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THE EFFECT OF CUSTOMARY FINNISH HEAT PREPARATION METHODS ON THE INFESTIVENESS OF DIPHYLLOBOTHRIUM LATUM FROM FISH TO MAN

AN EXPERIMENTAL TREATISE ON THE HEAT RESISTANCE OF DIPHYLLOBOTHRIUM LATUM PLEROCERCOIDS, AND ON THE TEMPERATURE VARIATIONS IN VARIOUS PARTS OF THE PIKE, PERCH AND BURBOT DURING FRYING IN PAN, BOILING, AND BAKING IN OVEN

By

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The tape worm disease caused by Diphyllobothrium latum has been and still is very common in Finland. Thus, it seems obvious that countermeasures against this disease have not been adequate, or they have not yet been carried out with enough efficiency.

Due to the fact that the infestation of man occurs through the consumption of insufficiently prepared fish, in a campaign against this disease good knowledge is needed of the tolerance of the plerocercoids against various physical agents, and of the methods for preparing the fish to ensure that the critical limit of treatment is exceeded. These questions have been studied in Finland and in other countries especially concerning the effect of heat and of salt concentration, but the results obtained are based either on a comparatively small sample or on experiments carried out in countries where the dietary customs and the methods of preparing the fish greatly differ from those used in Finland. In the present work, we have investigated to what extent the customary heat preparation methods of fish used in Finland affect the plerocercoids situated in various parts of the fish.

A. IN VITRO EXPERIMENTS ON THE HEAT RESISTANCE OF DIPHYLLOBOTHRIUM LATUM PLEROCERCOIDS

MATERIAL AND METHODS

Tape worm larvae infested fish were collected, and the plerocercoids separated and subjected to various heat treatments under rigidly controlled conditions. The effect of the treatment on the motility was determined under the microscope.

The pikes and burbots used in these experiments were obtained from the lake districts around Imatra and Tampere in southern Finland. The burbot, however, was taken only from the Imatra area. Data on the fish material and the number of plerocercoids are given in Table 1.

Table 1. Fish examined and plerocercoids found.

Fish	Pike		Burbot	Total
	Area of Tampere	Area of Imatra	Area of Imatra	
Number	18	33	66	117
Weight, total, kg	33	68	61	162
Weight range, kg	1.320—2.940	0.470—5.450	0.360—2.600	
Weight, average, kg	1.830	2.060	0.920	

Distribution of plerocercoids	Number	% of total	Number	% of total	Number	% of total
Free	35	12	64	15	33	15
Intestine	147	48	201	47	91	41
Spleen	3	1	3	1	—	—
Liver	12	4	8	2	1	—
Muscles	89	30	130	31	97	43
Spawn	15	5	17	4	2	1
	301	100	423	100	224	100

After weighing and measuring of length, the pikes were skinned and the burbots scaled. Evisceration was made after opening the stomach with a longitudinal incision from the anus to the head. After decapitation the head and the body cavity were inspected for plerocercoids. Finally, the fish were rinsed with cold water.

Technique of plerocercoid localization

The exploration for plerocercoids was done by inspecting point by point every part of the fish: the spawn sacs were opened and their content spread over an even surface; the liver and the muscles were sliced. The latter were cut longitudinally with a scalpel. Immediately after isolation, the plerocercoids were transferred into normal horse

serum on a watch glass for identication under the microscope, using a magnification of 32 ×. All damaged plerocercoids and those with a length of less than 4 mm were discarded. The plerocercoids to be used were stored in 0.5 ml serum, each in a separate test tube. The storage temperature varied between 2 and 5°C.

Heat treatment of plerocercoids

The plerocercoids used in the experiments were in most cases stored after isolation for less than one week. For heat treatment, the plerocercoids were immersed in 2 ml horse serum in test tubes with a length of 12 cm and a capacity of 10 ml. The motility and integrity of the plerocercoids were ascertained immediately before their immersion in the serum.

The test tubes in the rack were submerged into a preheated water bath. The serum surface was kept 5 cm beneath the water surface. A thermocouple was placed into one of the test tubes, its tip touching the bottom of the tube and connected to the temperature recording apparatus.

When the temperature of the serum became stabilized, the plerocercoids were transferred into the test tubes with a Pasteur pipette, and the time recording began. The recorder was adjusted to register the temperature at 6 sec. intervals.

After the appropriate time in the water bath the test tubes were removed and the first inspection of the plerocercoids was made with the larvae on a watch glass in less than 1 ml serum. After inspection the plerocercoids were carefully returned to the test tubes with Pasteur pipettes. After storing the tubes for two days at room temperature and prewarming them in a water bath at 35—40°C the second inspection was made. The average duration of the microscopic examination was 2—3 min. per plerocercoid. The first microscopic examination immediately after the heat treatment was omitted in case of the 56°C treatment, as handling seemed to injure the plerocercoids, which had become fragile as a result of the heat treatment.

The number of simultaneously treated plerocercoids varied between one and four.

Temperature measurement

Temperature measurements were carried out by using copper-constantan thermocouples. The thickness of the copper-constantan wire was 0.1 mm. The temperature measuring joint was placed at the tip of an injection needle. The length of the needles was 6—8 cm and the thickness 1—2 mm. The reference joints were placed in a reference warm bath at a temperature of 30°C ± 0.1. This temperature was controlled daily before work began. The potentials of the thermoelements were registered with a Honeywell Multipoint Recorder (Honeywell Regulator Company, Minneapolis, model Y 153 X 89). During the experiments two different recorders were used, one with three and another with six thermoelements. The accuracy of the temperature measurement was ± 0.5°C.

Table 2. The motility of Diphyllobothrium plerocercoids after various heat treatments.

