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Balancing act: Understanding nutrient interactions

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Abstract

Nutrient interactions refer to the dynamic relationship between various nutrients, including minerals, vitamins, amino acids, and fatty acids, for proper functioning. An excess or deficiency of one nutrient can affect the requirements for many others, and increasing or decreasing a deficient nutrient may require an increase in other nutrients. Many nutrients require other nutrients to convert into other forms, and chemical combinations or reactions between nutrients can change their biological availability. Direct metabolic requirements of one nutrient can change the biological activity of another. Structurally similar nutrients can compete for absorption and utilization, and one nutrient can replace another with a different action. This review deals with different types of interaction observed in between dietary carbohydrates, dietary proteins and dietary fats.

Keywords: Dietary carbohydrates; Dietary proteins; Dietary fats; Dietary interactions; Nutrient interactions;

1. Introduction

A nutrient is a substance used by an organism to survive, grow, and reproduce. These are chemical materials required by the body to sustain basic functions and are optimally attained by eating a balanced diet. There are six major classes of nutrients essential for human health: carbohydrates, lipids, proteins, vitamins, minerals, and water. Carbohydrates, lipids, and proteins are considered macronutrients and serve as a source of energy. Water is required in large amounts but does not yield energy. Vitamins and minerals are considered micronutrients and play essential roles in metabolism. Vitamins are organic micronutrients classified as either water-soluble or fat-soluble. The essential water-soluble vitamins include vitamins B1, B2, B3, B5, B6, B7, B9, B12, and C. The essential fat-soluble vitamins include vitamins A, E, D, and K. Minerals are inorganic micronutrients. Minerals can classify as macrominerals or microminerals. Macrominerals are required in amounts greater than 100 mg per day and include calcium, phosphorous, magnesium, sodium, potassium, and chloride. Sodium, potassium, and chloride are also electrolytes. Microminerals are those nutrients required in amounts less than 100 mg per day and include iron, copper, zinc, selenium, and iodine [1].

Macro and micronutrients can interact via a number of pharmaceutical, pharmacokinetic, or pharmacodynamic mechanisms showing complementary, antagonist, synergistic effects. Nutrient synergy refers to the concept that the combined effects of two or more nutrients working together have a greater physiological impact on the body than when each nutrient is consumed individually whereas nutrient antagonism refers to decrease in the efficacy of nutrients when combined together [2].

2. Dietary Carbohydrates interaction

Carbohydrates are the primary macronutrients that humans consume in large quantities in their daily diet to provide the energy needed in order to support various metabolic processes in the human body. Dietary carbohydrates, namely sugars, starch, and non-starch polysaccharides, are major energy sources in the human diet that support body

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metabolism. Food of any plant origin, such as fruits, vegetables, edible seeds, grains, legumes, and wholegrains, are reliable sources of dietary carbohydrates for humans. Some of the interactions in between carbohydrates and other nutrients are:

