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Unlocking animal genetic resources for enhanced productivity: The power lies in the genes

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Abstract

This article underscores the glaring divide in the application of animal breeding science between developed and developing countries, shedding light on the success of developed countries in leveraging breeding techniques for sustainable productivity and robust livestock industries. In contrast, developing countries grapple with challenges in recognizing the value of animal genetics as a transformative science to optimize their livestock production. Beyond the conventional barriers such as feed scarcity, high prices, and climate shifts, commonly attributed to poor livestock productivity in developing nations, the crux of the issue lies in the misconceptions surrounding genetics. The article contends that a comprehensive understanding of within-breed variation is pivotal to assess and appreciate animals based on their genetic potential, emphasizing that genes, not phenotypes, drive progress across generations. To address these challenges, specific breeding measures are advocated, and collaborative organizations among livestock owners are deemed essential. However, the scarcity of animal breeders, well-versed in classical genetics, poses a significant hurdle. Despite global initiatives from international and regional organizations, impactful change at the grassroots level remains limited. While acknowledging the transformative role of the digital revolution, it underscores the enduring value of traditional hands-on workshops, especially in pilot projects with local communities and large-scale farmers. For nations lacking established genetic improvement programs, adopting FAO guidelines is advised as a prudent starting point. In essence, the article advocates a holistic approach to bridge the gap and foster inclusive development in the realm of animal breeding science.

Keywords: Genetics; Productivity; Breeds; Gap

1. Introduction

Embarking on my journey as an Emeritus Professor, I am eager to delve into forthcoming publications that will intricately analyze the advancements and challenges within the expansive field of animal genetics. This exploration will span not only national but also regional and global dimensions. Reflecting on the nascent stages of my career, when I emerged as a freshly minted PhD graduate in Animal Breeding from Iowa State University in 1985, I proudly contributed to the scientific landscape by the development of a groundbreaking threshold sire model, as documented in [1]. This model, later introduced for US genetic evaluation in 1988 [2], left a lasting impact on the field [3]. Fueling my enthusiasm, this milestone prompted my return to Tunisia, my homeland, where I wholeheartedly embraced the role of an Assistant Professor. In this capacity, I engaged passionately in both teaching and research, setting the stage for a lifelong commitment to advancing our understanding of animal genetics.

At the outset, I seized the opportunity to initiate two groundbreaking Master's degree courses tailored for aspiring animal science students. Given Tunisia's commitment to a national program on animal identification and recording, particularly in dairy cattle and small ruminants, my research naturally gravitated towards practical applications. The

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task at hand was to lay the foundation for genetic studies, starting essentially from "scratch." This involved estimating genetic parameters for key economic traits and unravelling the influence of non-genetic factors and the environment on pivotal metrics such as milk yield, fat and protein percentages in dairy cattle, and, similarly, weights and weight gains in meat sheep [4,5,6]. In collaboration with dedicated graduate students pursuing their Master's and later, PhD degrees, I successfully developed sophisticated Genetic Evaluation Models. Leveraging advanced methodologies like the BLUP Animal Model, we made significant strides in predicting Animal Breeding Values for dairy cows and meat sheep [7,8,9]. This collaborative effort not only facilitated a deeper understanding of genetic intricacies but also contributed valuable insights to the enhancement of animal breeding practices in Tunisia and beyond [10,11,12,13].

With the accumulation of experience and knowledge, a compelling imperative emerged to disseminate my research findings, experiences, and perspectives among diverse stakeholders in the livestock sector, particularly livestock owners and official technical extension services. This commitment ran concurrently with my involvement in regional and international activities, whether as an invited expert or a representative of my country in organizations dedicated to the conservation and sustainable use of animal genetic resources [10,11,12,13].

Reflecting on nearly four decades of professional history, I find a sense of accomplishment in my contributions to my country. This includes empowering human resources in the field of animal genetics, rescuing a threatened native dairy sheep breed from the brink of extinction, and spearheading the establishment of Tunisia's inaugural Gene Bank encompassing plants, animals, and microorganisms [14,15]. However, as I survey the landscape of our achievements, challenges persist. Despite progress, our animal productivity remains suboptimal, with native breeds crossed at random with imported exotic breeds. The application of animal breeding as a science is not yet fully realized, resulting in the absence of coherent breeding strategies which led to poor productivity and threatened native breeds [14,15,16,17]. This paper seeks to elucidate these shortcomings, offering a critical analysis of where the implementation of animal genetics has faltered and highlighting areas requiring deeper understanding and precision hoping to find catalytic actions.

