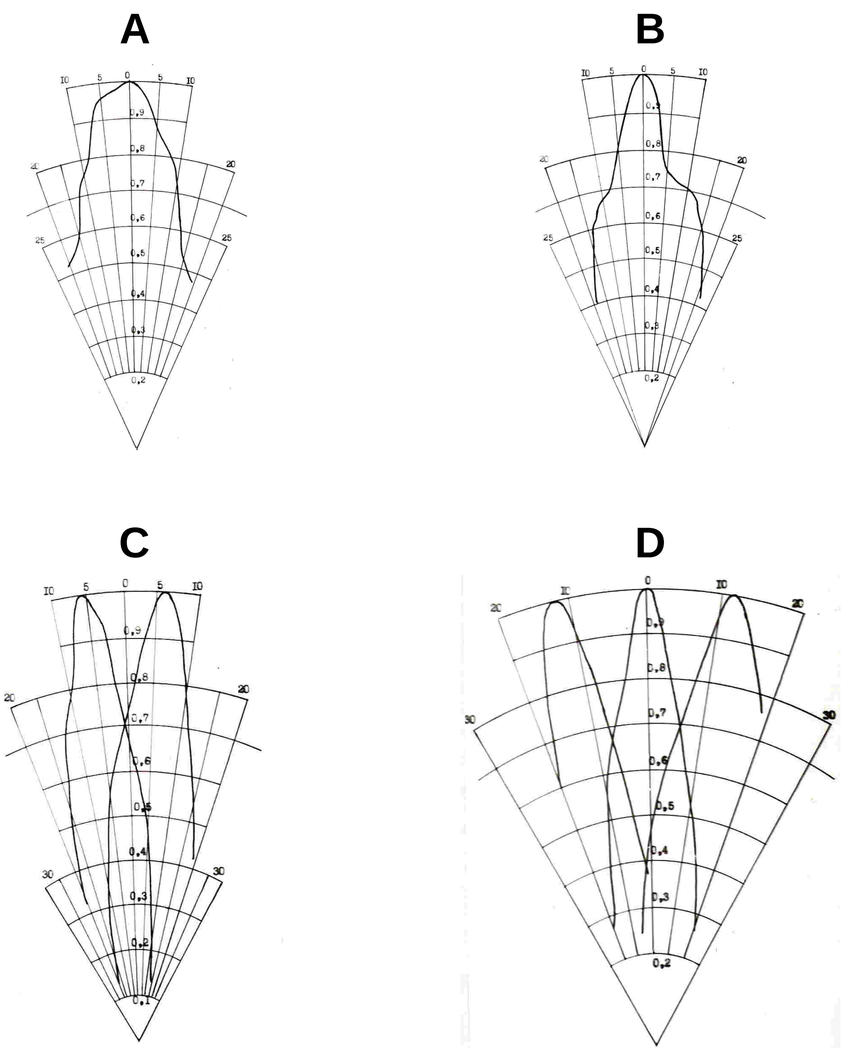

Fig. 2. The directional pattern formed by the preparation of the dolphin melon; A - for a frequency of 30 kHz; B - for a frequency of 66 kHz; C - the irradiation field at 1 cm; D - the irradiation field at 2 cm

The directional pattern formed by the preparation of the dolphin melon for a frequency of 30 kHz is shown in fig. 2-A, and for 66 kHz in fig. 2-B. Fig. 2 represents the results of measurement of spatial characteristics of the irradiation field at for 1 cm (fig. 2-C) and 2 cm (fig. 2-D) displacement of the transmitter to the left and to the right at a frequency of 80 kHz. As it is seen from the presented data, the maximum of the directional pattern is displaced to the right when the transmitter is shifted to the left and vice verse. The displacement of the sound source by ±1 cm caused a shift of the maximum of the directional pattern by ±6°; whereas the displacement of the sound source by ±2 cm shifted the a maximum of the a directional pattern by ±12°.Increase in the distance between the sound sources and receiving hydrophone up to 200 cm has not affected results of the experiment.

The pictures of frontal sections of the melon with the measurements of the sound velocity depending on a particular structure are shown in fig. 3. Structural formations of the dolphin's melon are clearly traced in the presented sections. The dolphin's melon consists of fatty tissues penetrated by veins and also muscular and collagenic filaments. Temperature of the arterial blood passing through the melon is 37°C, which, naturally, results in heating of ambient tissues. Muscles of the melon form its backing. Some muscles lie along the base of the fatty lens, projecting separate myofibrils into the stratum.

Topography of the muscular apparatus testifies to certain motility of all soft tissues forming the melon. The lipid nucleus changes its form from section to section, assuming spherical or ellipsoidal shape. The size of the lipid nucleus becomes maximal 7–10 cm from the beginning of the frontal thickening. As can be seen from the presented results, the velocity of sound in different structures of the melon varies continuously and smoothly. The minimal value of the velocity is 1160 m/s, and maximal - 1503 m/s. In some sections, asymmetry in the measured values in the left and right part of the frontal eminence is observed.

