Theses of doctoral (Ph.D.) Dissertation

DEVELOPMENT AND GROWTH PERFORMANCE OF ALL-FEMALE COMMON CARP (*CYPRINUS CARPIO* L.) STOCKS IN INTENSIVE PRODUCTION

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1. INTRODUCTION AND BACKGROUND OF THE THESIS

Both the global and the Hungarian carp production is considered to have been improved a lot in the recent years from a technological point of view. Yet, the operation of this sector is still fundamentally based on almost hundred-year-old methods. Considering the intensification of its production, carp keeping is still lagging behind the keeping of other fish species (such as salmon or trout), as to date, carp has still been grown almost exclusively in extensive fish ponds, in Europe just as well as in Asia, while today the above mentioned fish species can often be found in super intensive systems.

The conditions of Hungarian pond fish farms (climate, production area, natural environment) and the current fish keeping elements, carp is basically produced in a three-year mode of operation. Of course, this is not to be set in stone, and there are exceptions (two-year mode of operation, two-and-a-half-year mode of operation and three-and-a-half-year mode of operation) but having it studied it is found that most of the production comes from three-year carps. Three years take a long time and may involve several risk factors (such as fish diseases, wintering, harvests, damages caused by birds, theft). Consequently, it is worth to address the possibilities for shortening the production period, for which - as far as we know as of today - there are several opportunities available.

With regards to carp, it is scientifically proven that in certain periods, the growth rate and feed conversion rate of females exceed those of males, and that the monosex female stocks are more uniform (CHERFAS et al., 1996, KOCOUR et al., 2003; 2005). In the 1960-ies, Soviet researchers developed the foundations of this technology, and then this was adopted and further refined, among others, by Hungarian researchers, as well (NAGY et al., 1979; 1981). Then also Israeli and Czech researchers made studies involving the mature technology that covers multiple generations of brood fish - the so-called indirect monosex female carp breeding technology (CHERFAS et al., 1996, KOCOUR et al., 2003; 2005).

The relatively small amount of literature on the topic encouraged me to first establish monosex female carp populations in the already known "indirect" way for my research, and then to study the growth and meat yield indicators of these populations in the framework of intensive, recirculated fish rearing and other pond culture.

Another important objective was to find a much easier to implement way of establishing monosex female carp populations by changing the water temperature (which is suitable for changing the sex ratio in several other fish species).

The third point was that we wanted to test a combination of intensifying carp production, where the off-season propagation, the fry rearing in recirculation aquaculture system (RAS) and post-rearing in ponds (where carps were raised using the classic fish keeping while simultaneously feeding them with fish feed) are combined. As no such combination had ever been applied, we were eager to see the size of one-summer fish could be raised this way, and to find out whether this construction could be operated economically.

1. 1. AIM OF THE THESIS

The four experiments in my thesis and their overall and specific objectives were as follows:

1. In the first study, we raised 0-40-day old mixed sex carp populations at different water temperatures (22°C; 25°C and 29°C).

Overall objective: Our primary objective is that deviating from the indirect method described in the literature, using a much simpler method we establish monosex female carp populations. This direct method has been applied successfully to other fish species; therefore, it may lead to similar results with the carp.

Hipothesis: In this case, it is an open issue whether the different water temperatures would or would not cause any shifts in the sex ratio within a specific treatment, and whether a mostly female population could be established by having the carps treated in the time period preceding the development of their gonads.

2. In the second examination, we grew the 40 to 85-day old mixed sex carp populations at different water temperatures (24°C; 28°C; 32°C).

Overall objective: In the experiment, our objective is to develop monosex female carp populations, but unlike in the previous research, the heat treatment was started not right after hatching but from the 40th day on, this way, we studied the impact of temperature on the development of the sex during the phase of active sexual differentiation.

Hipothesis: Another open issue to address is whether the different water temperatures would or would not cause any shifts in the sex ratio within a specific treatment, and whether a mostly female population could be generated in a way treating the populations in the active, sensitive phase of their sex development.

3.-4. In the third experiment, unlike in the previous ones, we focused on studying the performance of already existing monosex populations, instead of focusing on the development of monosex female populations. In our experiment, we studied the production parameters of indirectly generated monosex female vs mixed-sex populations, throughout one year, in a recirculated system. Secondly, in the fourth experiment, we focused the growth parameters between male and female carps in traditional pond culture.

Overall objective: Based on data reported in the literature, monosex female populations in ponds have better growth factors compared to those of the mixed-sex ones. This experiment focused on two objectives. On one hand, since carps are not commonly produced in recirculation systems, the results of the experiment provide information on the possibility for economic production; while on the other hand, we wanted to see whether the higher growth factor of monosex female carp populations would be realized also when raised in an intensive system. Secondly, we examine the advantages and disadvantages of the female common carp stocks in pond culture.

Hipothesis: We assumed that throughout the one-year performance monitoring, the monosex female carp populations would have shown better production parameters (average body weight, body length, FCR, DGR, SGR, survival rate) compared to mixed-sex populations. The results that we would get in the intensive recirculation system would be similar to those achieved in fish pond experiments reported in the literature. We assumption, the female carps body weight will be bigger than male carps.

5. In the fourth experiment, we studied the production parameters of carp in a rearing system that had not yet been applied before. The core points of the method include the propagation of carp off-season (in February), performing pre-rearing in an intensive system and post-rearing the resulting fry in fish ponds applying various feeding strategies.

Overall objective: The aim of the experiment was to study the intensive fry rearing and fish-pond post-rearing of populations deriving from off-season, winter carp propagation, up to the one-summer age of the fish.

Hipothesis: We assumed that the fish pond post-rearing of intensively pre-reared populations deriving from off-season carp propagation would offer benefits by enabling the reduction of the three-year production period to two years. A shorter production period may have several advantages. The younger population has a greater growth factor, better feed conversion rate, resulting in less expensive production. Another advantage is the lower level of production risks, and that due to the two-year form of operation pond areas are released for producing table fish thus increasing the sales revenues.

2. MATERIALS AND METHODS

2.1. Treatments before sex-differentiation

In the experiment, the carp was treated until the 40th day after hatching. During the experiment 3 different treatment temperatures were applied (T22, T25 and T29), and application of each configuration was repeated 3 times. Part of the experimental population was reared at 22°C, another part was reared at 25°C and a third part at 29°C. 14 hours of artificial lighting was applied on a daily basis (from 06:00 to 20:00). For the test, we populated each aquarium with 30 carp larvae, with a total number of 270 larvae involved.

Up to the age of 12 days, the fish were fed with brine shrimp (*Artemia sp.*) ad libitum. Then they were transitioned to commercially available fish feed of 200 μm and then 400 μm sized particles (62% crude protein and 13% crude fat), which they have had - also ad libitum - until they reached the 25-day age. After that, all through to the end of the experiment they received feed with 0.5 mm particle size (58% crude protein and 15% crude fat). Due to the small volumes of feed, we hand-fed the fish 3 times a day at 9:00, 12:00 and at 16:00. During the experiment, once a day the feed that had not been consumed and the excreta of the fish were removed using a plastic-silicon tube, and once a week we replaced 50% of the water.

