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**REVIEW ARTICLE****OPEN ACCESS**

# POTENTIAL FUNCTIONAL FOODS FOR OBESITY

NEETU<sup>1</sup>, KIRAN BAINS<sup>2</sup>, MADHU<sup>3</sup>**Corresponding Author: NEETU<sup>1</sup>****ABSTRACT**

Functional foods are similar to conventional foods in appearance, but they have benefits that extend beyond their basic nutritional properties. For example, functional foods have been studied for the prevention of osteoporosis, cancer, and cardiovascular disease. They have yet to be related to the prevention of obesity, although obesity is one of the major health problems today. The inclusion of foods or the replacement of habitual foods with others that may enhance energy expenditure (EE) or improve satiety may be a practical way to maintain a stable body weight or assist in achieving weight loss; such foods may act as functional foods in body weight control. Some foods that might be classified as functional foods for weight control because of their effects on EE and appetite are reviewed here. Only human studies reporting EE, appetite, or body weight are discussed. When studies of whole food items are unavailable, studies of nutraceuticals, the capsular equivalents of functional foods, are reviewed. To date, dietary fats seem to be most promising and have been the most extensively studied for their effects on body weight control. However, the weight loss observed is small and should be considered mostly as a measure to prevent weight gain. Carefully conducted clinical studies are needed to firmly ascertain the effect of functional foods on body weight maintenance and to assess their potential to assist in weight-loss efforts.

**KEY WORDS:****Obesity, Energy Expenditure, Functional Foods****INTRODUCTION**

Maintenance of a constant body weight requires a balance between energy intake (EI) and energy expenditure (EE), and even a slight imbalance in this energy equilibrium can lead to significant changes in body

weight over time and may eventually result in obesity [1]. Obesity is one of the major health problems worldwide, and it is a risk factor for several chronic disorders, but there is no functional food for obesity, such as there is for cardiovascular disease (CVD) or cancer. In the Health Professionals

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Follow-up Study, mean weight change over a 10-y period was 1.8 kg [2]. Even small changes in energy balance may lead to such a weight gain, which therefore may be prevented by slight modifications in food intake, such as the inclusion of functional foods for weight management. Although it is known that dietary restriction and increased physical activity can lead to weight loss, such lifestyle changes may be difficult to implement and maintain—thus, the high rate of recidivism among weight losers [3]. Functional foods that effect energy metabolism and fat partitioning may be helpful adjuncts to a dietary approach to body weight control. The current review examines current literature to identify potential functional foods that may be useful in the prevention of weight gain or as adjuncts to weight-loss efforts. It is not within the scope of this review to examine overall diets or individual food components, such as vegetarian diets and fiber or protein, so that only foods that have been studied for their effects on body weight, EE, or satiety (or all 3) are reviewed.

With a global increase in the prevalence of obesity, both nutrition and exercise play key roles in obesity prevention and control. Natural product (nutraceutical) interventions are currently being investigated on a large-scale basis as potential treatments for obesity and weight management. Functional, health-enhancing foods, or nutraceuticals, are food-type products that influence specific physiological functions in the body. This function provides benefits to health, well-being, or performance beyond regular nutrition, and products of this nature are marketed and consumed for these value-added properties [4]. A convergence

of public events on a global scale has placed obesity at the forefront of food policies and corporate strategies. While it has generated innumerable conferences and an entire low carbohydrate food passion in the short run, its real promise is in long term proven product development of foods that are demonstrated to functionally impact obesity — or functional foods for obesity control.

Nutraceuticals, sometimes referred as functional food, have caused heated debate because they blur the traditional dividing line between food and medicine. When food is being cooked or prepared using “scientific intelligence” with or without the knowledge of how or why it is being used, then the food is called as “functional food”. Thus, functional foods provide the body with the required amount of vitamins, fats, proteins, carbohydrates necessary for healthy survival. When functional food aids in the prevention and/or treatment of disease(s)/disorder(s) other than deficiency conditions like anemia, then it is called a nutraceutical [5]. Thus, a functional food for one consumer can act as a nutraceutical for another. Examples of nutraceuticals include fortified dairy products (milk is such a nutrient as one of its natural ingredients, casein, is a pharmaceutical) and citrus fruits (orange juice is also a nutrient since its constituent ascorbic acid is a pharmaceutical) [5, 6].