Time, min.		45°C a no.	45°C a %	45°C b no.	45°C b %	46°C	47°C a no.	47°C a %	47°C b no.	47°C b %	48°C a no.	48°C a %	48°C b no.	48°C b %	49°C a no.	49°C a %	49°C b no.	49°C b %	50°C a no.	50°C a %	50°C b no.	50°C b %
2	Active movements																					
	Slight „																					
	Feeble twitches																					
	No movements																					
	Total																					
5	Active movements	10	100	10	100		8	80	10	100			31	74			7	54				
	Slight „						1	10			5	12	4	9.5	2	15	5	38			19	47.5
	Feeble twitches																					
	No movements						1	10			37	88	7	16.5	11	85	1	8	40	100	21	52.5
	Total	10					10				42				13				40			
10	Active movements						2	20	8	80												
	Slight „						4	40					13	56.5								
	Feeble twitches																					
	No movements						4	40	2	20	23	100	10	43.5					10	100	10	100
	Total						10				23											
15	Active movements	9	90	9	90				100	100												
	Slight „	1	10	1	10		1	10					7	20.5								
	Feeble twitches																					
	No movements						9	90			34	100	27	79.5								
	Total	10					10				34											
20	Active movements	8	80	9	90				10	83												
	Slight „	2	20	1	10				1	8.5												
	Feeble twitches																					
	No movements						12	100	1	8.5	10	100	10	100								
	Total	10					12				10											
30	Active movements	8	80	10	100																	
	Slight „	2	20																			
	Feeble twitches																					
	No movements						10	100	10	100												
	Total	10					10															
60	Active movements	4	100	4	100																	
	Slight „																					
	Feeble twitches																					
	No movements																					
	Total	4																				

a = inspection immediately after treatment.
b = inspection 2 days after treatment.

Table 2 (continued).

Time, min.		51°C a no.	51°C a %	51°C b no.	51°C b %	52°C a no.	52°C a %	52°C b no.	52°C b %	53°C a no.	53°C a %	53°C b no.	53°C b %	54°C a no.	54°C a %	54°C b no.	54°C b %	55°C	56°C a no.	56°C a %	56°C b no.	56°C b %
	Active movements																					
	Slight „					23	32	24	34			9	20									
2	Feeble twitches					42	59	23	32													
	No movements					6	9	24	34	46	100	37	80									
	Total					71				46												
	Active movements																					
	Slight „			5	16			2	2							1	2					
5	Feeble twitches					8	7	9	7.5							3	5.5				3	5
	No movements	31	100	26	84	110	93	107	90.5							49	92.5				50	95
	Total	31				118										53					53	
	Active movements																					
	Slight „																					
10	Feeble twitches																					
	No movements																					
	Total																					
	Active movements																					
	Slight „																					
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60	Feeble twitches																					
	No movements																					
	Total																					

a = inspection immediately after treatment.
b = inspection 2 days after treatment.

Determination of plerocercoid viability

In the microscopic examination the plerocercoids were judged viable, if distinct or feeble continuous or intermittend contractions could be demonstrated. Extremely weak twitches in otherwise immobile plerocercoids were, however, considered to be due to mechanic, thermal or drying effects on dead tissue.

RESULTS

The results of the heat treatment of the plerocercoids are shown in Table 2 and Fig. 1. The number of plerocercoids used in the heat treatment experiments was 640. This number is smaller than the total number of plerocercoids found in the

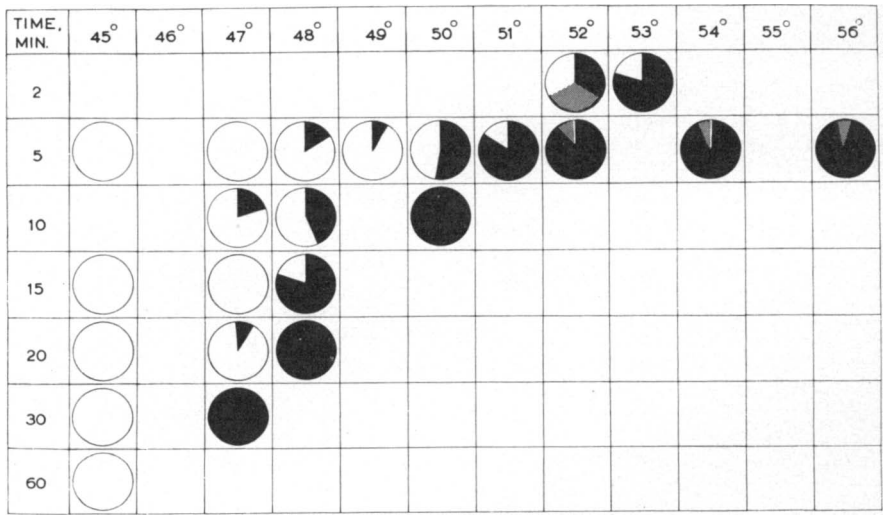


Figure 1. The motility of Diphyllobothrium latum plerocercoids two days after various heat treatments. Number of plerocercoids subjected to each treatment 10—118 (with one exception).

Black = plerocercoids with no movements.
Dark grey = plerocercoids with feeble twitches.
White = plerocercoids showing movements.

collected fish material. The smaller number used in the experiments is due to the fact that only lively, mobile and well-sized specimens were chosen for the experiments. This selection was made to obtain the tolerance level of the apparently most resistant plerocercoids.

The given experimental data show that less plerocercoids survive the treatment when the treatment time and/or temperature is increased. At 45°C the larvae seem to stand the heat for time periods longer than those which are commonly used in the preparation of fish for the table. Treatment at 47°C immobilized all the larvae in 30 min., and 50°C seemed to be the limit above which a pronounced effect was obtained in 10, or even 5 min.

At temperatures 52—54°C, feeble jerking movements were observed in otherwise immobile larvae. This movement was considered passive and not an indication of viability. No active movements could be seen after a 5 min. treatment at 56°C.

A comparison between columns a and b of Table 2 shows the importance of the heat shock described by *Agranovsky* (1). Especially at temperatures below 50°C, most of the plerocercoids that were found totally immobile immediately after the treatment showed contractions on inspection two days later. At these temperatures immobilization seems to be reversible. After stronger treatment, however, the plerocercoids were permanently immobilized.