At the end of the 40-day experiment, we measured the individual body weight, the standard body length and the full body length of each of the 30 fish, and determined their condition factors. Selecting 60 of each of the three experimental populations, we continued to grow them in a recirculation system with 1000 litre/unit effective capacity, until they reached the 12 months of age. During post-rearing we fed them a feed with 36% crude protein and 8% crude fat content, which we produced ourselves.

When determining their sex, using clove oil we over-sedated them, and then explored their gonads. The average body weights (g) and the average standard body lengths (cm) were determined based on the data of 60 fishes for each treatment. The weights of the fish and the gonads were measured using a VWR SE 422 -0.01g digital scale at an accuracy of two decimal spaces. To facilitate the identification of gonads we used a VWR VisiScope BL224T1 digital microscope.

2.2. Treatments meanwhile sex differentiation

The Hajdúszoboszló mirror native carp breed used for the experiment was produced at the Hatchery of Bocskai Halászati Zrt., in the course of the seasonal carp propagation. After propagation, the 3 day fries with gas-filled swim bladder were delivered to the Fish Biology Laboratory at the Faculty of Agricultural and Food Sciences and Environmental Management of the University of Debrecen (DE MÉK). Then the populations were placed in one 150-litre capacity aquarium without separating them, and reared them at a water temperature of 22±1.5°C. Their first food was live food, namely brine shrimp (*Artemia sp.*), then they were gradually transitioned to commercially available feed of 0.5 mm particle size (58% crude protein, 15% crude fat). Then the forty-day old stock was separated into nine parts, and applying identical population density, three groups with different temperatures (24°C, 28°C and 32°C) were created.

The water temperature treatments were set up in the aquarium system of DE MÉK Fish Biology Laboratory. In the experiment, the carp were treated between the 40^{th} and the 85^{th} day after hatching. During the 45-day study, for each unit we applied individual aeration, sponge filtering and temperature control, and the effective capacity of each aquarium was 150 litres. The rectangle-shaped aquariums were arranged in 2 rows, the system was made up of 9 units. For the experiment, we populated each aquarium with 20 carp fries, with a total number of 180 carp fries involved.

Before placing them in the aquariums, we measured the wet body weight and the length of the individual fishes, and at the end of the experiment, too, these parameters were determined individually. The body weight was measured using a digital scale with an accuracy of two decimal spaces (VWR SE 422 - 0.01g), and the standard and full body lengths were measured using a ruler with 1-mm graduation.

The solved oxygen content and concentration of water (mg/litre, %) and the water temperature were measured daily in each aquarium, using the HACH LANGE HQ30d instrument. 14 hours of artificial lighting was applied on a daily basis (between 6:00 and 20:00). The pH of the water was measured using, again, the HACH HQ 30d, on a weekly basis, and also the forms of nitrogen (ammonia and nitrite) were checked weekly using a HACH LANGE DR3900 spectrophotometer.

The fish were fed ad libitum. Throughout the duration of the experiment the fish were fed with commercially available feed of 0.5 mm particle size, which had 58% crude protein and 15% crude fat content. The daily feed ration of the fish was administered in 3 portions via hand feeding at 9:00, 12:00 and at 16:00 o'clock. During the experiment, using a plastic-silicon tube, the feed that had not been consumed and the excreta of the fish were removed once a day, and we exchanged 10% of the water once a day and 50% of that once a week. At the end of the 45-day experiment we measured the individual body weight, the standard and full body length of each of the 30 fish, and determined their condition factors, as well.

Then we continued to grow the populations in a recirculation system with 1000 litre/unit capacity, until they reached the 12 months of age. During post-rearing, we fed them a feed with 36% crude protein and 8% crude fat content, which we produced ourselves.

After over-sedating the fish by anaesthesia (using clove oil) we explored their gonads. The average body weights (g) and the average standard body lengths (cm) were determined based on the data of 50 pieces of fish for each treatment. The weights of the fish and the gonads were measured using a VWR SE 422 -0.01g digital scale at an accuracy of two decimal spaces. To facilitate the identification of gonads we used a VWR VisiScope BL224T1 digital microscope.

Statistical analysis:

At the end of the experiments in the aquarium, the following production parameters were determined:

- At the end of the experiments, we determined the fish survival (number of live individuals/number of releases * 100) and measured the individual wet body weight, standard and total body length of the fry in each tank
- Condition factor, K = W/L3 x 100, where W: wet body mass (g), L: standard body length (mm)
- Feed conversation ration, FCR (g/g) = F/(Wf-Wi), where: F: feed consumed during the experiment (g), Wf: final body weight (g), Wi: initial body weight (g)
- Special growth rate, SGR % = (ln BWf - ln BWi) / t x 100, where: Wf: final body weight (g), Wi: initial body weight (g), t: number of days

At the end of the post-rearing period, we measured the individual body weights, standard body lengths, condition factor of the fish and in addition to this, we measured the weight of the gonads of the fish, determined the average gonad weight, the GSI index and calculated the sex ratios:

- GSI (%)= (gonad weight (g)/body weight (g))*100
- Sex ratios = (number of male/total number of fish)*100 or (number of female/total number of fish)*100

Statistical analyses were carried out using IBM SPSS 22:

- The evaluation of the data from the experiments in the aquarium was determined by one-factor analysis of variance, one-way ANOVA with LSD test.
- Chi^2 test was used to compare the survival of the aquarium experiments
- To compare parameters 12-month-old fish and to examine parameters for male or female individuals a two-factor analysis of variance (two-way ANOVA), Tukey's HSD post hoc test was used

R Software Package 3.0 goodness-of-fit test with Chi^2 test was used to compare retention and sex ratios within groups.

2.3. Growth performance of common carp stocks in intensive and pond culture

2.3.1. Growth performance on all-female and mixed-sex common carp stocks

The experimental populations were established in Szarvas in cooperation with the staff of NAIK HAKI (*Research Institute for Fisheries and Aquaculture of the National Agricultural Research and Innovation Centre*). For each one, the roe of one Tata slate-grey female carp was fertilized with a third generation gynogenetic male's (Aquaexcel 6 tube 0415D4BD57 gynogenetic 'Papi') milt. In addition, we generated a population using normal male, and set up a control population, too, using the other part of the roe. The three populations established this way are the ***control*** – mixed-sex, the ***MS-T2*** **-** monosex female and the ***MS-T3*** **-** monosex female treatments.

Following the propagation and the pre-rearing phase, the experiment was performed in the recirculation system of DE MÉK Fish Biology Laboratory. There were 12 round polypropylene tanks, each with an effective capacity of 1000 litres, available for fish rearing. The round polypropylene tanks were arranged in 2 rows, the experimental system was made up of 9 units.

The 9-month populations were split into nine parts, then applying identical population density, we set up three treatments (control, MS-T2, MS-T3) with identical average initial body weights. In the experiment the carp was reared from their 9-month age to the age of 21 months (for 357 days).

The tests were set up in a configuration of 30 carps in each tank (90 for each treatment), a total of 270 fish. Later on, due to the increased biomass, the population density was changed to 10 and then to 8 fish per tank (30 and 24 fish per treatment, respectively). Before relocation, we measured the body weight and the standard length of each individual fish, and several times during the experiment, as well as at the end of that, the growth parameters were determined individually. The body weight was determined with two different scales, one with the accuracy of one and the other with two decimal spaces (VWR LP 6501 - 0.1g and MSZ Méréstechnika Kft MODEL 7515 - 0.01g, respectively), and standard body length was measured using a one-mm graduation measuring tape.

