Functional Foods, Natural Health Products and Nutrigenomics Research in Canada

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ABSTRACT

The relationship between food consumption and health outcomes has become a priority research focus in Canada. This has driven an emerging interest in functional foods, natural health products and nutrigenomics. Capitalizing on its abundant natural resources, world class research expertise, renown facilities and collaborative research environment, Canadian researchers are developing innovative approaches to reduce the incidence of diseases such as hypertension, diabetes type II and cardiovascular disease. Canada boasts approximately 15 government research centres, 16 universities and colleges, 4 technology centres and 2 institutes actively carrying out research in the area of functional foods, natural health products and nutrigenomics. These include three organizations, The Institute of Functional Foods and Nutraceuticals, The Richardson Centre for Functional Foods and Nutraceuticals, and The Canadian Centre for Agri-food Research in Health and Medicine, that are solely dedicated to food and health research. Many of the researchers at these organizations have benefited from investments from the Government of Canada through both the Advanced Foods and Material Network and the Canada Research Chairs Program, that have made significant investments in cutting edge functional food, natural health product and nutrigenomics research in Canada.

Key words: functional foods, nutraceuticals, natural health products, nutrigenomics, Canada

INTRODUCTION

Consumers are becoming increasingly aware of the connection between diet and health and are actively seeking out nutritional-based strategies that have the potential to prevent disease and improve health and well-being. Canada is home to many world-class functional foods and natural health products companies and research and development activities, that capitalize on this increased interest and Canada's strengths in the food and agriculture sectors. Canadian organizations are examining the mechanism and efficacy of functional foods, natural health products and other bioactive compounds in relation to the potential reduction and/or prevention of diet related chronic disease such as diabetes, obesity and cardiovascular disease. Recently, the influence of the relationship between genetics and diet (nutrigenomics) on the above relationships has also received increased attention.

WHAT ARE FUNCTIONAL FOODS?

There is currently no consensus on a standard definition for functional foods in Canada, however, the Bureau of Nutritional Sciences, of the Food Directorate of Health Canada, defines a functional food as a "food that is similar in appearance to, or may be a conventional food, that is consumed as part of a usual diet and that is demonstrated to have physiological benefits or that reduces the risk of chronic disease beyond basic nutritional functions." Functional foods may be created through activities such as fortification with vitamins and minerals, addition of bioactive components, or bioactive component enhancement through processing, plant breeding, or animal feed enhancement[(1)]. Examples include yogurt with probiotics; omega-3 eggs, milk and meat; fortified soy beverages; among others.

WHAT ARE NATURAL HEALTH PRODUCTS?

In 1998 the Bureau of Nutritional Sciences, of the Food Directorate of Health Canada recognized a nutraceutical as "a product isolated or purified from foods that is generally sold in medicinal forms not usually associated with food. A nutraceutical is demonstrated to have a physiological benefit or provide protection against chronic disease." The term nutraceutical has since been replaced by the Directorate by the broader term, Natural Health Products. Natural health products are defined as "vitamins and minerals, herbal remedies, homeopathic medicines, traditional medicines, probiotics, and other products like amino acids and essential fatty acids" that are "…safe to use as over-the-counter products and not need a prescription to be sold" .

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WHAT IS NUTRIGENOMICS?

Nutrigenomics is an emerging discipline of science that assesses how nutrients affect genes (e.g., gene expression) and how genes affect nutrient metabolism (e.g., genetic variation affecting caffeine metabolism), impacting specific health outcomes. The science of nutrigenomics is underpinned by bioinformatics, genomics, molecular biology and nutrition[2], which when combined are used to understand differences and similarities in genetic expression across a population in relation to diet. Nutrigenomics research assesses the relationship between genes and nutrient absorption, metabolism, taste perception and satiation[3].

CANADIAN BENEFITS

Canada's research and development expertise in functional foods, natural health products and nutrigeneomics is world renown for both quality and innovation. The sector takes advantages of Canada's competitive strength including its abundant natural resources; stringent regulatory system; world class research facilities; and collaborative environment involving all levels of government, academia, and private industry. In 2007 a functional foods and natural health products survey indicated that there were 689 firms, employing 100,353 individuals, in the field of functional foods and natural health products with a total revenue of $21.5 billion[4]. Additionally, there are approximately 15 government research centres, 16 universities and colleges, 4 technology centres and 2 institutes actively carrying out research in the area of functional foods and natural health products and nutrigenomics.

