Pocket K No. 41

Nutritionally-Enhanced GM Feed Crops

Livestock and poultry demand for feeds is expected to grow in the next 50 years, as food requirements increase parallel with the doubling of human population. Sufficient, nutritious and environment-friendly feed crops are breeding targets to indirectly provide food for an increasing population.

Genetic modification especially on the purposeful changing of substances in a particular pathway using recombinant DNA techniques, termed as metabolic engineering, is being conducted to generate new varieties with high yielding and nutrition-enhanced traits. Nutrition enhancement in crops targets manipulation of levels of proteins and amino acids, fats and oils, vitamins and minerals, carbohydrates and fiber quality, as well as decreasing the levels of undesirable components in major feed crops.

Feed Crops with Improved Proteins and Amino Acids

For animal requirement, most grains do not provide a balanced source of protein due to deficiencies in essential amino acids: lysine, methionine, and tryptophan. Biotechnology has been successfully utilized in the development of crops with increased level of limiting amino acids, thus providing alternative to the direct addition of supplemental amino acids in animal diets, as well as reducing N excretion into the environment.

GM maize with increased lysine (LY038) was developed by inserting a *cordapA* gene from a common soil bacteria *Corynobacterium glutamicum*. Enhanced production and accumulation of free lysine (Lys) in the GM corn kernel made body weight gain, feed conversion and carcass yields of experimental poultry and swine comparable with animals fed with Lys supplemented diets, and higher than those fed with conventional maize diets[1]. Rats fed with another Lys-enriched maize with the gene sourced from potato, was also found to be safe as conventional maize[2].

Similar result was found in poultry fed with rice expressing transgene *OASAID* with elevated free tryptophan (Trp) in the seeds. Body weight and feed efficiency of chicken fed with 55% GM high Trp rice was similar with those fed with conventional rice supplemented with crystalline Trp, but higher in the group fed with un-supplemented control diet[3].

Protein-enriched soybean event M703 was found to contain more digestible amino acids lysine, methionine, threonine, and valine, and had a higher level of metabolizable energy than conventional soybean meal in an experiment with cockerels[4].

Narrow-leafed lupin (*Lupinus angustifolius*) that express methionine-rich sunflower albumin has a two-fold increase in methionine content. When fed to broilers, the supplemental methionine required in diets containing 25% lupin meal can be reduced by 0.6 g/kg if GM high-methionine lupins are used instead[5].

Feed Crops with Biologically Active Substances

Barley with its inherent high ß-glucan content has not been used as a feed component. However, with the expression of a thermo-tolerant *Bacillus* ß-glucanase that acts on these glucans, GM barley could be a possible alternative or addition to feeds especially in areas where maize cannot be grown for climatic reasons. Barley is a more stress-resilient crop than corn. Feeding studies conducted in poultry showed that a barley-based diet with a small addition of GM grain expressing ß-glucanase can provide an alternative to a maize-based diet for broilers based on body weight gain[7].

Human lactoferrin (LF) and lysozyme (LZ) genes were introduced in rice grain for antibacterial and immune-stimulating properties. Antibiotics are used routinely in poultry farms to improve the intestinal microflora as well as to prevent and treat disease. Chickens fed with portions of GM LF or LZ rice as a substitute for antibiotics in poultry diets showed that the effect in the intestine was comparable with those fed with antibiotics[8]. In rats and pigs, another GM rice line expressing the human lactoferrin gene was evaluated and results of digestibility experiments showed that the nutritional quality of LF rice is superior to that of conventional rice[9].

Feed Crops with Improved Phosphorus Availability

The element phosphorus (P) is stored in plants as phytate salt. When consumed by monogastric animals such as horse, pig, poultry, cat, dog, among others, it is poorly soluble and utilized in the gastrointestinal tract, when accompanied with high dietary calcium concentration and absence of endogenous phytase (enzyme hydrolyzing phytate bonds that releases elemental P) activity. Hence, the undigested phosphates excreted by these animals when accumulated in soil and water leads to phosphorous pollution and organic matter accumulation, eventually reducing oxygen availability in the water[10]. In addition, phytic acid (the reactive form of phytate salt) forms insoluble salts with zinc and other cations reducing bioavailability of trace minerals in these animals. Thus, development of GM crops with phytase enzyme is an important solution to this problem.