The solved oxygen content and concentration of water (mg/litre, %) and the water temperature were measured daily, using the HACH LANGE HQ30d instrument. 14 hours of artificial lighting was applied on a daily basis (from 06:00 to 20:00) throughout the duration of the experiment. The pH of the water was measured using, again, the HACH HQ 30d, on a weekly basis, together with the various water parameters (total hardness, carbonate, ammonia, nitrite, nitrate, total phosphate level) that were checked weekly using a Hach Lange DR3900 spectrophotometer in samples taken randomly from three tanks of the recirculation system.

The daily rations of feed were determined as 2.5 to 1% of the biomass weight, subject to the water temperature, the growth rate and the current appetite of the fish. All throughout the experiment the fish were fed with a fish feed of 36% protein and 8% fat content and of large particle size (3 to 4.5 mm), which we developed ourselves. The daily feed ration of the fish was administered via automatic feeders in 5 portions a day at 8:00, 10:00 12:00, 14:00 and at 16:00 o'clock.

During the 12-month experiment, at least once a month, we performed body weight and body length measurements. At the end of the experiment we measured the individual body weight, and standard body length of each fish, determined their condition factors, SGR%, the FCR value as well as the daily growth rate (DGR). Further, we measured the head length, body height, body width and the caudal peduncle length of the fish, and determined their profile, cross-section, head and caudal peduncle indices. From each treatment, we chose four fishes of average body weight, which were processed based on the Code of Performance Analysis. We measured the live weight, the scale weight, the cleaned carcass weight, the weight of offal and head, the weight of the gills and the fins, and we determined also the fillet yield percentages.

Statistical analysis:

During the 12-month experiment, the following production parameters were determined after every 56 days and at the end of the experiment:

- At the end of the experiments, we determined the fish survival (number of live individuals/number of releases * 100) and measured the individual wet body weight, standard and total body length of the fry in each tank
- Condition factor, K = W/L3 x 100, where W: wet body mass (g), L: standard body length (mm)
- Feed conversation ration, FCR (g/g) = F/(Wf-Wi), where: F: feed consumed during the experiment (g), Wf: final body weight (g), Wi: initial body weight (g)
- Special growth rate, SGR % = (ln BWf - ln BWi) / t x 100, where: Wf: final body weight (g), Wi: initial body weight (g), t: number of days
- Daily growth rate, DGR (g/nap) = (Wf – Wi)/ t, where: Wf: final biomass mass, Wi: initial biomass mass, t: number of experimental days

Statistical analyses were carried out using IBM SPSS 22. Comparative analysis of production parameters of treatments was determined by one-factor analysis of variance, ANOVA with Tukey's HSD test at 5% significance level.

2.3.2. Growth performance of mixed-sex common carp stocks in pond, it focused between male and female carp differences

In our experiment, we tested carp reared in pond farm rather than in a recirculation system, but also compared the results with those of the intensive system. It is important to note that in case of fish reared in the intensive system, we only used the results from mixed sex stocks, because it is not meaningful to examine differences between sexes in case of monosex stocks.

The economic study was carried out at the fish processing plant of Hortobágy Fish Farm Ltd. in Elep. On three occasions (18 September, 25 September and 3 October 2021), 100 fish were dissected at a time, for a total of 300 three year old Hortobágy mirror fish. A digital scale with an accuracy of 50 g was used for the measurements. Live weight was measured, and after scaling and fin removal, sex was determinates, the weight of the reproductive organs was measured and the viscera were removed to determine the cleaned weight.

Weighed fish >1.5 kg; 1.5-1.8 kg; 1.8-2.1 kg; 2.1-2.4 kg; 2.4-2.7 kg; 2.7-3.0 kg; 3.0-3.3 kg; were categorised by their average weight, biomass, cleaned weight during processing and useful meat yields were calculated by sex. The comparative analysis of meat yield results was determined by one-way ANOVA LSD post hoc test at 5% significance level and Chi^2 test was used to compare the sex ratio of weight categories. The relationship between body weight and sex was also examined using polynomial trend function line, which allows the results to be used in practice. This methodology was not only applied to pond fish but also at intensively reared stocks.

2.4. Parameters of common carp out-of-season spawning, combined intensive production and pond culture production

The 3rd generation gynogenetic female and the normal mixed-sex populations were established in February, 2020 at the DE MÉK Fish Biology Laboratory, in the framework of an off-season carp propagation. Regarding the origins of the mother fish used for propagation, the females (2 specimens) were mother fish originating from the performance analysis of monosex female carp populations, while males (3 specimens) were scaled fish reared in the intensive system of the DE MÉK Fish Biology Laboratory, originating from the year 2018 seasonal propagation performed by the Bocskai Halászati Kft.

Preparation of the mother fish was performed in square mother fish tanks of 2000 litre effective capacity each, supplied with cooling/heating system and aeration, designed for this purpose. The preparation started on the 8th of January, 2020 and took 27 days. During this period of time we kept increasing the water temperature and the length of artificial lighting of the tanks (as compared to the then current natural daylight of 8 hours and 45 minutes - INTERNET 1), up to the day of propagation. During the 28-day preparation phase the water temperature was raised from 7.4°C to 21.2°C, and by the end of the preparation the illuminated period of time was 405 minutes longer compared to the initial stage. During the preparation, the mother fish were no longer fed with feed.

Artificial fertilization at the hatchery took place on the 4th of February, 2020, in line with the carp propagation protocol described by HORVÁTH and TAMÁSI (2011). Three males were chosen, whose semen was successfully stripped, and then this semen was split into two parts. We used one part to generate the mixed-sex control population. The other part was disrupted by gamma irradiation with the contribution of the staff of the Institute for Nuclear Research (ATOMKI) of the University of Debrecen. The sperms were treated at a dose of 100Krad, with 182 rad/sec intensity using a ^{60}Co cobalt unit.

Viability of the control and the radiated semen was checked. Motility was determined using a computer aided examination method, the CASA system in cooperation with colleagues from the Fish Management Faculty of Szent István University. The CASA system takes video records of the moving sperms, then, following the route of the sperm's head it records several parameters of movements, such as motility, progressive motility, speed and the length of the distance taken (KÁSA, 2017).

The analysis also showed that the 85 to 96% motility and 75 to 89% progressive motility prior to irradiation dropped to 40 to 72% and 13 to 43%, respectively, after the irradiation, but based on the values received, the treated semen was still suitable for fertilization.

For the fertilization, 200g eggs were split into two parts. One half was fertilized using the untreated sperms, while the other half was fertilized with the treated sperms, thus establishing one control and one gynogenetic carp population. Two minutes after fertilization the eggs fertilized with the treated sperms were placed in a 40°C water bath for two minutes to increase haploidity as described in the literature (HORVÁTH and ORBÁN, 1995).

Once the operation had been performed, the roe fertilized with the treated sperm, as well as the roe fertilized with the untreated sperm were made swollen using the Woynárovich fertilizer solution. Then, after removing stickiness (with milk) we hatched them in three days in Zuger jars at a water temperature of 22°C. The hatching rate was 90% in the control population, while in the gynogenetic population the rate of hatching hardly reached 10%, which, however, can be considered an especially good value for such populations (KOMEN, 1988).

