IMPORTANCE AND PRINCIPLES OF GENETIC IMPROVEMENT IN AQUACULTURE PRODUCTION

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ZNAČAJ I PRINCIPI GENETSKOG UNAPREĐENJA U AKVAKULTURI

Need for genetic improvement programs High yields obtained in agriculture rely heavily on the use of domesticated and genetically improved breeds and varieties. Until quite recently this has in general not been the case for most farmed aquaculture species that, in the genetic sense, are still much closer to the wild state than are the major terrestrial animals and food crops. Less than 10 % of the total world aquaculture production is based on improved strains. Due to a growing human population and a decline in production from capture fisheries, there is therefore a great disparity between the need for increased aquaculture production and the genetic quality of the strains available to meet that need. Moreover, full benefits of investments in management improvements (feed and feeding practices, rearing water quality, control of diseases, etc.) can only be obtained through the use of genetically improved animals.

Potential for genetic improvement Prospects of genetic improvement of economically important traits are well documented in several fish species (Gjedrem, 1997). In general, estimates of heritability for traits of economic importance in fish species are within the range of those observed for terrestrial species while the magnitude of non-additive genetic effects has been shown to be more important than previously assumed. For growth rate, genetic gains of about 10% of the mean per generation are frequently reported, implying that growth rate can be doubled over a period of seven to eight generations. Such changes will significantly increase both turnover of production and resource efficiency (feed, land, water) and hence reduce cost of production. Another benefit of genetic improvement programs is development of strains with better product quality for the benefit of both producers and consumers.

Research and education Most of the genetic research activities in aquaculture species in many countries have until quite recently been on the development of inter- and intraspecies hybrids and studies in cytogenetics, biochemical genetics and biotechnology including cell, chromosome and gene engineering. Very little research has been on quantitative genetics and genetic improvement through selection. The main reason is the shortage of courses in quantitative genetics and selection theory at fisheries colleges and universities. Consequently, the scientists have had little knowledge about the great potential for genetic improvement of aquaculture species through selective breeding.

Special characteristics of fish The very high fecundity and the possibility of collecting eggs and semen separately in many aquaculture species facilitates a wide range of mating designs, and allows very high short-term genetic gains through intense and accurate selection. On the other hand, the use of few breeding animals can lead to a rapid accumulation of inbreeding and therefore implementation of measures for restricting inbreeding is essential in fish nucleus selective breeding programs. In order to control inbreeding and to use information on relatives in selection decisions (and thus to increase accuracy of selection) genetic relatedness among the breeding candidates needs to be monitored. However, a specific problem in fish breeding programs is the difficulty of uniquely identifying individuals at hatching due to their small size. In most large scale programs this was solved by keeping fullsib families in separate units until the fish are large enough to be individually tagged, but to a relatively high cost. The separate rearing may also induce environmental effects common to the members of the same family which reduces the genetic gain. The application of DNA-markers (e.g. microsatellites) for parental assignment of individuals in mixed family groups can solve this problem, but the technology is still relatively expensive.

Opportunities and challenges The first large scale selective breeding program for farmed fish was set up for Atlantic salmon (and rainbow trout) in Norway in the nineteen seventies (Gjøen and Bentsen, 1997). Its design was based on basic knowledge in quantitative genetics, experiences from livestock breeding programs and available technologies. Full-sib families were reared separately until family identification was obtained by cold-branding and fin-clipping. With the exception of some improvements (e.g. individual tagging at a smaller size using PIT-tags), rather few changes have been taken place since then. Other family based programs for salmonids and also other species, developed mainly in the late nineteen eighties and nineties, have followed, to a large extent, the same breeding design. Presently, about 30 improvement programs that use sib information in the selection decisions are in operation in the word today involving nine different species.

The opportunities and challenges in designing sustainable fish breeding programs have been discussed in general terms (e.g. Gjerde *et al*., 2002), but studies on optimum designs are few and limited to programs that apply individual (mass) selection. The design of current programs is thus only partially based on well-defined scientific grounds and research is needed to adapt and develop new theory and tools to account for the special reproductive characteristics of fish species and their small size at hatching that make physical tagging not possible. In particular, research is required for determining how best 1) define optimum mating and selection decisions for maximising gain while restricting rate of inbreeding; 2) create sufficient connectedness between generations, sub-populations and cohorts in order to measure and monitor genetic levels and gain; 3) estimate and exploit non-additive genetic variance; 4) use DNA markers for genome wide selection; and 6) to efficiently disseminate the improved genetic material to the industry.

Interaction between cultured and wild fish Repeated cycles of reproduction and selection in captivity will inevitably result in genetic changes in the nucleus breeding population. This raises the concern of possible adverse impact of genetically improved escapees on wild strains. It is in all interest to prevent cultured fish from escaping, but no large-scale aquaculture operation can be regarded as completely escape proof. A limited gene flow from genetically well managed aquaculture strains into wild strains of the same genetic origin should be tolerated if the alternative is to ban selective breeding programs for aquaculture. As long as genetically improved strains are available somewhere, they will most likely find their way, legally or illegally, into aquaculture farms in the absence of improved local strains (e.g. Bentsen et. al., 1992).

