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IMPROVEMENT OF LIVESTOCK BY TRANSGENESIS

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Abstract: Transgenic animals are those animals which have been genetically engineered to carry one or more foreign genes. The foreign DNA is present in all tissue of the animal and transmitted to its offspring. The production of transgenic animals is one of several new and developing technologies that will have a profound impact on the genetic improvement of livestock. Improvement in livestock by this technology has been done through modification of milk quality and quantity, heat tolerant breeds, enhancement in carcass composition and growth traits, disease resistance, reproductive performance and fecundity in litter bearing animals, improving hair and fiber. Remarkable achievements have been made with this technology but due to the unavailability of simple, efficient and economic methods to produce transgenic animals, as well as our inability to identify appropriate genes to manipulate the livestock species, the utility of this technology in producing livestock is limited to meet consumer and market demand.
Keywords: Transgenesis, Livestock improvement, Milk, Disease resistance.

Introduction

Transgenesis is the introduction of foreign gene into a living organism so that it exhibits a new property and transmits it to its offspring. Transgenesis technology has great potential to develop new and improved strains of livestock. With ever-increasing world population, shift from vegetarian to non-vegetarian diet, changing climate conditions, such effective means of increasing food production are needed. Its practical application in livestock production among many include enhanced prolificacy and reproductive performance, increased feed utilization and growth rate, improved carcass composition, improved milk production and/or composition, modification of hair or fiber and increased disease resistance. Development of transgenic farm animals will allow more flexibility in direct genetic manipulation of livestock.

Modification of milk

Advances in transgenic technology provide an opportunity, either to change the milk composition or to produce entirely novel milk proteins. The improvement of livestock growth

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and survivability for the modification of milk composition involves production of transgenic animals which include (1) produce a greater quantity of milk; (2) produce milk of higher nutrient content; or (3) produce milk that contains a beneficial 'nutriceutical' protein. The major nutrients in milk are protein, fat, and lactose. Through elevating or altering the composition of any of these components, we can impact the growth and health of the developing offspring. Cattle utilized as milch animals, however sheep and goats are being used for meat production, thus farmers can be benefitted by the development of the transgenic animals of these species.

In tropical climates, heat-tolerant livestock breeds such as *Bos indicus* cattle are essential for the expansion of agricultural production. However, *Bos indicus* cattle breeds do not produce copious quantities of milk. Improvement in milk yield by as little as 2-4 liters per day may have a profound effect on weaning weights in cattle such as the Nelore or Guzerat breeds in Brazil. Similar comparisons can be made with improving weaning weights in meat-type breeds like the Texel sheep and Boer goat. This application of transgenic technology could lead to improved growth and survival of offspring and also serve as milch animal apart from drought purpose.

Milk composition can also be altered by a second mechanism, is the addition or supplementation of beneficial hormones, growth factors or bioactive factors to the milk through the use of transgenic animals. Bioactive substances present in milk possess important functions in the neonate with regard to regulation of growth, development and maturation of the gut, immune system and endocrine organs. Transgenic alteration of milk composition can enhance the production of certain proteins and/or growth factors that are deficient in milk. The over expression of a number of these useful proteins in milk through the use of transgenic animals may improve growth, development, health and survivability of the developing offspring. Some factors that have been suggested to have important biological functions in the neonate are obtained through milk includes IGF-I, EGF, TGF and lactoferrin. Recently, it has been found that oral administration of IGF-I may also improve nutrient absorptive function. Other properties of milk that are under consideration for modifications are those that affect human and animal health. Preformed specific antibodies produced in transgenic animals, that are capable of preventing a mastitis infection in cattle, sheep and goats and MMA (mastitis-metritis-agalactia) in pigs, and/or antibodies that aid in the prevention of domestic animal or human diseases. Also, increase of proteins, such as lysozyme that has physiological roles within the mammary gland itself or other anti-microbial peptides can also be beneficial to mammary health.