We kept on rearing the gynogenetic female populations in the recirculation system. While further rearing the fish, we observed a great extent of variation in the size, therefore, later we separated them according to the size, formulating small and large sized groups, and in separate tanks of 1000 litre/unit effective capacity we continued to rear each group until October. The daily feed rations were determined as 3 to 4% of the total biomass, and we supplied feed three times a day: at 9:00, at 12:00 and at 16:00 o'clock.

The control mixed-sex population was placed in 2 intensive rearing ponds at the Hajdúszoboszló site of Bocskai Halászati Kft. The total of 2x3000 carp with an average individual weight of 1 ±0.1 gram were stocked in 2x 6000m^2 ponds, which were prepared for receiving the fish using fertilizers. From this point on the experiment can be split into two parts. While one part of the populations kept under one-phase, semi-intensive small-pond rearing received feed till the end of the experiment, the other half - after a small-pond pre-rearing phase - was transferred to extensive production ponds, this way we had the opportunity to study the results of two-phase pond rearing, as well.

During the experiment, the population involved in one-phase rearing was fed with complete feeds, using automated feeders. The daily feed rations were determined as 3 to 4% of the total biomass.

Checking of the body weight gain of the populations was performed monthly via trial fishing, where the average body weight was determined based on the data of a number of 70 individual fish.

In the course of two-phase rearing, in the semi-intensive pond the fish were fed with complete feeds, using automated feeders. Then, after the fish were transferred to the extensive production pond, the complete feed was replaced with traditional supplementary feeding, in the course of which they were fed with coarse maize meal and extracted sunflower seed meal all through to the autumn.

At the end of the treatments, in October 2020, the individual body weights of each of the gynogenetic spawners kept in the intensive system, 10% of the stock introduced in the pond rearing system were measured, and the average body weights were determined. Since the three rearing techniques are not statistically comparable, only descriptive statistics were used in their evaluation:

- At the end of the experiments, we determined the fish survival (number of live individuals/number of releases * 100) and measured the individual wet body weight, standard and total body length of the fry in each tank
- Feed conversation ration, FCR (g/g) = F/(Wf-Wi), where: F: feed consumed during the experiment (g), Wf: final body weight (g), Wi: initial body weight (g)

3. RESULTS

3.1. Results of water temperature treatments

Despite having presented several production parameters above both for the 40-day experiment and the one-year post-rearing, we must keep in mind that the primary objective of the larvae rearing experiment was to find out whether we could influence the sex ratio of the population via changing the temperature. At the end of the experiment, after having explored the gonads of the one-year old fish, we determined the sex ratio of the populations treated at different temperatures. The results are shown in Figure 35. You can see that Treatment T22 showed a male-female ratio of (55.6%:44.4%), while at Treatment T25 the ratio was (46.7%:53.3%) and at Treatment T29 it was (50%:50%) (*Figure 1*).

Figure 1: Sex ratio of T22, T25, T29 treatments

The results clearly show that with regards to the sex ratios, there are no significant differences between the treatments. Similar percentages were observed under the different treatments. This is supported also by the statistical assessment performed using the Chi-square test, according to which none of the treatments show significant difference in the male to female sex ratio. The results obtained are equivalent to a nearly 50:50% male to female ratio characteristic of 'normal' carp populations (DWIVEDI and MAYANK, 2013).

In carp, gonads are differentiated by the 80th day after hatching. (KOMEN et al., 1992). The sex ratios obtained illustrate that water temperature treatments applied in the life stages prior to the differentiation of the gonads have no impact on the sex ratios within a given population.

At the end of the experiment, after having explored the gonads of the one-year old fish, we determined the sex ratio of the populations treated at different temperatures, the results obtained are shown in early. You can see that Treatment T24 showed a male-female ratio of (44.0%:56.0%), while at Treatment T28 the ratio was (48.0%:52.0%) and at Treatment T32 it was (44%:56%) (*Figure 2*).

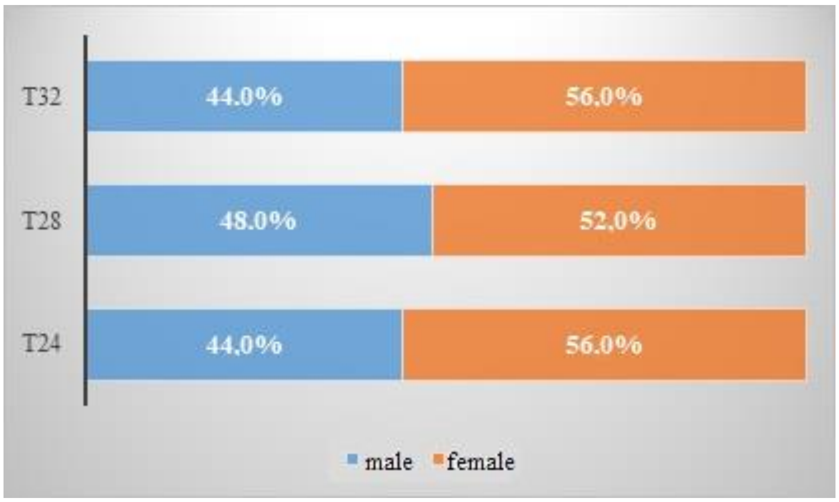

Figure 2: Sex ratio of T24, T28, T32 treatments

The results clearly show that, similarly to the previous experiment 4.1, there are no significant differences between the treatments with regards to the sex ratios here either, similar percentages were observed under the different treatments. This is supported also by the statistical assessment performed using the Chi-square test, according to which none of the treatments showed significant difference in the male to female sex ratio. Here again, the results obtained are equivalent to a nearly 50:50% male to female ratio characteristic of 'normal' carp populations.

3.2. Results of growth performance on all-female and mixed-sex common carp stocks

The comparative experiment was preceded by an intensive pre-rearing, following which, at 9-month age, we launched the examination on fish populations of identical body weights. When analysing and comparing the results it needs to be pointed out that both the mixed-sex population and the monosex female line were of Tata slate-grey native breed. At the same time, due to the technology requirements of the monosex female line, (gynogenetic sperm with XX chromosomes), had to involved an 'external', third generation gynogenetic male fish (Aquaexcel 6 tank 0415D4BD57 gynogenetic 'Papi'), as already mentioned under Section 3.2.1. In practice, it means that actually, the mixed-sex and the monosex female populations were half-siblings. This genetic variation might lead to deviations, nevertheless, when designing the experiment, we assumed that this difference might be negligible in the test carried out in the intensive recirculation system.

Figure 3 shows the change in bodyweight during the experiment. At the placement, the body weights in the separate populations showed no significant difference from each other, and it remained so until the middle of the experiment. Afterwards, however, based on the completed one-way variance analysis ANOVA LSD post hoc test the mixed-sex control group's fish stock reached a significantly higher average weight, and this difference remained to the end of the experiment. Then the age of the fish was 15 months.