Conclusions Genetic improvement programs are important to make farmers more competitive in future food markets. Highest priority should be given to the development of breeding programs for species with high present or future production. The breeding programs should be based on purebreeding (to capitalise on additive genetic effects) and utilise both individual and/or family information in selection of breeders. For less important economic species, simpler programs utilising only individual information primarily for growth should be initiated and later extended to more advanced programs if production increases. Crossbreeding (to capitalise on non-additive genetic effects) and sex and ploidy manipulation (Hulata, 2002) may be applied to further improve the productivity of the grow-out animals. Recent and future developments in molecular genetics present the possibility of using genotype selection for performance traits (either through marker assisted or genome wide selection. Methodology for efficiently integration of these technologies into classical selective breeding programs needs further investigation.

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ZNAČAJ I PRINCIPI GENETSKOG UNAPREĐENJA U AKVAKULTURI

Potreba za programima genetskog unapređenja. Visoki prinosi koji se dobijaju u akvakulturi oslanjaju se u ogromnoj meri na domestifikovane i genetski unapređene rase i podvrste. Do skora ovo nije bio slučaj za većinu gajenih vrsta u akvakulturi, koje su, u genetskom smislu, još uvek mnogo bliže divljim vrstama nego što je većina suvozemnih životinja i ratarskih kultura. Manje od 10 % ukupne svetske proizvodnje u akvakulturi se zasniva na unapređenim sojevima. Rast humane populacije i opadanje ulova ribe dovelo je do velike razlike između potrebe za povećanjem proizvodnje u akvakulturi i genetskog kvaliteta sojeva koji su na raspolaganju za povećanje proizvodnje. Povrh toga, puna korist investicije u unapređenje upravljanja u akvakulturi (hrana i načini ishrane, kvalitet vode, kontrola bolesti itd.) se jedino može dostići upotrebom genetski unapređenih životinja.

Potencijal za genetičko unapređenje. Mogućnosti genetskog unapređenja ekonomski važnih osobina dobro su dokumentovane za nekoliko vrsta riba (Gjedrem, 1997). Uopšteno, procene heritabilnosti za ekonomski važne osobine ribljih vrsta nalaze se u okviru vrednosti određenih za terestrične vrste, dok se pokazalo da je magnituda neaditivnih genskih efekata veća nego što se prethodno pretpostavljalo. Za stopu rasta, genetska dobit od oko 10 % od srednje vrednosti po generaciji je često prijavljivana ukazujući da se stopa rasta može udvostručiti u toku perioda od 7 do 8 generacija. Ovakve promene će značajno uvećati prihod od proizvodnje i efikasnost korišćenje resursa (hrana, zemljište, voda) te tako umanjiti troškove proizvodnje. Druga korist od genetskog unapređenja je razvijanje rasa sa boljim proizvodnim osobinama u korist i proizvođača i potrošača.

Istraživanje i obrazovanje. Većina genetskih istraživanja vrsta koje se gaje u akvakulturi u mnogim zemljama zasnivala su se do skora na razvijanju inter i intra specijskih hibrida, kao i studijama iz citogenetike, biohemijske genetike i biotehnologije uključujući ćelijski, hromozomski i genetski inženjering. Malo je bilo istraživanja iz kvantitativne genetike i genetskog unapređenja putem selekcije. Osnovni razlog je nedostatak kurseva iz kvantitativne genetike i teorija selekcije na visokoškolskim institucijama gde se izučava ribarstvo. Kao posledica, naučnici nemaju dovoljno znanja o ogromnom potencijalu za genetsko unapređenje vrsta koje se gaje u akvakulturi putem selekcije (selektivnog uzgoja).

Osobenosti riba. Veoma visoka plodnost i mogućnost odvojenog prikupljanja jaja i mleča od vrsta koje se gaje u akvakulturi omogućava širok raspon šema ukrštanja i dozvoljava veliku genetsku dobit u kratkom vremenskom roku kroz intenzivnu i preciznu selekciju. Sa druge strane, upotreba malog broja matica može brzo da dovede do aakumulacije efekata inbridinga (ukrštanja u srodstvu), tako da je implementacija mera za prevazilaženje inbridinga u središtu programa selektivnog uzgoja. U cilju kontrole inbridinga, ali i iskorišćavanja srodničkih odnosa u selekciji (a tako i u cilju povećanja preciznosti selekcije) genetička srodnost između kandidata za ukrštanje mora da se prati. Poseban problem u selekciji riba je poteškoća u identifikaciji individua prilikom izleganja, usled njihovih malih dimenzija. U većini velikih programa selekcije ovo se rešava čuvanjem sestrinskih familija u odvojenim jedinicama dok ribe dovoljno ne odrastu da budu tagovane (obeležene), i to se radi po relativno visokoj ceni. Posebno gajenje može da dovede do ispoljavanja sredinskog efekta kod članova iste familije što umanjuje genetsku dobit. Upotreba genetskih markera (na primer mikrosatelita) za određivanje roditeljskog porekla jedinki iz grupa izmešanih familija može da reši ovaj problem, ali je tehnologija još uvek relativno skupa.