2. Reasons for failure in implementing animal genetics

2.1. Within breed variation: An underestimated reservoir of genes

One of the pivotal concepts in animal biology, particularly concerning gene expression and the influence of the environment on the development and performances of domestic animals, revolves around trait variation. The efficacy of animal breeders hinges on their adept evaluation of this variation. Employing genetic methods and principles, animal breeders (scientists) can dissect the overall phenotypic variation into its two primary components: genetic and environmental. In essence, animals of the same breed reared in identical environments exhibit distinct performances. These divergent performances are indicative of the normal distribution of measured traits. It follows that animals within a breed necessitate individual evaluation in comparison to their herd or flock mates. Regrettably, this fundamental concept often goes overlooked by other animal specialists, leading to misguided counsel for herd or flock managers. These advisors may erroneously assert that unlocking genetic potential within a given breed merely requires optimal feeding. Such a perspective treats the breed as a singular entity rather than recognizing it as a composite of individual differences. This oversight has led in the majority of developing countries, with no or only a few academic animal breeders, to suboptimal breeding practices and hinder the realization of the full genetic potential within a population [10]. This is a reality in the majority of developing countries relating any animal performance to feeding while the main secret is in the animal genes.

2.2. Population dynamics: Culling and replacements lack optimization

A fundamental characteristic of animal populations lies in their dynamic nature. Herds or flocks are in a perpetual state of flux, never static. The continuous cycle involves the removal of animals due to sickness, reproductive failures, or low production (culling), coupled with the introduction of younger replacement females (replacements). This process unfolds annually. The hallmark of accomplished herd or flock managers is their ability to optimize the culling and replacement operations, a task contingent upon the accurate assessment of the real genetic values of their animals, commonly referred to as Breeding Values. The seamless execution of these operations relies on precise animal identification, meticulous performance recording, and robust genetic evaluation procedures that take into account various sources of variation, make adjustments for non genetic differences and predict animal real breeding values or genetic potential [8,9,10,18]. These essential components collectively form the backbone of a successful strategy for managing animal populations or breeds and generate a cumulative genetic responses for a sustainable productivity.

Presently, a stark contrast emerges when comparing animal productivity across global regions, underscoring the significant impact of embracing animal breeding as a tool for enhancing breed productivity. A compelling illustration of

this phenomenon is evident in the domain of dairy cattle. Notably, there exists a noticeable disparity between developed countries and the rest of the world. In developing nations, the struggle to augment milk production is often characterized by an increase in cow numbers, resulting in elevated feed expenses and a surge in greenhouse gas emissions. In contrast, advanced countries are steering toward a paradigm marked by a reduction in animal numbers and a concurrent rise in yields per animal, reflecting an upward trajectory in productivity. Figure (1) vividly illustrates this trend, highlighting that although India produces more milk through cow numbers, its cattle productivity lags behind. In North America and Europe, the forefront of global dairy cattle productivity is evident [19].