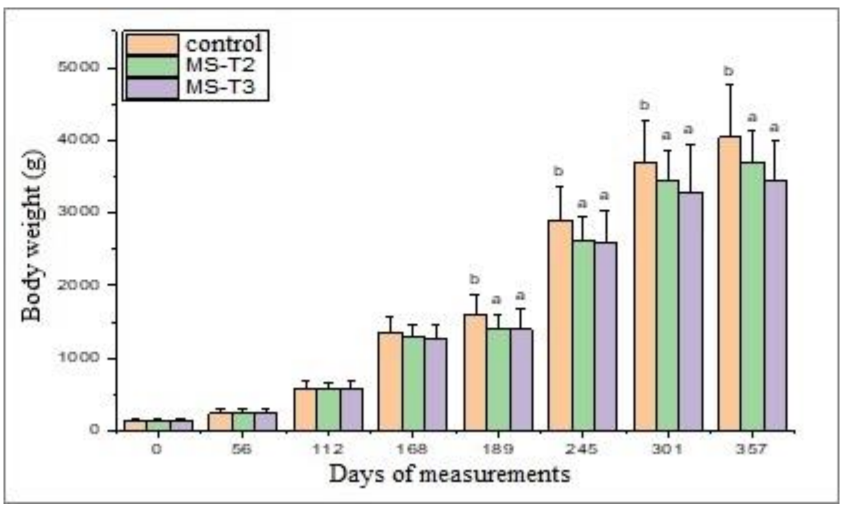

Figure 3: The average body weight of all-female and mixed-sex stocks

However, when checking the body length, the results are just the opposite of the above (*Figure 4*). Monosex female populations had significantly longer body lengths already from the start of the experiment, which means that they were slenderer, and this difference remained to the end of the experiment.

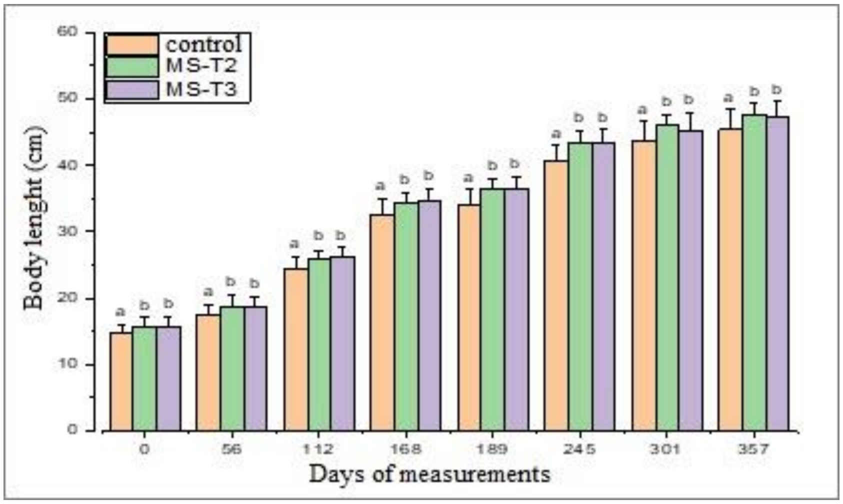

Figure 4: The average body length of all-female and mixed-sex stocks

The results of the body weight and length values are also supported by the results of the condition factor (K), according to which, based on the completed one-way variance analysis ANOVA, LSD post hoc test, the control population's K factor value was higher. This means that the individual fish of the control population had larger body weights but shorter body lengths as compared to the monosex females. They manifested a 'higher backed, more stumpy' phenotypes. An interesting point is that while considering consumption requirements, a high-backed carp is a good material for gastronomy, a more slender and wilder looking fish could be more attractive for the anglers.

Our experiment highlights that the growth advantage of monosex populations is not manifested in the intensive system, moreover, in this case, at the end of the experiment statistically, they were lagging behind the average body weights of and the biomass per cubic meter values of the mixed-sex populations (*Table 1*).

Table 1.

Average body weights of treatments and biomass per $1m^3$ at the end of the experiment

	Body weight (g)	Biomass ($kg/1m^3$)
Control	3692±590.5[b]	32.3±3.2
MS-T2	3438.8±415.4[a]	29.5±2.5
MS-T3	3294.1±659.1[a]	27.6±2.6

($p< 0.05$)

Our study confirms that with regards to table fish, there is no difference between the growth of the different sexes, just as it has been observed at the pond fish farms, as well. Although, from the researcher's point of view, there is significant difference in our measurements, but in practice it does not have a real importance, as on one hand, all the fish can be sold as table fish sized marketable fish, and on the other, hand the differences are of so small that could easily be adjusted during the production. The primary benefit provided by the intensive rearing is the time, since as opposed to two- or three-summer period of pond fish farms, here we reached the marketable size in 19 months, in a way that we kept a population under controlled conditions (there was no winter period, complete feed was provided etc.) and that population could produce approx. 30 kg/m^3 biomass by the end of the experiment.

In addition, we intentionally raised the stocks to marketable size, as once table size fish are involved, it is worth to examine also the meat yield parameters that are crucial from a processing point of view. *Table 2* below presents more detailed production parameters measured for each treatment at the end of the experiment.

Table 2.

Average production parameters of treatments

	Control	MS-T2	MS-T3
Body weight (g)	4042.9±728.8^{b}	3691±445.7^{a}	3454.6±553.4^{a}
Body length (cm)	48.7±3.4^{a}	51.0±2.0^{b}	50.6±2.7^{b}
Standard body length (cm)	45.4±3.1^{a}	47.6±1.7^{b}	47.3±2.3^{b}
Condition factor	4.3±0.7^{b}	3.4±0.3^{a}	3.2±0.3^{a}
Head length (cm)	12.3±1.0^{b}	11.5±2.1^{a}	11.1±0.5^{a}
Body size (cm)	20.4±1.6^{b}	18.2±1.3^{a}	17.4±1.1^{a}
Body width (cm)	11.0±1.2^{b}	10.4±0.7^{a}	10.1±0.9^{a}
Tail handle length (cm)	5.6±0.9^{a}	6.9±0.6^{c}	6.3±0.6^{b}

($p < 0.05$)

Differences of the production parameters were checked using one-way ANOVA, LSD post hoc test. What is worth to be observed here is that the previously described slenderer monosex female body shape is reflected by the significantly larger body length, the significantly smaller condition factor, and the larger caudal peduncle length, as well as the significantly larger body height of the control populations.

At the end of the experiment a total of 12 female fish - 4 for each treatment - were slaughtered and processed in accordance with the Code of Performance Analysis. *Table 3* below shows the results from processing the fish.

Table 3.

Parameters of processed meal fish

	Control (female)	Control (male)	MS-T2	MS-T3
Live weight (g)	3895±210.0	3627.6±186.5	3912.5±143.6	3097.5±226.1
Cleaned trunk weight%	56.3±2.8	57.4±0.5	58.8±1.9	57.1±2.2
Scaly weight%	3.0±1.3[a]	3.0±0.0[a]	3.1±0.4[a]	3.7±0.3[b]
Head weight %	14.3±2.7[ab]	13.9±0.2[ab]	13.1±0.6[a]	14.6±0.7[b]
Offal weight%	19.7±1.9	18.9±0.2	18.0±2.0	17.6±2.5
Gill weight %	1.7±0.6	1.7±0.2	1.8±0.1	1.6±0.1
Fin weight %	5.0±1.2	5.1±0.1	5.2±0.4	5.4±0.9
Sum %	100	100	100	100

(p <0,05)

Based on the one-way ANOVA, LSD post hoc test, significantly higher weight of scales and weight be observed at the MS-T3 group. However, statistic difference can be detected in the head weights, when considering use in practice, we can state that there is no difference between the fish of the monosex female populations and the mixed-sex populations fish.