## **CURRENT STATUS OF NUTRACEUTICALS IN OBESITY**

There is a very high prevalence of obesity globally, hence nutrition and exercise play key roles in its prevention and treatment. Nutraceuticals like conjugated linoleic acid (CLA), capsaicin, Momordica

Charantia (MC), and Psyllium fiber possess potential antiobese properties [4]. A blend of glucomannan, chitosan, fenugreek, G sylvestre, and vitamin C in the dietary supplement significantly reduced body weight and promoted fat loss in obese individuals. Further studies are needed to establish long term efficacy and adverse effect potential [6].

## PATHOPHYSIOLOGY OF OBESITY

Obesity is accompanied by adipose tissue hyperplasia and hypertrophy. The adipose tissue serves as an important initiator of a chronic low grade systemic inflammatory response.[7] This is characterized by infiltration of macrophages and other immune cells with subsequent release of proinflammatory cytokines like interleukin-1 (IL-1), tumor necrosis factor- $\alpha$  (TNF  $\alpha$ ), plasminogen activator inhibitor-1, leptin, monocyte chemoattractant protein-1 (MCP-1), serum amyloid A (SAA), retinol binding protein- 4(RBP-4), macrophage inflammatory protein (MIP) [8–10]. All these mediators lead to deranged insulin sensitivity, dysregulated energy, and vascular system homeostasis. Macrophage infiltration and inflammation in other organs like liver and skeletal muscle further contribute to insulin resistance.[11] Furthermore, plasma levels of vitamins and antioxidants are lower in the obese[12] and an inverse relationship has been shown between serum total antioxidant capacity and waist circumference. [13] Research also indicates the modulatory effects of vitamins and antioxidants on the immune system [14] and these reduced levels have a role in the development of inflammation

and ultimately disease, in obesity. Pharmacological approaches and various surgical procedures at disposal are associated with shear expenses. Nutritional strategies aimed to reduce positive energy balance by decreasing energy intake, increasing energy expenditure, and suppressing the inflammatory excursions seem to be a very logical and attractive alternative. A nutraceutical is 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.[15] These in combination with the lowering of saturated fats, and exercise intervention may hold the key to the treatment of the metabolic syndrome which is plaguing much of the world today.[16]

## THE CURRENT ARTICLE REVIEWS THE NUTRACEUTICAL AGENTS FOR OBESITY TREATMENT.

### CURCUMIN

Turmeric, derived from the plant *Curcuma longa*, is a gold colored spice commonly used in the Indian subcontinent for health care, preservation of food, and as a yellow dye for textiles. Curcumin is the pigment imparting yellow color to turmeric.

### EVIDENCE

(a) Animal studies have shown that curcumin administration ameliorated diabetes in obese and leptin-deficient ob/ob C57BL6/J mice, as indicated by glucose- and insulin-tolerance testing and the percentage glycosylated hemoglobin.[17]

(b) Jain et al. reported that curcumin

supplementation lowered the high glucose-mediated monocyte production of inflammatory cytokines, including TNF- $\alpha$ , IL-6, IL-8, and MCP-1. This same study also showed that blood levels of TNF- $\alpha$ , MCP-1, glucose, and glycosylated hemoglobin were decreased in diabetic rats on a curcumin diet.[18]

(c) Curcumin inhibits adipogenesis in 3T3-L1 adipocytes and angiogenesis in adipocytes and obesity in C57/BL mice. The suppression of angiogenesis is by reduced expression of vascular endothelial growth factor (VEGF) and its receptor VEGFR-2. Curcumin increases 5 AMP-activated protein kinase phosphorylation, reduced glycerol-3-phosphate acyl transferase-1, and increased carnitine palmitoyltransferase-1 expression, which led to increased oxidation and decreased fatty acid esterification in adipose tissue. The curcumin suppression of angiogenesis in adipocytes together with its effect on lipid metabolism in adipocytes may contribute to lower body fat and body weight gain.[19]

Taken together, these data suggest that curcumin may be a useful phytochemical for attenuating obesity-induced inflammation and obesity-related metabolic complications. For general use including weight loss, most practitioners recommend the following doses:

- Standardized curcumin powder: 400 to 600 mg three times daily
- Tincture (1:2): 15 to 30 drops up to four times daily
- Liquid extracts (1:1): 30 to 90 drops daily

## CAPSAICIN

Capsaicin, a biologically active ingredient found in red chili peppers. Capsaicin and several related compounds are called capsaicinoids and are produced as a secondary metabolite by chili peppers, probably as deterrents against certain herbivores and fungi. Pure capsaicin is a hydrophobic, colorless, odorless, and crystalline to waxy compound.