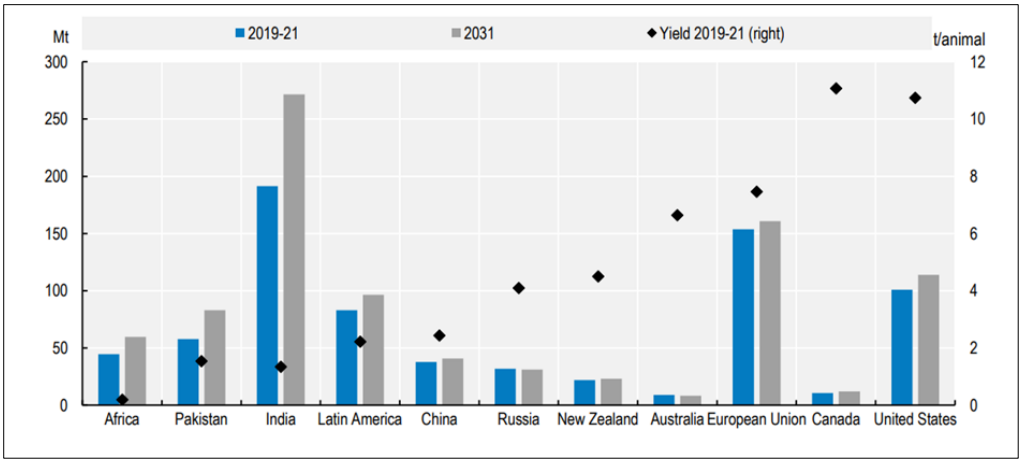

Figure 1 Milk production and milk yield in selected regions

2.3. Lack of a critical mass in Scientific animal breeders

A promising avenue for further exploration lies in a comprehensive study investigating the correlation between the number of professional animal breeders and animal productivity, categorized by region or country. An initial conjecture suggests that low productivity countries likely harbor a scarcity of genuine animal breeders, and if present, their full potential is not utilized. Delving into this dynamic could provide valuable insights into the factors influencing animal productivity on a global scale.

It is essential to highlight that animal breeding, as a scientific field, encompasses Mundelein genetics, population genetics, quantitative genetics, and the burgeoning field of genomics. This multidisciplinary approach involves the application of statistical models, intricate equations, and advanced programming. Unfortunately, a predominant number of animal science students tend to gravitate toward less mathematically intensive disciplines, such as nutrition, forage production, or livestock management. This inclination translates the weak capacity of developing countries to implement reliable breeding strategies. A challenge is becoming difficult to win as many recently trained PhDs in animal genetics find themselves specialized solely in genomics, neglecting the holistic spectrum of genetic principles crucial for sustainable breeding strategies. The broader integration of various genetic types is pivotal for advancing comprehensive and effective animal breeding practices.

2.4. Lack of sustainable breeding strategies

Developed nations have significantly enhanced animal productivity through effective livestock management, advanced feeding practices, optimal nutrition, and, notably, the power of genes translated in their advancements in genetics. In stark contrast, many developing countries grapple with persistent challenges across these dimensions, resulting in consistently low breed productivity. The blame is often attributed to feed scarcity and the impact of climate change. In response to the pressing demand for livestock products, policymakers in these regions opted for a shortcut by importing exotic, high-yielding breeds, whether in the form of live animals or semen. Although these imports partially addressed local demands, their incorporation in crossbreeding initiatives, particularly in cattle, has had detrimental consequences, leading to genetic erosion and the loss of crucial genes related to adaptation and disease resistance [20]. A significant contributing factor to this situation was the underestimation of the potential of animal genetics in enhancing overall productivity. This oversight hindered the adoption of essential practices such as animal identification, performance recording, genetic evaluation, the dissemination of superior genes, and the implementation of well-planned crossbreeding programs. Recognizing the pivotal role of animal genetics is crucial for sustainable improvements in breed productivity and ensuring the resilience of local breeds. A focus should be given to establishing suitable breeding strategies even under low input production system to value the variation within and across breeds.

In light of the escalating global loss of biodiversity, particularly within animal species, the international community convened in Rio De Janeiro, Brazil, in 1992, culminating in the signing of the Convention on Biological Diversity (CBD) [21]. Subsequently, specific United Nations international organizations were tasked with spearheading global strategies to enhance the conservation and sustainable utilization of Animal Genetic Resources (AnGRs), beginning in the early 2000s [10]. Despite noteworthy progress, evidenced through the issuance of guidelines, the implementation of training programs, and comprehensive data collection, a critical evaluation study is essential to measure the true impact of these efforts and the substantial funds allocated with a special focus on AnGRs and building capacity in the majority of developing countries. My experiences underscore the importance of effective lobbying, within certain international organizations potentially limiting the ability of representatives to advocate for their countries' and regions' interests. It is crucial to recognize that these international bodies may harbor lobbies that advocate for specific interests, potentially constraining representatives from robustly defending their countries' unique needs. Without the active engagement of competent human resources empowered to vocalize genuine national and regional requirements, there is a risk of significant losses both at the international and country levels. A comprehensive awareness of these dynamics is imperative to fortify endeavors aimed at conserving and sustainably utilizing animal genetic resources.

