EGG NUTRITION FOR HEALTH PROMOTION: HIGHLIGHTS FROM THE
SYMPOSIUM IN BANFF, CANADA

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Summary

This report summarises the main papers presented at the Third International Symposium on Egg Nutrition for Health Promotion, held in Banff, Canada in April, 2004. There are many marketing opportunities for eggs in forms other than shell egg and unmodified egg product. Eggs can be enriched with substances beneficial to human health such as selenium, zinc, vitamin E, folate, lutein, choline, phytoestrogens and omega-3 long chain fatty acids. Substances that inhibit the growth of microorganisms can be extracted from egg white and egg shell membranes. Eggs can be used for antibody farming and such antibodies can be used to treat lung infections in people with cystic fibrosis, dental caries, the organism that causes stomach ulcers and the organism responsible for diarrhoea in children in developing countries. Products from eggs are also used in the cosmetics industry. The challenges for the wider industry are to ensure that these ‘ovo-nutraceuticals’ and ‘bio-medical products’ can be produced cost-effectively, to increase the range of products available on the market, to increase market penetration and be competitive against rival products.

I. INTRODUCTION

The Third International Symposium on Egg Nutrition for Health Promotion was held in Banff, Canada on April 18-21, 2004, chaired by Dr. Jeong S. Sim from the University of Alberta. The first symposium was held in 1992 and the second in 1998. The papers presented at the third Symposium will be published in a Post-Symposium Book “The Amazing Egg: Nature’s Perfect Functional Food for Health”. Ordering information is supplied at the end of this paper. The papers presented highlighted the fact that the hen’s egg is, indeed, an amazing natural product and that there are many marketing opportunities for the hen’s egg, in addition to selling it as shell egg and raw egg product. However, some of the presenters highlighted the economic realities associated with the production and sale of the wide range of egg chemicals and this will be discussed further.

II. PROCESSING TECHNOLOGIES FOR OVO-NUTRACEUTICALS AND BIO-
MEDICAL PRODUCTS

The introductory speaker, Dr. G.W. Froning of the University of Nebraska-Lincoln, described the hen’s egg as a highly nutritious food containing high quality protein, twice as much unsaturated fat as saturated fat and an excellent source of minerals including iron and phosphorus and all the vitamins except vitamin C. In the U.S., egg consumption has increased between 1994 and 1999-2003 and about 30% of consumption is egg products such as liquid egg white, liquid egg yolk, liquid whole egg, extended shelf-life whole egg, frozen egg white, salted egg yolk, sugared egg yolk, salted whole egg, sugared whole egg, dehydrated egg products, and manufactured egg products. It is possible to influence the composition of the egg in terms of levels of selenium, zinc, vitamin E, folate, lutein and omega-3 fatty acids. Lutein and zeaxanthin which reduce the incidence of macular degeneration of the eye are easily transferred through the diet of the hen into the egg where they have a high bioavailability. Choline, which is important during pregnancy and may assist with dementia such as Alzheimer’s Disease, is found in other foods (beef liver, beef

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180
steak, cauliflower) but has a better bioavailability in the egg. Lysozyme is easily separated from egg albumen and can be modified in various ways. Lysozyme is used to prevent gas formation in cheese, increase the shelf life of meat products, enhance foaming of wines, as a food sweetener, in cold remedies and mouth washes. Shell membranes also contain enzymes which lyse gram positive bacteria (lysozyme), gram negative bacteria (β-N-acetylgulcosaminidase) and shell membrane extracts have been shown to inhibit Listeria, Escherichia coli, Salmonella, and Staphylococcus aureus. Proteins from the organic matrix of the egg shell have been shown to inhibit Pseudomonas, Bacillus and Staphylococcus and pancreatin-treated water soluble yolk protein has been shown to inhibit Streptococcus mutans. Avidin from eggs binds biotin and can be used as a pesticide. Transgenic maize containing avidin resists post- and pre-harvest pests and has been found safe when fed to mice. Biopolymer edible films and coatings made from egg white proteins are used to encapsulate foods and cosmetics, as carriers of antioxidants and flavours in the food, chemical and pharmaceutical industries. The main challenges in relation to products from eggs are the difficulty of extracting some proteins economically and the problem of allergies.