Canada has three major organizations solely dedicated to the research and development of functional foods and natural health products: The Richardson Centre for Functional Foods and Nutraceuticals, The Institute of Functional Foods and Nutraceuticals, and The Canadian Centre for Agri-food Research in Health and Medicine. Additionally, the Advanced Foods and Materials Network (AFMNet) has invested in cutting edge research in functional foods, natural health products and nutrigenomics.

RICHARDSON CENTRE FOR FUNCTIONAL FOODS AND NUTRACEUTICALS

The Richardson Centre for Functional Foods and Nutraceuticals is located at the University of Manitoba, in Winnipeg, Manitoba. It is dedicated the research and development of functional foods and natural health products, and economic viability of the industry with a strong focus on the crops of the Canadian Prairies (flax, canola, pulses, and buckwheat). The facility boasts world-renown analytical labs, animal model research facilities, a clinical research unit, pilot plants, and formulation development and natural health product manufacturing capabilities. The Richardson Centre boasts three Canada Research Chairs: Dr. Peter Eck, Canada Research Chair Nutrigenomics; Dr. Peter Jones, Canada Research Chair in Nutritional and Functional Foods; and Dr. Trust Beta, Canada Research Chair, Food Processing for Grain-Based Functional Foods. The Canada Research Chairs program is run by the Government of Canada and invests $300 million dollars per year to attract and retain some of the world's most accomplished and promising minds. Canada Research Chairs demonstrate research excellence in engineering and the natural sciences, health sciences, humanities, and social sciences. The program is designed to strengthen Canada's international competitiveness, train the next generation of highly qualified personnel and produce high impact research.

Dr. Peter Jones, Director of the Richardson Centre, focuses on cholesterol, fat and energy metabolism. Using stable isotope methodologies his group examines the impact of dietary interventions on metabolism. In particular his group evaluates plant sterols as functional foods used to lower cholesterol, and control weight gain. Dr. Peter Eck investigates the interaction between the human genome and nutrients and their relationship with health outcomes. His research program evaluates how genetic variations in membrane proteins impact metabolism, and ultimately disease development and outcome. These investigations may lead to dietary interventions for diseases such as obesity, type II diabetes, some cancers, cardiovascular disease and inflammatory diseases. Dr. Trust Beta investigates age related diseases and the potential of non-traditional plant components in the prevention of these diseases.

The Richardson Centre for Functional Foods and Nutraceuticals has particular strength in functional foods products from Canadian crops. Isolated components of Canadian crops have been implicated in the prevention and/or treatment of many diseases. Recently, Richardson Centre researcher, Dr. Rotimi Aluko, demonstrated the blood pressure lowering effect of a pea protein hydrolysate (PPH) using both mouse and human subjects[5]. *In vitro* the PPH demonstrated activity against renin and angiotension converting enzyme, enzymes implicated in hypertension. In a 3-week intervention trial, the authors reported a significant reduction in systolic blood pressures, suggesting a potential commercial opportunity for PPH as an anti-hypertension therapy. A second group, led by Dr, Peter Jones, evaluated the efficacy of a novel high-oleic rapeseed (canola) oil (HOCO) alone, and mixed with flaxseed oil, on cardiovascular health[6]. In a trial, hypercholesterolaemic subjects consumed three diets with 70% of fat content provided by either HOCO alone, a HOCO oil and flaxseed oil blend, or a blend of oils typical to a western diet. After 28 days, consumption of the HOCO/flaxseed oil led to a reduction of LDL-cholesterol by 15.1%, while consumption of HOCO oil alone led to a reduction of 7.4% when compared to the western diet. This suggested that consumption of the HOCO alone or when blended with flaxseed oil is cardioprotective through lipid-lowering effects. Another study, also conducted by Dr. Jones, using a hypercholes-

terolaemic, overweight participants found that consumption of a whole and fractionated yellow pea flours at doses equivalent to half a cup of yellow peas/d reduced insulin resistance, while whole pea flour reduced android adiposity in women[7]. The use of yellow pea flour as a functional food ingredient was validated in a related study that produced banana bread and biscotti with yellow pea flour. These low-glycemic functional products had sensory attributes that were comparable to identical food products containing whole wheat flour[8].

