Review [Revisión]

RABBIT: AN ANIMAL AT THE NEXUS OF FOOD PRODUCTION AND BIOSCIENCE RESEARCH FOR SUSTAINABLE DEVELOPMENT IN DEVELOPING COUNTRIES †

[CONEJO: UN ANIMAL EN EL NEXO DE LA PRODUCCIÓN DE ALIMENTOS Y LA INVESTIGACIÓN DE LA BIOSCIENCIA PARA EL DESARROLLO SOSTENIBLE EN LOS PAÍSES EN DESARROLLO]

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SUMMARY

Background. Malnutrition is the biggest problem currently threatening human wellbeing across the world directly affecting one-third of people and occurring in many forms. In developing countries, it expresses itself via stunted growth in children, diseases occurrences and deficiency of vital nutrients required for normal physiological functions. In the perspective of animal production, addressing poor animal protein intake by increasing supply of meat for consumption is a viable option for fighting the menace of malnutrition. **Main findings** This paper identified malnutrition and hunger as major problems in developing countries and suggested rabbit production as cheaper alternative for increasing protein supply because rabbit production is cheap and can supply affordable meat, it has short gestation interval hence it has potential for high yield per production period, it has superior meat quality and require minimal capital investment for its production compared with other animal production units. **Implications.** Apart from its roles in food supply; rabbit has strong relevance in bioscience research as model animal in studying pathophysiology of diseases and metabolic dysfunctions of man because of its genetical and physiological closeness to humans. **Conclusion.** This paper summarized and made cases for re-introduction of rabbit as micro-livestock for meat production and it use as model animal in biological research investigations.
Keywords: Malnutrition; rabbit production; developing countries; rabbit; biotechnology.

RESUMEN

Antecedentes. La desnutrición es el mayor problema que actualmente amenaza el bienestar humano en todo el mundo, afecta directamente a un tercio de las personas y se presenta de muchas formas. En los países en desarrollo, se expresa a través del retraso en el crecimiento de los niños, la aparición de enfermedades y la deficiencia de nutrientes vitales necesarios para las funciones fisiológicas normales. Desde la perspectiva de la producción animal, abordar la ingesta deficiente de proteínas animales mediante el aumento de la oferta de carne para el consumo es una opción viable para combatir la amenaza de la desnutrición. **Hallazgos principales**. Esta revisión identificó la desnutrición y el hambre como problemas importantes en los países en desarrollo y sugirió la producción de conejos como una alternativa más barata para aumentar el suministro de proteínas porque la producción de conejos es barata y puede suministrar carne asequible, tiene un intervalo de gestación corto, por lo que tiene potencial para un alto rendimiento por producción. período, tiene una calidad de carne superior y requiere una mínima inversión de capital para su producción en comparación con otras unidades de producción animal. **Implicaciones.** Aparte de sus funciones en el suministro de alimentos; El conejo tiene una gran relevancia en la investigación de biociencias como animal modelo en el estudio de la fisiopatología de enfermedades y disfunciones metabólicas del hombre debido a su cercanía genética y fisiológica a los seres humanos. **Conclusión.** Este documento resumió y presentó casos para la reintroducción del conejo como micro-ganado para la producción de carne y su uso como animal modelo en investigaciones de investigación biológica.
Palabras clave: Desnutrición; producción de conejos; países en desarrollo; Conejo; biotecnología.

† *Submitted July 25, 2019 – Accepted August 7, 2020.*
ISSN: 1870-0462.

INTRODUCTION

Malnutrition is a major food crisis in developing countries; intake of animal protein is 4.5 g *per capita* daily which is very low compared with the minimum global requirement of 35 g *per capita* daily (FAO, 2015). In Nigeria for example, more than 11 million children under 2 years old are malnourished and stunted due to poor nutrition – a situation which require strategic active solutions (USAID, 2018). Similarly, in India a leading population in developing world; malnutrition and hunger are threatening millions of people which are mostly children and pregnant women. Access and affordability to right quality and quantity of food is also a challenge; more than 50 % of rural households income is being spent on purchases associated with procurement of food items alone, malnourished children population is in millions while adults women and men are as well malnourished ranking the country 100 out of 119 in global hunger index despite excellent interventions by its governments through targeted public distribution of foods items, schools mid-day meal and integrated child development services (WFP, 2017).

