

Livestock Nutrigenomics Applications and Prospects

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Abstract

Livestock performance is thought to be affected by genotype (heritable) and environment (non-heritable). Nutrition is among the greatest environmental determinants. Genes are turned on and off according to metabolic signals that the nucleus receives from internal factors like hormones and external factors like nutrients. Currently, Nutrigenomics which encompasses the three crucial -omics stages (Transcriptomics, Proteomics and Metabolomics), is emerging in the area of livestock to develop feeds that can be matched to genotypes of animals for a better production, productivity and health. It deciphers how food ingredients and nutrition affect gene expression, metabolic pathways and diet-related disease development. Hence, Nutrigenomics makes clear that how gene interacts with nutrients and how DNA and genetic code affect the needs for certain nutrients and quantities which suggests the possibility to change the way we feed and manage livestock and poultry. The tools of molecular genetics are expected to have much more impact in the future. The interaction between diets and genes could be evaluated through DNA microarray techniques and quantitative real-time polymerase chain reaction (PCR). These profiling techniques are reported to allow examination of nutrient effects that was not possible in the past. Nutrigenomics is feasible to apply in livestock production but can only provide part of the solution in response to non genetic factors involved in livestock health and production. In this paper, the Principles, current status of its application in different areas, challenges and opportunities of livestock Nutrigenomics with emphasis to developing countries like Ethiopia has been thoroughly reviewed.

Keywords: Livestock performance; Nutrigenomics; PCR; DNA

Introduction

Nutrigenomics is the all-encompassing study of the genome-wide influences of nutrition. Genes are turned on and off according to metabolic signals that the nucleus receives from internal factors, for example hormones, and external factors, for example nutrients, which are among the most influential of environmental stimuli. Early in evolutionary development, the nutrients that organisms ingested functioned as primitive signals that turned on and off pathways of synthesis or storage during periods of starvation or excess organisms developed into more complex forms of life they retained the ability to respond to nutrient or nutrient/hormonal signals that govern the expression of genes encoding the proteins of energy metabolism, cell differentiation and cell growth [1,2].

The emergence of nutrigenomics is to develop foods and feeds that can be matched to genotypes of animals for a better production, productivity and health [3]. Diet on its own or by interaction with other environmental factors can cause epigenetic changes that may turn certain genes on or off [4]. The central role that nutrients play in governing the cell content of different proteins has been further investigated and a recognition of their role as regulators of gene transcription, nuclear RNA processing, mRNA stability and mRNA degradation (Ribonucleic Acid) has emerged [5]. Nutrigenomics has great emphasis due to its great potentiality for treating chronic disease, to select animals for feed conversion efficiency, production and quality improvement of products [4].

Nutrigenomics-aided research should ultimately provide a sound basis for dietary management of maintenance and protection of health, eventually positioning nutrients in the context of individual genetic background. Presently, demand of meat/ animal products is rapidly increasing due to globalization and increasing population. Now days, in the developed country cereals are used for biofuel companies for production of biodiesel and ethanol [6]. So that, the consumption of crops in farm animal is important to hold good revenue and this could be possible via nutrigenomics approach [7]. Application of this technique provides anew rapid tests for evaluating nutrient induced physiological changes and efficient methods to evaluate interaction between nutrients for better production and health [8].

Approaches of Nutrigenomics

New tools available in modern research allow nutritionists to screen genetic background through Transcriptomics, Proteomics and Metabolomics are the three crucial stages of nutrigenomics. Tools of transcriptomics (microarray technologies) allowed new information concerning the physiological effect of dietary proteins; proteomics tools (two-dimensional electrophoresis) might be an important tool to explore the effect of individual amino acid on protein composition [9].

Nutrigenomics clarify that the system of gene interacts with nutrients and how DNA and genetic code affect the needs for certain nutrients and quantities [10,11] and helps to understand the nutritional effect on gene expression. To explore the importance of diet and diet formulation it is a need to understand physiological, biochemical and metabolic pathways and gene expression in livestock including a poultry [4,12].

