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Reproductive health-promoting effects of functional foods

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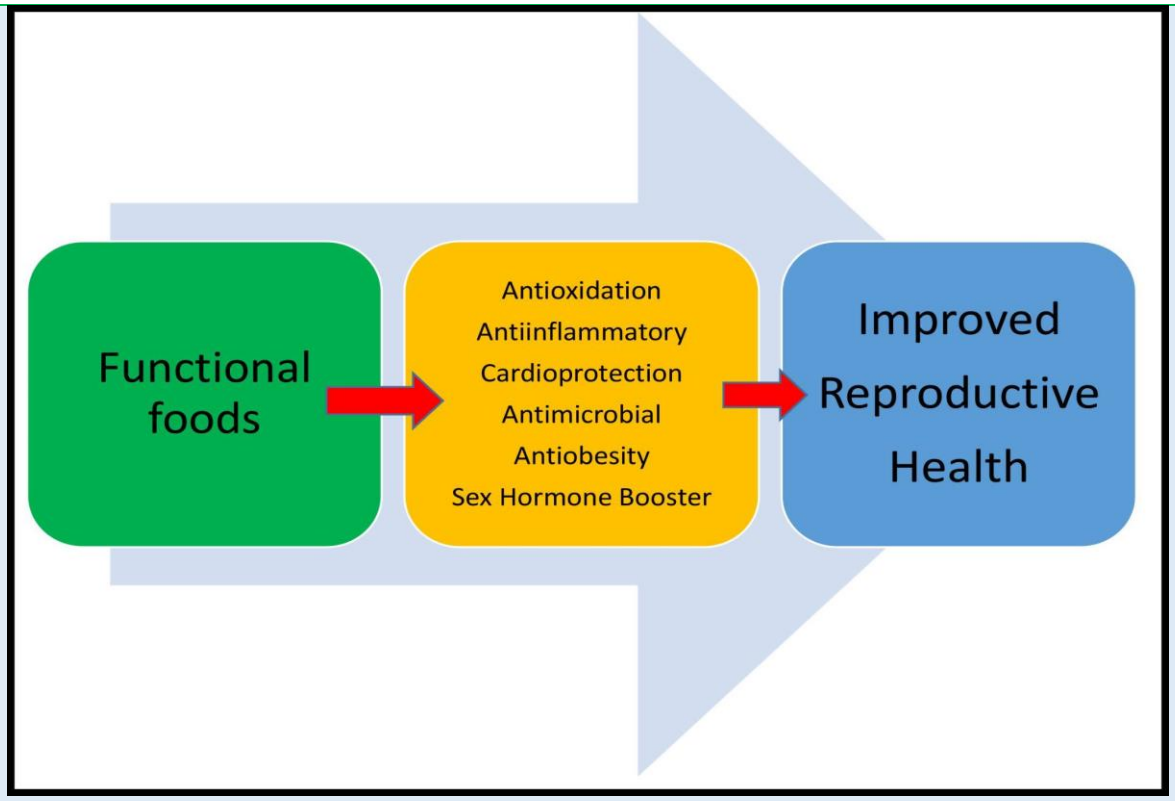
ABSTRACT

Functional foods are foods that, in addition to providing basic nutrients, have health-promoting effects when ingested consistently over a period of time. These foods can exist in their natural forms or might have been enhanced through fortification, biotransformation, or genetic modification. Globally, a lot of attention has been drawn to its consumption as a cheaper and safer remedy for the prevention, treatment, and management of several health-related conditions, including those of reproductive difficulties such as infertility. Infertility is a condition that is prevalent among some married couples and involves difficulty in procreation after about twelve months of unprotected intercourse between heterosexual couples. Oxidative stress-related infertility can be managed by functional foods rich in antioxidants and other phytochemicals with modulatory effects on reproductive tissues. Consumption of prescribed functional foods can alleviate functional disorders of the reproductive tissues and hence encourage higher success rates at conception trials.