- Interaction between carbohydrates and vitamin D3 activates the insulin signaling pathway. The present study confirmed that 36.5% of dietary carbohydrate and 1000 IU/kg of dietary vitamin D3 significantly increase the growth of abalone. The interaction between dietary carbohydrate and vitamin D3 were significant on the growth, gluconeogenesis, pentose phosphate pathway and glycogenolysis [3].
- Insulin is essential for metabolizing carbohydrates, fats, and proteins. The glycemic response is primarily determined by the total amount of carbohydrate ingested, rather than the carbohydrate source. High fat intake along with carbohydrate can contribute to insulin resistance.
- Thiamine is a member of the vitamin B family. It plays a fundamental role in regulating energy metabolism, specifically in coordinating mitochondrial and cytosolic biochemical processes. Dietary thiamine supplementation can promote growth performance and intestinal mitochondrial biogenesis when taken along with carbohydrate diets. This might be achieved through the improved intestinal digestive and absorptive functions, the activation of the AMPK/PGC-1 axis, the up-regulation of the fusion-related genes, and the enhanced activities and transcriptions of mitochondrial enzyme complexes [4].
- Co-ingestion of fructose and glucose reduced insulin sensitivity and glucose tolerance. The increased consumption of fructose has been linked to increased obesity rates in humans. Studies have shown an increase in de novo lipogenesis and decreased insulin sensitivity in response to high fructose levels [5].
- Fats can enhance the absorption of certain nutrients, such as fat-soluble vitamins (A, D, E, and K) and phytochemicals, from plant-based sources. Consuming a small amount of healthy fats with carbohydrates from plant-based sources can enhance nutrient absorption and provide optimal nutrition. The liver plays a crucial role in regulating carbohydrate metabolism in response to feeding and fasting statuses. Experiments in rodents show that both hypervitaminosis A and hypovitaminosis A affect carbohydrate metabolism in the liver. In Vitamin A deficiency, the liver glycogen content is abolished due to decreased glycogenesis from acetate, lactate, and glycerol, rather than directly from glucose. This decreased glycogenesis can be recovered by the administration of glucocorticoid hormones. In Hypervitaminotic A have higher liver glycogen deposition in the fed state but higher hepatic glycogenesis after fasting. Excessive Vitamin A intake can prevent hepatic glycogenolysis under fasting conditions and enhance hepatic glycogenesis from glucose. Vitamin A is an important regulator of hepatic glycolytic enzymes and regulates gluconeogenesis, a metabolic pathway essential for maintaining fasting blood glucose levels. The regulation of gluconeogenesis by Vitamin A can also occur at the transcription level of Pck1 expression in the liver [6].
- Epidemiological and clinical studies have shown an inverse relationship between the consumption of dietary fiber-rich and wholegrain foods with obesity. The consumption of dietary fiber-rich foods was reported to benefit weight management due to lower energy intake and absorption, an increase in postprandial energy expenditure due to improved gastrointestinal motility, and efficient elimination of bile acid that drives body fat mobilization. This is because diets that are high in fibers often tend to have lower fat content and generate a strong satiety sensation, which leads to reduced total food (or energy) intake. Since dietary fibers are generally indigestible, they provide a lower energy yield to that of digestible carbohydrates, too [7].

3. Dietary Protein interactions

Dietary proteins are essential macronutrients for the human body and also critical food components to impart unique functionality and quality to related products. Dietary protein provides amino-acids to maintain the proteome's content, structures and function of the organism and to provide for growth and special needs [8]. In complicated hybrid systems, dietary proteins are known to interact with other ingredients, such as phenolic compounds, carbohydrates, and lipids to generate aggregates, resulting in structural changes that are closely associated with their nutritional and biological characteristics. Some of the dietary protein interactions are:

The interactions between dietary proteins and phenolics, either via non-covalent or covalent processes, are ubiquitous in food systems and are closely associated with chemical structures of both compounds and the surrounding conditions, mainly temperature, pH, and the presence of phenolic oxidases [9].

High dietary protein intakes are known to increase urinary calcium excretion and, if maintained, will result in sustained hypercalciuria if consumed along with calcium supplements. Studies on calcium balance in humans have not found an effect of dietary protein on intestinal calcium absorption or serum parathyroid hormone. However, recent research suggests that dietary protein can significantly affect intestinal calcium absorption. In short-term dietary trials, increasing dietary protein led to hypercalciuria and a significant increase in intestinal calcium absorption. Dietary protein intakes below 0.8 g/kg were associated with a reduction in intestinal calcium absorption, potentially causing secondary hyperparathyroidism. The long-term consequences of these changes in mineral metabolism are unknown, but the diet could be detrimental to skeletal health. Recent epidemiologic studies have shown reduced bone density and increased rates of bone loss in individuals habitually consuming low-protein diets [10].