Nutrients in food and supplements may affect the expression and even the structure of specific genes. Nutrigenomics application connects multiple disciplines including dietary effects on genome stability, epigenome alterations, RNA and micro-RNA expression, protein expression and metabolite changes, all of which can be studied independently or in an integrated manner to diagnose health status and/or disease trajectory [4,13].

Application of Nutrigenomics in Animal Sector

Application of genomic principles in a nutrigenomics helps to formulate a specific association between nutrients and genetic factors [14]. Nutrigenomics could be applicable to determine a personal diet (individual nutritional requirements based on the genetic makeup of the person), clarifies diet related disease and could find out the associated genes that are concerned in diet- gene interaction, detects polymorphism of gene that may have significant nutritional and environmental factors on genetic expression. Also through the application of single nucleotide polymorphism clarifies the different responses to same nutrient by different individuals and explores the effect of genetic variation on the interaction between diet and disease.

Nutrigenomics will relate optimal diet to choose from many and different nutritional availability while nutrigenetics will formulate information for identifying the optimal diet for a given subject [15]. On the road to define the optimal diets for an individual's; it is a need to clarify the health status at molecular stage with the consideration of metabolic and epidemiological studies. Nutrigenomics correlates diet, health and genomics in term of phenotypic effect also include different -omics such as proteomics and transcriptomics [9,16]. Through different molecular and nutritional researches there are several factors including environmental which are associated with animal health.

To evaluate the interaction between diets and genes, DNA microarray techniques and quantitative real-time Polymerase Chain Reaction (PCR) and DNA sequencing can be applied [17]. The interaction between diets and genes could be evaluated through DNA microarray techniques and quantitative real-time polymerase chain reaction (PCR). Now a days, microarray or DNA chip technology in nutrigenomics research enables to screening large numbers of genes and giving comprehensive picture of the variation of gene expression patterns [18].

These profiling techniques allow researchers for examination of nutrient effects which were not possible in the past. Also possible to examine and comparison of gene expression profile, it has now possible to finger print the control mechanisms for all metabolic activities. Presently, in addition to the previous tools oligo-based and cDNA microarray techniques is possible to understand many of the factors controlling the regulation of gene transcription and globally evaluate gene expression profiles by looking at the relative abundance of gene-specific mRNA in tissues; helps to generate information on reproductive, developmental and performance characteristics in livestock [19].

It is well known that dietary manipulations and nutritional strategies are key tools for influencing production and health. According to the investigation of Byrne, [20] poor quality feed intake which is characterized by nutritional restriction, expression of specific genes associated with protein turnover, cytoskeleton remodeling and metabolic homeostasis was clearly influenced by diet. These changes in expression could be predicted from observed changes in animal growth and physiology during nutrient restriction, the cell level and

neuron expression will be studied through microarray technology. According to the finding of Long et al. [21]. Nutrient restriction during early gestation in beef heifers affects their calves through expression of genes controlling fatty acid transport in adipose tissue and muscle. Unlike application of transgenesis which very expensive [22], nutrigenomics in livestock agriculture can easily be employed with minimum cost and may be effective in increment of growth rate, milk production and composition, feed usage and carcass composition, disease resistance, enhanced reproductive and prolificacy enhancement. Generally, nutrigenomics can bridge the gap between genetic profile and feeding for better conversion efficiency in livestock production and productivity (Figure 1).