Keywords: functional foods, reproductive, infertility, health, antioxidants



INTRODUCTION

Functional foods are foods that have been identified to offer therapeutic functions besides their nutritional roles in diets [1]. The foods may possess these functional properties naturally, or they can be obtained through fortification, enrichment, or genetic engineering [2]. Historically, functional foods classification originated from "foods for specified health use" [FOSHU] in Japan since 1991 and occupies a distinct position different from supplements [3]. Over the years, it has gained wide acceptance and approval as a cheaper and safer approach to managing several metabolic diseases in humans. Several functional foods have been subject to testing, which involves clinical trials to ascertain and verify the medicinal claims associated with each food type [1]. The available evidence to date is very encouraging to suggest that careful and consistent consumption of the specified functional food will yield expected health benefits at the proper time. Some of the health benefits of functional foods include anticholesterolemic, anticancer, anti-inflammatory, cardioprotective, antihypertensive, immune boosters, and fertility enhancers [1-2, 4]. This review addresses the benefits and concerns of the ingestion of specific functional foods for the management or treatment of reproductive tissue disorders.

Functional foods: Natural or processed foods that provide disease-averting characteristics and health-promoting benefits beyond basic nutrition are termed "functional foods" [5]. These are not pills or dietary supplements, but food consumed as part of a daily food

pattern [6]. The term "functional food" was introduced in Japan in the mid-1980s, although some have been known since ancient times and are traditionally consumed for their health benefits. The functional food market has developed rapidly, reaching over $21.3 billion and $8 billion in the United States of America and Europe over the past few years [7]. These foods could be formed by the elimination of a deleterious component (e.g., removal of allergenic proteins, yogurt with reduced fat). Also, the concentration of a natural component present in the food that can induce beneficial effects could be increased (e.g., tomatoes enhanced with lycopene, vegetable oils fortified with vitamin E, rice enriched with vitamin A, etc.). The addition of a beneficial component that is absent in many foods is also another method for the formulation of functional foods (e.g., margarine fortified with phytosterols, the addition of ginseng and guarana to energy drinks). Lastly, functional foods could be formed by increasing the bioavailability or stability of a bioactive component of food with marked beneficial effects [8]. Functional foods are widely used in promoting the health and well-being of children, adolescents, youth, and the elderly owing to their physiological effects. Currently, the use of functional foods has received considerable attention, and a vast number of functional foods have been widely employed in the management of several health concerns, especially as they relate to reproductive health [9].

Phytopharmaceuticals have been studied for their potential to aid in both weight reduction and fertility, although evidence for their efficacy is mixed. For instance, berberine, a chemical present in a number of plants, has shown promise in reducing body weight and enhancing insulin sensitivity in PCOS patients [10]. Another study indicated that the component in turmeric called curcumin may help increase insulin sensitivity and decrease body weight in those who are overweight or obese [11].

Classification of Functional Foods: Functional foods widely utilized for the effective management of several disease conditions are classified based on their origin as follows:

Plant-Derived Functional Foods: Plant foods, plant-derived products, and plant bioactive ingredients have been investigated for their role in disease prevention and health and classified as functional foods. Some of the plants' foods with FDA-approved health benefit claims include sterol- and stanol-ester-fortified margarine, oat soluble (beta-glucan) fiber, soy protein, and soluble fiber from psyllium seed husk [12]. Other plant-derived functional foods include plant proteins (soy protein isolate and amino acids; vegetable protein; beta-glucans found in oats); and omega-3 fatty acids in flaxseed, whey, and casein [12]. Secondary metabolites in plants that serve as functional foods include gamma-linolenic acid (GLA), phytoestrogens, antioxidants, steroids, and phase II enzyme inducers [13].

Animal-Derived Functional Foods: Animal-derived functional foods are also known as Zoochemicals. They include omega-3-fatty acids, omega-6-fatty acids, conjugated linolenic acid (CLA), small peptides, whey and casein, glucosamine, chondroitin sulfate, docosahexaenoic (DHA), and eicosatetraenoic (EPA) fatty acids [14]. The main source of EPA and DHA is fatty fish, such as salmon. Whey and casein are milk proteins while CLA is a fatty acid present in milk, yogurt is also a dairy product, a functional food that supplies essential nutrients such as vitamins B6 and B12, folic acid, riboflavin, thiamine, and niacin) [15].

Microbial Functional Foods: These are mostly bacteria that modify the constituents and metabolism of the gut

microflora, thus preventing the invasion of harmful bacteria in the gastrointestinal tract. Microbial-derived functional foods include synbiotics, prebiotics, symbiotics, and probiotics [16–17]. Examples of probiotics with health-promoting effects include *Bifidobacter* species and *Lactobacillus casei* [18]. Some functional foods could be derived from mushrooms and algae.

