Innovation brief

Centre for Tropical Livestock Genetics and Health

CGIAR RESEARCH PROGRAM ON Livestock

Photo ILRI/Stefano Bianco

BIOBANKING AFRICAN POULTRY BREEDS FOR THE FUTURE

KEY MESSAGES

Previously, avian genetics have been unable to be cryopreserved, making these genetic resources untenable for biobanking initiatives – an essential way to conserve animal genetic diversity for the future.

A new research innovation utilizing Primordial Germ Cells (PGCs) allows for biobanking of avian genetic materials.

Use of sterile recipient birds as surrogates for the preserved genetic lines allows for efficient reproduction of the donor birds.

PGC collection and storage are transferable skills. Training of Trainers (ToT) workshops can efficiently scale this technology to make avian genetic biobanking possible across Africa.

Biobanked chicken material can be used to reintroduce a specific breed into production systems or to support research to isolate certain traits that can be introduced into existing chicken populations.

EXECUTIVE SUMMARY

As the world increasingly relies on a handful of chicken breeds in intensified systems, fewer indigenous breeds are kept in backyard chicken systems and on small farms. As indigenous breeds disappear, countries and researchers stand to lose access to adaptive genetic traits that have been developed over millennia.

The conservation of animal genetic resources through cryopreservation, referred to as biobanking, is an important component for the conservation and revival of rare or endangered species. While previously it was not possible to biobank avian genetic material, a recent scientific innovation using Primordial Germ Cells (PGCs) is changing the landscape and providing a way forward to preserve the biodiversity of African poultry breeds.

This innovation includes the development and use of chickens that are devoid of their own sperm or eggs as recipients of the biobanked germ cells. With the introduction of the PGCs into the growing 'sterile' chick, the chick then develops into a fertile animal, but only produces gametes (egg or sperm) that are genetically those of the donor chicken breed.

This process allows restoration of indigenous chicken breeds from biobanked material in a manner that supports the 3Rs–Reduction, Refinement, Replacement–and is animal welfare-friendly. Most importantly, the lab-based techniques developed as part of this innovation are teachable and transferable to partner institutions, thereby enabling countries across Africa to adopt chicken genetic resource biobanking.

INTRODUCTION

Over 1600 local chicken breeds have been identified globally (Eda 2021), of which 126 are in Africa (DAGRIS 2021). These breeds contain vast ranges of phenotypic and genetic diversity derived from the varied pathogenic, environmental and selection conditions under which these ecotypes were developed. Unfortunately, many of these local breeds are considered at risk due to the introduction and adoption of non-local breeds, the acceptance of intensive chicken production systems, changes in environment and disease conditions and adverse development policies.

To minimize this genetic erosion, it is essential to increase knowledge of local breeds and production systems, improve planning and raise awareness of the threat at the policy level. New innovations in genetic preservation technologies for chickens are also needed.

Conservation of poultry breeds and genetic lines pose particular challenges. One means of genetic diversity conservation in livestock species has been biobanking, whereby sperm, eggs or zygotes are preserved for future use. Cryopreservation of eggs and zygotes are not possible in avian species due to the large amount of lipid deposited in the female oocyte (Petitte 2006; Whyte and McGrew 2015). Other genetic preservation and propagation technics such as cloning using somatic cell nuclear transfer are not possible as embryo transfer cannot be done in avian species (Kjelland et al. 2014).

Recent developments by researchers from the International Livestock Research Institute and the Centre for Tropical Livestock Genetics and Health (CTLGH), at the Roslin Institute, University of Edinburgh in the UK, have shown that the isolation and freezing of PGCs from chicken embryos can provide a new approach for biobanking poultry material. Biobanking of these PGCs will have a significant role in the conservation of African poultry genetic resources; further adding safeguards against the population and diversity losses that could threaten a breed's survival (Hall 2013).

Photo ILRI/Stefano Bianco

Many local breeds are at risk due to adoption of non-local breeds, especially in intensive chicken production systems.

Photo ILRI/Mann

Local chicken breeds contain vast ranges of genetic diversity resulting from centuries of selection and adaption.