### EVIDENCE

- (a) Several studies have shown potential benefits of capsaicin for treating obesity and insulin resistance in animal models and clinical studies[20,21]
- (b) Capsaicin was shown in animal studies to increase the insulin-stimulated uptake of glucose in muscle cells[22]
- (c) Zhu et al. have demonstrated that activation of transient receptor potential vanilloid type-1 (TRPV1) by capsaicin prevents adipogenesis.[23]

The exact amount found to be effective is between 8 and 25 micromoles of capsaicin per day. These results indicate that capsaicin may be useful for the treatment of obesity-related inflammatory metabolic dysfunctions.

## CONJUGATED LINOLEIC ACID

Conjugated linolenic acid (CLA) is found primarily in the seeds of flax, and nut oils, as well as fish, and more readily in poultry eggs. CLA is very sensitive to temperature change and should not be used to cook food. It should rather be administered in its original state in salad dressings or taken as a therapeutic dosage.

## EVIDENCE

(a) Supplementation of CLA reduced fat mass of obese individuals.[24](b) In one specific study, multiple dosages were experimented with, which included placebo (9 g olive oil), and dosages of up to 6.8 g of CLA. A reduction of fat mass was observed to be significant with the 3.4 g ( $P = 0.05$ ) and 6.8 g ( $P = 0.02$ ) groups, respectively. However, it should be noted that no greater amount of fat mass was noticed when the dosage was higher than 3.4 g, respectively. [24](c) In a recent study it has been shown that adding CLA to a high fat diet fed to rodents actually prevented the onset of obesity-induced muscle insulin resistance. [25]

However, what may be problematic is that there have been few clinical evaluations on humans.[26] Thus it is important to further explore the mechanisms and evaluate further weight loss in humans.

## POLYUNSATURATED FATTY ACIDS

Fatty acids (FAs) can function as endogenous ligands that modulate inflammatory responses. Saturated FAs promote inflammation by activating toll-like receptor 4 (TLR4) on fat cells and macrophages and unsaturated FAs are weakly proinflammatory or neutral.[27] However,  $\omega$ -3 polyunsaturated fatty acids (PUFAs) from fish oils, such as docosahexanoic acid (DHA) and eicosapentaenoic acid (EPA), are known antiinflammatory factors.[28] These agents suppress obesity mediated activation of inflammation.

## EVIDENCE

(a) Sekiya et al. have demonstrated that

PUFA markedly decreased the mature form of sterol regulatory element-binding protein (SREBP-1) protein and thereby reduced the expression of lipogenic genes such as fatty acid synthase (FAS) and stearoyl-CoA desaturase 1 (SCD1) in the livers of ob/ob mice. Consequently, the liver triglyceride content and plasma alanine aminotransferase (ALT) levels were decreased. Furthermore, both hyperglycemia and hyperinsulinemia in ob/ob mice were improved by PUFA administration, similar to the effect of PPAR  $\alpha$  activators. They concluded that PUFAs ameliorate obesity-associated symptoms, such as hepatic steatosis and insulin resistance, presumably through both down-regulation of SREBP-1 and activation of PPAR  $\alpha$ . [29]

(b) Robinson et al. have demonstrated that dietary n-3 polyunsaturated fatty acids modulate each of the components of the triad of adiposity, inflammation, and fatty acid metabolism, with particular attention to the role of the postprandial period as a contributor to the pathophysiology of metabolic syndrome.[30]

In conclusion, fish oil supplements can alleviate metabolic disease by modulating inflammatory signalling pathways.

## PSYLLIUM FIBER

Psyllium fiber is extracted from the husks of its seeds. These seeds are used commercially for the production of mucilage.

## EVIDENCE

(a) It has been implicated in the reduction of low density lipoprotein levels in humans.[31]

(b) Minolest is a mixture of psyllium fiber and guar gum, and was administered in a randomized placebo control study. Patients who received Minolest, revealed improvement of overall cholesterol and LDL levels as compared with the placebo group.[32]

(c) Another clinical study has indicated that doses of 5.2 g were effective in a clinical cohort of men with type 2 diabetes. The group receiving psyllium fiber showed significant improvement in glucose and lipid values. Furthermore, it was observed that serum LDL levels were 8.9% ( $P < 0.05$ ) and 13.0% ( $P < 0.07$ ) lower as compared with the placebo group.[33]

Examination of current literature would indicate that anywhere between 5 and 10 g of psyllium fiber could be used in a nutritional-based intervention. The FDA guidelines have suggested 1.78 g per serving (four servings daily) for prevention of CVD.[34] Some contraindications include inhibition of iron absorption, as well as certain minerals including vitamin B12, when used in excess amount. Psyllium reduces adiposity and improves glucose homeostasis in pediatric and adolescent patients suffering from obesity. It also works with the current pharmaceutical Orlistat 1 to limit the number of side effects suffered by patients.[35]

### **MOMORDICA CHARANTIA**

Momordica Charantia (MC) is found in Southeast Asia, and in sub-tropical areas of South and Central America, respectively. The active agents within MC contain both antiviral and antidiabetic properties.