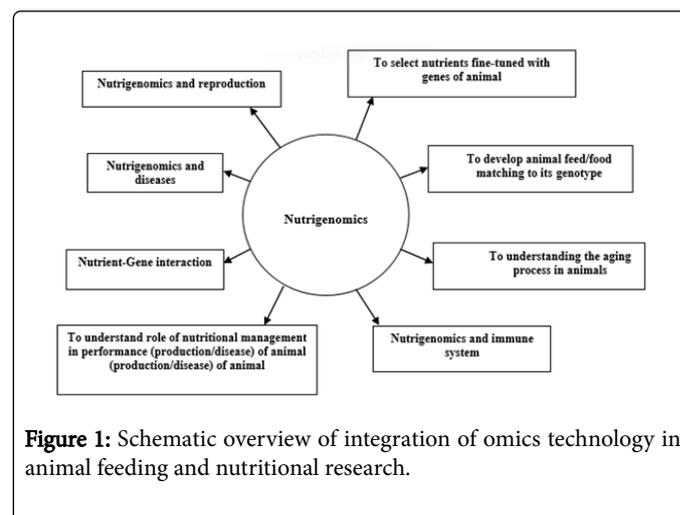


Figure 1: Schematic overview of integration of omics technology in animal feeding and nutritional research.

Nutrigenomics in poultry and pork industry

Nutrigenomics approach is carefully selecting nutrients for fine-tuning genes and DNA presents in every cell and every tissue of an animal. It is possible to measure the effects of certain nutritional supplements and how they alter the gene interaction of the body using gene chips that contain the genetic code of animal [3]. Demand of meat (poultry and pork) is increasing rapidly due to globalization and increasing population all over the world and due to increase of cereal cost there is a need to consider the nutrigenomics approach.

Researchers are actively involved to increase the feed efficiency using different combination of feed. Diet with glutamine supplement is better for a piglet to modulate the expression of genes that are necessary for intestinal metabolism and function [7]; other finding showed that low protein content in diet increase the intramuscular fat by regulating heart fatty acid-binding protein or H-FABP, peroxisome proliferator activated receptor γ or PPAR γ gene which enhances the quality of pig meet [23].

Feed and health optimization in chicken farm could be possible through the application of nutrigenomics research. Also it will lead to the implementation of improved precision feeding strategies by the poultry industry. Lipid metabolism in female chicken of two broiler strain could be regulated by nicotinic acid [24]. Transcriptional regulator of gene involved in lipid oxidation and antioxidant gene expression could be induced via vitamin E diet which has an effect to reduce stress and enhance meat quality [25]; and can increase immune protection against bacterial lipopolysaccharide associated infection in chicken [26].

Current Progress of the Area with Emphasis to Developing Countries

Area of research in farm animals were mainly focusing on nutrient requirement of animal for maintenance, production and reproduction, diet formulation in order to optimize feed and production efficiency. Efficient nutrient utilization has strong correlation with farm animal production and which it relates with methane production, proper utilization of nutrient and competition in use for feed, food or fuel [27]. Hence, the intricate interactions between diet and many aspects of animal health is poorly understood [28].

There is a considerable interest in the application of molecular genetics technology for the inheritable traits of growth rate, body weight, carcass merit, feed intake, milk yield and composition [29,30]. Proteomics and metabolite techniques can be used for determination of protein and metabolite composition of livestock products. -Omics techniques (transcriptomics, proteomics and metabolomics) which helps the current animal production to highlight the metabolic, nutrient status of an animal, act to adjust the metabolism to the nutrient status, in body fluids such as blood and saliva, and in excrements (faeces, urine, breath) [27].

Feed cost comprises the variable expense in animal production system making feed efficiency an important economic consideration. Gruffat et al. [31] and Bernabucci [32] et al. gene expression of aetiology of fatty liver in dairy cows at calving and gene expression of gluconeogenesis in early lactation in cows [33,34], transcriptome analysis of cattle muscle identifies potential markers for skeletal muscle growth rate and major cell types were understood [35].

According to the finding of Bing Guo et al. the deposition of intramuscular fat (IMF) altered the relationship between the expression of these genes and growth rate [35]. Concentrations of glucose, cholesterol, urea, insulin, insulin-like growth factor- 1, triiodothyronine, and thyroxine (T4) in blood plasma and of lactose and urea in milk were positively correlated with energy balance. Jansmal and Tepas, revealed that there are direct association between diet composition and dietary nutrient supply and the expression level of proteins [27].