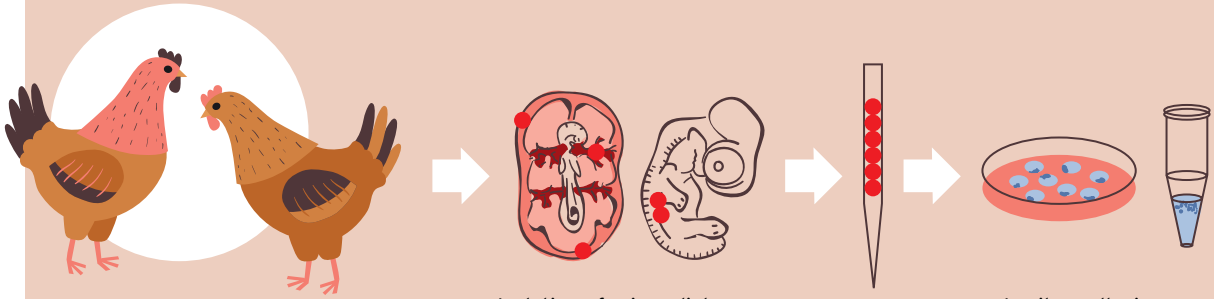
APPROACHES AND RESULTS

PGCs are specialized stem cells that can be isolated from chick embryos, which–depending on the sex of the individual embry–will eventually form a sperm or egg. Following isolation, these PGCs can be cultured and cryopreserved. Chickens are one of the few species from which PGCs can easily be propagated *in vitro* to increase cell numbers up to 100,000 cells from a single embryo in four weeks (Whyte et al. 2015) and these cells can easily be cryopreserved (Glover and McGrew 2012; Glover et al. 2013).

Biobanked chicken material is important in cases where a specific breed in the future is selected to be scaled up to useful production levels. The genetic material can also be used to support research to isolate certain traits that can then be introduced into existing chicken populations.

When these biobanked chicken genes are needed, the preserved PGCs can be transferred into a two-day-old 'recipient' chick embryo. Part of this PGC biobanking innovation is the development and use of sterile recipient chicks. Because the recipient two-day-old chick embryo is sterile it lacks its own PGCs, and this eliminates the need to manage the PGCs of the recipient bird. Implanted with biobanked PGCs, the recipient chick grows up into a fertile bird. These adult birds have only had their reproductive cells changed to the genetics of the donor bird and will now act as surrogate parents. The recipient birds will still look like and have the genetic components of their breed, but they will produce sperm or eggs that are genetically of the original biobanked donor breed implanted into them.

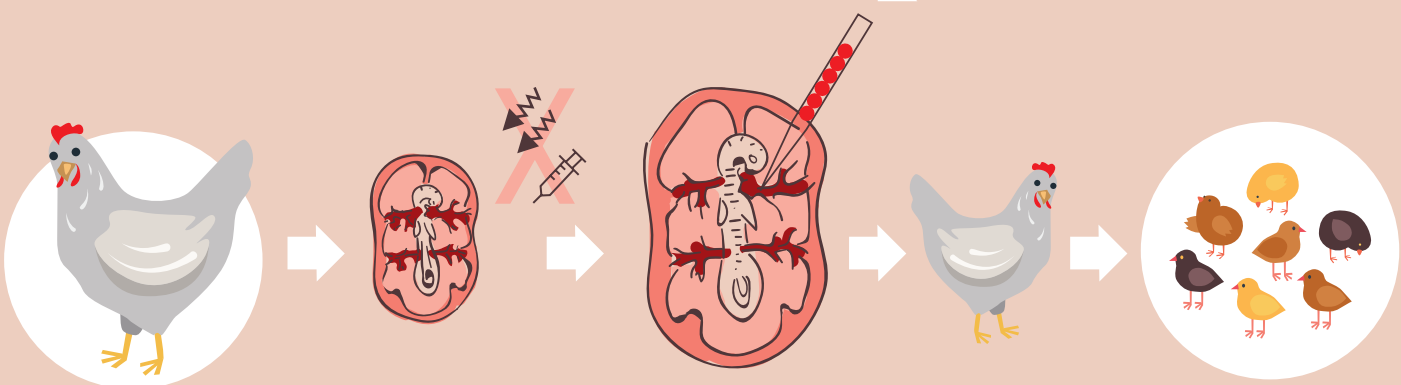
Our Innovative Approach



Local chicken donor

Isolation of primordial germ cells from the blood (cPGC) or from the gonads (gPGC)