In fig. 4 measurements of the density of melon lipid structures are presented. The measured density varies in a range 0.74-1.34 $\pm$0.01 g/cm^3. Both tissue density and velocity of sound vary smoothly, which is apparently accounted for by smooth changes in histological structure of the frontal eminence.

The results of experiments on dependence of acoustic properties of melon tissue on aging were presented in [5]. Heating of the preparation and its "aging" lead to some decrease in the velocity of sound and wave resistances, this effect being dependant on the histological structure of the investigated sample. Extrapolation of the results to this 37° temperature causes decrease in acoustic characteristics by 4-7 %. According to the results of this work the measured values of local sound velocities are distributed in a range 1378-1784 m/s and values of wave resistances in a range (1.4-2.09)$\times 10^6$kg/m^2•s. The average density varies within the limits of 0.99-1.23 kg/m^3, the local sound velocity changes no more than by 9% for the distance of 2 cm and wave resistance by 15%.

Smooth changes in sound velocity and tissue density ensure smoothness of changes in wave resistance. According to the presented data, increment of the wave resistance for the distance of one wave-length is small in comparison with unity, which is known to increase efficacy of forming directed radiation with a low level of side lobes. To trace the increment of wave resistance, velocity and density were measured for the same space coordinates on one of the melon preparations.

So, for example, in some zones, the increment of wave resistance $\rho_1 c_1/\rho_2 c_2$ for the distance of 2 cm was equal to 0.17. In other cases this increment was even less significant: 0.076 for the length of 4 cm.

Thus, one should expect that in the investigated frequency range 30-130 kHz the sound wave in such heterogeneous medium as melon would pass from a layer to a layer without being reflected from inner structures. The obtained data testify to the fact that insignificant displacement of the transmitter from the origin results in scanning of the directional pattern. This result supports the hypothesis [6] about scanning due to spatial displacement of the transmitter. Thus, the experiments reported in this paper convincingly show the role of the melon in forming the directed acoustic field.

