SZENT ISTVÁN UNIVERSITY

The oppurtinity of integrating food deprivation, as a technological element into intensive pikeperch rearing system, and the effect of the reproduction processes of male fish

PHD THESIS

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1. THE HISTORY OF WORK, OBJECTIVES

1.1. Antecedents of work

According to the hungarian pond-fishing statistics of year 2017, from the production (14 893 tons) of market size fish, pikeperch share only 0,25%, with 37,6 tons, despite it could be exported in unlimited quantities. For increasing the production wolume of predator fish species, using production systems (water flow through, RAS) - unlike traditional pond production - where fish reared intensively (based on commercial feed), under controlled conditions, could be a solution. In Hungary, based on the available data, currently there are total of five farms deal with intensive pikeperch rearing, and by my knowledge, market size fish production and sale is only in Kisbajcs, at the farm of Fisheries Cooperative of Győr.

In my experience, one of the biggest problem of intensive pikeperch production is, that a specific feed fully fits for the physiological needs of the species is not available, therefore their rearing are based on fish feed, in current commercial production. After several years of my observations, the most common problem is, that the obesity of fish by the high energy content of feed, causing physiological and reproduction biological problems, besides may cause organ disorders (fatty liver), which has direct effect on mortality during rearing.

One of the easiest solution (beyond developing species specific feed) is “starvation” and testing of the proper usability of it in production from the physiological, practical and economical point of view. Only few research data are available of the practical

usefulness of starvation and compensational growth, and their effect on efficiency for the endproduct (market size fish) in regarding pikeperch.

1.2. Objectives

- My aim was to measure the rate of harvesting yield and the sex effect on yield production in intensively reared pikeperch, considering the production system, the used feed and the local conditions on the farm of Fisheries Cooperative of Győr, in Kisbajcs.
- Furthermore, my aim was to reduce the fattening level of intensively reared pikeperch, and initiating research of developing favorable nutritional technologies – targeted primarily the periodic deprivation of feed - in rearing.
- My goal also was to survey the rate of relative growing in cutting yield, compared to the live weight, therefore it is well known, that under different starving periods, the weights of visceral organs, that give slaughter losses (primarily abdominal fat and liver) reduce, although in parallel sizes of the carcass and fillet increasing, thus considering the body composition and lipidperoxidation, caused by the changed fatty acid profile, a favorable quality of foodstuff could be produced.
- My further aim was to examine the potencial usability of production and economical adventages in compensation growth, under intensive rearing conditions.
- I also wished to investigate the ability of preparing male individuals from production for reproduction (including with food deprivation), their response for different hormone

treatments, furthermore their sperm quality, the shelf live of sperm without deep-freeze, and the effect of the way of storing.

2. MATERIALS AND METHODS

2.1. Slaughter yield in intensively reared pikeperch

For my further investigations, at first I was testing the slaughter yield of market size pipke-perch (500-1000 g each) from the farm of Fisheries Cooperative of Győr, in Kisbajcs, where all my research took place. These results were used for analyzing the results of my further tests.

Under the examination, I documented the living weights, the slaughter weights after cleaning, gutting and washing, and also gender. Following electrical shocking and cleaning, the removal of the viscera and the genitals, than the bladder and the peritoneum were taken out. Feed content of the alimentary tract, the blood and the visceral liquids were also the part of slaughter losses.

2.2. The effects of feeding and starving in market size fish

2.2.1. Setup the experiment, way of processing fish

The randomly chosen fish were located into 4 m^3 (4000×1000×1000 mm, 4-5 liter/minute water exchange) tank, took apart in 4 sections (1000 liter/section), where 3 groups were created:

- Group A: starting control, sampled az starting pont of the experiment (n=8)
- Group B: continuously fed group (n=2×4, 2 repetition)
- Group C: fish, deprived from feed (n=2×4, 2 repetition)

During the experiment, the daily feed portion of group B was the 0,5% of the bodyweight (Biomar Efico Sigma 6,5 mm, Biomar

Group, Aarhus, Denmark). By the producer, this feed is recommended especially for percids, so pikeperch as well.