In vitro culturing and freezing of the PGCs



Sterile recipient

Treatment of the recipient embryo with harsh chemicals eliminate recipient PGCs is **not needeed**

Injection of donor PGCs into the heart of the recipient embryo

Germline chimeras

Donor-derived chicks

The development of this PGC innovation has revolutionized the ability to preserve chicken genetics. So far at ILRI-Nairobi, a total of 675 individual genotypes from 15 distinct African indigenous chicken ecotypes have been biobanked.

These include:
- **Kenya: 7 ecotypes and 337 PGC lines**
- **Tanzania: 5 ecotypes and 236 PGC lines**
- **Ethiopia: 3 ecotypes and 102 PGC lines**

Photo ILRI/Christian Tiambo

Training of Trainers (ToT) on Reproduction Technologies for Cryoconservation of African Animal Genetic Resources, 16-20 July 2019, ILRI-Nairobi, Kenya

Photo ILRI/Christian Tiambo

ToT on Technologies for the Promotion of Local Poultry Value Chain in Africa, 16-20 November 2020, Douala-Cameroon

Our Innovative Approach (continued)

Photo ILRI/Christian Tiambo

ToT on Technologies for the Promotion of Local Poultry Value Chain in Africa, 6-10 April 2021, Kinshasa-Democratic Republic of Congo

Photo ILRI/Christian Tiambo

Training of KALRO Staff on Kenyan chicken biobanking at the Reproductive Technology lab, CTLGH-ILRI Nairobi

Along with the active biobanking of these ecotypes and PGC lines, this innovation is being scaled up through active knowledge transfer. With logistical support from the African Union-Inter African Bureau for Animal Resources (AU-IBAR), the technology is being transferred to African scientists through Training of Trainers (ToT) workshops. Three such workshops have already been run in Kenya (July 2019), Cameroon (November 2020) and the Democratic Republic of Congo (April 2021).

These workshops have led to increased knowledge of the role and importance of locally adapted chicken breeds and fostered greater understanding of the need for indigenous breeds conservation. The Kenyan Agricultural and Livestock Research Organization (KALRO) has already embraced the technology for the conservation of indigenous chicken ecotypes and plan to use it to sustain the development of the kinyeji chicken breeding programme. Further collaboration with KALRO is creating opportunities for greater upscaling and uptake by National Research Systems across Africa.

Prime beneficiaries of this innovation are the African National Agricultural Systems (NARS), which will have the capability and technology to cryopreserve all avian genetic resources. Similarly, this avian genetic biobanking could benefit other stakeholders in poultry value chains worldwide. Scientific and research communities, as well as public and private breeding organizations will have access genetic to material from biorepositories across Africa. However, further work is needed to support countries to enforce regulations outlined in the Nagoya Protocol related to the fair and equitable sharing of benefits arising from the utilization of genetic resources.

CONCLUSION

An extensive indigenous breed avian PGC biobank will not only support research and development to prevent problems with inbreeding and preserve at risk poultry breeds but also reduce the large number of live animals needed to be kept for research across the world. It could also have an important role within poultry breeding companies to maintain important parental lines of mainstream poultry breeds used in commercial poultry production without the need to keep large populations of live birds.

Having cracked the difficult problem of chicken biobanking, this new innovation of PGC preservation, coupled with sterile surrogate use, will revolutionize the preservation and future use of diverse chicken genetics.

Photo ILRI/J.Bruno

Biobanking local chicken breeds can play a significant role in the conservation of African poultry genetic resources, safeguarding against population and diversity losses that can threaten a breed's survival.