DISCUSSION

The aim of the investigation was to determine the lethal temperature treatment of the plerocercoids, and to correlate this finding with temperatures in various parts of fish during preparation according to common household methods. The best method for this purpose would be to study the plerocercoids *in situ* in their natural surroundings in the fish muscle tissue. This could be achieved by determination of the viability of the plerocercoids after the fish had been prepared. As a result of the coagulation of the protein in the tissues exploration for plerocercoids is, however, in this case very difficult. The reliability of the results would also be questionable because of the great temperature differences between various parts of the fish. The percentage of dead plerocercoids, too, would be difficult to assess, as the total number of plerocercoids in the intact fish is practically impossible to determine.

In view of the above mentioned difficulties, some trials were carried out in which small pieces of fish meat containing the plerocercoids were cut off and then subjected to the experimental

heat treatment. In using this method, some difficulties were encountered with the exact temperature regulation. The pilot runs showed, however, that in these experiments the plerocercoids had a tendency to resist heat treatment better than when the treatment was given to separated plerocercoids.

Due to the difficulties connected with the heat treatment of plerocercoids *in situ*, a method using the separation of the plerocercoids from their natural surroundings was chosen. Other investigators have used various salt solutions, such as physiological saline or Ringers solution, as a medium for the plerocercoids during the treatment. As these media greatly differ from the natural surroundings of the plerocercoids we chose horse serum. Our own experience has shown it to be very good for this purpose. Plerocercoids have survived in horse serum for more than one year in our laboratory at a temperature of 4°C.

Agranovsky (1) has found that a 45°/20 min. treatment is lethal for separated plerocercoids. According to the studies of *Pesonen & Wikgren* (3), the plerocercoids survive only a very short time at 52°C and they are killed at 54°C. These investigators did not use horse serum, which might explain the differences between their findings and ours. One of *Agranovsky*'s objects was to compare the effect of gradual increase in temperature with that of instant exposure to the experimental temperature. In our trials we used the latter method. The plerocercoids that died by this method would obviously have done so also in case their resistance had been weakened as a result of the preliminary heat treatment involved in the process. Our results, therefore, can be assessed to have a certain safety margin.

In our experiments the motility of the plerocercoids was determined twice. Between these two determinations they were kept at room temperature and not at 37°C, which would correspond to natural conditions during infestation if any. We chose room temperature, as the viability of the plerocercoids seems to be better at this temperature than at body temperature.

CONCLUSION

The obtained results lead us to the conclusion that the plerocercoids die in 5 min. at 56°C.

B. TEMPERATURE CHANGES IN FISH PREPARED ACCORDING TO CUSTOMARY METHODS IN FINLAND

To study the effect of temperature increase in various parts of fish on the viability of Diphyllobothrium latum plerocercoids in fish prepared according to customary methods in Finland, the following method was used. First, information was collected, principally from the literature, about which fish species acting as intermediate hosts of this parasite were most common in the diet of the population; and secondly, which methods were the most frequently used for fish preparation in Finland. Then, a series of fish preparation trials were carried out, in which the temperature changes in various parts of the fish were registered. The obtained results, together with those of the *in vitro* trials described in part A, were used for evaluating the problem raised by this paper.

The share of pike, perch and burbot in the total fish consumption in Finland

The estimation of pike and perch consumption was based on data obtained in social and statistical studies of the urban population during 1955—1956 (5), and the rural population during 1959—1960 (6). In both of these investigations the data were collected by keeping records of the consumption of various foods in individual households. Fish consumption in the various parts of Finland is shown in Table 3. It can be seen that the average annual fish consumption both in rural and urban areas is about 10 kg per person. The amount of pike consumption is also about equal in rural and urban areas, but the consumption of perches is greater in the countryside than in the towns. Furthermore pike consumption is about 13 % of the total fish consumption of the country, the corresponding figure for perches is 12 % in rural areas and 5 % in urban areas. The investigations mentioned above do not include data on burbot consumption. Some information could be inferred from the official records of the total catch of fish (4). On the basis of these records, and by disregarding a possible burbot export, the annual per capita consumption would be 350 g which corresponds to about 3 % of the total fish consumption.

Periodical variations seem to be common in fish consumption. This is clearly shown by an investigation carried out by *Pekka-*

Table 3. Annual per capita fish consumption in Finland.

	Fish, total	Fish, fresh		Pike, fresh		Perch fresh	
	kg/ head	kg/ head	% of total	kg/ head	% of total	kg/ head	% of total
Urban areas, 1955—1956 (485 households)							
All households	10.3	7.1	68.9	1.4	13.6	0.5	4.9
Helsinki	9.1	6.1	67.0	1.0	11.0	0.5	5.5
Turku and Tampere	9.4	6.6	70.2	1.3	13.8	0.5	5.3
Middle size towns	10.7	7.2	67.3	1.3	12.1	0.4	3.7
Small towns	11.8	8.2	69.5	1.9	16.1	0.7	5.9
Rural areas, 1959—1960 (1423 households)							
All households	9.8	7.7	78.6	1.3	13.3	1.2	12.2
South Finland	9.7	7.3	75.3	1.0	10.3	0.9	9.3
Middle Finland	12.4	10.1	81.5	2.4	19.4	2.2	17.7
Ostrabothnia	6.2	4.7	75.8	0.6	9.7	0.2	3.2
North and North-East Finland	10.7	8.9	83.2	1.1	10.3	1.6	15.0

rinen (2) in some parishes in West and East Finland, in which the food consumption was studied in 184 family households by the weighing method. Data of the results are shown in Table 4.

Table 4. Fresh fish consumption in some parishes of East and West Finland.

	East Finland			West Finland		
	Summer 1956	Winter 1957	Autumn 1959	Summer 1956	Winter 1957	Autumn 1959
	g/person/day					
Fish, total	44	11	22	22	7	0
Pike	7	2	2	1	–	–
Perch	26	2	1	0	4	–

Prevalence of customary pike, perch and burbot heat preparation methods in Finland

To our knowledge, no papers have been published dealing specifically with the commoness of various fish preparation methods in Finland. The publications on the consumption investigations do not always include information on this question. Some data can be obtained, however, from the investigation

of *Pekkarinen* (Table 4) in which the material consisted of altogether 400 meals, including fish dishes. In the eastern part of the country pike was served fried in 31, and boiled in 24 cases out of the total number of 55 pike containing meals. The material from western Finland contained only three meals with pike. In all these cases the fish had been fried. Perch was served at 31 meals in the eastern part, and at four meals in the western part of the country. Frying was used in the preparation of more than 60 % of these meals. In the rest of the cases the perches were boiled. Burbot appeared at meals in this investigation only in four cases. The preparation method was boiling.