Before every sampling, a 24 hours long starvation were carried out, in reason to avoid effecting visceral weights by the different levels of the fullness status of the alimentary tract. Based on literary data I assumed that after 24 hours of fasting at 20 °C, the significant part of the intestinal contents are eliminating. Before measuring, I removed all the remaining intestinal contents.

In addition to the total body weight, I measured the weights of 10 different body parameters. Namely the gonad, the complete alimentary canal (without the intestinal contents), the liver, the abdominal fat, the vertebral with the unmatched fins (the dorsal fin and anal fin), the head with the double fins (pectoral fins and pelvic fins), the two side fillets and the skins cut from the fillets on both sides. I took *Post mortem* meat samples from all pikeperch individuals.

2.2.2. Chemical meet composition epxeriment

Samples were taken at the starting point and then at 3rd and 6th weeks of the experiment.

The chemical analysis was performed by weende analysis, using 8-8 fish in every group in every repeat. In addition to dry matter, crude protein, crude fat and crude ash were determined. Prior to the analysis, the individually taken fillet samples were homogenized and I measured the samples were taken from it, than the average values of the treatment groups were compared.

Statistical evaluation of the data was done in pairs, by a Tukey-Kramer post-hoc T-test with GraphPad InStat, Windows version 3.05 (GraphPad Software, San Diego, California, USA).

2.2.3. Lipidperoxidation process experiment

The test was done after measuring the body composition parameters from the same fish samples.

To investigate the lipid peroxidation, its biomarkers, conjugated dienes (CD) and conjugated trienes (CT), and malondialdehyde (MDA) concentration were determined from liver, and MDA concentration also form meat.

The concentration of reduced glutathione (GSH) was measured by 5,5'-dithio-bis-2-nitrobenzoic acid (Ellman reagent, Sigma, St. Louis, Missouri, USA) with photometric method. The activity of glutathione peroxidase (GPx) was determined by end-point direct assay, in the presence of reduced glutathione (Reanal, Budapest, Hungary) and cumene hydroperoxide (Sigma, St. Louis, Missouri, USA) co-substrates.

Statistical evaluation of the data was done in pairs by a Tukey-Kramer post-hoc T-test with GraphPad InStat, Windows 3.05 (GraphPad Software, San Diego, California, USA).

2.3. Compensational growth investigations

2.3.1. Compensational growth with juvenile pikeperch

In my experiment, I used 6-month randomly selected pikeperch (average baseline body weight 78.7±0.7 g) in 200 liter, 150 cm high round pools (n=6×100, installation density=39.35 kg/m^3).

The measurement of th fish groups was by 10 individuals in one time, so each group (n=100) was weighed in ten parts, without narcotism.

Fed groups of fish consumed 1.5%/kg body weight of Biomar Efico Sigma 3 mm (Biomar Group, Aarhus, Denmark) feed for the entire duration of the experiment. Feeding and fasting periods were 7 days, and the total duration of the experiment was 6 weeks. In the case of juvenile fish, I estimate the amount of feed waste up to 5-10%.

Specific growth rates (SGR) and feed conversation ratio (FCR) were calculated for the growth of pikeperch.

2.3.2. Compensational growth with market size pikeperch

The experiment took place in 4 m^3 pools with 2 sections of each pool. The pool sections were separated by grids of 5 mm mesh size, avoiding the feed drifting from one part of the pool to the other.

The placement of 18 months old fish, following random selection was done in groups with 10 individuals. Three control (with continuous feeding) and three compensation groups were made, with individually weighed fish (average body weight 672.30±22.20 g). The fed and compensating groups were placed in separate pools. The feed intake of fish - Biomar Efico Sigma 6.5 mm (Biomar Group, Aarhus, Denmark) - was set at 1%/kg body weight. Fed fish consumed their feed completely, and I did not experience feed wastage. Specific growth rates (SGR) and feed conversation ratio (FCR) were calculated for the growth of pikeperch.

At the end of the test, I also examined the slaughter yield of 8-8 individuals to measure the effect of 6 week compensation treatment on the slaughter value.