IMPLICATIONS AND RECOMMENDATIONS

Considering the high demand coming from various NARS, future project activities should be scaled up in Africa and Asia through collaboration with the AU-IBAR and the ILRI-led Tropical Poultry Genetics Solutions (TPGS) program. Several countries in Central and West Africa have already identified the poultry value chain as their priority for development under the Live2Africa Project of AU-IBAR, which was to support the biobanking through the regional gene banks. Other countries like Kenya and Uganda have also shown interest.

It is further recommended that the technology be used by the Animal Seed Working group of the African Seed and Biotechnology Partnership Platform; a continental program led by the African Union Commission that frames the development of the seed sector in Africa through improved decision making and policy formulation, supporting evidence-based advocacy, and enhanced knowledge sharing.

The critical factors of success of this initiative will be:

- The effective operationalization of the regional gene banks implemented by the genetic project of AU-IBAR,
- Continuous support from donors and investors for spearheading research,
- A harmonized legal framework for access to poultry genetic resources and knowledge sharing.

Acknowledgements

This research was funded in part by the Bill & Melinda Gates Foundation and with UK aid from the UK Foreign, Commonwealth, and Development Office (Grant Agreement OPP1127286) under the auspices of the Centre for Tropical Livestock Genetics and Health.

It was also conducted as part of the ILRI-led CGIAR Research Program on Livestock, which is supported by contributors to the CGIAR Trust Fund: https://www.cgiar.org/funders/.

Special recognition is made the to CTLGH's reproductive technology and precision breeding programme:

Steve Kemp
Yao-Jing Yue
Charity Muteti
Nakami Wilkister
Moses Ogugo
Christian K. Tiambo
Pauline Kibui
Bruce Whitelaw
Mike McGrew
Simon Lillico
Maeve Ballantyne
Tuan Jun Hu

References

Domestic Animal Genetic Resources Information System (DAGRIS). http://dagris.ilri.cgiar.org/species. (Accessed 9 September 2021).

Eda, M. 2021. Origin of the domestic chicken from modern biological and zooarchaeological approaches. *Animal Frontiers* 11 (3): 52-61 https://doi.org/10.1093/af/vfab016.

Glover, J. D., McGrew, M. J. 2012. Primordial germ cell technologies for avian germplasm cryopreservation and investigating germ cell development. *Journal of Poultry Science* 49 (3): 155-162.

Glover, J. D., Taylor L., Sherman A., Zeiger-Poli C., Sang H. M., and McGrew M. J. 2013. A novel piggybac transposon inducible expression system identifies a role for Akt signaling in primordial germ cell migration. *PLOS ONE* 8 (11): e77222. http://doi.org/10.1371/journal.pone.0077222.

Hall, S. J. G. 2013. Defra Project Report GC0146: Development of coordinated in situ and ex situ UK Farm Animal Genetic Resources conservation strategy and implementation guidance. (unpublished report)

Kjelland M.E., Romo S. and Kraemer D. 2014. Avian Cloning: Adaptation of a Technique for Enucleation of the Avian Ovum. *Avian Biology Research* 7 (3): 131-138. https://doi.org/10.3184/175815514X14065426847114.

Petitte J. N. 2006. Avian germplasm preservation: Embryonic stem cells or primordial germ cells? *Journal of Poultry Science* 85 (2): 237-242. http://doi.org/10.1093/ps/85.2.237.

Whyte J. B. E., and McGrew M. J. 2015. *Increased Sustainability in Poultry Production: New Tools and Resources for Genetic Management*. In: Burton, E., Gatcliffe, J., O'Neill, H. M. and Scholey, D. Sustainable poultry production in Europe. UK: CABI Publishing. 214. http://doi.org/10.1079/9781780645308.0214.

Whyte J. B.E., Glover J. D., Woodcock M., Brzeszczynska J, Taylor L., Sherman A., Kaiser P., and McGrew M. J. 2015. FGF, insulin, and SMAD signaling cooperate for avian primordial germ cell self-renewal. *Stem Cell Reports* 5 (6): 1171-1182. http://doi.org/10.1016/j.stemcr.2015.10.008.

CONTACTS

Christian K. Tiambo
C.Tiambo@cgiar.org
ILRI

Mike McGrew
mike.mcgrew@roslin.ed.ac.uk
The Roslin Institute, University of Edinburgh