Optimal lipid metabolism with disease-preventing functional foods

Dietary lipids (fats) from plant and animal sources are important components of the human diet as they provide essential nutrients for growth and development. However, overconsumption of lipid-rich foods can lead to hyperlipidaemia – a key risk factor for metabolic diseases, such as cardiovascular diseases and diabetes. Modulating lipid digestion and absorption through the design of food structures, matrices and compositions could lead to the creation of novel foods that can help to control postprandial lipaemia while triggering feelings of fullness. Professor Harjinder Singh and Dr Alejandra Acevedo-Fani of the Riddet Institute, New Zealand, are exploring the underlying science leading to the design of these novel foods.

In their recent research, Professor Harjinder Singh and Dr Alejandra Acevedo-Fani of the Riddet Institute Centre of Research Excellence, Massey University, New Zealand collaborated to explore the mechanisms behind the digestion of dietary fats (also known as lipids) in food emulsions. More specifically, they have been examining how to modulate the rate of lipid digestion and absorption, and the consequence on postprandial lipaemia (the level of lipids in the blood following a meal). The hope is that this wider knowledge will pave the way for producing foods specifically designed to tackle modern population health challenges, including obesity and other metabolic diseases.

OIL-WATER INTERFACES

Where the lipids contained within most foods take the form of oil droplets dispersed in a matrix made up of different connected parts. Stable oil-water interfaces are needed to create food emulsions. These interfaces are critical for establishing how the lipid droplets interact with the other components within the food matrix. They can, therefore, be manipulated to affect the stability of an emulsion within a food before it is consumed. Conversely, relatively little is known about how emulsions behave during their journey through the gastrointestinal tract (GIT). Yet understanding the behaviour of emulsions in the GIT is key to understanding the digestion of lipids, their uptake by the human body and the possible effect of health.

FACTORS AFFECTING LIPID DIGESTION

Evidence suggests that the physico-chemical properties of emulsions affect the way they behave in the GIT. Furthermore, it is suggested that the structural properties of foods regulate lipid digestion and, therefore, affect the ability of nutrients within lipids to be absorbed. However, as Singh and Acevedo-Fani point out, further research is needed in this area before this knowledge can be used to influence strategies for regulating fatty acid absorption and the bioavailability (the fraction of released nutrient that is available for absorption) of lipid nutrients. More specifically, it will be necessary to understand 1) how the makeup of interfaces of the lipid droplets affects lipase activity (an enzyme the body uses to break down dietary lipids); 2) how bile salts (liver secretions that aid to break down lipids) disrupt the original oil-water interfaces; and 3) what the state of the droplets is just before absorption.

MEMBRANE TRANSPORT OF LIPIDS

Emulsion interface functions as a protective barrier that controls the rate at which lipids are digested. It is also possible to select certain elements of emulsions that can bind to digestive enzymes and bile salts to reduce their ability to solubilise and transport the products of lipid digestion. Additionally, the intestinal lumen contents can be made thicker and stickier by adding gelling or thickening agents in the emulsions. This slows the transport of enzymes towards the emulsion droplet and the diffusion (moving from an area of higher concentration to an area of lower concentration) of the digestion products towards the gut epithelium, where they are absorbed.

FATS AND FUNCTIONAL FOODS

Functional foods with reduced fatty acid bioavailability could be particularly beneficial to people with hyperlipidaemia, who are at high risk of cardiovascular disease and obesity. Indeed, there is awareness of the need, among both consumers and the food industry, to address the serious public health issue of the obesity epidemic. However, in tackling this problem, it will be important not to forget the nutritional value of dietary fat, which provides an important, immediate source of essential fatty acids.

FACTORS AFFECTING FULLNESS

MRI scans have been used to explore the relationship between how emulsions behave within the GIT and their effects on feelings of fullness. This research has improved understanding of how the contents of the GIT are distributed as well as stomach emptying. Oil-in-water emulsions that are stable in the acidity of the stomach appear to slow the rate of emptying while increasing levels of cholecystokinin (CCK; a gut hormone which signals fullness) after eating. Conversely, emulsions that break down in these acid conditions result in rapid layering of fat in the stomach, which speeds up emptying and releases less CCK.

TAILORING EMULSIONS FOR LIPID METABOLISM

As our understanding of how different food emulsion systems interact with a range of biochemical and biophysical environments in the GIT has been increasing over the last decade, this has created the potential to design emulsions with specific structures and properties. These emulsions can modulate the rate of lipid transport, digestion, and absorption. However, most existing studies in this area have relied upon comparatively simple model systems and lab-based digestion models. Furthermore, attempts to alter the interfacial layers of emulsions to affect lipid digestion have had limited success because of the high levels of surface activity of bile salts. Additionally, while encapsulating emulsion droplets inside hydrogel particles has been shown to delay lipid digestion, this method is unlikely to be widely applicable in real foods.