2.4. Reproductional survey of market size male fish on the farm

2.4.1. Keep and preparation of broodstock

The fish were moved from production stock into a recirculation system with a red low light (30-40 lux) and 18 °C, were kept in a 3 m^3 pool divided into 3 sections (1m^3/section). Fish were kept without feeding until the end of the experiment (3 months). During the preparation before spawning, the water temperature was cooled below 10 °C over 30 days and the photoperiod was gradually reduced from 12 hours to 8 hours. The artificial winter was maintained at a temperature of about 8 °C (about 40 days), and the water temperature was gradually increased to 12 °C, 25 days before treatment, and the photoperiod was gradually increased to 10 hours.

2.4.2. Hormone treatments

10 males of the experimental fish were selected and divided into two groups in the separated sctions of a tank. After narcotism, the groups were marked by different truncation of the two pelvic fins to separate the treatment groups from each other. After weighing, salmon gonadotropic releasing hormone (sGnRH-Syndel 1 mg, Syndel, Nanaimo, British Columbia, Canada) and human chorionic gonadotropin (hCG - CHORAGON 5000 IU, Choragon injection, Ferring Hungary Kft., Budapest, Hungary) solutions (using 0.9% NaCl solution) was injected next to the pelvic fin, into the abdominal cavity of males (50 μg sGnRH/kg and 100 IU hCG/kg).

2.4.3. Sperm collecting and testing

Following five days of the hormone treatment, after stunning, an elastic rubber catheter with a length of 5 cm and a diameter of 1 mm was sticked into the urogenital opening avoid contamination with the urine, and the sperm doses dropped through the catheter were collected into individually labeled eppendorf tubes. In all cases, samples were divided into two parts (200-200 µl sperm), one was open, the other was closed all time. Thus, during storage (4 °C) two sets of data were recorded from each sperm samples.

The motility of fresh and stored sperm samples was recorded by Computer-Assisted Sperm Analysis (CASA) method, where Sperm VisionTM v. 3.7.4. (Minitube of America, Venture Court, Verona, USA) system was used. Activation of sperm carried out in Makler chamber (Sefi-Medical Instruments Ltd., Israel), performed by mixing 0.01 g/ml with cattle serum albumin (BSA, bovine serum albumin).

Measurements were made within six hours, while samples were stored on ice at 4 ° C.

3. RESULTS

3.1. Slaughter yield in intensively reared pikeperch

In 155 investigated and processed pikeperch, sex had no effect on slaughter yield. The results of the farm survey served as a basis for further observations and experiments (subsections 3.2 and 3.5).

3.2. Feeding and starving in market size fish

3.2.1. Body weight measurements

The body weight changes of the fed and fasted groups were as expected, and the weight of the fasted group was steadily decreasing while the fed group was continously increasing. At the first measurement (day 21), the weight of the fasted group was statistically lower than the baseline ($p < 0.05$), while the weight gain of the fed group was not statistically justified. However, there was a significant difference between the two groups at the first measurement.

In terms of slaughter value, starved fish showed proportionally smaller slaughter losses, but no statistically verifiable difference was found compared to the control and basic stock.

Among the slaughter parameters, the fed group showed significant change of the liver somatic index (+25.6%) and the abdominal fat (+30.2%) furthermore the relative values of fillet with skin (+1.6%) and the skinned fillet (+2.7%) showed statistically demonstrable growth ($p < 0.05$). In the fasted group, the proportion of skin (+ 7.5%) and head with the doubble fins (+ 8.2%) increased statistically.

The chemical analysis of the fillet samples showed that while the meat content of the fed animals remained unchanged, in the samples of fasted individuals, a significant but statistically unjustifiable ($p = 0.079$) decrease was observed in the fat content. This reduction was caused by a decrease in intramuscular fat content, which may also be responsible for the relative weight loss of the fillets. There was no statistically verifiable difference between $p < 0.05$ in the data of the examined groups.

3.2.2. Lipidperoxidation process tests

In addition to weight loss and the mobilization of energy storage, I also observe that in parallel with fasting, increasing intensity has been observed of lipid peroxidation, indicated by a significantly increasing level of malondialdehyde (MDA) in liver and meat. This change is probably due to the weakening of the glutathione redox system.