Protein metabolism is influenced by the presence of Vitamin A, a substance that plays a crucial role in the body's energy production. In Vitamin A deficiency, urinary nitrogen excretion increases with a negative nitrogen balance, while plasma urea levels rise. Vitamin A deficiency also increases mRNA levels and enzyme activities of most urea cycle enzymes in the liver, suggesting increased protein catabolism. The effect of Vitamin A deficiency on protein anabolism is controversial, with some studies showing no adverse effect on protein synthesis, while others show enhanced protein synthesis capability [11].

Proteins and fats are digested differently. Proteins are broken down into amino acids and absorbed in the stomach and small intestine, while fats are broken down into fatty acids and glycerol and absorbed in the small intestine. Consuming proteins and fats together can slow down the digestion of proteins, which can help regulate blood sugar levels and provide a sustained source of energy.

4. Dietary Fats interactions

Lipids comprise a group of polar and nonpolar compounds, including triglycerides, diglycerides, monoglycerides, fatty acids, phospholipids, and sterols. In the diet, lipids contribute to the taste, texture, and energy content of a food. In the body, lipids have many roles including a source of readily available and stored energy, a structural and functional component of all cell membranes, and precursors for eicosanoids and cell signaling molecules, in addition to helping with the absorption of fat-soluble vitamins and other food components [12]. Dietary fat is an important energy source and if insufficient intake (together with inadequate protein and carbohydrate) occurs, an individual will go into negative energy balance and lose weight and/or not grow. Some of the dietary interactions encountered with fats intake are:

- The effects of dietary fat depend on an interaction between protein quantity and quality. Although increasing dietary fat increased bodyweight gain and tissue weight irrespective of protein quantity and source. Jejunum and liver transcriptomics revealed increased intestinal permeability, low-grade inflammation, altered lipid metabolism, and liver dysfunction was noted when dietary fats are combined with dietary proteins [13]. Protein and fat are both known to promote feelings of fullness and satiety, which can help regulate appetite and prevent overeating. Consuming a combination of protein and fat can help promote satiety and reduce hunger.
- Among the macronutrients, dietary lipids have been studied most extensively in conjunction with dietary fiber. The inclusion of dietary fiber in diet not only displaces lipids, but it also frequently alters or diminishes their physiological and nutritional contributions. This is usually demonstrated in reduced calorie density of the diet, in reduction of blood and hepatic lipids, and in alteration and output of fecal lipids. These changes are of a major significance since they are believed to be beneficial in preventing or reducing serious diseases which include obesity, coronary heart disease as well as certain types of cancer [14].
- Vitamin A, or hepatic acylcholinesterase, plays a crucial role in the metabolism of lipids and lipids. Excessive Vitamin A supplementation along with Fatty diet can lead to hypercholesterolemia, hypertriglyceridemia, and high serum low density lipoprotein levels. severe type V hyperlipoproteinemia-associated hypertriglyceridemia have an increased risk for developing hypervitaminosis A. Excessive Vitamin A intake can lead to increased hepatic lipid synthesis and oxidation, leading to lipid accumulation in the liver. Conversely, Vitamin A deficiency can cause a partial hypolipidemic effect, with decreased hepatic phospholipid content and decreased serum levels of Triglycerides, cholesterol, and high-density lipoprotein. The hypolipidemic effect may be due to decreased fattyacid synthesis activity in the liver and impaired cholesterol synthesis from mevalonate. The dyslipidemia in Vitamin A deficient and hypervitaminotic A is a multicausal effect, with distinct responses of hepatic lipid metabolism to Vitamin A status [15].
- vitamin D controls energy metabolism in adipose tissue by affecting fatty acid oxidation, expression of uncoupling proteins, insulin resistance, and adipokine production. Adipose tissue inflammation can have a significant impact on the metabolic disorders often associated with obesity, and vitamin D can modulate the inflammatory response of immune cells and adipocytes within the adipose tissue [16].

5. Conclusion

Interactions between dietary nutrients present complex and challenging problems. They may arise either from alteration of the absorption, distribution, biotransformation, or excretion of one nutrient by another dietary supplement or from a combination of their actions or effects.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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