Due to the comparatively small number of meals studied, no far-reaching conclusions can be drawn about the comparative commoness of the various heat preparation methods. However, on the basis of the prevailing opinion of nutritionists in the country it seems justifiable to consider frying and boiling to be the most common preparation methods of pikes and perches, and boiling to be nearly the only method for burbot preparation. Accordingly, in this study we have concentrated explicitly on the effect of these methods.

MATERIAL

The fish preparation trials were carried out on marine fish caught on the average 1—2 days earlier. Most of the experiments were done in wintertime. In a few cases fish that had frozen during the transport to the laboratory were used. A total of 97 kg fish was used. Of these 91 kg were pikes and 6 kg perches. The weight of the pikes varied between 700 and 2000 g, and that of the perches between 250 and 450 g.

METHODS

The fish to be used in the experiments were weighed, the pikes and perches were scaled and the burbots were skinned. The abdominal cavity was opened with a longitudinal incision from the anal orifice in the cranial direction. The viscera were removed, and finally the fish were washed.

The technique of temperature measuring is described in Part A.

Frying in pan

Pikes and perches were used in the pan frying experiments. Pans with a diameter of 180 mm and a bottom thickness of 7 mm were used. A 1000 w electric plate was used as the heating device. Corn oil or butter was used as frying fat in a 1—2 mm thick layer in the bottom of the pan. The plate was preheated with the energy regulator in the

maximum position for 5 min.; the frying pan was warmed on the plate for 3 min. Then, the fat was poured into the pan and heated for 1 min. before beginning the frying. The maximum position was kept for 1 min. after which the regulator was turned towards lower heating.

For frying, the fish were cut into transverse sections of about 5—7 cm length. The slices were rolled in a mixture of wheat flour and table salt, and three or six thermocouples were inserted through one of the cut surfaces to a depth of 2—3 cm. The sites of the thermocouples were chosen to give information about places with the least expected temperature rise.

The distance of the thermocouples from the surface of the fish was measured. The time when the fish section was placed in the pan was noted as the beginning time of frying. The fish section was turned over in the middle of the time period. After the fish section was turned over the temperature regulator was again kept at the maximum position for 1 min. The frying time periods used in the experiments were 10, 15 and 20 min. After frying, the fish sections were transferred to a steel plate for cooling. Temperature changes were followed during cooling for 10—15 min. Finally, organoleptic tests were carried out on the fish sections.

The temperature changes of the frying pan as such during the procedure described above was measured separately. For this purpose a thermocouple was soldered to the bottom of the pan, and registration of the temperature began at the time when the pan was placed on the heating plate. The plate was preheated for 5 min. The temperature rose rapidly and after 3 min., at the time when the oil was poured in, a temperature of more than 100°C was recorded. One minute after the fish section was placed in the pan and the heat plate was turned on maximum for 1 additional min., the regulator was turned towards lower heating. The highest temperature was recorded 2—3 min. later, when the temperature was 200—225°C. After the peak the temperature decreased with a rate of 5—10°C per minute. The 1 min. heating in connection with the turning the fish over raised the temperature 10°C. The temperature at the time the fish were taken out of the pan varied between 190° and 195°C. Short heat periods in the experiments gave comparatively high final temperatures.

Boiling

The fish were boiled in a 6 liter aluminium kettle with a diameter of 23 cm and bottom thickness of 4 mm. Enough water was used to totally cover the fish. The fish were immersed either in cold or in boiling water. The thermocouples were placed 2—3 cm deep in the muscles of the back, 4—6 cm from each others. When the water began to boil the fish were either removed or cooked for various time periods. After cooking the fish were transferred to a steel plate and the recording of the temperature changes continued for 10 to 15 min. Finally, the readiness of the fish was tested organoleptically.

