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Development of functional food products in relation to obesity

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Abstract:

The development of new eating habits, as well as actual trends in production and consumption, has a health, environmental and social impact. The entire world is fighting diseases characteristic of the modern age such as obesity, osteoporosis, cancer, diabetes, allergies, and dental problems. With a global increase in the prevalence of obesity, both nutrition and exercise play key roles in its prevention and treatment. Natural product (nutraceutical) interventions are currently being investigated on a large-scale basis as potential treatments for obesity and weight management. With advancing nutritional sciences, several nutrients such as; low-glycemic-index carbohydrates, 5-hydroxytryptophan, green tea extract, and chromium have been shown to promote weight loss. The first two nutrients decrease appetite, green tea increases the 24 hr energy expenditure, and chromium promotes the composition of the weight lost to be fat rather than lean tissue. These have been assembled, in efficacious doses, into a new functional food product and described in this review. Each component has already been shown to promote weight loss independently in clinical trials.

Key words: obesity, weight loss, functional foods

Introduction:

Obesity and excessive weight gain are the fifth leading risk factors for global deaths. At least 2.8 million adults die each year due to obesity-related complications. In addition, 44% of the diabetes burden, 23% of the ischemic heart disease burden, and 7% to 41% of certain cancer burdens are attributable to excessive weight gain and obesity [1]. Developed countries are also faced with problems relating to aging populations, such as high energy foods, and unbalanced diets.

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 [2]. 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 foods*", 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" [3]. 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) [3, 4].

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 [2]. 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 [4].

Obesity

Obesity is a major contributor to the global burden of chronic disease and disability. It has reached epidemic proportions globally with more than 1 billion adults overweight, and at least 300 million of them clinically obese. Often coexisting in developing countries with under-nutrition, obesity is a complex condition, with serious social and psychological dimensions, affecting virtually all ages and socioeconomic groups. The worldwide existence of obesity nearly doubled between 1980 and 2008 [5]. According to country estimates for 2008, over 50% of both men and women in the WHO European Region were overweight, and roughly 23% of women and 20% of men were obese [5]. Given the worldwide increase in obesity and its health consequences, efficient strategies for its prevention and treatment are important. It has been recommended that weight reduction programs focus on achieving a modest weight loss of 7–10% of the initial weight [6].

Obesity arises from an energy imbalance whereby energy intake exceeds energy expenditure. Dealing with obesity — by either prevention or treatment — requires modification

of one or both components of energy balance. Approaches to weight management (including a functional food approach) therefore can target multiple aspects of the energy balance systems: food intake, energy expenditure, and energy storage. All of these approaches are currently being taken by pharmaceutical companies; however, developing functional foods designed for weight management may be a more attractive approach for dealing with the 61% of the population that is currently overweight or obese [7].

The purpose of this article is to explain the rationale for the development of new food products that can be used adjunct to current therapies. The ingredients in the product are described in terms of their clinical efficacy.

Functional foods to reduce energy intake

One promising avenue to reduce energy intake using functional foods, is through increased satiety. The approach to achieving this goal is to provide foods that increase the sense of fullness and encourage the individual to stop eating sooner, thereby reducing total energy intake. In general, the three most promising areas to increase satiety are to: (1) modify the energy density of the diet; (2) modify the macronutrient composition of the diet; and (3) modify the glycemic index of the diet.

The energy density of the diet is the energy content per unit of weight or volume, and seems to be correlated with total energy intake. Energy density is relatively easy to measure for most foods, and can be calculated by dividing the energy content of the food in kilo joules (kJ) by the weight or volume of the food in grams [8]**.** There are substantial data to suggest that total energy intake over the short term (a few days) varies directly with the energy density of the diet. One physiological signal for satiety may relate to the total weight or volume of food ingested. This suggests that modifying the energy density of the diet could be a way to reduce total energy intake, and therefore reduce obesity. The main determinant of energy density is the non-caloric content of the food, primarily the water content. Foods with high water content have a lower energy density [9]**.**