In the study of biomarkers indicating the initiation phase of the lipid peroxidation process, a significant change was observed in the liver of the 42 day fasted fish group, because the amount of conjugated dienes (CD) was significantly higher ($p < 0.05$) compared to the control group.

The concentration of the malathialdehyde, the metastable end product of the termination stage of the lipid peroxidation process, also showed a radical increase due to starvation. After three weeks, in the liver of the starved group, the MDA concentrations were statistically higher ($p < 0.001$) compared to the control group, retaining this significant difference ($p < 0.001$) after sixth week in the samples of fish from the fasted group.

The MDA value of the fillet samples did not show a statistically verifiable change for the third week after starvation, however, there was a significant difference ($p < 0.05$) compared to the fed group by the sixth week.

Due to starvation, a statistically detectable decrease ($p < 0.001$) was measured of reduced glutathione (GSH) concentration in fish liver after 21 days of fasting, as well as after 42 days. A similar change was found in the fish liver of the glutathione peroxidase (GPx) activity, as significantly lower GPx activity was measured in the third ($p < 0.001$) and sixth ($p < 0.05$) weeks of the experiment. Thus, long term starvation reduces the amount and/or activity of the glutathione redox system and consequently increases the level of lipid peroxidation in the body of the pikeperch.

3.3. Results of compensational growth investigations

3.3.1. Results of compensational growth with juvenile pikeperch

In the experiment, to observe the compenastional growth of intensively reared pikeperch, the continuously fed group showed a steady growth curve, whereas the growth of the compensated group's fish due to food deprivation fell every two weeks. However, at the end of the feeding weeks of the compensation group, a significantly higher daily growth rate and specific growth rate was calculated on the same amount of feed, compared to the body weight, than the continuously fed control group. In the second week, the average weight of compensation growth group, significantly exceeded the weight of the continuously fed group ($p < 0.05$), but in the subsequent feeding weeks, it only approached the values of the continuously fed group.

3.3.2. Results of compensational growth with market size pikeperch

In my experiments on compensatory growth of the market size pikeperch, in reason of integration it into the production technology, the individuals in the continuously fed group showed a steady growth curve, whereas the growth of the compensated group's fish due to periodic food deprivation fell every second weeks. In contrast to the juvenile groups, at the end of the fed weeks of compensation group, the acceleration of the daily growth rate did not reach the control group.

From the experimental results, I found no statistically verifiable difference in slaughter yields (84.6-87.7%) based on the comparison of the feeding methods.

3.4. Induced propagation with male fish, selected from production

There were no statistical differences in the quality parameters of sperm production (progressive motility, sperm quantity, osmolality, sperm density) between the effect of two hormone preparations been used (sGnRH, hCG). In addition, there was no statistically valid difference between the open or closed eppendorf tube sperm storage methods within the observation days, because in both cases the progressive motility of the sperm showed decrease of 80-90% after 24 hours of storage, and after 48 hours the motility was almost completely gone.

3.5. New scientific results

1. Under intensive conditions, size of pikeperch from 550 to 1100 g, reared on commercially available feed, that was recommended for pikeperch, at a water temperature of 20±1 °C, sex has no effect on slaughter weight and slaughter yield.
2. I have shown in continuously fed and 42 days fasted pikeperch with a starting weight of 770-800 g, that the relative weight of the liver and skinned fillet in the continuously fed pikeperch at both sampling times (day 21, day 42), the abdominal fat content, the fillet with skins on the sampling day 42 was statistically higher. In contrast, in the food-deprived group, the head with the double fins and the skin at both sampling times was larger compared to the continuously fed group, while the vertebral with the unmatched fins showed statistically higher values only on the measurement day 21.
3. As a result of starvation of pikeperch, there was no statistically significant difference between the fed and fasted groups in the dry matter, crude protein, crude fat and crude ash content of the fillet.
4. I was the first to examine lipid peroxidation parameters from fillet and liver samples in the case of pikeperch. I found that the intensity of the lipidperoxidation processes increases moderately in the early stages of starvation and then more strongly, which correlated with the reduction of the glutathione redox system.
5. I examined the compensatory growth characteristics firstly between farm conditions with market sized pikeperch. In case of juveniles, during the 6 week compensatory growth

test, full compensation was only at week 2, while in the following weeks it was only partial. In the case of market size pikeperch, only partial compensation was during the 6 week study.