MANIPULATING OIL DROPLETS

Manipulating the physical state and internal structure of oil droplets is another potential strategy. This can be achieved by altering the ratio of solids to liquids (lipids). However, this could lead to part of the lipid (solid, crystalline fat that melts above body temperature) being completely indigestible. Therefore, as Singh and Acevedo-Fani highlight, before approving this strategy for use in foods, it is necessary to understand any potential physiological effects of allowing these undigested lipids to enter the large intestine. What is more, in terms of human health, it would not be advisable to increase the saturated and trans fat content of foods.

DESIGNER FOOD MATRICES

Controlling the rate at which the stomach empties lipids is the most realistic strategy for delaying lipid
Behind the Research

Professor Harjinder Singh

Dr Alejandra Acevedo-Fani

Research Objectives

Professor Harjinder Singh and Dr Alejandra Acevedo-Fani research lipid digestion.

Detail

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Bio

Harjinder Singh is Distinguished Professor and the Director of the Riddet Institute (Centre of Research Excellence), Massey University, New Zealand. His research expertise includes food proteins, food colloids, and food structures and digestion interface. He has published over 350 research papers in international journals. He is a Fellow of the Royal Society of New Zealand and a Fellow of the International Academy of Food Science and Technology, and has received several international awards, including the New Zealand Prime Minister’s Science Prize.

Dr Alejandra Acevedo-Fani is a Research Officer at the Riddet Institute, New Zealand. Her research involves investigating modifications of the food structure in the digestive tract, particularly bioactive compounds-enriched foods, food emulsions, and plant protein-based foods. Alejandra is also a Marie Curie Fellow at the International Iberian Nanotechnology Laboratory in Portugal jointly with her role at the Riddet Institute.

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References


Personal Response

What action are food industry stakeholders taking in response to your research findings?

The area of lipids and health has been of major interest for the global food industry for many decades. To date, the focus has been on developing food products with low fat content and in particular low levels of saturated and trans fats. However, the challenge has been to match the consumers’ organoleptic properties of fully fat products. Some high fat products with added plant sterols are commercially available to reduce the absorption of cholesterol. The concept of controlling the rate of lipid digestion through food structure design is relatively new and has not been yet translated into commercial products, to our knowledge.

INTERCONNECTED FOOD COMPONENTS

Most foods are complex in structure and composition. The emulsion is just one of the components of a food. It can help to form the structures of more complex components, such as proteins and polysaccharides, which then form a matrix to trap or interact with emulsion droplets, such as in yoghurt, processed cheese, and other gels. However, the way in which emulsion structures designed to modulate lipid digestion behave in these complex systems is not yet fully understood. Therefore, when designing complex foods in future, it will be important to ensure that the emulsion system behaves in the desired way within the body.

MANIPULATING MULTIPLE INTERACTIONS

Another approach could involve manipulating the interactions between a range of components within the complex food system in order to affect the way the emulsified droplets behave during digestion. As understanding of the complexity of lipid digestion in relation to food systems increases, it will eventually be possible to design functional foods with specific lipid digestion profiles. These foods will induce specific responses within the body, helping to increase feelings of fullness after eating and reduce the prevalence of obesity and cardiovascular disease risk. First, as Singh and Acevedo-Fani highlight, more human trials are needed to determine the long-term effects on health of delaying or controlling lipid digestion.

BIOPOLYMER INTERPLAY

Singh and Acevedo-Fani also reviewed the existing evidence on interactions of biopolymers, such as proteins and polysaccharides, relating to the physiology of digestion in the stomach. Along with lipids, foods are made up of a wide range of biopolymers, and the ways in which these biopolymers interact during food processing and formulation play a part in creating different structures and different physical and sensory properties of food products. These structures have been used to develop new functions and textures in processed foods, along with matrices to encapsulate and deliver flavours and nutrients.

BREAKDOWN AND CREATION OF FOOD STRUCTURES

Through their research, Singh and Acevedo-Fani found that the way in which biopolymer interactions work during digestion, and how they impact on stomach emptying and nutrient absorption, is not yet fully understood. What is known, however, is that the stomach is critical to both the physical disintegration of food structures and the formation of entirely new structures. Its unique environment, with low pH, high salt strength, and enzymatic hydrolysis, allows macromolecules to interact, which can result in the formation of gels and coagulation. Yet while there is some understanding of this area, determining the characteristics of structures formed of different food components and biopolymers within the stomach and the way within the body.

Controlling the rate at which the stomach empties lipids is the most realistic strategy for delaying lipid digestion.

FURTHER RESEARCH

As Singh and Acevedo-Fani explain, the ultimate aim of understanding lipid digestion is to reduce health problems associated with hyperlipidaemia without reducing the health benefits of consuming fat. Understanding the interplay between food structures and rates of nutrient digestion will facilitate the production of foods designed for specific health characteristics. Moving forward, intensive clinical studies are needed to test the effectiveness of functional foods.