Fiber also reduces energy density since it contributes substantially more to food weight than to caloric content. Dietary fiber intake seems to affect total energy intake best, with several reports of lower total energy intake with high-fiber v. low-fiber diets. There are several reasons why high-fiber diets are associated with lower food intake. First, high fiber diets may trigger maximal sensory stimulation in the mouth due to the increased need for chewing. High fiber diets also lead to slower gastric emptying and a slower rate of nutrient absorption. Finally, high fiber content reduces the energy density of the overall diet. Regardless of the reason, increasing dietary fiber is generally thought to aid in weight management [10].

Energy density is also affected by the macronutrient composition of the diet. Since fat is more energy-dense (38 kJ/g) than either protein or carbohydrate (17 kJ/g), reducing the proportion of fat in the diet can have a major impact on reducing the energy density of the diet. Since there is solid data which shows that reducing energy density reduces energy intake (at least in the short term), functional foods aimed at modifying energy density may be useful in managing obesity. It would be helpful to have more long-term data substantiating the effect of energy density and relating energy density to changes in body weight. Modification of dietary fat

type is not a commonly accepted strategy for weight loss. There is some suggestion that diets high in polyunsaturated fatty acids stimulate total fat oxidation more than diets high in saturated fatty acids, but this is somewhat controversial. Other fats such as short- and medium-chain triacylglycerols and n–3 fatty acids may have a greater impact on energy metabolism, but it is unclear whether or not these would play a major role in weight management [7].

The glycemic index of a food is determined by the rise in glucose that occurs after eating that food in relation to the rise in glucose seen after eating a standardized food such as white bread. High glucose levels following eating would stimulate insulin secretion which may consequently increase appetite and facilitate other disease processes linked to insulin action. Whether or not the glycemic index of the diet affects energy intake and obesity remains controversial. There is no convincing evidence that food intake is directly related to glycemic index, although there is some evidence that high glycemic diets are linked to weight gain. The glycemic index of the total diet could be modified by eating foods with a low glycemic index. If the glycemic index were shown to affect food intake, a good target would be to develop more good-tasting, low-glycemic foods [11].

Functional foods to increase energy expenditure

Another way to reduce the likelihood of developing obesity or in order to treat obesity completely would be to increase the total energy expenditure without increasing energy intake. While some food supplements make the claim of increasing energy expenditure, there is very little data available to support the efficacy of these products.

Caffeine and ephedrine:

A combination of caffeine and ephedrine has shown to be effective in long-term weight management, likely due to different mechanisms that may operate synergistically, e.g., respectively inhibiting the phosphodiesterase-induced degradation of cAMP and enhancing the sympathetic release of catecholamines. There has, however, been recent concern about the long-term safety of ephedrine [12].

Green tea:

Green tea, by containing both tea catechins and caffeine, may act through the inhibition of catechol O-methyl-transferase, and the inhibition of phosphodiesterase. Here, the mechanisms may also operate synergistically. In addition, tea catechins have antiangiogenic properties that may prevent the development of obesity. Furthermore, the sympathetic nervous system is involved in the regulation of lipolysis, and the sympathetic innervations of white adipose tissue may play an important role in the regulation of total body fat in general [13].

Oolong tea:

Oolong tea is another food that may have some impact on increasing energy expenditure, perhaps through its catechin content. Resting metabolic rate was increased by 3–4% during three days of oolong tea consumption at five cups per day. Interestingly, most of the rise in metabolic rate was from increased fat oxidation, which would have the greatest impact upon decreasing

body fat stores [14]. The mechanism for increasing energy expenditure by green tea has been postulated to be its flavonoid content, and even more specifically its polyphenolic content. One class of these compounds, the catechins, has been shown to inhibit catechol O-methyltransferase (COMT), an enzyme that degrades norepinephrine [15]. Although there are numerous catechins in green tea, probably the most influential is epigallocatechin gallate (EGCG). This cannot be obtained in appreciable amounts from any other food source. The inhibition of COMT by catechins allows norepinephrine to exert a prolonged influence on thermogenesis and fat metabolism. Both of these metabolic processes are controlled by the sympathetic nervous system via norepinephrine. The delay in degrading norepinephrine allows it to remain in the sympathetic synaptic cleft longer and therefor exert its effect. Caffeine also has an effect on norepinephrine by inhibiting phosphodiesterases and prolonging the life of cAMP in the cell. These actions coupled with the sustained effect of norepinephrine caused by EGCG greatly affect thermogenesis [16].