GM corn expressing the *Escherichia coli*-derived phytase gene when studied with broiler chicks showed that the use of an increasing dietary level of transgenic maize linearly increased dry matter P, calcium (Ca) and nitrogen (N) retention. It shows that the GM corn is as efficacious as the commercial, microbial phytase in P- and Ca-deficient broiler diets and would thus minimize the need for supplemental dietary P[11]. Additional studies showed improved digestive tract physiology, elevated phytase activity, and decrease phytic acid P content[12]. *E. coli* phytase gene introduced into rice showed similar results of safety and nutritional availability in experiments on rats[13].

Genetically modified soybean that express *Aspergillus niger* phytase transgene was tested in broiler chicks in comparison with phytase-supplemented commercial feed[14]. On the basis of performance, P retention and excretion, the authors indicated that phytase from GM soybeans gave a positive effect, similar to the one provided by commercial phytase supplement. Tobacco and wheat containing the same gene showed similar beneficial influence on P availability in broiler chicks[15].

Use of GM canola with phytase gene from *Aspergillus fucuum* in broiler chicks and weaning pigs also showed that bone ash, P and Ca retention were comparable with that of feeds containing commercial phytase supplement[16].

Developing Feed Crops with Improved Fatty Acids

Most of the GM crops modified to improve fatty acid content have been used for direct food or for food industry use such as the oleic acid soybean DP305423, which has a better oxidative ability for improved food frying performance. Safety and nutritional value of the processed meal, hulls and oils from the GM soybean plant determined from experiments in birds showed that it is nutritionally equivalent to non-modified control as shown in body weight, hen-day egg production, egg mass, feed intake as well as egg production and quality[6].

Feed Crops with Reduced Toxins and Anti-nutritive Factors

Non-ruminants are adversely affected by anti nutritive factors in plant tissues including protease inhibitors, tannins, phytohaemogglutinins and cyanogens in legumes, and glucosinolates, tannins and sanapine in oilseed and other compounds in feeds belonging to the Brassica group. A combination of genetic engineering and conventional plant breeding should lead to substantial reduction or removal of the major anti nutritive factors in plant species of importance to animal feeds.

Soybeans contain raffinose and stachyose, the antinutritive oligosacharides that cause osmotic problems in laboratory animals. Genetically modified soybeans that contain these low oligosaccharides was developed. In an experiment with three conventional soybean meals and five low-oligosaccharide GM soybean meals fed to broilers, the mean raffinose, stachyose, and galactinol levels in the GM soybean was significantly much lower than the conventional soybean meal, and the crude protein and sucrose contents were slightly higher. Additional data showed that true metabolizable energy was also higher in the GM soybean[17].

In another experiment using 28 to 32 day-old chicken, the apparent metabolizable energy of the GM soybean is higher compared to the conventional soybean. A succeeding experiment on broiler chicks fed with 43% GM or non-GM soybean as the sole source of protein showed that the standardized digestibility coefficients of amino acids methionine, lysine, threonine, valine and isoleucine were significantly higher in the GM –fed soybean. These results show the potential nutritional improvements in soybean cultivars that are genetically modified for low oligosaccharide levels[18].

Cottonseed meal, a by-product of the cotton industry, has been a component of cattle feeds because of its protein, fiber, and oil content that improves cattle growth and breeding ability. However, cotton seed contains a yellow phenolic pigment gossypol, which at high concentration in the diet, result to panting and reduced livestock performance. A pioneering work to reduce the gossypol in the cottonseed was conducted through genetic modification that interferes with the expression and activity of δ-cadinene synthase, the enzyme involved in gossypol production. The gossypol content in the foliage and floral parts of GM cotton were not affected maintaining the crop's ability to resist insect pests. This work allows the use of cottonseed to extract edible oil also for human consumption[19].

Gaps in Nutrition Enhancement of GM Feed Crops

The preceding overview of nutritionally enhanced feed crops developed through genetic modification provided information on crops and traits that are under field trial or are already in the early commercialization stages. Nutritionally-enhanced genetically modified feeds have consistently shown efficacy in providing safe and available nutrients to poultry and livestock in various studies. Sufficient and cheap feedstocks are expected to come as more countries are adopting biotech crops. Research on increasing other nutrients in feed crops such as vitamins, minerals, and fats, reducing anti nutrition factors in plant-based feeds, efficient anaerobic fermentation of silage through genetically modified microorganisms will surely contribute to this endeavor.

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