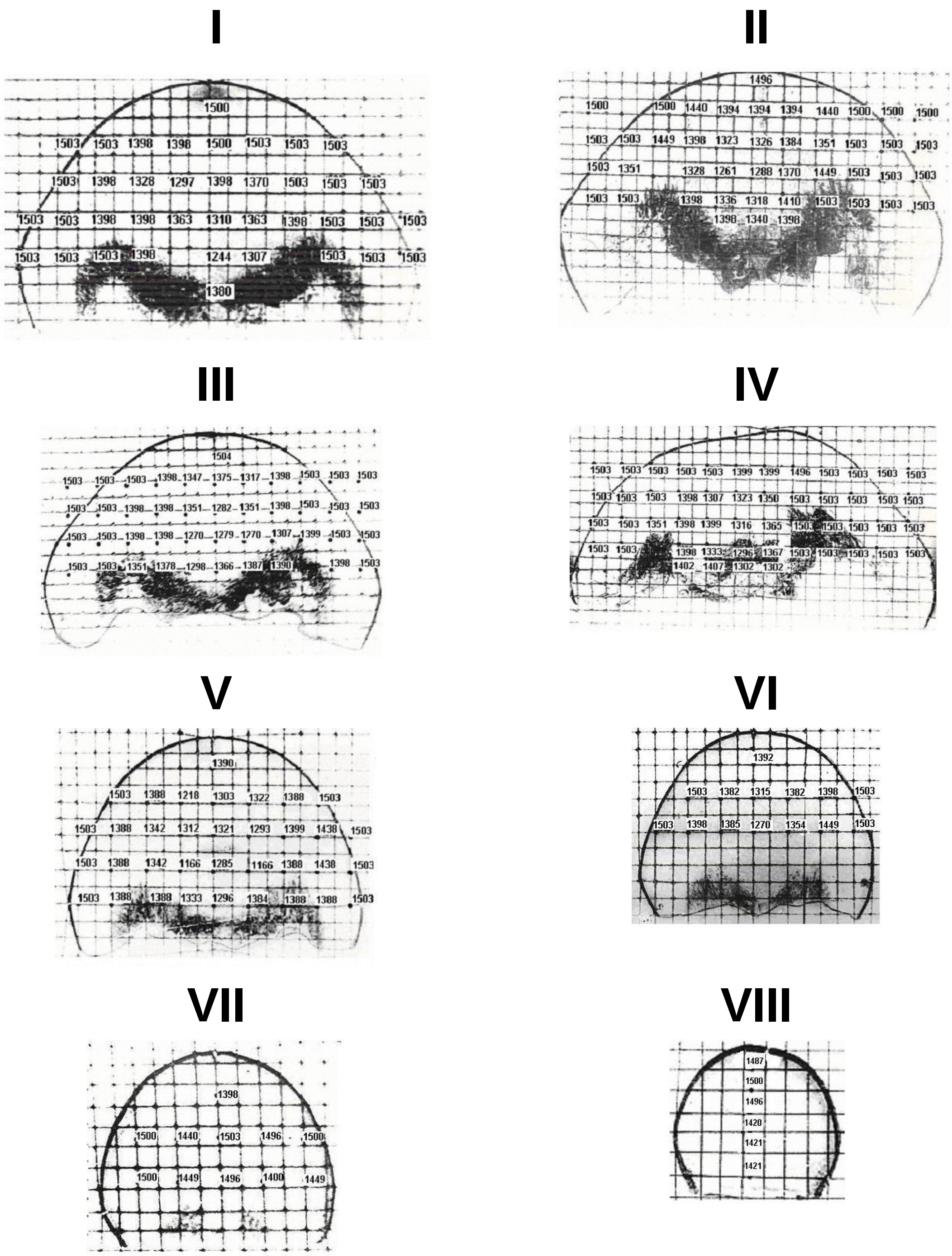

Fig. 3. Pictures of frontal sections of the melon and velocity of sound propagation in different zones of the melon

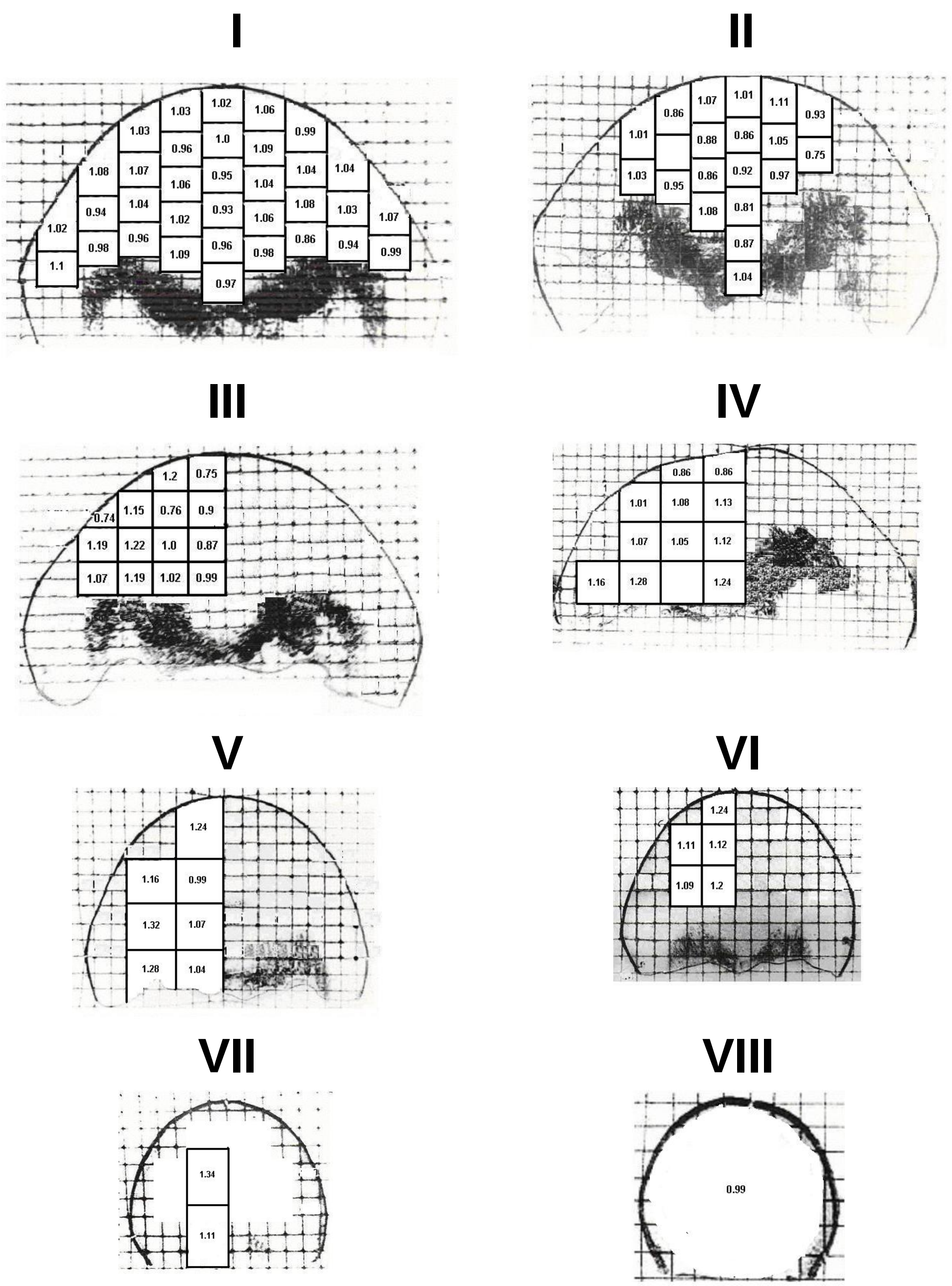

Fig. 4. Pictures of frontal sections of the melon and distribution of tissue density in different zones of the melon

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