#### **EVIDENCE**

(a) MC has been implicated in the reduction of adiposity in mice, lowering lipoprotein levels, and as well lowering blood glucose in streptozotocin (STZ) induced rats and human participants as well.[36–38]

(b) This vegetable combined with exercise has also been observed to increase insulin sensitivity.[39]

Clinically effective dosages range between 20 and 50 mg/ kg. [40,41] In fact in STZ rats it was observed that MC worked just as effectively as the oral hypoglycaemic glibenclamide. Further testing with human participants is required before this supplement can be used to treat insulin resistance. However, the potential of such a herb provides a novel direction of therapeutic usage of nutraceuticals as preventative measures to counter growing rates of obesity.

### **RESVERATROL**

Resveratrol, a polyphenolic compound found in the skin of grapes and related food products, has been shown to prevent a number of diverse pathologic processes, including CVD, cancer, oxidative stress, and inflammation.[42]

#### **EVIDENCE**

(a) In a recent study by Sinclair et al., resveratrol ingestion was associated with reduction in mean systolic blood pressure, leptin levels, systemic markers of inflammation, plasma glucose, and insulin increased energy expenditure.[43]

(b) Another study on rats demonstrated fat

lowering effects by a reduction in fatty acid uptake from circulating triacylglycerols and also in de novo lipogenesis by reducing the activity of lipogenic enzymes like lipoprotein lipase, acetyl-CoA carboxylase, malic enzyme, glucose-6P-dehydrogenase, acetyl-CoA carboxylase, and fatty acid synthase.[44] Resveratrol to be safe and reasonably well-tolerated at doses of up to 5 g/day.[45]

## FLAVONOIDS

Flavonoids belong to polyphenol subclass, widely distributed in plants, and in the (diet fruits, vegetables), and certain beverages (including tea, coffee, fruit juices, and wine) and they exhibit a variety of health benefits. The anti inflammatory properties of flavonoids have been extensively studied to establish and characterize their potential utility as therapeutic agents in the treatment of inflammatory diseases.[46]

### EVIDENCE

(a) In humans, green tea consumption has been inversely correlated with liver damage and with the levels of inflammation markers. [47]

(b) Citrus flavonoids in animals decrease plasma lipid levels, improve plasma lipid levels, improve glucose tolerance, and attenuate obesity. They reduce hepatic levels of the mRNA for stearoyl CoA desaturase-1 (SCD-1), leading to repression of hyperlipidemia. [48]

(c) Tiliroside enhances fatty acid oxidation via the enhancement adiponectin signaling associated with the activation of both AMP-activated protein kinase and PPAR  $\alpha$  and

ameliorates obesity-induced metabolic disorders, such as hyperinsulinemia and hyperlipidemia, although it does not suppress body weight gain and visceral fat accumulation in obesediabetic model mice. [49]

## GINGER COMPONENTS

The two major pungent and structurally similar compounds of ginger, 6-gingerol and 6-shogaol, have potent anti inflammatory activities and can improve diabetes and insulin resistance.[50,51]

### EVIDENCE

(a) A Chinese study on rats demonstrated significant weight reduction, possibly attributed to inhibition of intestinal absorption of dietary fat by inhibiting its hydrolysis.[52]

(b) The combination of Indian gooseberry and ginger lead to significant reduction in serum total cholesterol, triglycerides, LDL cholesterol, VLDL cholesterol, and increase in serum HDL cholesterol levels. [53] Thus, these studies suggest that ginger has the potential to prevent inflammation and inflammation-linked metabolic dysfunction.

## CARALLUMA FIMBRIATA

Caralluma fimbriata is an edible cactus, used by tribal Indians to suppress hunger, quench thirst, and enhance endurance. It is a traditional Indian famine food. The key phytochemical ingredients in Caralluma are pregnane glycosides, flavone glycosides, megastigmane glycosides, bitter principles, saponins, and various other flavonoids. [54] The appetite suppressing

action of *Caralluma* could be attributed to the pregnane glycosides, which are particularly rich in plants belonging to the Asclepiadaceae family.