2.5. Pathways to speed up developing countries capacities in conservation and breeding strategies

Improving animal productivity is a paramount objective, and it requires a dual focus: firstly, on a continual basis and secondly, by recognizing and harnessing within-breed variations annually. This necessitates the implementation of specific breeding measures. Fundamental to this process are the practices of animal identification, performance recording, and genetic evaluation, enabling the mating of the best with the best. In addition to these technical components, livestock owners should collaboratively form organizations that facilitate the promotion of their breeds and the exchange of crucial information. Adopting suitable breeding selection schemes is imperative, contingent upon the prevailing circumstances, including community-based breeding or participation in a genetic improvement enterprise collaborating with a breed association. Developed countries have been leaders in their animal genetic improvement programs and they are now exploring and valuing genomics [18,22].

For countries lacking established genetic improvement programs, it would be prudent to draw inspiration from the guidelines provided by the Food and Agriculture Organization (FAO), referred to, in this article, as the Livestock Populations Governance Model. By aligning with such frameworks, nations can establish robust structures to systematically enhance their animal conservation and sustainable use practices, fostering sustainable improvements in productivity.

3. Adoption of livestock populations governance model

3.1. Conducting inventories and breed characterization

The first step of this animal governance model is to start by conducting comprehensive inventories to meticulously identify the diverse range of animal species present in the country. This comprehensive approach extends to the detailed exploration and documentation of production systems associated with each identified species. Once identified, an in-depth characterization of these breeds, incorporating both phenotypic and genetic dimensions, will serve as a crucial tool for disentangling the complexities within the animal genetic landscape. By making finer distinctions between breeds that might share visual similarities but possess distinct genetic profiles, this methodological precision aids in preventing misclassifications and ensures accuracy in breed identification.

This meticulous process is not merely an academic exercise; rather, it plays a pivotal role in informed decision-making. Through the lens of these detailed inventories and characterizations, countries are empowered to evaluate the risk status of various breeds. This evaluation is carried out with a methodological rigor aligned with the criteria set forth by the Food and Agriculture Organization [23]. As a result, nations can proactively manage and safeguard their animal genetic resources, fostering sustainable practices and contributing to the broader global effort in biodiversity conservation.

3.2. Conservation

Preserving breeds identified as at risk is imperative for the biodiversity of our planet. Various animal conservation methods are implemented globally, with a prominent approach being *Ex- situ* conservation, primarily through well-established gene banks. This method encompasses the preservation of genetic material such as semen, tissue, ova, and embryos, as well as maintaining live animals in reserves or zoos. According to a study by Harvey et al. [24], gene banks are operational in over 50 countries, spanning diverse geographic regions. Their findings reveal a global collection

exceeding 34,000 animals and over 3,300,000 units of germplasm/tissue across different species. Notably, the United States leads with 38 conserved species, followed by Brazil (12), and Canada and France with 9 species each.

Despite the establishment of gene banks in some developing countries, their capacity to effectively manage them remains suboptimal. In this context, a combination of *In-Situ* conservation methods for breeds at risk and the preservation of genetic material, such as semen, could be viable strategies. The concept of Regional Gene Banks emerges as an economical approach to animal conservation, encouraging countries to pool financial resources and leverage a critical mass of human expertise for collaborative efforts. This collaborative model not only promotes effective management of genetic resources but also enhances the overall conservation impact by fostering international cooperation [13].

3.3. Sustainable use

When determining the sustainable utilization of an identified breed, two key approaches come to the forefront: "selection" and "crossbreeding." The choice between these directions hinges on specific considerations. The "selection" path is preferred when there exists significant within-breed variation, particularly in terms of genetic types. In such cases, collaboration between breeders, breed owners, and policymakers is crucial. Together, they deliberate on which traits should be prioritized for selection typically those with a high heritability and economic significance. To facilitate this process, an effective program for animal identification and performance recording is established. This program enables the computation of animals' breeding values, forming the basis for a well-structured breeding scheme. Superior genes are then disseminated within the breed, promoting the enhancement of desirable traits [22,23,25,26].