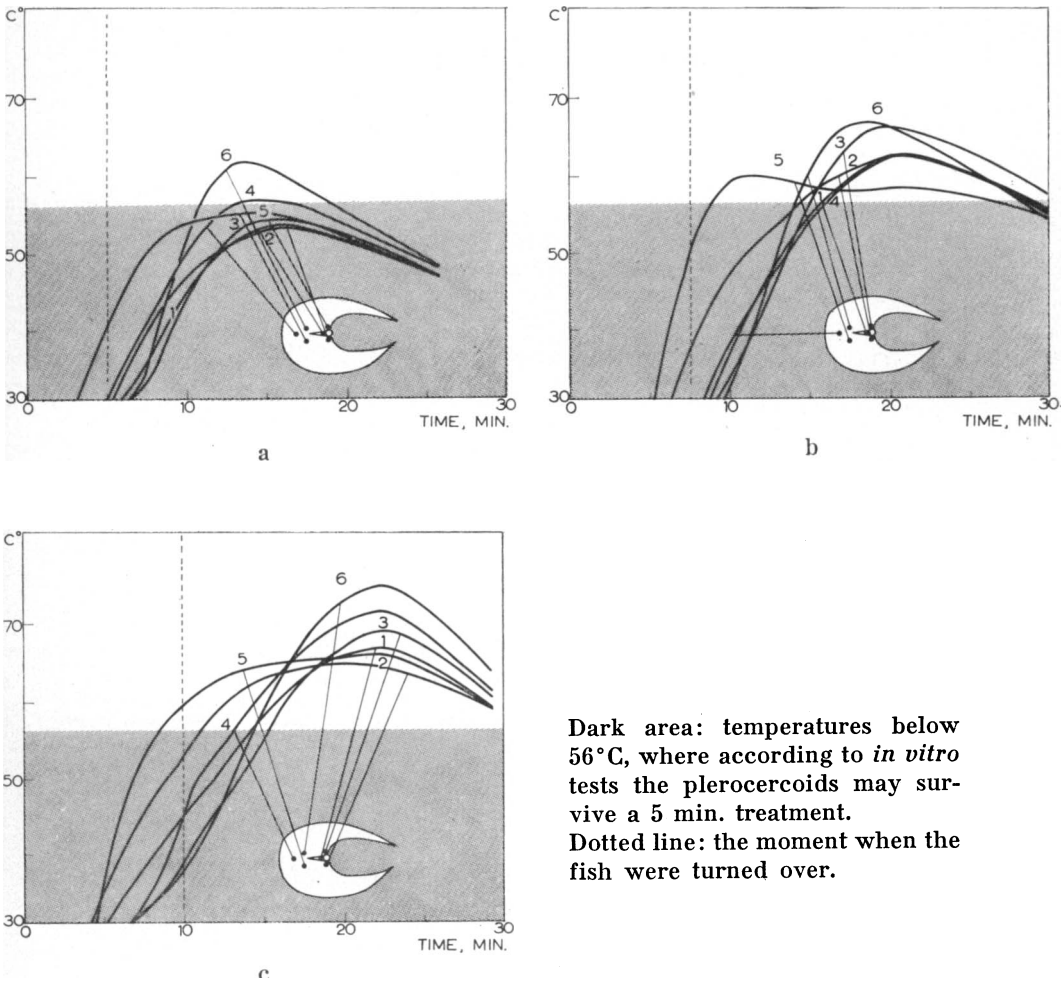


Figure 2. Temperature changes at sites of least temperature rise during frying of pike sections. The results of three typical experiments out of a total of 75 are shown. The sections were kept in the position shown in the picture during the first half time of the frying.

a) frying time 10 min., thickness of section 3.9 cm, weights of fish 810 g.
b) „ 15 min., „ 4.0 cm, „ 1040 g.
c) „ 20 min., „ 3.8 cm, „ 830 g.

Baking in oven

An electric oven was used for baking of whole pikes. The oven was preheated to a temperature of 200° or 250°C. The cleaned pikes were filled with cooked, cold rice and butter. The filled abdominal cavity was then closed by sewing. Finally, melted butter was poured on the surface of the fish. The thermocouples were placed as described for the boiling of fish. The baking time was 30 or 36 min. After baking the fish were transferred to a steel plate at room temperature and the recording of the temperature changes continued for an additional 15 to 20 min. Finally, the readiness of the fish was tested organoleptically.

Organoleptic testing

The prepared fish and fish sections were organoleptically tested separately by two persons. The following notations were used as criteria to determine how well the fish was prepared. The surface of a well prepared fish is attractively brownish; the fish bones, especially the vertebral column, are easily detachable from the flesh and not even tiny bits of flesh stick to the bones; the blood vessels of the ventral side of the column are grey and not reddish; the flesh of a well prepared fish is dry and firm, with easily divisable muscle bundles. In contrast, the flesh of raw fish is moist, reddish and tough. The surface of the coeloma of raw fish looks moist and gleaming, in contrast to a well prepared fish with a white, dry and dim surface. Raw pike has, in addition, an objectionable taste that gradually disappears during the preparation process.

RESULTS

Frying in pan

The results of the frying experiments with the sections of pike are shown in Figs. 2 and 3. In the first figure comparative temperature changes are shown at six sites, with the least expected temperature rise in three typical frying experiments representing frying times of 10, 15 and 20 min. respectively. The site with the least temperature rise was found near the column in the part of the fish which was turned towards the pan during the first half-time of the frying. The temperature rise was found to be of the same magnitude on the corresponding site on the opposite side of the column and also in the column itself. The differences were not greater than 2 or 3 degrees.

The temperature rise at the other sites of the thermocouples was comparatively greater, which indicates that if the rise at the first mentioned site would be enough to kill the plerocercoids then the effect of frying would be even more certain in all other parts of the fish section.

To indicate the temperature changes in the pike sections during the 75 separate frying experiments, only changes at the site with the least temperature rise, and with the greatest opportunity for the plerocercoids to survive, are shown in the graphs.

The curves in Fig. 3 show that all the pike sections with thicknesses of 3.0—3.4 cm were heated to the critical temperature of 56°C during the experimental 10 min. frying. With a section thickness of 3.5—3.9 cm only 5 out of 17 were heated up to this temperature; and with a thickness of more than 4.0 cm none of the sections had the temperature 56°C at the site of the least temperature increase. Thus, only sections with a thickness of less than 3.5 cm were heated up to 56°C during a 10 min. frying.

With a frying time of 15 min. a pike section with a thickness of less than 4.0 cm was heated well above 56°C. However, only 4 of the 11 sections with thicknesses between 4.0 and 4.4 cm reached this temperature.