#### EVIDENCE

(a) One gram *Caralluma* per day lead to 20% decrease in hunger levels accounting to 8% decrease in energy intake and 3 cm decline in waist circumference.[55] There was a there was a trend toward a greater decrease in body weight, body mass index, hip circumference, body fat, and energy intake.

(b) *Caralluma fimbriata* induced significant and dosedependent inhibition of food intake, with dose-related prevention of gains in body weight, liver weight, and fat pad mass. Alterations in serum lipid profiles associated with weight gain were similarly inhibited, as were the typical increases in serum leptin levels. It also conferred protection against atherogenesis.[56]

#### CALCIUM RICH FOODS

There is a wide range of calcium rich foods such as margarine and dairy products (milk, yoghurt, cheese). There is increasing evidence that dietary calcium plays a role in body weight regulation.[57]

#### EVIDENCE

(a) Cross sectional studies have found an inverse relation between milk or calcium consumption and body weight. [58] However, a meta-analysis has not shown any link between calcium intake and greater weight loss. [59]

(b) Diet including three or more daily servings of dairy products resulted in

significant reduction in adipose tissue mass in obese humans.[57]

#### OTHERS

(a) Chitosan is a polyglucosamine (the second-most common dietary fiber, after cellulose). It is produced commercially by deacetylation of chitin, which is the structural element in the exoskeleton of crustaceans (such as crabs and shrimp) and cell walls of fungi. Being a soluble dietary fiber, it increases gastrointestinal lumen viscosity and slows down the emptying of the stomach. Chitosan is relatively insoluble in water, but can be dissolved by dilute acids, which would make it a highly viscous dietary fiber.[60] Such fibers might inhibit the uptake of dietary lipids by increasing the thickness of the boundary layer of the intestinal lumen, which has been observed in animal experiments.[61] Having very few acetyl groups, chitosan contains cationic groups. Thus chitosan binds to negatively charged bile acids, which causes mixed micelles to be entrapped or disintegrated in the duodenum and ileum.[60] This would interrupt bile acid circulation and increased sterol excretion, due to lack of bile salt, fat will not be digested, thereby reducing fat and cholesterol absorption. Several animal experiments have proved its worth.[60,61]

(b) Carnitine is a quaternary ammonium compound biosynthesized from the amino acids lysine and methionine. It is present in a wide variety of foods including milk, cheese, whole-wheat bread, asparagus, fish, and chicken. Carnitine is the key material for oxidation of fatty acids. Carnitine transports long-chain acyl groups from

fatty acids into the mitochondrial matrix, so they can be broken down through  $\beta$ -oxidation to acetyl CoA to obtain usable energy via the citric acid cycle. It removes excess fat and other fatty acid residues. It reduces fat mass, increases muscle mass, and reduces fatigue. All of these effects may contribute to weight loss.[62] It has substantial antioxidant action.

(c) Hydroxycitric acid (HCA), an extract from the dried fruit rind of *Garcinia cambogia*, has been reported to cause weight loss in humans without stimulating the central nervous system.[63] HCA has been demonstrated to reduce food intake in animals, suggesting its role in the treatment of obesity and has been demonstrated to increase the availability of serotonin in isolated rat brain cortex. [64,65] HCA is a competitive inhibitor of ATP citrate lyase, an extramitochondrial enzyme involved in the initial steps of de novo lipogenesis. Consequently, HCA reduces the transformation of citrate into acetyl coenzyme A, a step necessary for the formation of fatty acids in the liver. In addition, there is increased production of hepatic glycogen in the presence of HCA, which may activate glucoreceptors, leading to a sensation of fullness and reduced appetite.[64,65]

## CONCLUSION:

Obesity is of epidemic proportions in the world, affecting adults and now children in almost equal percentages. Millions are spent on trying to control weight, but few treatments have been successful. Both patients and practitioners welcome new products that could help control

this epidemic. The present accumulated knowledge about functional foods has transpired into a nutritional supplement that contains active ingredients to increase satiety, increase the rate at which calories and fat are burned, and cause fat instead of lean tissue to be lost. Each active ingredient is a food that has been clinically proven to work. To ensure efficacy, active ingredients have been combined in the correct amounts and from the same sources as those clinically studied.

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