THE INSTITUTE OF NUTRACEUTICALS AND FUNCTIONAL FOODS

The Institute of Nutraceuticals and Functional Foods (INAF), is situated at the Université Laval in Quebec City, Quebec. INAF was created in 1999 and is now comprised of 38 regular, 29 associate and 2 honorary members. The Institute conducts multi-disciplinary research with the aim of identifying and isolating bioactive compounds and the development of functional ingredients and foods for the benefit of human health. INAF research focuses on sectors significant to the Quebec economy.

INAF boasts six Canada Research Chairs including: Research Chair in Lactic Culture Biotechnology for Dairy and Probiotic Industries (Denis Roy); Research Chair in Nutrition, Functional Foods and Cardiovascular Health (Benoît Lamarche); Research Chair in Physical Activity, Nutrition and Energy Balance (Angelo Tremblay); Research Chair in Protein, Biosystem and Functional Food Physical Chemistry (Muriel Subirade); Research Chair on Use of Dietary Fatty Acids and Cognitive Functions During Aging Process (Stephen Cunnane) and; Research Chair in Animal Reproductive Applied Functional Genomics (Marc-André Sirard). This group of high caliber researchers is investigating numerous areas including natural health product delivery systems, the use of functional foods for the prevention and treatment of obesity-related diseases and cognitive disorders and probiotics.

A particular strength of INAF is its contribution to the investigation of the health benefits of marine derived products. Ouellet *et al*.[9] recently demonstrated that cod protein (CP) improved insulin sensitivity in insulin-resistant subjects. Low-grade inflammation has been implicated in the development of insulin resistance and type II diabetes with studies demonstrating that high levels of C-reactive protein and interleukin (IL)-6 are associated with the development of the disease. Consumption of a diet containing CP decreased high-sensitivity C-reactive protein, suggesting a possible functionally of CP in the prevention of type II diabetes. This result was confirmed by a second study that demonstrated expression of both tumor necrosis factor-α and interleukin-6 in rats was reduced in visceral adipose tissue when fed fish protein from bonito, herring, mackerel, or salmon compared to the control group[10]. Another study, led by Dr. Fédéric Calon[11] demonstrated that in a mouse model, consumption of DHA extracted from fish oil, has a direct effect on neuronal function. Using an Alzheimer disease mouse model, 3xTg-AD, the researchers demonstrated an improved object recognition (↑12%), and partial prevention of seizure-like akinetic episodes (↓50%). This study demonstrated that DHA can play a possible protective role against epilepsy and the deterioration of cognitive performance in Alzheimer patients.

THE CANADIAN CENTRE FOR AGRI-FOOD RESEARCH IN HEALTH AND MEDICINE (CCARM)

The Canadian Centre for Agri-food Research in Health and Medicine (CCARM) is located in Winnipeg Manitoba and is a partnership between St. Boniface Hospital, the University of Manitoba, and Agriculture and Agri-Food Canada. It is dedicated to conducting research to add value to traditional agriculture commodities and produce functional foods and natural health products. The Centre has particular strength in conducting human clinical trials on products that have been shown in the lab to have potential beneficial effects on diseases affecting millions of Canadians. Currently, CCARM focuses on immune disorders, diabetes, obesity, and cardiovascular and vascular diseases.