Mogućnosti i izazovi. Prvi veliki program selektivnog uzgoja za gajenu ribu uspostavljen je za Atlanskog lososa i kalifornijsku pastrmiku) u Norveškoj sedamdesetih godina 20 veka (Gjøen and Bentsen, 1997). Dizajn ovog programa zasnivao se na osnovnom znanju kvantitativne genetike, iskustvu iz uzgoja stoke i tehnologiji koja je bila na raspolaganju. Sestrinske familije su gajene odvojeno do trenutka označavanja familija hladnim žigosanjem i obeležavanjem (zasecanjem) peraja (cold-branding and fin-clipping). Sa izuzetkom nekih poboljšanja kao što je individualno obeležavanje PIT čipovima, malo je izmena u metodi od tada učinjeno. Drugi programi zasnovani na selekciji familija kod salmonida i drugih vrsta, razvijeni krajem osamdesetih i devedesetih sledili su u velikoj meri isti dizajnuzgajanja . Trenutno u svetu postoji oko 30 programa unapređenja osobina koji koriste informacije o sestrinskim familijama u procesu selekcije za 9 različitih vrsta u akvakulturi. Mogućnosti i izazovi dizajniranja održivih programa selekcije riba razmatrani su načelno (e.g. Gjerde *et al*., 2002), ali i dalje nedostaju istraživanja u vezi optimalnog dizajna ukrštanja koja su ograničena na individualnu (masovnu) selekciju. Dizajn trenutnih programa je tako samo delimično zasnovan na dobro definisanoj naučnoj osnovi i neophodno je dalje istraživanje za prilagođavanje i razvijanje novih teorija i tehnika. Nove metode su neophodne za prevazilaženje specifičnih reproduktivnih karakteristika ribljih vrsta i nemogućnosti obeležavanja usled malih dimenzija jedinki. Neophodna su istraživanje radi određivanja kako najbolje: 1) definisati optimalno ukrštanje i selekcione odluke koje će uvećati genetsku dobit i umanjiti stopu inbridinga; 2) stvoriti dovoljnu povezanost između generacija, subpopulacija i kohorti da bi se izmerili genetski parametri i dobit; 3) proceniti i iskoristiti ne aditivnu genetsku varijansu; 4) upotrebiti DNK markere za selekciju genoma; 6) efikasno umnožiti i proslediti unapređen genetski materijal proizvođačima.

Interakcije između gajenih i divljih vrsta. Ponovljeni reproduktivni ciklusi i selekcija u uzgoju će neminovno rezultirati genetičkom promenom u nukleusu uzgojne populacije. Ovo izaziva zabrinutost o mogućem nepovoljnom uticaju genetiski unapređenih odbeglih jedinki na divlje sojeve. U interesu je svih strana je sprečavanje bežanja gajene ribe, ali nema velikih operacija u tom smislu. Ograničen genetski upliv u divlju iz genetski unapređenegajene sorte istog genetskog porekla može se tolerisati ukoliko je alternativa zabranaprograma selekcije u akvakulturi. Dokle god genetski unapređene sorte negde postoje, naći će svoj put do farmi riba, u nedostatku lokalnih sorti, legalno ili nelegalno (e.g. Bentsen et. al., 1992).

ZAKLJUČCI

Programi genetskog unapređenja su značajni jer povećavaju kompetitivnost farmera na budućem tržištu. Potrebno je dati veći prioritet razvoju uzgojnih programa selekcije za vrste sa viskom sadašnjom ili budućom proizvodnjom. Programi selekcije bi trebalo da budu zasnovani na iskorišćavanju aditivnog genetičkog efekta i korišćenju i individualnih i/ili informacija o familijama prilikom izbora matica. Za ekonomski manje važne vrste jednostavniji programi koji koriste samo informacije o individuama, uglavnom prirast, trebalo bi da ubuduće prerastu u naprednije programme, ukoliko dođe do povećanja proizvodnje. Ukrštanje radi iskorišćavanja neaditivnog genetskog efekta i pola i manipulacija ploidijom (Hulata, 2002) mogu se primeniti za dalje unapređenje produktivnosti životinja u uzgoju. Skorašnji i budući razvoj molekularne genetike predstavlja mogućnost upotrebe selekcije genotipova za proizvodne osobine, ili kroz upotrebu markera ili selekcije celog genoma. Metodologija efikasne integracije ovih tehnologija u klasične programe selekcije zahteva dalja istraživanja.