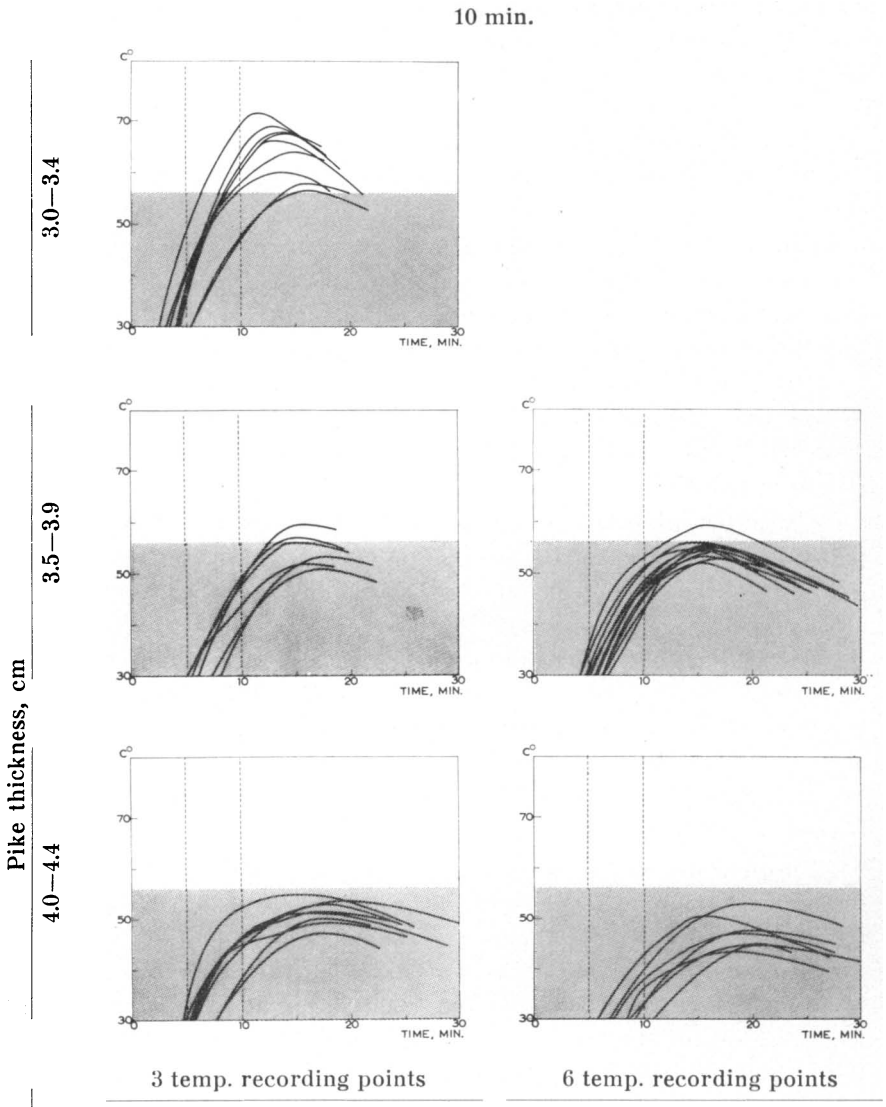
Altogether 21 pike sections were fried for 20 min. The temperature rose above 56°C in all sections with thicknesses between 3.5 and 4.4 cm, and in 3 out of 7 with thicknesses between 4.5 and 5.5 cm.

The frying time of whole perches was 10 min. The results of 10 frying experiments are shown in Fig. 4. It will be seen that in 9 out of 10 perches the temperature rose well above the 56°C, and even in the tenth it nearly reached this limit.

Boiling

Temperature changes during and after cooking at the sites of the least temperature rise of pikes are shown in Figs. 5 a and 5 b. In the former figure the curves refer to experiments in which the fish were dipped in boiling water, and in the latter to experiments in which they were put into cold water. It will be seen in Fig. 5 a that all the curves rise above the critical 56°C level for fish which had been kept submerged until the water re-boiled. The temperature of the pike, which was kept in boiling water for 10 min., reached a temperature of 70°C, but the temperatures of the two pikes that were removed from the kettle before the water re-boiled did not reach 56°C. Consequently one may conclude that if the fish are kept in the kettle until the water re-boils the temperature in all parts will rise enough to destroy any possibly present plerocercoids.

Figure 3 a



Figures 3 a, b and c. Temperature changes at the site of least temperature rise during 10, 15, and 20 min. frying of pike sections.

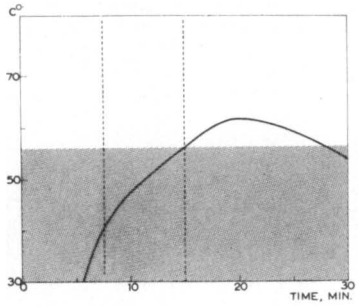
Dark area: temperature below 56°C, where according to *in vitro* tests the plerocercoids may survive a 5 min. treatment.

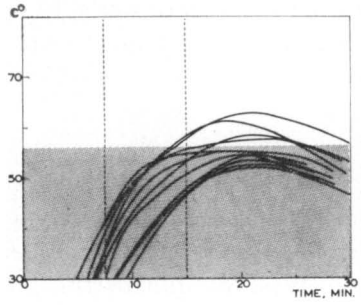
Left dotted line: the moment when the fish were turned over.

Right dotted line: moment when the fish were removed from the pan.

Figure 3 b

15 min.

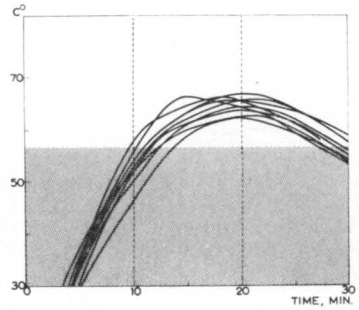


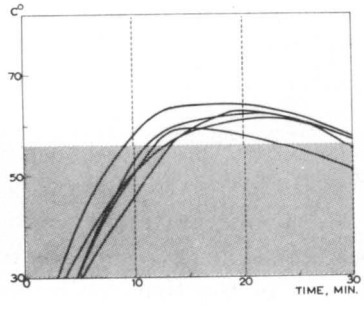


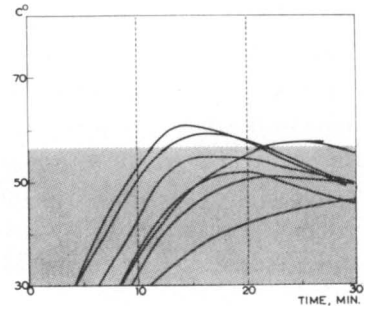
6 temp. recording points

Figure 3 c

20 min.







6 temp. recording points

Figure 4

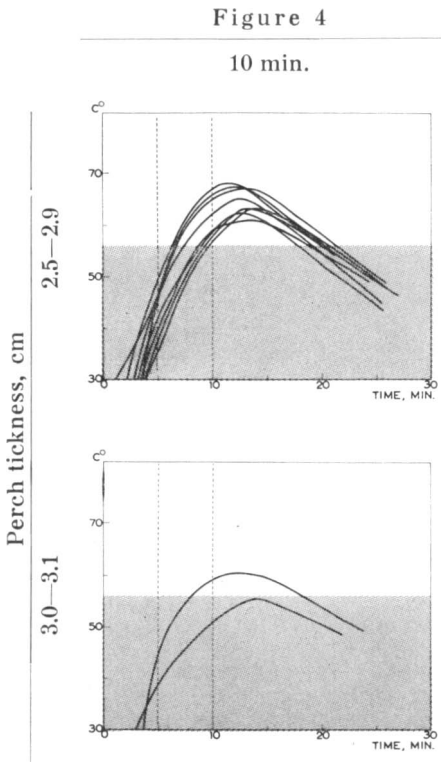


Figure 4. Temperature changes at the site of least temperature rise during 10 min. frying of whole perches.