Major underlying cause of these situations is insufficient supply of animal protein. Hence, there is need for strategic efforts geared towards promotion of adequate protein supply through affordable livestock production in a nutrition food (nutri-food) systems for sustainable development - a reason why rabbit production is a suitable animal production approach for sustainable development. Rabbit an animal discovered in Spain about 100 B.C. by the Phoenicians; domesticated at about the l6th century apart from food supply, it is also a model animal for bioscience studies because rabbits are practically cost effective and efficient tool to speed-up research and the development of investigations into human diseases considering its gene sequence which is similar to most mammals and man. For instance, reproductive studies and developmental biology of embryo has been successfully conducted using rabbit's laboratory models; hence their potential for advancement of bioscience research in developing countries is feasible (Fisher *et al*, 2012).

However, in the areas of both food and bioscience research the use of rabbits in most developing countries still remains grossly unexplored. Despite the fact that developing countries form the largest population of hungry and malnourished people in the world whereby protein malnutrition is in the lead but commercial rabbit production is not common. Therefore, a re-introduction of rabbit production for meat is a feasible approach to solving the problem of food insecurity because unlike societies where people are used to monotonous food culture where acceptability of rabbit meat as food may be difficult, because rabbit is highly acceptable as meat in developing countries. In developing countries with predominant poor rural population, rabbit production and consumption has been tested and proven to serve as a social security and economic safety net for poor farmers. According to reports of Khatun *et al.* (2012), rabbit production in rural communities of Bangladesh by poor farmers is affordable cost-wise, intensive production is feasible, and a contributor to household food consumption and regarded as an important micro-livestock component that can produce meat for meeting up extra demand of the country. Rabbit meat was also described as a meat with superior qualities compared with some other meats because it is richer in protein, minerals and vitamins as well as less in non-desirable lipids (Cholesterol) which was another reason attributed to promotion of rabbit production in the country.

Similarly in Kenya - a developing country of sub-Saharan Africa, it was discovered that bulk of people rearing rabbits are adults making up more than 75 % of people sampled in rural districts; these rabbit keepers were characterized as being heads of their households who engages in rabbit production as major source of income to support their family needs. The study concluded that rabbit production is viable economic endeavours in the areas studied where incomes are generated from rabbit meat and manure sales. The meat command good prices in the market due to awareness created about its qualities while the manure is a cheaper alternative to expensive non-sustainable chemical fertilizers hence, more efforts by the country's National Livestock Extension department was recommended for promotion of rabbit production (Mbutu, 2013). Therefore, in order to further contribute to roles of livestock as bridge between poverty and food security, as well as meet up with increasing demand for livestock products stimulated by high population, increased household income and urbanization deliberate introduction of rabbits as a major component of household protein supply will contribute to food security and other sustainable development goals –SDGs in developing countries (Alexandratos and Bruinsma, 2012).

RABBIT PRODUCTION IN DEVELOPING COUNTRIES: CURRENT TRENDS AND FUTURE PROJECTIONS

Rabbit production can be regarded as one of the least developed livestock production practices in developing countries despite natural endowment capable of supporting its production. Problems responsible for this include poor reproductive performances, climatic factors occasioned by high temperature which characterized most part of the developing countries, diseases and unorganized markets. Feeds and feeding are another problems facing rabbit production development in some of the developing countries. In Nigeria for example, full advantages of rabbit nutrition have not been taken and this currently limit interest in rabbit production (Okpanachi *et al.*, 2010). In addition to nutrition, another challenge to rabbit production is poor documentation of rabbit meat consumption records. Records of rabbit meat *per capita* consumption in most developing countries is very hard to come by considering the situation of the rabbit industry which is grossly unorganized and backyard dominated livestock production system.