Dr. H.R. Ball of Michael Foods, U.S.A. discussed the challenges facing the egg industry in the development and marketing of “ovo-nutraceuticals” and “bio-medical products”. The composition of the egg is altered by regulating the hens’ dietary intake or immune system and extracting egg components. These products are not produced by genetic modification. The proportion of eggs consumed as product is currently 30% but is expected to reach 40% in the U.S. It was pointed out that there is currently a limited range of offerings of ovo-nutraceuticals and biomedical products and that market penetration is relatively small. Challenges facing the expansion of these markets include costs of production, scale of operation, regulatory issues, consumer awareness and receptivity, the competitive environment and the finding of outlets for the residual egg components that remain following the extraction of the target compound. Unless such outlets are available, the enterprise is not cost-effective. Dr. Ball discussed the business model adopted by Michael Foods. For shell eggs such as enriched eggs and egg product such as dried eggs, the proprietary position is that there are patents of limited scope, the know-how to produce them exists and there are relatively low competitive barriers. For extracted egg components, there are higher capital investment requirements, higher barriers to entry and higher risks.

Dr. D.U. Ahn from Korea described advances in the extraction from egg yolk of components such as immunoglobulin, lipids, phospholipids and yolk proteins. Egg yolk is diluted and then subjected to freeze-thaw cycling. Various methods (ultrafiltration, precipitation with ammonium sulphate) are used to concentrate the product. Factors such as temperature, pH and salt all influence the process.

Methods of reducing the cholesterol content of shell eggs were discussed by Dr. R.G. Elkin from The Pennsylvania State University, U.S.A. Between 15% and 30% of individuals exhibit a hyper-response to dietary cholesterol. In order to manipulate cholesterol levels, different parts of the cholesterol biosynthetic pathway may be targeted. Established approaches include genetic selection (this appears to be effective only in increasing cholesterol levels), alteration of the hen’s diet, hormones, non-pharmaceutical biochemicals, pharmacological agents. The use of various nutrients, non-nutritive factors or pharmacological agents have, at best, reduced egg cholesterol by 10% whereas oral administration of statins, garlic paste or pharmacological amounts of copper reduced egg cholesterol by 46%, 32% and 34% respectively. Dr. Elkin expressed the opinion that further reductions in egg cholesterol levels will be achieved by manipulation of key genes associated with the uptake and synthesis of lipids.
III. NUTRITIONAL ENHANCEMENT OF SHELL EGGS

Dr. P.F. Surai from the Scottish Agricultural College, Auchincruive, discussed the importance of adding antioxidants such as selenium, vitamin E and lutein to the diets of hens in order to increase the levels of these substances in the egg. These antioxidants have potential benefits in themselves and may also be used to reduce lipid peroxidation in omega-3 enriched eggs, thus reducing the fishy taste. Dr. J.E. Dvorska of the Sumy National Agrarian University, Ukraine, described the advantages of using organic selenium, as opposed to inorganic selenium, in the diets of hens to increase the selenium content of eggs.

The health benefits accruing from xanthophylls in eggs were outlined by Dr. D.J. McNamara of the Egg Nutrition Centre, Washington D.C., U.S.A. The xanthophyll carotenoids, lutein and zeaxanthin, have been used in the poultry industry for many years as cosmetic colouring agents for egg yolks and broilers, often in combination with red carotenoids. In humans, lutein and zeaxanthin accumulate in the lens of the eye and also the macular region of the retina, helping to maintain normal visual function and protecting against macular degeneration and cataracts. There is also some evidence that lutein is protective against cardiovascular disease and some cancers (breast, colon). Eggs can provide lutein in a form that is highly bioavailable and the lutein content of eggs can be modified by manipulation of the diets of the hens.

Dr. S. Leeson of the University of Guelph, Canada, discussed the relatively low transfer efficiency of lutein from the diet to the hen’s egg and possible mechanisms for increasing this efficiency. Lutein is found in spinach, broccoli, alfalfa, corn gluten and marigold meal. Lutein absorption is related to fat utilization and digesta viscosity.

Dr. C.A. Adams, from Kemin Europa, discussed the difference between a nutrient and a nutricle. Nutricines include organic acids and antioxidants that are used to maintain feed quality and hygiene, flavours used to increase feed intake, enzymes used to increase digestion and absorption, organic acids and oligosaccharides that modulate the function of the gastrointestinal tract, carotenoids, glucans and herbal extracts that modulate the immune system and antioxidants that reduce oxidative stress and reduce the incidence of some non-infectious diseases. Dr. Adams discussed the carotenoid, lutein, in further detail, pointing out that, while they were previously used as a cosmetic colouring agent in eggs and broilers, they are now considered an important nutricle in poultry and human health. Lutein absorbs free radicals so helps protect against oxidative damage and supports the immune system. Lutein is a naturally occurring carotenoid which usually occurs with zeaxanthin and occurs in all green leaves, whereas barley, rice, sorghum, wheat and oilseed meals are low in lutein. Dr. Adams outlined the benefits of lutein in protecting the chick during hatching and presented data indicating that lutein can improve immune function in dogs and avian species.