Considering food processing and culinary purposes, there is one more key parameter, the fillet yield% in relation with the total body weight. Today's modern consumer requirements and easy usability demand by default boneless fish meat products. That is why studying the percentage of the boneless fillet, as presented in *Table 4*.

Table 4.

Fillet percentage %

	Live weight (g)	Fillet percentage %
Control (female)	3895±210.0	45±2.7
Control (male)	3627.6±186.5	46.1±2.1
MS-T2	3912.5±143.6±	46.3±1.3
MS-T3	3097.5±226.1	42.2±4.4

(p <0,05)

Based on the one-way ANOVA, LSD post hoc test there are no significant differences between the treatments. Although, the number of specimens examined (n=4) was low, still we can state that from a culinary point of view it does not matter whether the carp came from a monosex female population or from a mixed-sex population.

From the gastronomy's point of view, edible flesh and head might be important, too; for example, many use also the head for preparing Hungarian fish soup, in addition to using the edible flesh (by slicing the edible flesh you get the horseshoe-shaped sliced carp steak).

3.3. Results of common carp out-of-season spawning, combined intensive production and pond culture production

Our results presented under this section are a little different from the results of classic experiments, as in this case we aimed at elaborating a complex production technology. Our goal is that by advancing the carp reproduction time, we leverage the spring plankton peak, enabling the one-summer carp to grow much larger than the ones raised using the traditional fish keeping method; as a direct consequence of this the three-year mode of operation can be changed to two-year mode, without any reduction in the size of the marketed fish.

3.3.1. Results of common carp out-of-season spawning

We prepared one-and-a-half-year old individuals for the propagation, which had been reared from the start in closed recirculation system, this way they got fully adapted to the artificial circumstances and got used to constant presence of humans. The preparation started on the 8th of January, 2020 and took 27 days. During this period of time we kept the water temperature and the length of artificial lighting of the tanks increasing (as compared to the then current natural daylight - 8 hours and 45 minutes (INTERNET 1)), up to the day of propagation. During the 28-day preparation the water temperature was raised from 7.4°C to 21.2°C, and by the end of the preparation the illuminated period of time was 405 minutes longer compared to the initial stage (*Figure 5*). During the preparation the mother fish were no longer fed with feed.

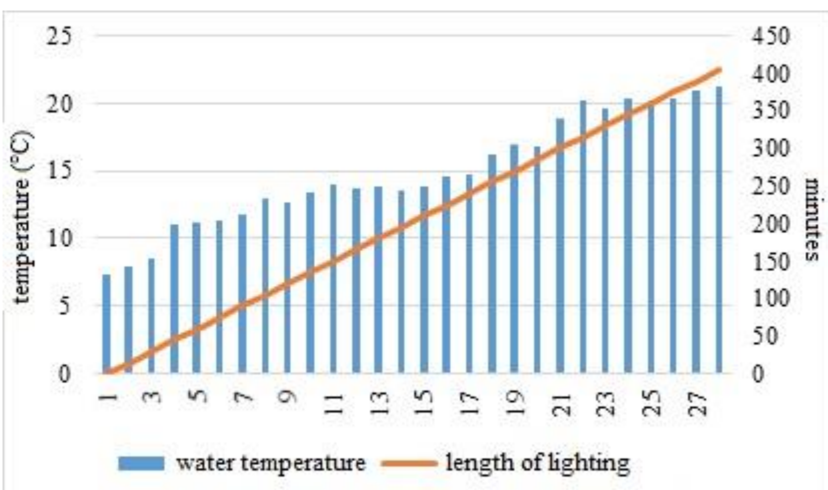

Figure 5: Water temperature and lighting during prepare

Based on examination of the gonads using catheters, and based on the overall condition, applying visual health heck we selected 3 males and 2 females, which were then prepared for the propagation. The artificial fertilization at the hatchery took place on the 4th of February 2020, in line with the carp propagation protocol described by HORVÁTH and TAMÁSI (2011). Three males were chosen, whose semen was successfully stripped, and then this semen was split into two parts; one part was used for traditional fertilization, and the other part was used for establishing gynogenetic populations.

Fertilization took place the same way in both treatments. The fertilized eggs were washed in salty urea solution for 1 minute each. After discarding the salty urea solution, the roe was made swollen and at the same time its stickiness was removed in a watery-milky solution. 1 litre of milk with 3.5% fat content was mixed with 8 litres of water, and in this mixture we stirred the roe for 1 hour, until their full swelling. In the meantime, we refreshed the solution on the eggs five times. The milk reduced the stickiness, therefore, we only a quick 30-second tannin treatment was applied at the end of the swelling phase, to ultimately remove the stickiness of the roe. Then the fertilized eggs were placed in the hatchery system, 50 grams of roe into each Zuger jar, into a total of 4 jars. The embryogenesis took 3 days at 22°C, i.e. the hatching occurred by 66 day-grades. When the first hatched larvae appeared, the Zuger jars were drained, and the roe that had not yet hatched was placed in plastic bowls, where due to the oxygen-deficient condition, the quickly warming water and the increased enzyme concentration at the hatching, the larvae hatched at the same time, in a synchronized way. Based on the quantity of the hatched larvae the control stock produced a 90% hatching, while the gynogenetic stock hatched at 10%, which is corresponding with what is reported in the literature (KOMEN et al., 1987).

3.3.2. Intensive production

After the successful hatching, rearing of the gynogenetic and the control populations was continued in intensive recirculation system with a capacity of 100 l/unit, at 22°C, and after getting the fish accustomed to feed, we used recirculation system with 1000 litres of effective capacity per unit, at a water temperature of 22°C. The period of intensive pre-rearing lasted till the 10th of April, 2020. During pre-rearing, first we used as feed a live food, *Artemia* (*Artemia sp.*) for 5+2 days. After the 5th day, we were letting the fish accustomed to feed for 2 days. In these 2 days they received a mix of both live food and fish feed. After getting them accustomed to fish feed, the larvae were fed with a commercially available starter feed (63% crude protein, 11% crude fat). Then as the size of the fish grew, they were given feed of larger particle size, first with 58% crude protein and 15% crude fat content, and then, in the last phase they received feed that contained 56% crude protein and 18% crude fat. For the detailed feeding protocol, please see *Table 5*.

Table 5.

The intensive feeding protocol

Time	Feed type	Feed parameters
Spawning: 2020.02.08.	-	-
Hatching: 2020.02.11.	-	-
Non-feeding stage 0.-3. Days	-	-
3.-7. Days	*Artemia sp*.	Live food
8.-10. Days	*Artemia sp*. + starter feed	
11.-29. Days	400 micron starter feed	63% crude protein, 11% crude fat
30.-34. Days	Starter feed + 0.5 mm feed	
35.-52. Days	0.5 mm feed	58% crude protein, 15% crude fat
53.-58. days	0.8 mm feed	56% crude protein, 18% crude fat

At the end of the two-month intensive pre-rearing period, both the gynogenetic and the control stocks showed a survival rate of 60%, and in both populations the average bodyweight was 1 gram.