Capsaicin:

Capsaicin has been shown to be effective, but when it is used clinically it requires a strong compliance to a certain dosage. This dosage has not been shown to be feasible yet. Scientists are reporting new evidence that capsaicin may cause weight loss and fight fat buildup by triggering certain beneficial protein changes in the body [17].

Calcium*:*

Recently it has been suggested that diets high in calcium may be protective against weight gain and that part of the mechanism may be an increase in energy expenditure[18]. In several data-sets, high Ca intake is associated with a lower BMI, but there has yet been no clear demonstration that this is a causal relationship [19].

Other compounds helpful in weight reduction

Brain serotonin

Brain *serotonin* has an inhibitory effect on eating behavior. This work suggests a role for amino acids in regulating food intake. The brain neurotransmitter serotonin becomes available through the conversion of tryptophan to 5-HTP. Serotonin appears to influence both energy balance and the circadian patterns of eating (i.e., three times a day) by activating satiety neurons in the medial hypothalamus. Serotonin seems to interact antagonistically with norepinephrine to decrease appetite and carbohydrate consumption. No side effects occurred with 5-HTP at this dose, and no one dropped out of the study due to any reported conditions [16].

Dietary chromium

Dietary chromium is an essential trace element involved in potentiating the action of insulin. Chromium deficiency results in impaired glucose tolerance, insulin resistance, and elevated blood glucose concentrations. Supplementation can reduce the severity of these symptoms. Improvement in insulin utilization may also lead to reductions in body fat. In addition, correcting insulin resistance may have a positive effect on muscle mass by slowing its catabolism.

Chromium picolinate does not promote weight loss. Rather, during weight loss it seems to shift the direction of the weight loss to fat rather than fat-free mass. Doses of 200 or 400 g appear to be effective, and chromium in picolinate form rather than bound to yeast appears to be most preferable [20, 21].

Development of functional food product

In the creation of this product, Scientists undertook a whole new approach to weight loss by using clinically proven bioactive ingredients assembled in a nutritional supplement (Table 1).

Table 1. Nutritional composition of functional food product

Nutrient	Amount/kcal/%kcal	Benefits
Beverage portion: Carbohydrate	7g/28/62 3g fructose 1.8g psyllium 1g barley 1g others	Low-glycemic index carbohydrates source and fiber to promote satiety and reduce the risk of developing chronic diseases of aging
Protein	2g/8/18 2g whey protein	High biological value sources
Fat	1.0g/10/20 1g cotton seed and soybean oils 0.1g others	Polyunsaturated fatty acids
Tablet portion: Green tea extract	75mg caffeine and 135mg epigallocatechin gallate	Shown to increase resting energy expenditure
5-Hydroxytryptophan	10 mg	Shown to decrease appetite
Chromium Picolinate	100µg	Shown to promote loss of body fat instead of lean tissue during weight loss

Each serving of the product contains 45 kcal and is most effective if taken as a structured snack mid-morning and mid-afternoon — two times identified as difficult for people trying to lose weight. Each serving of the product is an 8-ounce beverage, which contains a majority of the macronutrients, and one tablet, which contains the remaining other nutrient additives. The product contains only food-grade nutrients in the correct and safe doses, and from sources that, as clinical trials have previously showed, induced weight loss. This particular structure was chosen because liquids have been shown to promote satiety[22], and structured snacks help patients lose weight and maintain it long term[23]. The nutrients (green tea, 5-hydroxytryptophan, and chromium picolinate) that were included in a tablet-form have a poor flavor when consumed in a beverage.