6. I prepared market size male pikeperch from production stock for sperm production in out of season spawning time after a preparing period (3 months feed withdrawal, artificially set thermo-circadian rhythm) and hormonal induction (hCG and sGnRH hormone treatment). There were no statistically verifiable differences between the two hormone treatments in either sperm volume or progressive motility of sperm.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Slaughter yield

In the 155 examined and processed pikeperch, reared in farm conditions showed no sexual effect on the slaughter yield presumably because the examined fish were small and young, therefore their genitals were also underdeveloped. In conclusion, an economic advantage can be gained if the fish is processed for sale before the significant increase in their sexual organs.

The fattening of the pikeperch was significant, therefore reducing it is required, because the lipid reserves of the fish during the processing are removed, which is a technological loss.

Comparing the results of the farm survey with the literature data, compared to them, pikeperch reared at the farm in Kisbajcs, raised on a Biomar compound feed, developed for the perch, resulting lower slaughter yields. From the tests investigating slaughter yield, the weight of the skinned fillets differs significantly from my own measurement result (40.3%). However, the yield of the carcass is the same, or even precedes the values previously published by others. Compared to literary data, the weight of the skin and the head are close to those intensive reared pikeperch. One of the possible explanations for the differences may be the different nutritional value of the different feeds (crude protein%, crude fat%), the different rearing technology, the feeding methods, the genetic background, and the fact that currently there is no uniform methodology for cutting and processing the pikeperch, that may cause differences and distortions in data.

In my opinion, it would be recommended to create and a commercial feed, that is suited better for the needs of pikeperch, but without it, periodic starvation/purging periods should be insert into the rearing technology.

4.2. Effects of starvation on body parameters and the lipidperoxidation process

In the case of pikeperch, the different duration of feed deprivation had a significant effect on the body weight and on some parameters of fish meat. These phenomena could be explained by that as an effect of starvation, in the animal body, in order to maintain homeostasis, the body mobilizes the glycogen content and lipid reserves of the tissues as energy source.

There is a significant difference between the various fish species, even within percid species, in the weight change caused by starvation. In my study, after 21 and 42 days of fasting, the pikeperch showed a weight loss of 7% and 14% of their baseline body weight. Based on my results, the fish showed less weight loss compared to fasted European perch (*Perca fluviatilis*) at the same temperature (20 °C) and at lower temperature but at the same fasting period to Walleye (*Sander vitreus*).

I experienced significant weight loss in the digestinal tract, the liver and the abdominal fat at the end of the fasting period. My results showed similarities with fasted Tench (*Tinca tinca*), where significant histopathological changes were measured in the intestinal epithelium and liver, with European bass (*Dicentrarchus labrax*) where losses were measured in liver and adipose tissue and with starved *Silurus meridionalis* where their hepato-somatic index value decreased, caused by the reduction of liver and digestional tract

weights. Similar results have also been reported in Ide (*Leuciscus idus*), Atlantic salmon (*Salmo salar*), Wolf fish (*Hoplias malabaricus*), *Pterygoplichthys disjunctivus*, and *Prochilodus lineatus* species.

In progresses of the starvation period, body weight is continously decreased, which can be explained by the mobilization of lipid content, although decreasing fillet weights decreasing tendencies of fat content, it can be concluded that nder starvation the abdominal lipid reserves are mobilized besides intramuscular. The mobilization of certain lipid reserves during starvation, such as abdominal or the intramuscular fat content differs fobetween fish species, but for example, but the mobilization of abdominal fat for Rainbow trout (*Oncorhynchus mykiss*) is considered to be the primary, and it appears to be similar in pikeperch.