Dark area: temperature below 56°C, where according to *in vitro* tests the plerocercoids may survive a 5 min. treatment.

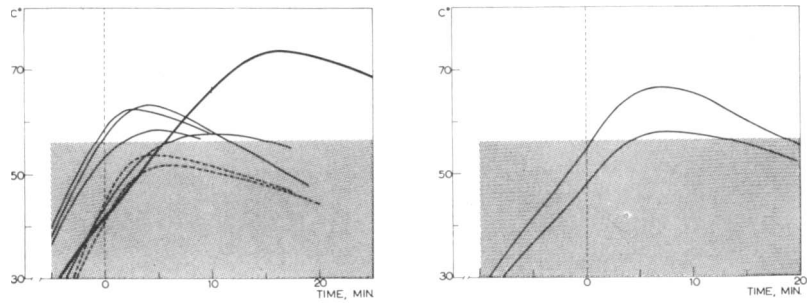
Left dotted line: the moment when the fish were turned over.

Right dotted line: moment when the fish were removed from the pan.

The curves in Fig. 5 b show that if the fish are put into cold water and kept there until the water boils, the temperature in all parts of the fish will rise above the critical level of 56°C.

Baking in oven

The temperature changes at the least heated sites of whole pikes baked in an oven are shown in Fig. 6. The rise of temperature in the fish was comparatively slow, due to the great size of the fish used in the experiments. Thus, in 2 out of 5 pikes the temperature had not risen even to 50°C at the time when the fish were removed from the oven. However, even in these two cases the temperature maxima (56 and 61°C) were high enough to destroy any possibly present plerocercoids. The curves in the figure show that all baked pikes reached the critical temperature of 56°C. The lowest temperatures in fish baked at 200°C varied between 56 and 70°C, and corresponding temperature of the pike baked at 250°C was 73°C. All the pikes were found well



a b

Figure 5 a. Temperature changes at the site of least temperature rise during boiling of whole pikes. The pikes were immersed in boiling water.

Dark area: temperature below 56°C, where according to *in vitro* tests the plerocercoids may survive a 5 min. treatment.

Thin curves: heating ended at moment of boiling, weights of fish 1470—2720 g.

Thick curve: heating ended 10 min. after moment of boiling. Moment when the fish was removed from the kettle shown by a short dotted line, weight of the fish 2270 g.

Dotted curves: fish were removed from the kettle when the water temperature had risen to 97—98°C, weights of fish 1400—1450 g.

Dotted vertical line: moment when the fish were removed from the kettle.

Figure 5 b. Temperature changes at the site of least temperature rise during boiling of whole pikes. The pikes were immersed in cold water and removed at the moment when the water began to boil again.

Dark area: temperature below 56°, where according to *in vitro* tests the plerocercoids may survive a 5 min. treatment. Weights of fish 1790 and 2120 g.

Dotted vertical line: moment when the fish were removed from the kettle.

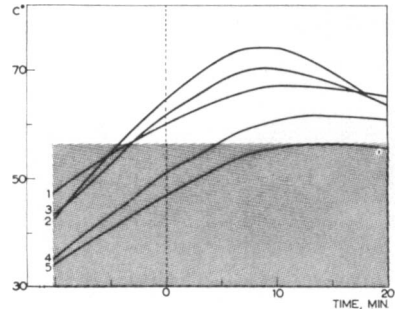


Figure 6. Temperature changes at sites of least temperature rise of whole pikes baked in an oven.

	Weight, g:	Baking time, min:	Temperature of oven C°
Pike 1	2020	36	200
„ 2	1720	30	250
„ 3	1620	30	200
„ 4	1870	30	200
„ 5	2000	30	200

Dark area: temperature below 56°C, where according to *in vitro* tests the plerocercoids may survive a 5 min. treatment.
Dotted line: moment when the fish were removed from the oven.

cooked at the organoleptic tests carried out after the baking. It may be noted that the curves have a rather flat shape, indicating that even in the case where the temperature just reached the critical level, this temperature could be continuously measured at the same site for a period of approx. 10—20 min.

Organoleptic testing

Organoleptic testing of the treated fish showed that fish in which the temperature had risen above 60—65°C were found to be cooked. Although the variation is wide, even the lowest temperature is well above the critical temperature of the plerocercoids, indicating that cooked fish is without hazards in this respect.

DISCUSSION

The second part of this investigation dealt with the temperature changes in various parts of fish during customary Finnish fish preparation. This was done to make possible an estimation of the effect of the preparation on the viability of

plerocercoids. Of the most common preparing methods, boiling and frying, the former can be considered a rather safe method. Therefore, the main interest was focused on the study of the effect of frying.

Frying was done with the method which is most commonly used in the homes in Finland. There are not many variations in the mode of scaling and eviscerating. In some cases, however, small perches are fried unscaled. The effect of the scales on the heating of the fish can not be great, and in any case, considering that whole perches in our experiments reached much higher temperatures than 56°C, it is insignificant. The pikes are always fried scaled.

In the frying method used the fish was turned only once during the procedure. This method differs from the customary one, whereby the fish is turned several times. Thus, the treatment in our experiments has to be considered less efficient for raising the inner temperature of the fish. Consequently, use of the customary method would give the consumer an additional safety margin. The heat treatment will be still stronger if the frying pan is covered with a lid during the frying, or if the fried fish is left in the warm pan until it is served.

The conclusion can be drawn that if a certain effect on the plerocercoids is obtained with our method, then the effect presumably will be still greater if the frying is done under regular conditions in the homes.

In our experiments we used corn oil or butter for frying. The effect of frying in corn oil is greater because it begins to give off smoke later than butter does under the same conditions. Experiments showed, however, that under identical conditions this does not exert an effect on the results as the temperature rise in the inner parts of the fish was not apparently dependent on the kind of fat used.