The macronutrient percentages in this product are similar to the composition of a balanced deficit diet (62% carbohydrate, 18% protein, and 20% fat) [24].The protein comes from a source of high biological value to promote protein synthesis [25]. Fat is from a blend of cottonseed and

soybean oils. The key macronutrient component is carbohydrate, which has a greater influence on weight management than protein and fat. Eating the recommended two servings per day of the food product will provide 14 g of low-glycemic index carbohydrates. Most patients normally consume at least 200 g of carbohydrates. Dietary carbohydrates contain a mixture of high and low glycemic indexes. However, patients who eat a diet containing more low-glycemic-index carbohydrates than high ones will have the best results. This diet would include meals rich in vegetables, fruits, and legumes, moderate amounts of protein and healthful fats. All of which should be coupled with a low intake of refined grain products, potatoes, and concentrated sugars.

Sources of Carbohydrate/Fiber

The carbohydrate components in this food product include the low-glycemic-index carbohydrates of fructose and barley as well as fiber in the form of psyllium. These promote satiety [26, 27] and their consumption is associated with weight loss [27, 28] and fewer co-morbities [29, 30].

Fructose:

The main sweetening ingredient seen in this product is fructose. This is the sugar commonly found in fruit. Fructose is sweeter than ordinary table sugar (sucrose) and most commonly derived from beet or cane sugars. It is proven to have a low glycemic index ([GI]= 32). Taken as part of a meal, fructose produces a smaller incremental rise in plasma glucose levels than sucrose, glucose, potato starch, or wheat starch. Each serving of the functional food product contains 3 g of fructose [26].

Psyllium:

Psyllium husk fiber is a viscous, mostly water- soluble fiber prepared from blonde psyllium seed (*Plantago ovata*). Psyllium, because it is a dietary fiber, promotes satiety and minimizes weight gain. It also has been shown to reduce blood lipid concentrations and blood glucose levels. Each serving of this product contains 1.8 g [31].

Barley Flakes:

Of all the grains, ceryain forms of barley have among the lowest glycemic indexes [26, 32]. Pearled barley (GI = 36) and cracked barley (GI = 72) have lower glycemic indexes than sweet corn (GI = 78), rolled barley (GI = 94), and instant white rice (GI = 128). Barley is a low glycemic source of carbohydrates and a great source of fiber (1.5%), both of which are advantageous in maintaining good glucose levels and weight control. Each serving in this product contains 1 g.

Sources of the Other Ingredients

Green Tea:

Two servings of this functional food product provides green tea extract in the exact amount which has been previously identified to promote weight loss. Each serving supplies 135 mg of EGCG and 75 mg of caffeine. Some patients may have concerns about the use of caffeine to

promote weight loss, but these are unfounded. First, the dose of caffeine offered by two servings of the product is 150 mg. This is not excessive when compared with the amount contained in other foods. Coffee has an average of 180 mg per 8-ounce cup, and a can (12 ounces) of cola contains 64 mg. Similarly, a standard dose of a commonly used pain reliever (Excedrin) contains 130 mg, and a weight loss product (Dexatrim) contains 200 mg. Second, at doses of 100 mg taken during the day, residual effects were not shown to have an effect at night, because the half-life of caffeine is only 3 to 3.5 hours [33].

5-Hydroxytryptophan:

Each serving of the food product contains 10 mg of 5-hydroxytryptophan, which is significantly lower than the 450 mg per serving shown to be clinically effective [34].

Chromium Picolinate:

Each serving of the food product contains 100 mcg of chromium. This corresponds to the lower end of the efficacious dose. However, we assumed that those who use the product would be obtaining another 200 mcg from their everyday diet, thereby giving them the highest end of the efficacious dose [21, 35].

Conclusions:

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.

Competing interests: No competing interests

Authors' contributions: I (author) have written this paper under the supervision of my advisor (co-author).

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