Dr. House of the University of Manitoba described how eggs can be enriched with folate and that the form of folate found in eggs is more available than crystalline folic acid. Excess crystalline folic acid can risk masking the symptoms of pernicious anaemia (vitamin B12 deficiency), whereas the folate in eggs does not cause this problem. Dietary folate is known to be important in the human diet for normal cell division, synthesis of red blood cells and metabolism of proteins and amino acids. It is also important in reducing the incidence of neural tube defects (e.g. spina bifida) and miscarriages. There is also some evidence that folate reduces the incidence of cardiovascular disease as it is a cofactor in the metabolism of homocysteine and elevated levels of homocysteine are an independent risk factor for cardiovascular disease. As Alzheimer’s Disease and dementia are linked to cerebrovascular disease, folate may have a role in reducing the incidence of these diseases also.

Many nutraceuticals currently targeted at older women contain soy isoflavones (phytoestrogens). Dr. M.A. Ottinger described how the eggs of Japanese quail can be...
enriched with the soy isoflavone genistein which has a structure similar to the female hormone, oestradiol.

IV. EGG LIPIDS

Dr. Cherian from Oregon State University described the process of feeding conjugated linoleic acid (CLA) to chickens in order to produce CLA-enriched eggs. CLA is a natural trans fat that is produced in the rumen of ruminant animals so is therefore found mainly in dairy and beef products. The interest in CLA isomers arises from evidence that they possess anticarcinogenic properties and can modulate the immune system. They have also been shown to improve feed efficiency and decrease body fat deposition in pigs and broiler chickens (Watkins et al., 2000). Evidence suggests that more than 3 grams per day needs to be consumed by humans in order to accrue health benefits. Because CLA is found in fat, reduced consumption of fat in dairy and beef products means that less CLA is consumed from these sources. The incorporation of CLA into eggs is an easy and efficient way to increase CLA intake. Addition of CLA to the diets of hens changes yolk shape by making the yolk more round but there is no effect on egg weight, Haugh units or the nutritional value of the eggs. CLA ingestion was found to increase the deposition of lipid droplets in the liver of laying hens but not broilers. When CLA enriched eggs were stored under refrigeration for 40 days, the water content of the yolk increased. Long term storage (3-4 months) resulted in a reddish colour in the yolk.

The presentation of Dr. A.P. Simopoulos from the Centre for Genetics, Washington D.C., U.S.A., was delivered by Dr. Sim who explained the evidence that human diets in earlier times had a ratio of omega-6 to omega-3 essential fatty acids of approximately 1 whereas most present day Western diets have a ratio of from 15 (U.K.) to 16.7 (U.S.A), as compared to Japan where the ratio is 4. This means that the current Western diets contain excessive amounts of omega-6 fatty acids and are deficient in omega-3 fatty acids. This imbalance is thought to contribute to diseases such as cardiovascular disease, cancer, and inflammatory and autoimmune diseases. One way of increasing the consumption of omega-3 fatty acids is via enriched eggs.

Omega-3 fatty acids have been shown to be beneficial in the human diet in terms of affecting plasma lipid levels, visual function and child growth and development. Dr. Jones from McGill University in Canada addressed the benefits of the omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) from fish oils and alpha-linolenic acid (ALA) from plant oils in reducing plasma triglyceride levels in humans. High triglyceride levels are a risk factor for cardiovascular disease and stroke. However, these compounds appear to have little effect on low-density lipoprotein (LDL) cholesterol, another risk factor. There is potential for an improved effect on plasma lipids if EPA and DHA are conjugated to plant sterols as a study conducted with guinea pigs showed that both triglycerides and LDL cholesterol were reduced by such a combination.

The importance of dietary omega-3 fatty acids in visual function was addressed by Dr. Suh from the University of Manitoba, Canada. The long chain polyunsaturated fatty acids (LC-PUFA, C20:4n-6 and C22:6n-3) are essential for normal visual development in infants. These fatty acids are found in mothers’ milk and it has been recommended that they be added to infant formula. There is also evidence that LC-PUFA have a role to play in reducing the incidence of degenerative diseases of the retina of the eye such as retinitis pigmentosa and macula dystrophy.