The properties of the heating device has a great effect on the results of the frying. Working with a comparatively hot temperature burns the surface of the fish, and, on the other hand, too little heating leaves the surface of the fish only slightly brownish and the inner parts raw. We chose to have the 1000 w electric plate to give an effect which was between these two extremes. Thus the surface became brown but it was not burnt.

The experimental frying times of 10, 15 and 20 min. cover

well the range commonly used in the homes. To use longer times is of no advantage, as then the taste and flavour will change.

The effect of boiling on plerocercoids of whole fish has been investigated by *Agranovsky* (1), who found that the fish is safe for consumption if it has been kept in the water until its temperature has risen to the boiling point. His results were confirmed by our experiments. If the fish is still kept in the boiling water for an additional 10—15 min., as indicated in the common recipe books, then its consumption does not involve any hazards of tape worm infestation.

The baking of whole pikes in an oven is not as common a method of preparing fish as boiling or frying in the pan. In our experiments this method was found to be effective as to the destruction of plerocercoids. The experimental temperature of 200°C is low compared with the common temperatures in households. To use 250°C gives a still broader safety margin. Our frying time of 30 min. is long enough to destroy the plerocercoids as well as to render the fish cooked.

CONCLUSIONS

The results show that the temperature in all parts of pikes fried in the pan rose above the critical temperature of D.latum plerocercoids (56°C) during 10 min. if the weight of the fish was less than 750 g, in 15 min. with weights less than 1000 g, and in 20 min. with weights less than 1200 g. Practically all whole perches reached this temperature during 10 min.

Boiling was found to be a safe method for fish preparation as in all the tested fish the critical temperature was reached already at the time the water began to boil independent of whether the fish was put into cold or hot water.

Baking in an oven using customary methods also rose the temperature of the pikes with weights less than 2000 g enough to destroy any possibly present plerocercoids.

In all tests, fish heated to the critical temperature of the plerocercoids were organoleptically found to be ready for the table.

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SUMMARY

In part A of the investigation the heat resistance of isolated Diphyllobothrium plerocercoids was determined. Treatments for 5 min. at 56°C, 10 min. at 50°C, 20 min. at 48°C, and 30 min. at 47°C were found to be lethal as indicated by cessation of spontaneous movements. The number of plerocercoids in the tests was 640.

In part B the consumption of pike, perch and burbot, which are known to be most important carriers of D. latum plerocercoids, and the customary methods of preparation of these fish species in Finland are first reviewed. Then the results of 85 frying and 7 boiling experiments are described, in which the temperature change at the sites of the least temperature rise was followed. During frying in the pan the inner temperature of the fish rose to the critical 56°C limit during 10 to 20 min., depending on the size of the fish. Normal boiling and frying in an oven were found to be rather safe in this respect.

In all tests fish heated to the critical temperature of the plerocercoids were organoleptically found to be ready for the table.

ZUSAMMENFASSUNG

Der Effekt von den in Finnland gebräuchlichsten Wärmebehandlungsmethoden auf die Ansteckungsfähigkeit von Diphyllobothrium latum von Fisch auf Mensch.

Im Abschnitt A der Untersuchung wurde die Hitzebeständigkeit von isolierten Diphyllobothrium Plerocercoiden untersucht. Die Behandlungen von 56°C in 5 Min.; 50°C in 10 Min.; 48°C in 20 Min. und 47°C in 30 Min. wurden als ausreichend befunden um das Aufhören von spontanen Bewegungen zustande zu bringen, welches als letaler Effekt angesehen wurde. Die Zahl der Plerocercoiden in den Experimenten war 640.

Im Abschnitt B werden die Konsumtion von Hecht, Barsch und Aalroupe, die als wichtige Träger von den D. latum Plerocercoiden bekannt sind, und die gebräuchlichen Zubereitungsweisen dieser Fischarten in Finnland beschrieben. Die Ergebnisse von 85 Brat- und 7 Kochexperimenten werden beschrieben, in denen die Temperaturschwankungen an den Stellen mit den kleinsten Temperaturerhöhungen registriert wurden. Während der Erhitzung in der Bratpfanne stieg die Temperatur in den inneren Teilen der Fische zu der kritischen Temperatur von 56°C innerhalb von 10 zu 20 Minuten, je nach der Grösse der Fische. Das übliche Kochen und das Backen im Backofen wurden in dieser Hinsicht als verhältnismässig sichere Methoden befunden.

In sämtlichen Versuchen, in denen die Fische zu der für die D. latum Plerocercoiden kritische Temperatur erhitzt wurden, waren die Fische, organoleptisch bewertet, essbar.

SAMMANFATTNING

Effekten av de i Finland vanligast använda värmebehandlingsmetoderna på infektiviteten av Diphyllobothrium latum från fisk till människa.

I den första delen av undersökningen bestämdes värmetoleransen av isolerade Diphyllobothrium plerocercoider. Följande värmebehandlingar förorsakade upphörande av spontana rörelser, vilket ansågs vara tecken på letal effekt: 5 min. vid 56°C; 10 min. vid 50°C; 20 min. vid 48°C och 30 min. vid 47°C. Antalet plerocercoider i försöken var 640.

I den andra delen av undersökningen behandlas först enligt tillgängliga uppgifter konsumtionen av gädda, abborre och lake, vilka arter äro kända som de viktigaste bärarna av D. latum plerocercoider, samt de vanligaste beredningsmetoderna av dessa fiskarter i Finland. Därefter beskrives resultaten av 85 steknings- och 7 kokprov, i vilka temperaturväxlingarna hade följts på de ställen av fiskarna, var temperaturhöjningen var minst. Vid stekning i stekpanna steg fiskens värme i de inre delarna till det kritiska värdet av 56°C under 10 till 20 min., beroende på fiskens storlek. Vanlig kokning samt stekning i ugn befanns vara rätt säkra metoder i detta hänseende.

I samtliga försök befanns de fiskar, vilka blivit upphettade till den kritiska temperaturen, vara organoleptiskt sett ätbara.

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