Presently, protein and metabolites level expression measurement, provide new ways and important additional knowledge for determining and managing nutrient balances in farm animals with the determination of nutrient imbalances and these omics techniques in livestock feeding studies is technically feasible, and that the hypotheses for such studies can be translated from similar human studies also helps to optimize diet composition and dietary nutrient supply in defined populations of livestock species or in individual animals.

Selecting nutrients for fine tuning genes and DNA present in every cell and tissue of an animal is possible via nutrigenomics. For example, keeping stresses response gene turned off through proper nutrition, as a result animal is healthy and more producer. Therefore, nutrigenomics is a tool to develop animal feed/food matching to is genotype, to select nutrients fine-tuned with genes of animal and to understand the role of nutritional management in performance of animal [3]. The technology hold much promise for providing better nutrition, health and production in both developing and developed countries [13].

Challenges and Opportunities

The demand for animal products has been increasing in line with urbanization and population growth. In addition, some of the cereal

feeds used for animal production could also be served for humans as well. This phenomena needs an innovation solution to convert small amount of feed for a production, this may be possible via 'omics' technology. Optimization of productivity and efficiency in nutrition utilization could be possible. However, there is limitation in nutrigenomic information how to effectively analyze and correlate genes and nutrition conversion in livestock production [36]. To manipulate this, the genetic potential is partially utilized, the utilization of most nutrients appears to be low and hence, there is a huge variation in performance [37]. From a Nitrogenomics point of view, it is possible to expect to change the way we feed and manage livestock and poultry [19]. Molecular genetics tools having substantial impact in the future include DNA-based tests for genes or markers are affecting traits that are difficult to measure, such as meat quality and disease resistance [17]. This could be used as an opportunity to breed for improvement of production and productivity, such as product quality, increasing animal welfare, disease resistance, disease receptivity and reducing environmental impact [13]. This approach will help the breeder or researcher for a precise determination of nutrient beneath specific condition.

The level of expression for a same nutrition is different in individuals [10,11]. For example the changes in plasma cholesterol can be due the dietary of cholesterol; however this expression is dependent upon the individual [15,38,39]. Possible to change the way we feed and manage livestock and poultry that the nutrition is genotype dependent and nutrient could bring expression of genotype. Nonetheless, it is most difficult challenge will appear in establishing these basic relationships and applying them to improving this relationship and applying them to improving the health and production of all individuals at all ages. Nutrigenomics can only provide part of the solution in response to non genetic factors involved in an individual's health and production.

Environmental, cultural and economic factors also play an essential role in individual food choices and accessibility [13]. Malnutrition in the form of under nutrition or obesity can also modify gene expression and genome stability, resulting in changes in phenotype, and hence it is difficult to choose one population as a reference. The availability of genomic information is important to determine a specific nutrient under specific condition. Usage of this genomic information raises questions on how to apply such knowledge and how to use such information. Interpretation and consideration of genotype of individual for nutritional suggestion financial, ethical and customer preference aspect may affect the revolution of nutrition [40].

Conclusion

Nutrient and food components can affect gene expression/ regulation directly and indirectly, transcription and plays a regulatory role in intermediate metabolites of signaling pathways, with positive or negative effects. Now a days, microarray or DNA chip technology in nutrigenomics research enables to screening large numbers of genes and giving comprehensive picture of the variation of gene expression patterns which allowed researchers for examination of nutrient effects which were not possible in the past. There is a considerable interest in the application of molecular genetics technology for the inheritable traits of growth rate, body weight, carcass merit, feed intake, milk yield and composition. Nutrigenomics can only provide part of the solution in response to non genetic factors involved in an individual's health and production.

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