More general aspects of the importance of omega-3 polyunsaturated fatty acids (DHA and arachidonic acid, AA) in child development were addressed by Dr. Makrides from the Child Health Institute in Adelaide and Dr. Clandinin from the University of Alberta, Canada.
Dr. Makrides commented on the fact that there is now a tendency to use iron-fortified cereal as the first semi-solid food for infants whereas, traditionally, eggs and brains were fed. Egg allergies affect approximately 3% of infants under three years of age. Dr. Clandinin described the benefits of supplementation of diets with DHA and AA in improving mental and psychomotor development and development of the immune system in children and saw the main role of eggs as being during the weaning period. Dr. Clandinin made the comment that infant formula manufacturers are not willing to reformulate their product to incorporate the omega-3 fatty acids, they just want a small volume of AA and DHA to add to existing formula. Enriched eggs remain a potentially important source of the omega-3 fatty acids in the diets of infants, children and adults.

V. ANTIBodies FROM EGGS

Hens are able to deposit antibodies into the yolk of the egg for the purpose of protecting the developing chick. These yolk antibodies are collectively referred to as IgY which stands for immunoglobulins from yolk. Antibody-farming technology exploits this capability of the hen to produce a range of different types of antibodies in the eggs by immunizing the hen with specific substances and is an easy and inexpensive process. Hens are immunized several times and then require booster doses every 2-3 months. The antibodies, which are stable for several months, act by preventing adhesion of microbes to epithelial cells, inhibiting the growth of microbes and neutralizing the toxins produced by microbes. Dr. Larsson from University Hospital, Uppsala, Sweden discussed the production of yolk antibodies for oral treatment of cystic fibrosis patients against Pseudomonas aeruginosa infections in their lungs. The life expectancy of cystic fibrosis patients is 40-50 years and the main killer of these patients is Pseudomonas aeruginosa. This organism is impossible to eradicate but treatment with the yolk antibodies prolongs the time between active infections, reduces the need for antibiotics, postpones the onset of chronic infections and helps to preserve lung function. The formulation of the yolk antibodies has now been changed to contain 6 strains. Dr. Larsson discussed the need for a double blind study to determine the effectiveness of the product and the fact that it requires orphan drug status (that is, it has a limited market).

Dr. Sunwoo described the production of a new product, NutraGuard™ for treatment of people with coeliac disease. This disease was first described in 1888 and can be controlled by a gluten-free diet which was first introduced in 1950. The symptoms of the disease are chronic diarrhoea, weight loss, anaemia, bone pain, behavioural changes, gastrointestinal disease and delayed growth. There is a genetic basis to the disease which interacts with environmental factors. NutraGuard™ contains specific IgY along with vitamin E, DHA, folic acid and selenium and can be administered as capsules or added to foods.

Dr. Schade from Humboldt-University in Germany outlined the ongoing work that is attempting to develop IgY anti-prion antibodies for use in assays to detect the presence of prion diseases such as bovine spongiform encephalopathies (BSE- assays). Prions are proteinaceous infectious particles consisting of 151-190 amino acids. It has proved difficult to produce specific antibodies in mammals because of the similarity of the amino acid sequences to those found in other mammalian proteins. However, the use of a different class of animals, the birds, has resulted in some breakthroughs. Dr. Schade explained how a shortage of BSE positive and negative brain material and blood samples was hampering the research.

Antibodies from egg yolk can even be used to treat dental caries, as described by Dr. Smith from the Forsyth Institute, Boston, U.S.A. Streptococcus mutans is the main cause of dental caries and infection of humans does not occur until the final primary tooth eruption.
Once a person is infected, they are always infected. Immunisation of hens with *S. mutans* glucan binding protein B results in the appearance of antibodies in egg yolk that have been shown to protect against dental caries in a rat model. The best time for this product to be applied would be at the time of initial *Streptococcus mutans* colonization and after mechanical/chemical cleaning of teeth.

The organism *Helicobacter pylori* causes gastric ulcers in humans. *Helicobacter pylori* specific IgY prepared from the yolk of hens immunized with has been shown to be effective in treating *Helicobacter pylori* infections, as described by Dr. Kim from Dankook University, Korea. Apparently, approximately half the world’s population is infected with *H. pylori*, with the incidence being higher in developing countries (80-90%) than in developed countries (10-50%). The antibodies, which are usually given in combination with antibiotics, appear to work by inhibiting the adhesion of the bacteria to the epithelial cells of the stomach. Dr. Sarker from Bangladesh described ongoing work that is investigating the use of egg yolk antibodies for the treatment of human rotavirus which causes diarrhoea in children and is a major problem in developing countries. Dr. Korhonen from Finland described how the same principle of “designer” antibody production can be achieved in bovine milk, following immunization of the cow.