However, despite all these challenges, rabbit production is contributing meaningful to agricultural development in some developing countries notably Kenya where it was described as a potential entreprise that is economically viable; in some other countries as well because of its low capital outlay to produce which makes it highly suitable and economical by both poor and rich farmers. Rabbit production can contribute to supply of quality meat across all social classes. Wool from rabbit production can also be processed into sewing threads for clothing and the garment industries as well as production of cotton for textiles. International trade opportunities also exist for rabbit meat in developing countries in form of export and foreign exchange earnings as well as the promotion of bilateral socio-economic relationship. China which is one of the countries where rabbit production is very popular and well organized as a developing country herself, potential international market for rabbits produced in other developing countries can be harnessed in the country where large consumers of rabbit meat exist as well huge market for rabbit hides and skin.

In China as of 2008, more than 660,000 metric tons of rabbit meat was produced, out of these, only very few were exported while finished products such as rugs, cotton and thread are being produced from rabbit raw materials for export into international markets (Lebas, 2009; and Li, 2010). Rabbit apart from just been an Easter bunny and pet for children; holds significant potential to ease hunger and supply modest income for impoverished rural families all over the world through provision of quality meats, sales of manure and production of fur; hides and skin as industrial raw materials (Hilmi, 1998). Rabbits are categorized generally based on their production for show, meat, fur and pet as small, medium, large and giant rabbits but within each category there is similar growth pattern because of their body conformations which determines growth rate and thermoregulations. Lukefher and Ruiz-Feria (2003) compared growth and body weight changes of Altex and New Zealand White rabbits which are both meat-type rabbit and reported that despite differences in breeds; they both have similar performance. The rabbits were kept under the same condition and were fed the same feeds although different breeds but the results showed no statistically significant differences in the growth patterns of the two rabbit breeds.

Similarities in sizes of the rabbit ears have strong positive correlation with body weight changes and growth pattern because the ear is responsible for homeostasis regulation which determine to a great extent rabbit metabolic success as well as failures and hence similar growth pattern. These observations were earlier reported by Hanafi *et al* (1984) who concluded that thermoregulatory functions of rabbit ears contribute to growth and body weight changes in breeds of the same categories irrespective of breeds as confirmed in the report for Altex and New Zealand White breeds of rabbits. Altex rabbit is a commercial breed developed for producing bucks that can be use as sires in terminal cross-breeding in meat rabbit production. They produce offspring which grow faster and go to market sooner compared with other breeds. They are suggested for meat production in developing countries for better nutrition of people in enhanced rabbit production system. It is a mixed breed developed from Flemish Giant, Champagne d' Argent, and Californian rabbits; genetically selected for heavy weight gain and attainment of market weights within 70 days over 20 generations (Karen, 2018). Meanwhile New Zealand White rabbit on the other hand originally bred in the United States for meat and fur trading. The breed is characterized by exceptional calmness and docility in addition to excellent fecundity. However, because they are both medium size rabbit breeds their growth pattern was similar. Rabbit production across the world is vast and widely distributed; the production is led by developing countries (Table 1); but higher *per capita* consumption is found in developed countries such as Italy where almost 100 million animals are slaughtered each year and annual consumption is 2.3 kg *per capita* (Dalle Zotte, 2014).

RABBIT: MODEL ANIMAL AND ITS APPLICATIONS IN BIOSCIENCE RESEARCH

Rabbits are suitable model animal for bioscience research because the sequencing of rabbit genome was reported to open opportunities for genomic information exploits due to its multitudinous array of similarities with other mammals including man for many basic and applied biological researches. Investigation of copy number variation in OryCon 2.0 concluded on the fact that rabbit is a perfect model for immunological research because of possible highly promising outcomes observed in expression of immune related genes of man in rabbit models (Fontanesi *et al* 2012). However, apart from immunological research, rabbit genome is also identified to be highly valuable for studies associated with annotation of human genes which are imperatives for understanding mechanisms associated with development of many diseases (Broad Institute, 2018).