Conversely, when the goal is to leverage the complementarity among distinct breeds, well-planned crossbreeding programs become essential. In these instances, a thoughtful and strategic approach to crossbreeding is employed to ensure that the resulting combinations bring out the desired traits and characteristics. Ensure dedicated efforts towards safeguarding a proportion of local genes when breeding exotic and native genotypes.

In both scenarios, collaboration and communication among stakeholders, including breeders, owners, and policymakers, play a pivotal role in determining the most appropriate course of action for the sustainable use of the identified breed. This holistic approach, unusually followed by the majority of developing countries, ensures that the selected direction aligns with the specific characteristics of the breed and contributes to the overall goals of conservation and sustainable breeding practices.

3.4. Training, education and technology transfer

Undoubtedly, the widening gap between developing countries in the field of animal genetics utilization and conservation is a pressing concern. Despite the United Nations' global strategies led by the Food and Agriculture Organization (FAO) to provide technical and financial support to countries in need, their impact at the grassroots level, particularly among breeders and livestock owners, remains limited. Closing this gap is not only essential but also feasible through strategic investments in training, education, and technology transfer. The digital revolution has revolutionized training methodologies, enabling the online education of thousands. However, traditional hands-on workshops remain invaluable, especially when conducting pilot projects on effective breeding strategies with local communities and large-scale farmers.

The transfer of methods for predicting animal breeding values is within reach, and organizing workshops on animal identification, data recording, and Artificial Insemination is both practical and achievable. Simplifying breeding schemes is a viable option, contingent upon securing adequate funding. These proposed pathways, if given priority, have the potential to empower developing countries in optimizing their animal genetic resources, thereby enhancing productivity, ensuring food security, and fostering increased incomes for improved livelihoods. To bring these proposals to fruition, collaboration among international and regional funding agencies, as well as regional livestock development bodies, is crucial. Their concerted efforts, in partnership with member countries, can pave the way for the implementation of these initiatives. Moreover, fostering exchanges of experiences among livestock owners, technicians, and policymakers within regions will create a fertile environment for the transfer of suitable, low-input solutions. This collaborative approach will play a pivotal role in advancing the goals of enhancing agricultural practices and ensuring sustainable development.

4. Conclusion

The existing disparity between developing and developed countries in animal productivity has undeniably widened. Developed countries have remained limited to conventional methods to improve production, primarily focusing on

feeding practices or expanding animal populations. Unfortunately, there is a tendency to overlook the genetic potential and variation within breeds, with the misconception that optimal feeding alone can unlock the desired potential. This approach neglects the fact that genetic potential resides in the within breed variation and also in the need for appropriate breeding strategies. Regrettably, sustainable breeding practices are often neglected, and many countries resort to relying on exotic breeds or random crossbreeding. The scarcity of skilled animal geneticists further compounds this issue, as their voices are often drowned out both nationally and in international organizations due to their limited critical mass. It is imperative to prioritize proposed pathways that, if given due attention, possess the capacity to empower developing countries. These pathways focus on optimizing their animal genetic resources, thereby elevating productivity levels, ensuring food security, and ultimately boosting incomes for improved livelihoods. By recognizing and investing in sustainable breeding strategies, countries can bridge the productivity gap and pave the way for a more equitable and prosperous future.

References

[1] M. Djemali, P. J. Berger, A. E. Freemen, 1987. Ordered Categorical Sire Evaluation in Holsteins. J Dairy Sci 70:2374-2384

[2] C. P. Van-Tassel,G. R. Wiggans, I. Misztal,1988. Implementation of a Sire-Maternal Grandsire Model for Evaluation of Calving Ease in the United States, J. Dairy Sci. 86:3366–3373.

[3] C.M.B. Dematawewa and P. J. Berger, 1997. Effect of Dystocia on Yield, Fertility, and Cow Losses and an Economic Evaluation of Dystocia Scores for Holsteins. J Dairy Sci 80:754–761.

[4] M Djemali, R Aloulou, M Ben Sassi, 1994. Adjustment factors and genetic and phenotypic parameters for growth traits of Barbarine lambs in Tunisia. Small Ruminant Research, 13:41-47.