In one studying undertaken at CCARM the potential of conjugated linoleic acid (CLA), found in meat and dairy, as a natural health product for the treatment of cardiac hypertrophy, a major factor in heart failure, was evaluated. In hypertensive heart failure rats, CLA supplementation was shown to significantly reduce blood pressure and cardiac hypertrophy[12]. The authors noted these findings were particularly significant given that ~44% of heart failure patients resort to nutrition-based therapies. A second study, led by Dr. Grant Pierce, demonstrated that dietary flaxseed may have the potential to protect against atheroscerlosis development caused by consumption of industrially hydrogenated *trans* fatty acids (TFA)[13]. Using low-density lipoprotein receptor deficient (LDLr-/-) mice, the team demonstrated that addition of flaxseed to a diet high in TFA and cholesterol significantly reduced atherosclerosis as compared to groups that did not receive the addition of flaxseed. This work is significant because despite recommendations to reduce dietary TFAs, it is impossible to completely avoid their ingestion.

NUTRIGENOMICS IN CANADA

Canada has world-renown expertise in nutrigenomics with a two Canadian Research Chairs, Dr. Ahmed El-Sohemy, and Dr. Peter Eck. Dr. Ahmed El-Sohemy at the University of Toronto, leads a research program that identifies biomarkers of dietary exposure and elucidates the genetic basis for variability in nutrient response and dietary preferences. His research group has established the Toronto Nutrigenomics and Health

Study, a cross-sectional analysis of diet, genotype and biomarkers of chronic disease in an ethnoculturally diverse population of ~2000 young adults. Using the Study, his research group has demonstrated that genetic variation in the main target of caffeine action in the central nervous system affected habitual caffeine consumption, demonstrating the genetic reason behind an individual's desire to consume coffee[14]. In another study, it was demonstrated that genetic variation of GLUT2, a transmembrane glucose carrier protein, influences sugar consumption for some individuals[15]. The group has also demonstrated the impact of dietary fatty acids on cardiometabolic diseases is influenced by small nucleotide polymorphisms in genes associated with the body's inflammatory response[16]. Alternatively, Dr. Peter Eck investigates genetic variations in membrane transporters. These proteins are involved in absorption, distribution, and elimination of a large number of dietary components, and are implicated in disease susceptibility. Dr. Eck and his team of researchers are characterizing variations of membrane transporters transporting Vitamin C[17,18] and glucose[19]. Investigations undertaken by researchers such as Drs. El-Sohemy and Eck, elucidate the relationship between genes and diet, enabling the design of tailoured and novel functional foods and natural health products for the benefit of the health and well-being of the consumer.

THE ADVANCED FOODS AND MATERIALS NETWORK

AFMNet was launched in 2003 as a federally funded Network of Centre of Excellence. Now a not-for-profit, AFMNet has positioned itself as a leader in food and health research and innovation, with an international network of researchers, industry professionals and government agencies. Its multidisciplinary approach has brought together researchers and partners who have not traditionally collaborated in the past. Over the past 7 years, AFMNet funded researchers have investigated topcis such as: nutrigenomic studies on the effectiveness of stabilizing reduced folates using nano-encapsulation technologies (Dr. David Kitts); engineering the oil binding capacity and rheological properties of nanocrystalline fat networks with the aim to reduce partially hydrogenated fats for the Canadian diet (Dr. Alejandro Marangoni); the impact of apolipoprotein E polymorphisms on the risk of cognitive decline (Dr. Stephen Cunnane) and; the impact of diet and gut health and general well-being (Drs. Martin Kalmokoff and Brent Selinger). The investments made in AFMNet's research program are yielding new strategies to improve the health and well-being of Canadians.

CONCLUSIONS

It is widely recognized that preventable food-related chronic disease such as hypertension, cardiovascular disease, and type II diabetes impose an enormous social and economic burden on Canadian society. Efforts to reduce the incidence of many of these chronic diseases have been of questionable effectiveness. In part, this reflects the complexity of relationships between food and health status. The research and development of functional foods and natural health products, in conjunction with elucidation of the impact of genetics on diet-health relationships has enormous potential of preventing and treating chronic diseases. Canada's investment, through various funding programs including the Canada Research Chair program and various centres, in functional foods, natural health products and nutrigenomics research is leading the innovative approaches to improve the health and well-being of all Canadians

ACKNOWLEDGMENTS

The support of the Natural Sciences and Engineering Research Council of Canada, the Canada Research Chairs Program and the Advanced Foods and Materials Network is gratefully acknowledged.

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