Table 1. Global distribution and production of rabbits for meat supply.

Regions	Rabbits population share (%)	Output (million tonnes)
Africa	7.96	87.68
Americas	1.41	16.55
Asia	72.59	1088.32
Europe	18.04	289.90
Rabbits production in Africa		
Eastern Africa	11.50	11.97
Middle Africa	2.33	2.14
Northern Africa	75.11	64.53
Southern Africa	0.77	1.07
Western Africa	10.29	7.96
Rabbits production in Asia		
Central Asia	0.13	0.40
Eastern Asia	99.76	1086.91
Western Asia	0.11	1.01
Rabbits production in the Americas		
Caribbean	1.25	0.24
Central America	32.39	4.44
South America	66.37	11.86
Rabbits production in Europe		
Northern Europe	0.13	0.27
Southern Europe	54.56	112.03
Western Europe	45.31	87.54

Source: FAOSTAT, 2017.

This is possible because genetic annotation involves identifying locations of genes and all coding regions in a genome for determining genes functions and dysfunctions - a process of unbundling structural location of genes via their expression for elucidation of their biological functions for the purpose of deriving maximum benefits of their upward or downward regulations (Stein, 2001). Rabbit has benefited human society as animal model of choice for years; for example, the first embryo transfer work which was performed by Walter Heape in 1890 used rabbits to answer basic scientific question concerning influence of the uterine environment on the phenotype of the developing embryo. Rabbit has also been used in all types of basic science studies, including nutrition, reproduction, embryology and monoclonal gammopathies (Ron, 1989). Rabbit was the first animal model used in the study of cancer in human, it is also a source for production of antibodies and investigation into immune system. In the study of cardiovascular related diseases, rabbits were used for investigating and understanding hypertension and atherosclerosis (UAR, 2015).

In study of diseases mediated by oxidative stress, Mesa *et al*. (2011) reported suitability of rabbits as animal model because rabbits have facility to develop metabolic dysfunctions with specific diets such as cholesterol-rich diets. This is a feature similar to natural human condition whereby atherosclerosis develops as results of high consumption of cholesterol-rich diets. Inclusion of cholesterol and other fat sources at varied level over a short period of time led to development of atherosclerosis in rabbits in a similar manner as human being. Atherosclerosis developed in rabbits by feeding between 0.5 % and 4 % cholesterol in diets for a period of 3 and 12 weeks as reported in studies of Zulli*et al*. (2005), Shakuto*et al*. (2005), Zhang *et al*. (2005), Juzwaik*et al*. (2006) and Pfister (2006) gave insights into understanding pathophysiology of oxidative stress in atherosclerosis. Rabbit as model animal for understanding human reproductive challenges was used for studies associated with mechanisms of periconceptional programming and its effects on metabolic health in adulthood. This was reported in the work of Fisher *et al*. (2012) which stated that the use of rabbits as model animal in periconceptional studies has led to elucidation of even the smallest changes in metabolism and development in embryo. Viebahn (2001) also stated that rabbits were model animals used for earliest investigations in embryology and reproductive biology because of their structural and functional properties which facilitated landmark achievements in the studies of seminal functions including endocrine and paracrine regulations in embryo (Fisher *et al*. 2012). The interactions between the maternal uterine environment and the embryo in rabbit models also contributed to understanding of Ashrman’s syndrome which is a cause of infertility and recurrent pregnancy loss. In addition to these, understanding of rabbits genital functional physiology has also led to gaining insights into developmental activities in reproductive science ranging from fertilization to blastocyst formation and entire embryonic development.