At the beginning of the ***one- and two-phase pond rearing***, on the 10th of April, 2020, we placed 3000 pieces of fish into each of two half-intensive rearing ponds of Bocskai Halgazdaság Zrt. located in Hajdúszoboszló, 6000 m^2 each, which were prepared for receiving the fish using fertilizers. When the fish were placed in the ponds, the temperature of their water was 16°C, and the total biomass placed into each pond was 3 kg per pond. At the beginning of the examination, the one- and two-phase rearing the method of fish keeping was the same, applying a separate half-intensive small pond for each. During this period, on the 17th of June and on the 9th of July, 2020, trial fishing was performed. With regards to the two-phase rearing this involved overall harvesting of the small pond (*Table 7*).

Table 7.

The result of two fisheries measure

	One phase pond rearing		Two phase pond rearing	
Date	Average body weight (g)	Water temperature (C°)	Average body weight (g)	Water temperature (C°)
2020.06.17	76	18.7	63	18.6
2020.07.09	173	23.1	156	22.8

Following the measurements taken on the 13th of July, 2020, the fish involved in one-phase rearing remained in the half-intensive lake while the stock under two-phase rearing was restocked to a 35 hectare extensive pond.

All throughout the ***one-phase rearing*** complete feed was administered. Until June, the population restocked on the 10th of April consumed only a small amount of feed, since the ponds were so abundant in planktons that the fish had not switched over to consuming feed. The 'real' feed consumption started actually no sooner than in June, as by this time the ponds had run out of planktons, so the fish had to switch to the feed. *Table 8* below shows the dates of trial fishing, the average weights of the fish measured, the amount of feed fed and the current water temperature.

Table 8.

Dates of trial fishing, the average weights of the fish measured, the amount of feed fed and the current water temperature

Date	Average body weight (g)	Feed ratio to biomass %	Water temperature (C°)
2020.06.17	76	3	18.7
2020.07.13	173	3,5	23.1
2020.08.04	235	4	26.3
2020.08.25	269	4	25.1
2020.09.18	391	3	20.4
2020.11.04	787.55	°ad libitum	10.5

After the trial fishing on the 18th of September, we provided feed to the fish ad libitum all through till the harvesting on the 4th of November, when were measured 1770 pieces of fish with an average weight of 787.55 grams, a total weight of 1394 kg. *Figure 7* below shows the growth curve of the one-phase rearing.

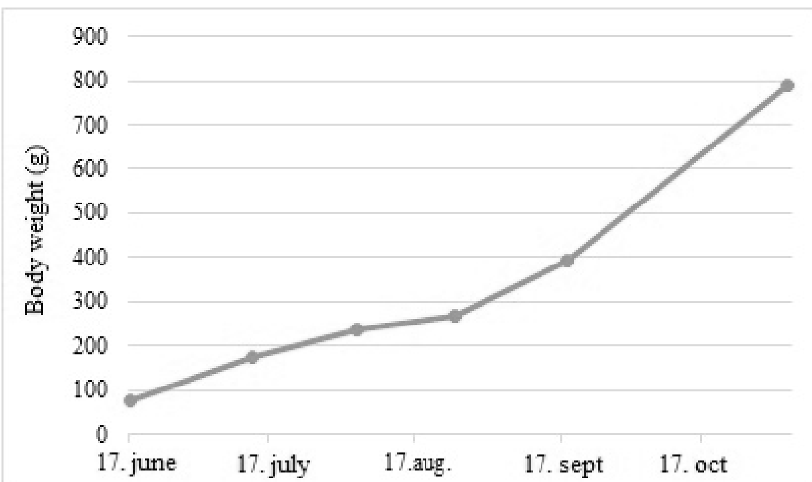

Figure 7: Results of one phase rearing (g)

The average weight calculated upon harvesting is a weighted average, as the fish we measured were separated into two fractions (small sized and large sized). The average weight of the small sized fraction was 513 grams, and they represented 15% of the entire population, while the average weight in the large sized fraction was 836 grams, and they constituted 85% of all the fish.

The 1770 pieces of fish harvested means that the survival rate was 59%. At the pond post-rearing in the production period 1760 kg feed was used, based on which the feed conversion rate (FCR) of the semi-intensive rearing can be calculated (*Table 9*).

Table 9.

Feed use for one phase rearing

Initial biomass (kg)	3.6
Final biomass (kg)	1394
Yield (kg)	1390
Feed use (kg)	1760
FCR (kg/kg)	1.27

The ***two-phase rearing*** was separated from the former after the 13th of July. This is when the fish involved in two-phase rearing was relocated into the extensive, 35-hectare rearing pond. The feeding protocol of two-phase rearing is different from that of one-phase rearing, as in this case feed was provided while being raised in the small pond, but when grown in the large pond only traditional supplementary feeding was applied, using maize and extracted sunflower seed meal. *Table 10* below shows the feeding protocol applied in the course of the two-phase rearing.

Table 10.

The quantity of the supplementary feed during the two phase rearing (kg)

	2mm feed (kg)	corn (kg)	Extracted sunflower(kg)
April	25		
May	85		
June	200		
July		439	
August		896	465
September		1914	500
Total	310	3249	965

Results of the harvesting on the 29th of September, at the end of the experiment are shown in *Table 11*.

Table 11.

The results of the harvesting

Date	Pieces	Average weight (g)	Biomass (kg)
2020.09.29	1748	754	1318

The FCR values determined on the basis of the yields were FCR=0.99 (kg/kg) and FCR=4.21 (kg/kg) in the time period when fed with complete feed and when fed with supplemented feed, respectively.

When comparing the body weight results of one-phase vs. two-phase rearing, it was found that very similar average weights were reached (one-phased = 787g; two-phased=754g), and also the survival rates (%) of the two systems were nearly the same. The one-phase rearing shows a greater yield and better FCR, due to the controlled and more intensive rearing technology and the complete feed that was used for feeding. However, what is worth to be examined from a practical point of view is whether this better yield was more economical, as in the one-phase rearing, when complete feed was applied all through, the feed costs were much higher than the costs of the traditional supplementary mash feed's costs in the two-phased approach. In this regard, the results of the two-phased rearing could offer an attractive alternative, since - compared to one-phased rearing - the fish need to be fed with the relatively expensive feed for a shorter time. Nevertheless, the one-phased rearing is more competitive in some other points. The bottleneck here is that the feed costs should be reduced, as in this case, the smaller sized, easier to control fish keeping method would be beneficial as compared extensive fish keeping, where we can exercise 'less' influence on the fish and which has many orders of magnitude greater demands of area, water, investment and infrastructure.

4. NEW SCIENTIFIC RESULTS

1. I determine that there was no significant difference in sex ratios at 22°C, 25°C or 29°C in the pre-hatching life stage, i.e. in the flocks treated for 0-40 days post-hatching. The milk to egg ratio was (55.6%:44.4%) at 22°C, (46.7%:53.3%) at 25°C and (50%:50%) at 29°C. After 0-40 days post-hatching, fish treated at 25°C had significantly higher body weights, a result that points to the optimum for fry rearing. The differences in body weight at fry age were maintained later on, at age 1 year, so that fish treated at 25°C had significantly higher body weights. Examination of the fry showed that all three temperature treatments resulted in significantly higher weights for age-1 fry, but significantly higher GSI indices for the milk fry.