[5] M. Djemali and P.J. Berger, 1992. Yield and Reproduction Characteristics of Friesian Cattle Under North African Conditions. J Dairy Sci 75:3568-3575.

[6] S. Bedhiaf Romdhani, M. Djemali, 2006. New genetic parameters to exploit genetic variability in low input production systems. Livestock Science 99:119 – 123.

[7] M. Djemali, P.J. Berger et M. Miladi. 1992. Contrôle de performances et amélioration génétique en Tunisie. EAAP Publication N° 47:97-107.

[8] P. J. Berger, 1992. Genetic evaluation-of dairy cattle. EAAP Publication N°47:97-107 108-119.

[9] Bedhiaf, S. et M. Djemali, 1998. Evaluation génétique des ovins à viande par le modèle animal. Ann. INRAT Volume 86, 2013:93-138.

[10] FAO, 2007. The State of the World's Animal Genetic Resources for Food and Agriculture, FAO Publication, Rome.

[11] AU-IBAR, 2019. The State of Farm Animal Genetic Resources in Africa. AU-IBAR publication.

[12] The EAAP Mediterranean Working Group:https://www.eaap.org/working-groups/Mediterranean.

[13] C Ligda, D Tsiokos, G Hadjipavlou, M Djemali, M Fadili, E Charvolin-Lemaire, E Sturaro, 2022. Documenting animal genetic resources in the Mediterranean: interaction and cooperation in the region. Options Méditerranéennes, A, no. 129 :49-58.

[14] M'Naouer Djemali et S. Bdhiaf. 2010. Setting Up A Cryobank In Developing Country: Lessons To Be Learned. https://www.researchgate.net/publication/320765835.

[15] M. Djemali, S. Bedhiaf-Romdhani, L. Iniguez, I. Inounouc, 2009. Saving threatened native breeds by autonomous production, involvement of farmers organization, research and policy makers: The case of the Sicilo-Sarde breed in Tunisia, North Africa. Livestock Science 120: 213–217.

[16] Djemali M. and Hamrouni A., 2019. Ingredients and Pathways for Sustainable Sheep Breeding Strategies under Low Input Production Systems: The Example of Two Distinct Sheep Breeds. Journal of Veterinary Science & Animal Husbandry. www.annexpublishers.com.

[17] Yousra Ben Sassi-Zaidy, Aziza Mohamed-Brahmi, Melek Chaouch, Fabio Maretto, Filippo Cendron, Faouzia Charfi-Cheikhrouha, Souha Ben Abderrazak, Mnaouer Djemali, and Martino Cassandro, 2022. Historical Westward Migration Phases of Ovis aries Inferred from the Population Structure and the Phylogeography of Occidental Mediterranean Native Sheep Breeds. Genes 2022, 13, 1421.

[18] J. B. Cole and P. M. VanRaden, 2018. Symposium review: Possibilities in an age of genomics: The future of selection indices. J. Dairy Sci. 101:3686–3701.

[19] OECD/FAO (2022), OECD-FAO Agricultural Outlook 2022-2031, OECD Publishing, Paris, https://doi.org/10.1787/f1b0b29c-en.

[20] M'N. Djemali, 2020. Dairy Livestock Value Chains North Africa. AU-IBAR Regional Report.

[21] The United Nations Environment Programme Secretariat for the Convention on Biological Diversity, 2011. Convention on Biological Diversity, text and Anexes.

[22] Ajmone-Marsan, P., Boettcher, P.J., Colli, L., Ginja, C, Kantanen J. & Lenstra, J.A., eds, 2023. Genomic characterization of animal genetic resources – Practical guide. FAO Animal Production and Health Guidelines No. 32.

[23] FAO, 2007. Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration, FAO Publication, Rome..

[24] S. R. Paiva, C. McManus, H. Blackburn. 2014. Conservation of Animal Genetic Resources: the Next Decade. Proceedings, 10th World Congress of Genetics Applied to Livestock Production.

[25] M Djemali, and J Wrigley, 2002. Tailoring genetic improvement to meet the overall livestock development objective.

[26] FAO. 2010. Breeding strategies for sustainable management of animal genetic resources. FAO Animal Production and Health Guidelines. No. 3.