Manjeet *et al*. (2012) described rabbits as perfect model animal for scientific experimentation because they are docile, non-aggressive and easy to handle as well as good for observation to obtain biological data for clinical applications. They have short reproductive life-cycle hence they are excellent for reproductive studies involving data on puberty attainment, gestation and lactation. Wang *et al*. (1998) also reported that rabbits are commonly used animals for screening of implant materials prior to testing in a larger animal model. In order to determine biocompatibility and mechanical stability as well as safety of a newly developed implant materials. According to Himanshu *et al*. (2011), it was stated that rabbits are one of the most commonly used animal models for dental experiments despite dissimilarities existing between rabbits and human bones because rabbits are easy to handle and have rapid sexual maturity. Bosze and Houdebine (2006) referred to rabbits as translational model of choice because they are valuable animals whose experimental findings have direct applications in biomedical investigations. Rabbits are bioreactors where production of monoclonal and polyclonal antibodies is being produced and recently, they are being used for production of recombinant proteins. Rabbits unlike other animal models which are primarily used in the discovery phases of research are also suitable for pre-clinical and translational investigations because phylogenetically they are in the mid-point between primates and rodent models which offer more diverse genetic background than rodents hence better for experimentation as model for human studies (Kingfisher, 2017).

Comparative advantages of using rabbits as model animal in biological researches includes but not limited to easy handling since they are very docile and non-aggressive animals; and can be easily manipulated for collection of biological samples. Unlike some animal models, rabbits are widely bred and very economical. Rabbits due to short reproductive cycles gestation, lactation, and puberty can reproduce required number of animals at uniform physiological states for research. Rabbits are also well-known bioreactors without complexities hence obtaining institutional animal ethics committee approval for use of rabbits in research is easier compared with some other animal models. Compared with larger animals, rabbit use as model in biological sciences research is cheaper, require less complicated facilities and can be maintained in a small area (Mapara *et al*, 2012). Comparing rabbits with smaller animal models such as mice, rats and guinea pigs; rabbit is bigger hence larger quantity of test materials in a quantity closer to human can be used and as well obtained from rabbits therefore more suitable for translational research; for example, because of bigger size of rabbits it is possible to carryout blood sampling in quantity and numbers allowing greater access to many cells and tissues from a single animal (Esteves *et al*, 2018).

In similarities with human, rabbits are more suitable as animal models for understanding mechanisms behind immune compromise as well as development of immune therapy. Rabbits has been used in the development of vaccines, human immune antibodies and elucidation of zoonotic diseases mechanism due to similarities between rabbits and human immune system which are better and closer compared with animal models such as mice and rats (Graur *et al*, 1996). Rabbit is also a suitable model animal in pathology of human viral diseases; it has been successfully used in biomedical investigations of myxomatosis and oncolytic activity, human noroviruses and hepatic fulminant diseases, syphilis, tuberculosis, human papillomaviruses (HPV), human immunodeficiency virus (HIV), Ocular herpes infection and immunity; in addition to infectious diseases, rabbits has also served as important and reliable models for the understanding of human non-infectious diseases (Esteves *et al*, 2018; Getz and Reardon, 2012).

USE OF RABBIT IN MOLECULAR REPRODUCTIVE PHYSIOLOGY: POTENTIAL FOR INCREASING FOOD PRODUCTION AND PROMOTION OF HUMAN WELL-BEING