2. I determine that there was no significant difference in sex ratios during the life stage of spawning differentiation, i.e. for stocks treated for 40-85 days post-hatching, at 24°C, 28°C and 32°C. The milk to egg ratio was (44%:56%) at 24°C, (48%:52%) at 28°C and (44%:56%) at 32°C. After 40-85 days of post-hatching treatment, fish treated at 24°C had significantly higher body weights, a result that points to the optimum of fry rearing. The differences in body weight at fry age were also maintained later, at 1 year of age, so that fish treated at 24°C had significantly higher body weights. There was no significant difference in body weights between age-1 year old fry and milk fry in any of the treatments, but milk fry had significantly higher GSI indices in all treatments. This means that in our present experiment, 1 year olds reared in a recirculation system had a more advanced sexual maturity than the dairy fish.

3. I conclude that when comparing market size monosex egg stocks reared in recirculation with mixed stock, the mixed stock showed significantly better growth. Within the mixed stock, where it was relevant to examine breeding differences, the higher weight categories (above 3.6 kg) had a significantly higher incidence of egg laying and the weight-sex variable was also strongly correlated for both sexes ($R2>0.9$).

Thus, it can be concluded that for the market-sized mixed carp reared in our recirculation system, a higher weight within a stock indicates a higher probability of spawning.

Compared to the intensive system, the market size mixed stocks reared in the pond farm had a significantly higher incidence of eggs in the higher weight classes (above 2.7 kg) and the weight-sibling variable was also strongly correlated for both sexes ($R2>0.9$). It can be concluded that for the market-size mixed-breed carp reared in our pond farm, a higher weight within a stock indicates a higher probability of spawning.

4. The recirculation experiment showed no significant difference in meat yield (head + trunk %, cleaned trunk %, fillet yield %) between monosex and mixed stock. There is also no significant difference between egg and milk within the mixed stock. For the intensive farming technique we used, the spawning size of the fish is not relevant for meat yield, so the larger mixed stock spawners did not result in better meat yield.

Comparing this with the results for pond-reared mixed stock carp, the head+trunk % variable within stocks shows that there is no significant difference in meat yield between dairy and egg fish. Thus, at the stock level, the higher average weight of spawners does not result in better meat yields.

5. The efficiency of off-season carp spawning in terms of fry quantity, hatching and survival is equivalent to that of seasonal spawning, but requires more preparation in terms of infrastructure and preparation. During one month of intensive pre-rearing, fish survival (80%) was excellent and average fry weight (1g) was adequate for stocking into rearing ponds.

6. At the beginning of both single-phase and two-phase pond rearing, the food preferences of the fish have changed. Due to the abundant plankton, the fish immediately switched to live food, and until sufficient zooplankton was available, they did not really consume the feed, In mid-July, when zooplankton levels in the ponds dropped spectacularly, the fish almost immediately returned to eating the feed.

7. Harvest results showed that fish from both the single-phase and two-phase rearing systems reached similar average weights of 754 g and 788 g, respectively, which is well above the average single-phase fry weight (104 g) (AKI, 2021). Retention was 59% for the single-phase and 58% for the two-phase. FCR was 1.27 kg/kg for the single phase, 0.99 kg/kg for the two phase and 4.12 kg/kg for the two phase. Net yields per hectare were 2316 kg for single phase and 1312kg for two phase.

5. PRACTICAL USE OF THE RESULTS

In this chapter, I summarise some of the tangible practical implications of the experiments we have carried out, which may help researchers or producers with regard to carp strains and production technology.

1. In our experiments in n recirculation system, the production benefits of single broodstock carp did not materialise because the fish grow and mature much faster in an intensive system compared to pond culture. Our experience has shown that dairy fish become mature sooner, in about 1 year, but that even spawners are reproducible after about 1.5 years. This means that the growth advantage of egg-laying dairy cows from sexual maturation does not show up in intensive systems. Given the near equivalence in growth rate and the expensive design and operation of the technology, it can be argued that it is not worth the effort and cost to develop monosex egg stocks if carp are to be reared in an intensive system.

2. There is no difference in slaughter value between monosex female stocks and mixed stocks in the production of food fish, so monosex stocks, whether twin or dairy, are only of value if the demand for the spawning product itself is what drives the producer to work with monosex carp stocks. However, the comparative pond experiments confirmed the assumptions in the literature that if market-size carp are reared, there is relevance even for monosex egg stocks, due to the better growth and biomass results of the eggs.

3. Within our other main study topic, the timing of off-season spawning is very important for economical carp production. Carp spawned too early will increase the demand on infrastructure and increase operating costs due to prolonged intensive rearing. Well-timed off-season spawning and a short period of intensive brood rearing coupled with pond rearing can be a good solution to intensify or secure production.

4. Intensive pre-nursing can be continued with intensive small-scale or combined intensive small-scale-extensive large-scale post-nursing. When starting fish pond rearing, the timing of the optimum release into the ponds and the size of the fish are the most important factors. A prerequisite for successful rearing is that the size of the carp is at least large enough to release them without plankton selection. In practice, fish of a size that can safely consume Daphnia should be reared in an intensive system.

Based on our current experience, this size is 0.5g. The most important factor for successful pond rearing is the ideal timing of the release, which is the peak period for the spring plankton spawning, but this factor is highly climate and weather dependent, so timing is key to successful rearing.

5, A further important lesson after release is that carp will immediately revert to plankton-centric feeding, meaning that they will need to be re-accustomed to feeding on feed later. Here it is also very important to ensure that the released fish are given the right size and content of feed.

6, Of the two types of rearing methods, whether the producer prefers to keep his carp stock intensively in small ponds throughout or switches to extensive large pond rearing after intensive rearing is mostly infrastructure dependent. Conversely, whichever method is chosen, the results suggest that it is safe to reduce the production time for table fish from three years to two years and thus gain a market advantage over competitors.

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7. PUBLICATION LIST

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Idegen nyelvű tudományos közlemények hazai folyóiratban (2)

1. **Kovács, L.**, Minya, D., Homoki, D. Z., Toviho, O. A., Molnár, Á., Fehér, M., Stündl, L., Bársony, P.: Comparision of growth of mature all-female and mixed-sex Common carp (Cyprinus carpio L.) stocks in RAS.
   Agrártud. Közl. 1 (1), 65-68, 2020. ISSN: 1587-1282.
   DOI: http://dx.doi.org/10.34101/actaagrar/1/3748
2. **Kovács, L.**, Simon, Á., Minya, D., Homoki, D. Z., Kertész, A., Fehér, M., Stündl, L., Bársony, P.: Influence of 17-alpha methyl testosterone on the production parameters of common carp (Cyprinus carpio L.) fry.
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Idegen nyelvű tudományos közlemények külföldi folyóiratban (1)

3. **Kovács, L.**, Minya, D., Homoki, D. Z., Toviho, O. A., Fehér, M., Stündl, L., Bársony, P.: Effect of different water temperatures on sex ratio, gonad development and production parameters of common carp (Cyprinus carpio L.).
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