Besides the reduction in the weight of the fillet of the starved fish suggests, that the body partially mobilized the intracellular energy reserves (lipids) in the fish meat, to maintain the body's homeostasis during lack of food. Although the crude fat content of the starved fish fillet has decreased not significantly but tendentiously, suggests that during long-term starvation, when the blood glucose and liver glycogen reserves are depleted the body use the lipid reserves as energy source.

I did not experience any aggressive (cannibalism) or stress-related condition during my study. Fasted individuals stayed motionless at the bottom of the tank. My experiences showed similarities with those literary data, that starving body is trying to limit its energy demand by changing its behavior (slower change in position and movement intensity).

Significant changes were detected in some parameters of the glutathione redox system, in pikeperch under starvation, that in case of reduced glutathione can be explained due to the lack of continuous amino acid supply (methionine and/or cysteine), that is needed to synthesize the antioxidant sulfhydryl group of this tripeptide. Besides the other functions of reduced glutathione (for example ensuring the free sulfhydryl content of the cells) it is the cosubstrate of glutathione peroxidases (GPx), so the decrease in its concentration has a negative effect on the activity of the enzyme.

The results show similarity to those previous experiences, that GPx is an allosteric enzyme that uses reactive oxygen intermediates and GSH as substrate, but in the lack of them, its activity decreases.

The decrease in GPx activity is significant in the enzymatic part of the antioxidant protection system, caused by its effect on the decreases of the antioxidant protection effectivity, which is also related to amino acid and carbohydrate supply, and consequently leads to a significant increase of free radical generated lipid peroxidation in the liver of starving fish.

The amount of these process markers showed a significant increase in the liver, however significant change was observed in individuals fasted over 42 days. But the mount of malondialdehyde, the metastable end product of lipid peroxidation was significantly higher both after 21 days and 42 days of starvation, suggesting that a even low level of reduction in glutathione redox system induces strong lipid peroxidation.

These changes in time can be explained by the differences in fatty acid mobilization during starvation, because saturated (SFA) and monounsaturated fatty acids (MUFA) mobilized first. However,

polyunsaturated fatty acids (PUFA) mobilized later, those are more sensitive for peroxidation damage.

My observations showed relations with the increasing MDA values and with the decreasing GSH concentrations, measured in the liver of fasted Gilt-head breams (*Sparus aurata*). In the liver of Brown trout (*Salmo trutta*) was also measured increase in MDA levels after a long-term fasting, as well as in the liver of a Large yellow croaker (*Pseudosciaena crocea*) after 12 days of starvation.

In the samples from pikeperch fillets, the MDA concentration also increased significantly at 42 days of starvation, but it was not found any change after 21 days of fasting. In this case, these results suggest, that in the early stages of starvation, saturated and monounsaturated fatty acids were mobilized first from fish tissues, but at the sixth week of starvation, polyunsaturated fatty acids were also mobilized, resulting increased lipid peroxidation, especially because at this point, the antioxidant protection also significantly weakened.

4.3. Compensational growth in juvenile and market size pikeperch

In my experiments, I found the importance of aquacultural use of compensatory growth in case of pikeperch, confirming the previous results with hybrid Sunfish (*Lepomis cyanellus* ♀ × *L. rnacrochirus*), that compensatory growth is an effective and fast method for increasing fish body weight in appropriate nutritional systems.

Taking advantage of compensation can evolve economic benefits, in reason that the most significant cost under the whole rearing period of fish farming, beside human manpower, is the feed,

and if the producer can reduce it, production can be made more economical, because the feed used in aquaculture for rearing is 50% of the variable costs.

In addition, on those days when fish are deprived from feed, the demand for manpower reduces, dealing with these groups of fish takes a smaller part of the working time. On the other hand, the water of these pools will be cleaner during this time, the water quality will improve and the load of organic matter will be reduced. In case of water flowing through pools, this also means less daily work per fish group, by their cleaning could be skipped on these days.

For the whole study, there was a significant difference in the feed consumption of groups, because in case of fish groups using compensatory growth, it showed to be 61% more effective, compared to the continuously fed fish. In the case of market size pikeperch, the feed consumption of the compensated group was 17.2% more efficient.