Single largest stock-wide problem facing livestock productivity under modern livestock production and management systems is negative impacts of metabolic demand on reproductive performance. High metabolic rates as result of improved feeding, housing and animal welfare promotion have been implicated for substantial breakdown in endocrine functions that are important for reproduction; an example of this is oestrogen and progesterone catabolism which is reportedly causing decreased fertility as result of decreased oestrus expression – a condition justifying need for improved reproductive performance research to increase food production and supply (LeBlanc, 2005). Apart from animals; in human societies, reproductive failures today remain a major public health challenge facing humanity; although several break-throughs and success were recorded in modern period for managing the menace but infertility is still a challenge facing large population of couples worldwide (Roupa *et al*, 2009). These couples reportedly keeps growing in numbers especially in developing countries where global burden of infertility was identified to be higher. Hence, suggested research including investigation into prevention of recurrent spontaneous miscarriage and prevention of neo-natal complication were recommended as a way of solving human problems (Mascarenhas *et al*, 2012). Molecular reproductive physiological because of its integrative approach of identifying critical roles of biomolecules in functional system of reproduction can provide solutions to these problems through early discovery of ailments that are inheritable from parents to their offspring (Darnell *et al*, 1990). Rabbit are suitable model of use in this area of research because of rabbits high breeding rate, large litter size, and induced ovulation nature of rabbits. Modelling rabbits for molecular understanding of reproductive performance can unravel human infertility problems and contribute to production of more foods since rabbits can serve as model for mammals including food producing farm animals.

Specific areas of molecular reproductive physiological exploits where rabbit can serve as model animal includes studies involving gonadal differentiations, foetus stability, evaluation of intrauterine microenvironment and foetal malformation, embryo culture, ultrasonographic characterization of foetus and gene expression at pre and post implantation stages of embryo development. Annotation of sex-determining region Y (SRY) proteins and genes in rabbit can also contribute to sex skewing research in food producing animals (Hill, 2018). This is possible because meiosis occurs at birth in females rabbits not during foetal life a situation similar to some other mammalian species. Therefore protein and gene annotation during foetal and early life-time (15 days) of rabbit can lead to identification of sex differentiating markers that can be use in other mammals (Daniel-Carlier *et al*, 2013; Jørgensen and Rajpert-De Meyts, 2014). Understanding molecular mechanisms regulating meiosis signalling during this period can also contribute to identification of genomic and transcript markers for sex differentiation research in livestock such as cattle and buffaloes where more female animals are needed for milk production (Kobolak *et al*, 2009; Püschel *et al*, 2010; Marshal and Carney, 2012). Rabbits are also suitable animal model for understanding congenital deformation associated with negative effects of drugs on embryo-foetal development especially in view of the chronological stability of spontaneous or drug-induced malformations in the foetuses because thalidomide a drugs popular for use among pregnant women was recently proved in rabbit to be harmful to foetus and cause birth defects (Leck *et al.*, 1962; Kawamura *et al.*, 2012). Finally, as a model for reproductive physiology; rabbit apart from short gestation period also has similar embryonic structure and function compared with human which makes rabbit a perfect model animal for embryological investigation (Sultana *et al.*, 2009).

CONCLUSION

Developing countries of Africa, Asia and Caribbean currently have growing population; however, there is no commensurable supply of foods especially animal protein capable of catering for the population increase causing severe shortage of animal protein intake. Therefore, promotion of rabbit production as a cheap and affordable source of protein in these countries was suggested especially for poor people living in rural and sub-urban areas of these regions of the world. In addition to food production, rabbits are untapped model animal for bioscience research in developing countries; hence it was also recommended as model animals for scientific studies associated with understanding human diseases and systemic dysfunctions.

Acknowledgement
We are grateful to The World Academy of Sciences (TWAS), Trieste, Italy and The Department of Biotechnology (DBT), Government of India for joint award of PhD Fellowship to Sikiru A.B. at ICAR-NIANP, Bengaluru, India where experimentation associated with this study is currently been carried out. We acknowledge and thank authorities of Federal University of Technology, Minna, Nigeria and The Director of ICAR-National Institute of Animal Nutrition and Physiology (NIANP), Bengaluru, India for providing enabling supportive facilities and environment for study.

Funding. Sikiru, A.B. receive funding from The World Academic of Science (TWAS) and Department of Biotechnology (DBT), Government of India (GoI) for his PhD research at the ICAR-National Institute of Animal Nutrition and Physiology, Bangalore, India.

Conflict of interest. The authors declared no conflict of interest.

Compliance with ethical standards. Not applicable.

Data availability. Not applicable.

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