### VI. EGG MARKETING STRATEGIES

The final session of the symposium focused on egg marketing strategies which are essential if the potential additional markets for eggs are to be realised. Dr. Watson from the University of Arizona, U.S.A., discussed the egg as a vehicle for delivery of a range of products such as fruit bioflavonoids. Administration of a product JuicePlus® to older people (60-86 years) resulted in improved indicators of immune function. As the active ingredients are fat soluble, it was suggested that they could be incorporated into eggs to produce a functional food supplement with the potential to reduce the incidence of cancer. Dr. De Meester from Belgium described the process of development from Dr. Sim’s Designer Egg to the Columbus® Concept. The Columbus® Concept is the return of alpha-linolenic acid (ALA, C18:3), described as “wild fatty acid” to the rations of land-based bred animals so that their fatty acid ratios (ω6: ω3) returned to 1:1, the ratio characteristic of fat deposits in wild animals. As discussed in Section IV, above, such a change would have health benefits for these animals and the humans who consume them.

Dr. Junega from the Taiyo Kagaku Company of Japan gave an extremely entertaining and informative presentation on the wide range of marketing opportunities for egg nutriceuticals. He outlined the uses for sialic acid which he described as the “sugar” in egg. It is found in all parts of the egg: yolk, white, chalazae, yolk membrane, egg shell, in order of diminishing content. Sialic acid has been shown to inhibit rotavirus. Dr. Junega referred to the work mentioned in Section V and suggested that IgY against *Streptococcus mutans* could be added to foods such as chocolate and chewing gum. He amused the audience by describing the obsession that young Japanese women have with their hair and, particularly, the prevention of “split ends”. Hair cuticle IgY has been shown to repair damaged hair and can be added to shampoo. The use of egg shell calcium has marketing potential as the calcium contained in it is highly bioavailable and it doesn’t give a chalky taste. Products utilizing egg shell calcium are already on the market. The egg shell membrane can be used to treat wounds as it promotes collagen synthesis, absorbs moisture, releases proteins and has antimicrobial activity. Yolk protein contains all the essential amino acids required by 2-5 year old children. Lysozyme obtained mainly from egg white is able to lyse gram positive bacteria (but not gram negative ones). Yolk lecithin is a safe and natural source of AA, DHA, cholesterol and choline as an additive for infant formula. Dr. Junega finished up by
describing how his company has won awards for its products: in London in 1997 for sialic acid; Frankfurt in 1998 for Suntheanine and Sunphenon and in Paris in 1999 for Sun Active Fe and Sun GY.

The importance of egg lecithins was further discussed by Dr. Lange from Degussa Food Ingredients, Germany. Sales of egg lecithin have increased from 1995 to 2002 by 340% worldwide, 475% Far East, 320% Europe and 245% U.S.A. Of the lecithin sold, 60% is used in infant formula, 15% in injection solutions for clinical nutrition, 15% in cosmetics and 10% as functional foods. The composition of egg lecithin (the fatty acid profile) can be optimized by pure vegetable feeding of hens and use of different production technologies. Infants are not able to synthesise AA and DHA from fatty acid precursors so they need to obtain these either from mothers’ milk or infant formula. There is competition from other fatty acid sources for inclusion in infant formula. Egg lecithin is used for total parenteral nutrition and injections because of its emulsifying properties. In cosmetics, it emulsifies and stabilizes, acts as a skin nutrient and moisture regulator of skin, protects skin and hair and acts as a carrier for pigments and liposomes. Egg lecithin has a range of applications in food products.

Dr. Basu from the University of Alberta, Canada, discussed the fact that the designer food concept is currently very strong. He described the period 1920-1950 as the vitamin era, 1970-1990 as the mega-vitamin era and 1990 to the present day as the functional food era. He defined functional foods as foods that encompass potentially healthful products including any modified food or food ingredient that imparts benefit beyond the food that they contain. Dr. Basu mentioned the dilemma resulting from the fact that there is no universally accepted provision in the current food regulations for functional foods. The situation is further complicated by the fact that some foods work synergistically with other foods.

VII. CONCLUSIONS

In conclusion, the egg of the hen is a natural product which, by virtue of its role in nature has many properties that can be exploited by humans. It can be used as a means of delivering substances beneficial to human health in a form that is natural and highly bioavailable. The hen’s egg can be used for the extraction of its component parts and it can be used for the production (“farming”) of antibodies to a wide range of agents. However, the commercial realities of the production of this range of products are an important determinant of the extent of the market for the ovo-nutraceuticals and bio-medical products from eggs.

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REFERENCES

Ordering information for the Post-Symposium Proceeding Book “The Amazing Egg: Nature’s Perfect Functional Food for Health” Email: jssim@ualberta.ca; Web Site: www.afns.ualberta.ca/eggsymposium/book

186