4.4. Classification of sperm in males fish from intensive rearing

There were no differences in the quality parameters of sperm production (progressive motility, sperm quantity, osmolality, cell concentration) between the two hormone preparations used (sGnRH, hCG). Furthermore, the studies did not show any difference between the storage methods of sperm in open or closed eppendorf tubes. In the other hand, even after 24 hours, the progressive motility rate decreased to such, that it is not recommended to use cooled stored samples for fertilization, therefore only fresh or deep-frozen sperm worth using for propagation.

In pikeperch, treated with hormone at different times (26th March, 21st April, 13rd June) was found, that the length of the cold period had no significant effect on sperm quality parameters, but had an effect on the quantity of sperm production. We can conclude from it, that in our case we could have achieved a larger amount of sperm production with a longer period of cold, but this can not be clearly stated on the basis of the experiment.

As a result of the sperm classification, it can be said that the males that were brought into production were mature and can be used for propagation despite the fact, that the condition of fish was not really favorable for propagation due to the consumption of high energy feed. However, during the preparation, as a result of starvation, and the heat and light program, males became fully capable for propagation.

On the basis of the results it can be stated, that the examined fish can be involve for propagation and are suitable for fertilization, therefore, in case of problems in the preparation of the broodstock on field conditions, than male fish can be replaced with selected individuals from production.

4.5. Recommendations

I would like to make the following suggestions from the results of my studies and from my practical experience for their effective future use:

1. I recommend setting up further tests to improve the feeding technology of pikeperch.
2. I suggest examining the frequency and the intensity of feeding, and the possibilities of periodic and partial feed deprivation.

3. I suggest to further investigate of the practical usability of compensatory growth and to determine the thermal optimum of compensation for pikeperch and other economically important fish species.
4. I suggest further study of the effect of starvation, extending on the fatty acid profile of fish meat, as well as its texture, structure, consistency and flavor
5. I recommend further studies on the usebility of broodstock fish from intensively reared population for reproduction.

5. PUBLICATIONS RELATED TO THE TOPIC OF THE DISSERTATION

5.1. Publications in scientific journals

Varju, M. & Mézes, M. (2016). Éhezés hatására bekövetkező élettani folyamatok halakban. Állattenyésztés és Takarmányozás, 65(3), 23-39.

Varju-Katona, M., Müller, T., Bokor, Z., Żarski, D., Mézes, M. & Balogh, K. (2018). Excessive starvation effects on antioxidant defence and lipid peroxidation in intensively reared, commercial-size pikeperch (*Sander lucioperca* L.). Egyptian Journal of Aquatic Research, 44, 349-352.

Varju-Katona M., Müller T., Bokor Z., Balogh K. & Mézes M. (2018). Effects of various lengths of starvation on body parameters and meat composition in intensively reared pikeperch (*Sander lucioperca* L.). Iranian Journal of Fisheries Sciences, DOI: 10.22092/ijfs.2019.118095

5.2. Conference proceedings

Bernáth, G., Mosonyi, G,. Szilágyi, G., Várkonyi, L., Varjú, M., Urbányi, B. & Bokor, Z. (2016). Post-thaw motility and longevity of movement in pre-season collected pikeperch (*Sander lucioperca*) sperm. European Aquaculture Society - Aquaculture Europe 2016, Abstract book, 100-101. pp.

Bokor, Z., Szári, Zs., Ferincz, Á., Szilágyi, G., Várkonyi, L., Varjú, M., Urbányi, B. Bernáth, G. (2017). Post-thaw motility and post-thaw storage in off-season collected Pikeperch (*Sander lucioperca*) sperm. European Aquaculture Society - Aquaculture Europe 2017, Abstrackt book, 133-134. pp.

Varju-Katona M., Szilágyi G., Bokor Z. & Müller T. (2018). Intenzíven nevelt piaci méretű süllők vágási kihozatalának telepi felmérése a Győri "Előre" HTSz Kisbajcsi halnevelő telepén. XXXVII. Óvári Tudományos Napok, Konferencia kiadvány 2. kötet, 341-345.

5.3. Poster

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