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Embryology

ELASTICITY OF EGG SHELLS OF SALMONID FISHES
ELASTYCZNOŚĆ OSŁONEK JAJOWYCH RYB ŁOSOSIOWATYCH

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The egg shell is equally elastic throughout the embryonic development and all its properties remain unchanged until the hatching of larvae. In exceptional conditions as a result of mechanical pressure on an egg, the egg covering increases its measurements up to four times

Although there is rather an abundant literature concerning the physical properties of fish egg shells, the problem of their elasticity has hardly ever been considered, and even if it was described it was only marginally and partially. As a result, it is often said that the egg shell is elastic especially at the beginning of embryonic development (Gray, 1932; Hayes, 1942; Winnicki and Domurat, 1964), and that in the last period of development it becomes brittle and fragile (Hayes, 1942). Such statements are based only upon some vague observation without any specified criteria and without experimental basis. Especially such terms as "fragility" and brittleness are not very specific ones. To the terminology concerning physical properties of egg shells they were introduced rather incidentally. A closer observation has shown that there is no basis for stating that the egg shell is to some extent brittle or "fragile".

The purpose of this work was to clear up the problem of the elasticity of egg shells, that is the possibility of the egg shell to distend under mechanical pressure to which the egg is subjected.

MATERIAL AND METHODS

The experiments were carried out during the autumn of 1958 and in winter and spring of 1959 at the Department of Fish Physiology of the College of Agriculture in Olsztyn. Eggs of the brown trout (*Salmo trutta m. fario*) and the rainbow trout (*Salmo gairdneri* Rich.) were used.

The eggs, artificially spawned and fertilized with a dry method, were transported to the laboratory in vacuum flasks. They were then placed in crystallizin dishes filled with water (water surface being 0,5 cm above the eggs), or with paraffin oil (in this case the eggs were dried with the use of filter paper). The crystallizing dishes were placed in California hatching apparatus with water flowing constantly, the temperature of water being $10 \pm 1^\circ\text{C}$.

The measurements of the elasticity and resistance of egg shells were carried out at 3-day intervals during the whole period of development. In the period proceeding hatching measurements were made every day.

The apparatus for measuring the elasticity of the egg shell under mechanical pressure is shown in Fig.1. On the weight scale of the spring balance

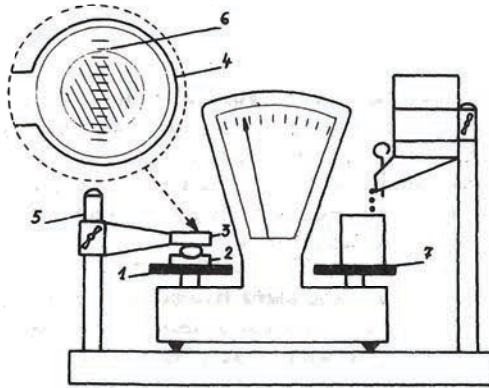


Fig.1. Apparatus for measuring egg elasticity (explanation in text)

(1) a small plexiglass disk was placed (2). The disk had a little hole where the egg was placed. A similar disk (3) with a metal ring (4) was placed above the egg. It was connected to the tripod (5). This disk had a millimetre gauge (6). While the subject scale (7) was loaded, the weight scale and at the same time the disk with the egg moved upward. Under pressure the egg flattened, increasing its diameter, which was easily observed on the mm gauge. Such tests gave the possibility to obtain some data concerning the elasticity of the egg shell under different mechanical pressure - from the smallest, through average (in 100 g steps), up to the maximal one which caused the breaking of the egg covering.

The surface of the flattened egg (that is the area of the shell), could be found by the formula for the surface of a cylinder:

$$S = 2\pi \cdot r^2 + 2\pi rh \quad (1)$$

The height - h was, of course unknown. But assuming that the egg shell is impervious (K r o g h and U s s i n g, 1937), and even under pressure does not change its volume (V), its height (h) also does not change, and may be easily obtained from equation for the volume of a cylinder:

$$V = 2\pi r^2 h \quad (2)$$

Since V of a cylinder equals V of an egg ($\frac{1}{3}\pi r^3$) before the experiment, the height of an egg was:

$$h = \frac{V \text{ of an egg}}{2\pi r^2} \quad (3)$$

and substituting h (3) into the formula (1) it can be seen that the surface (S) of a flattened egg with given r is:

$$S = 6,28 r^2 + \frac{V}{r} \quad (4)$$

where: S - surface of the egg shell,
 r - radius of the flattened egg,
 V - volume of the egg.