It is important to consider the use of transgenics to increase specific component(s), which are already present in milk for manufacturing purposes and increasing its food value. An increase in one of the casein components in milk could increase the value of milk in manufacturing processes such as production of cheese or yogurt. Alteration of physical properties of a protein such as-casein, increasing the glycosylation of casein, one could increase casein solubility in milk. Increasing the casein concentration of milk would reduce the time required for rennet coagulation. Whey expulsion, leading to production of firmer curds that are important in cheese making, also result in increased thermal stability of milk that could improve manufacturing properties as well as storage properties of fluid milk and milk products. The deletion of phosphate groups from casein would result in softer cheeses and better tasting low fat cheese, could result in dairy foods with improved characteristics.

Through transgenesis, it may also ultimately be possible to increase the concentration of milk components while maintaining a constant volume. This could lead to greater product yield, i.e. more protein, fat or carbohydrate from per liter of milk and would also aid in manufacturing processes as well as potentially decreasing transportation costs of the more concentrated products in fluid milk. The end result would be more saleable products for the dairy producer. The overall results of the transgenic modification of milk being the creation of more uses of milk and milk products in both agriculture and medicine. This will surely give a “value-added” opportunity for animal agriculture by increasing the concentrations of existing proteins or producing entirely new proteins in milk.

Enhancing growth rates and carcass composition

Growth factors and its receptors and modulators can be manipulated by transgenic technology. Increase in porcine growth hormone (GH) leads to enhancement of growth and feed efficiency in pigs [1]. To provide a protein source for the increasing world population, there is a need for more efficient and rapid production of fishes. Without diminishing the wild stocks and the production of GH transgenic fish has led to dramatic (30-40%) increases in growth rates in catfish through the introduction of salmon GH into these animals (Dunham and Devlin 1999). Introduction of salmon GH constructs has resulted in a 5-11 fold increase in weight after one year of growth [2]. This shows how effective transgenic methodology can prove that increased growth rate and ultimately increased protein production per animal can be achieved.

Another aspect can be altering the fat or cholesterol composition of the carcass for more nutritive carcass composition. By altering the metabolism or uptake of cholesterol and/or fatty acids, the content of fat and cholesterol of meats, eggs and cheese could be lowered. Introduction of beneficial fats such as the omega-3 fatty acids from fish or other animals into the livestock [3] can also be achieved through this technology. A good application would be the use of these strategies in the production of transgenic salmon, trout and catfish. Receptors such as the low-density lipoprotein (LDL) receptor gene and hormones like leptin can be potential targets to decrease the fat and cholesterol in animal byproducts. Transgenic technology can be used to modify the feed efficiency and/or appetite, alter the enzyme profiles in the gut, which could increase feed efficiency and increased uptake of nutrients in the digestive tract. Enzymes such as phytase or xylanase can be introduced into the gut of species where it is not normally present such as swine or poultry, which would increase the bioavailability of phosphorus from phytic acid in corn and soy products. [4] Reported that the production of transgenic pigs expressing salivary phytase as early as seven days of age. The salivary phytase provided essentially complete digestion of the dietary phytate phosphorus in addition to reducing phosphorus output by up to 75%. These transgenic pigs also required almost no inorganic phosphorus supplementation to the diet to achieve normal growth. Phytase transgenic pigs in commercial pork production could result in decreased environmental phosphorus pollution from livestock operations. Introduction of cellulolytic enzymes through transgenic technology, into the digestive tracts of non-ruminants could allow for increased digestion of plant cell wall material, allowing for the increased utilization of fibrous feedstuffs in the diets of poultry and swine. The ultimate result would be decreased competition with humans for cereal grains and an increase in the potential feedstuffs, which could be used for these livestock species.

Improved disease resistance

A very beneficial aspect of transgenics is the potential to increase disease resistance by introducing specific genes for disease resistance into livestock. Identification of single genes in the major histocompatibility complex (MHC), which influence the immune response was instrumental in the recognition of the genetic basis of disease resistance/susceptibility. Application of transgenic methodology to specific aspects of the immune system would provide opportunities to genetically engineer livestock possessing superior disease resistance. Manipulation of the MHC in farm animals through embryonic cells or Nuclear Transfer transgenics could have a major beneficial effect on disease resistance for livestock producers.