It should be added that in this case a deliberate simplification was made because in reality the egg was never a real cylinder, since the area of its circle was not flat, but spherical. The error made by such simplification is rather small; when great loads are used (4-6 kg) it does not exceed 1%, and thus it did not have any particular effect on the results.

Beside elasticity, the resilience was also investigated. Eggs were measured under mechanical pressure and when pressure was removed. Using the apparatus described in previous paper (Winnicki and Domurat, 1964), the degree of shortening of eggs height under different loads and its ability to return to its normal shape were also investigated.

RESULTS

Data concerning the stretching of the egg shells under mechanical pressure is illustrated by the curve (Fig. 2). Every point is an average of at least 10 measurements (sometimes of even 50 or more); and thus the results can be taken as representative. The curve shows that there is a relationship between the stretching of the egg shell and the pressure; this relationship is directly proportional - some small differences are probably caused by the differences in egg size.

From the curve it can be also easily seen that the egg shells are very elastic. In extreme cases, when eggs were placed under high pressure (7000 g), their area increased even 4 times.

It should be underlined that the elasticity does not change during the whole period of development; such results were obtained when eggs were tested in different periods of the embryonic development. For example, an egg under the pressure of 2000 g tested two days after fertilization, as well as the egg under the same pressure at the time of hatching, increased their surface

twice. Conversely, if the egg just before hatching breaks under the pressure of 200 g, its surface increases by 10%; the same applies to eggs (under the same pressure) both on the second day after fertilization and a few days later, that is in the period of maximal resistance of the egg coverings.

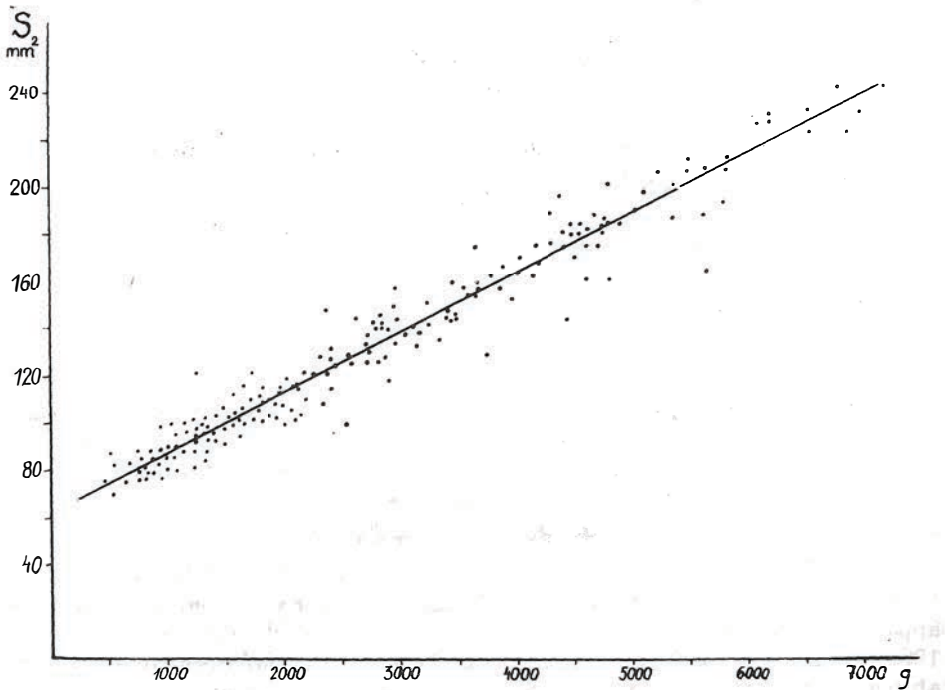


Fig.2. Stretching of the egg shells under mechanical pressure

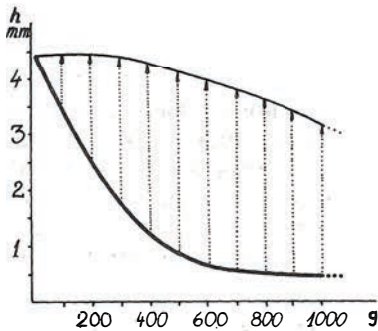


Fig.3. Egg covering resilience in relation to the magnitude of the pressure

Fig.3 shows the results of investigations of the contraction of the egg shells after the pressure is removed. It indicates that with the increase of a single pressure and consequently a greater flattening of the egg caused by this, the deformation of the egg and the return to its previous shape is more difficult. Full resilience is maintained when the pressure is not greater than 200-300 g. As the pressure increases, the vertical axis of the egg becomes shorter. It should be added that such shortening of the vertical axis is not connected with a "squeezing out" of water, since the volume of an egg did not change during the experiment.

DISCUSSION AND CONCLUSIONS

The results obtained showed that the egg shell of the Salmonid fishes is made of a very elastic material. The degree of stretching of the egg shell under mechanical pressure is rather high. The stretching of the egg shells is not the only measure of their elasticity. The other one is their resilience. This ability varies with the pressure applied. The egg shell returns completely to its previous shape if the pressure used is about 200-300 g (that is 0,34 - 0,5 atm), and was acting upon the egg only once and for a short time. Greater pressures cause a permanent deformation of the egg.

A pressure of 200-300 g is within the range of pressures that could act the egg in normal conditions. If we take the specific gravity of the gravel as 2,3 (which after subtraction of the weight of the water replaced by the gravel gives only 1,3), and the diameter of an egg as 4,5 mm, then even an 80 cm layer of gravel over the egg gives the pressure of only 0,02 atm. Even such thick layer of gravel would not be dangerous, since newly-laid eggs of the rainbow trout have a resistance of 100 g (W i n n i c k i and B a r t e l, 1968). Thus the eggs would remain unchanged even under layers of gravel 8 times thicker (6-7 mm).

The results obtained do not confirm the opinion that at the end of the embryonic development the egg shell becomes less elastic. In reality, the elasticity of the egg shells in the period of hatching is the same as in the period of maximal resistance or just after spawning. This could be, to some extent, explained by the study of W i n n i c k i and coop. (1970) which showed that changes in mechanical properties of the egg shell in the period of hatching take place only in some parts of the egg shell, and not over its whole surface. Thus such terms as "brittle" and "fragile", frequently applied to the egg shell in the period of hatching do not comply with the facts, and should not be used.

It seems that the great elasticity of the egg shell, in connection with its plasticity after the egg is laid to water (W i n n i c k i, 1967) play the greatest role during the "building-in" of the eggs into the egg to avoid great tensions of the egg shell.

Taking all this into account we can state that:

1. The material the egg shell of the rainbow trout is made of is very elastic; in extreme cases it can increase its surface even 4-times.

2. The pressure of 200-300 g acting upon an egg causes a shortening of its vertical axis by about 30-36%, and increase in the area of an egg of about 10 and 13%. It does not exclude, though, the possibility of the returning of the egg to its normal shape after the pressure is removed. Greater pressure cause permanent deformations of the eggs.

3. The elasticity of the egg shell during the whole period of embryonic development remains the same, and does not decrease in the period of the hatching of larvae.

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ELASTYCZNOŚĆ OSŁONEK JAJOWYCH RYB ŁOSOSIOWATYCH

Streszczenie

Badania stopnia rozciągliwości osłonek jajowych *Salmo trutta m. fario* i *Salmo gairdneri* Rich. pod wpływem ucisku działającego na jajo wykazały, że materiał, z którego zbudowana jest osłonka jajowa jest bardzo elastyczny, dzięki czemu powierzchnia jaja w końcowym przypadku może zwiększyć się ponad 4-krotnie.

Krótkotrwały ucisk na jajo rzędu 300 g jakkolwiek zwiększa powierzchnię jaja pstrąga do 13%, jednak nie wyklucza możliwości powrotu jaja do stanu pierwotnego, natomiast ucisk większy powoduje zmiany stałe.

Elastyczność osłonek jajowych podczas całego okresu rozwoju zarodkowego pstrąga jest jednakowa i nie spada również w okresie wykluwania się larw.

ЭЛАСТИЧНОСТЬ ЯИЦЕВЫХ ОБОЛОЧЕК ЛОСОСЕВЫХ РЫБ

Резюме

Изучение степени растяжимости яичевых оболочек *Salmo trutta m. fario* L. и *Salmo gairdneri* Rich. под влиянием механического нажима на яйцо показало

значительную эластичность материала из которого построена оболочка. Благодаря этому поверхность яйца в экстремальных случаях может увеличиваться свыше 4 раз.

Кратковременное механическое воздействие в 300 г. хотя и увеличивает поверхность яйца на 13 - 15%, не исключает возможности возвращения яйца до начального состояния. Более высокий нажим на яйцо ведёт к стабильным изменениям.

Эластичность яйцевых оболочек во весь период эмбрионального развития форели является неизменной и не снижается также в стадии выклёва личинок.

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