Pigs that are resistant to influenza have been attempted through transgenesis. Previously, mice and mouse fibroblast cell lines that contain the Mx 1 protein were shown to be resistant to infection with influenza virus. “Knocking-out” the intestinal receptor for the K88 antigen has been shown to confer resistance to both experimentally and naturally induced infection of K88-positive *E. coli*.

Transgenic dairy cows that secrete lysostaphin into their milk have higher resistance to mastitis due to the protection provided by lysostaphin, which kills the bacteria *Staphylococcus aureus*, in a dose-dependent manner [5]. Lysostaphin is an antimicrobial peptide that protects the mammary gland against this major mastitis-causing pathogen. Prions are the bovine spongiform encephalopathy (BSE) or ‘mad cow disease' in cattle and in Creutzfeldt-Jacob disease (CJD) in humans, can be controlled by producing prion-free and suppressed prion livestock through transgenesis. This manipulation is an example of how transgenesis could be used to increase disease resistance in livestock.

Improving reproductive performance and fecundity

Several potential genes profoundly affecting reproductive performance and prolificacy have recently been identified. Introduction of a mutated or engineered estrogen receptor (ESR) gene could increase litter size in a number of diverse breeds of pigs. A single major autosomal gene for fecundity, the Boroola fecundity (FecB) gene, which allows for increased ovulation rate, identified in Merino sheep [6] is used for production of transgenic sheep containing the appropriate FecB allele that could increase fecundity in a number of diverse breeds. Other applications of transgenic in reproduction could be a visual indicator of estrus in farm animals. Transgenic pigs could be made to have bright red posteriors, like baboon at the time of estrus, which could save time, money and possibly increase conception rates. The use of the so called “suicide genes” to specifically kill cells could be a great benefit to livestock production. Their incorporation could allow for precise control over the reproduction of certain strains and even specific sex distributions of livestock. For example a testis specific promoter that when expressed would kill “Y” chromosome bearing sperm in the case of sex selection and would kill all sperm in the case of control of reproduction. Similar strategies could be envisioned for female transgenics. This type of manipulation could produce sterile individuals specifically used for food production without fear of an accidental release of a reproductively competent transgenic animal into the environment.

Improving hair and fiber

Using transgenic methods, the quality, length, strength, fineness and crimp of the wool and hair fiber from sheep and goats can be manipulated [7] for better returns. To alleviate the need for hand shearing of fiber producing animals, transgenesis technology can be used, to induce sheep to shed their wool at specific times. Genes such as Epidermal Growth Factor with inducible promoters have been introduced into sheep, which would produce a weak spot in the wool fiber that allows the fleece to be removed with hand pressure. Similar strategies could be developed for mohair goats, alpacas, camels and other fiber-producing animals. Using the milk of transgenic goats, an approach to producing spider silk, a useful fiber, has been accomplished [8]. Spiders producing orb-webs synthesize as many as seven different types of silk for making these webs among it one of the most durable varieties is dragline silk. This material can be elongated up to 35% and has tensile properties close to those of the synthetic fiber Kevlar^{TM}, whose energy-absorbing capabilities exceed those of steel. Using transgeneis the spider silk can have numerous potential applications in medical devices, sutures, ballistic protection, tire cord, air bags, aircraft, automotive composites and clothing.

Conclusion

There are tremendous potential applications of transgenesis with the advancement of science. However, due to the unavailability of simple, efficient and economic methods to produce transgenic animals, as well as our inability to identify appropriate genes to manipulate the livestock species, the utility of this technology in livestock is limited. Still the recent advances prove the use of this tool will have a great impact toward improving the efficiency of livestock production and animal agriculture in a timely and more cost-effective manner and could profoundly impact livestock production.

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