Production Mechanisms of Functional Foods: The procedures that are used to make functional meals are quite diverse, and the particulars of each process alter based on the kind of functional food that is being manufactured. Functional foods are made using industrial processes like fermentation, fortification, selective breeding, metabolomics-assisted biotechnological therapies, and changing the gut microbiota. The creation of functional foods may be performed via a broad number of techniques, and these processes are able to vary depending on the kind of functional food that is being produced. The following are a few examples: Fermentation: Yogurt, kefir, kimchi, and sauerkraut are all examples of fermented foods that start off with the addition of live bacteria and yeasts. Beneficial compounds like probiotics and bioactive peptides are produced by these microorganisms when they ferment the meal by breaking down the carbs [19]. Some functional meals are made through the process of fortification, which involves improving the primary food with extra nutrients or other bioactive components. Orange juice, for instance, might have calcium and vitamin D added to it so that it may be drunk with the purpose of improving one's bone health [20]. Through a technique known as "selective breeding," plants may be bred to produce greater amounts of a variety of different bioactive chemicals when cultivated in a controlled environment. For instance, with the use of selective breeding, it is possible to increase the amount of the powerful antioxidant lycopene that is found in tomatoes [21].

Metabolomics - Enhanced Interventions in Biotechnology: Metabolomics is a technology that may be used to discover which plant compounds and metabolites are helpful to human health. This can be accomplished through the study of metabolomics. It is possible that putting this information to use would be beneficial in the production of functional foods and nutraceuticals [22].

Manipulation of Gut Microflora: Several functional foods achieve their effects by modifying the make-up of the gut microbiota, which, in turn, may have a beneficial impact on one's health. For instance, prebiotics may be added to meals to encourage the expansion of beneficial bacteria in the digestive tract [23].

FUNCTIONAL FOODS THAT IMPROVE REPRODUCTIVE HEALTH

Reproductive health is a state of total wellness of the functions and processes of the reproductive system, thereby resulting in complete social, mental, and physical well-being [24]. It encompasses an individual’s ability to make decisions regarding sexual life and also have gratifying and safe sex [25]. The entire reproductive function and process at all stages of life are considered in reproductive health [26]. The burden of reproductive health problems is reflected in infertility in fully grown adults of fertility age, especially couples. The statistical record shows an approximately 15% global prevalence of infertility in couples, and 50% of these reproductive health problems result from infertility in the male counterpart, majorly due to civilization, industrialization, and dietary malnutrition [27].

Infertility is described as a condition of repeated failure at achieving conception despite continuous sexual

activity engagement up to a period of about fifty-two weeks [18]. The condition may be a result of male or female reproductive health problems, and sometimes both couples contribute in equal capacity, although epidemiological data associate's forty percent with male factor infertility [18].

Traditional Ayurvedic treatments for polycystic ovary syndrome (PCOS) have included the use of fenugreek seeds. Fenugreek seeds have been linked to lower testosterone levels, better insulin sensitivity, and regular menstrual periods in women with polycystic ovary syndrome (PCOS) [28]. The elevated levels of beneficial nutrients in flaxseeds, such as omega-3 fatty acids, lignans, and fiber, have been linked to a variety of health advantages. Women with polycystic ovary syndrome (PCOS) may benefit from eating flaxseeds since they have been shown to increase insulin sensitivity, decrease testosterone levels, and normalize menstrual periods [29].

Globally, infertility affects about one-fifth of couples attempting to have children [24]. This prevalence has also contributed to the search for remedies that can bring forth increased success at conception, including functional food consumption. Functional foods that function as fertility enhancers are foods that, in their natural or modified forms, can improve the functionality of the reproductive tissues and consequently increase the chances of conception in heterosexual couples [19]. The ability of functional foods to reduce the incidence of infertility is a welcomed scientific development that comes at a reduced cost and is also less invasive compared to other contemporary treatment strategies. Some of the functional foods with modulatory effects on reproductive health are listed in Table 1.

Table 1. Functional foods that improve reproductive health

Functional foods	Active component	Mechanism of action	Benefits	Reference
Salmon, fatty fish (1.84 g /day)	Ω-3-fatty acid	Antioxidant Cardio protection	Protects sperm and ovaries integrity, increased blood flow to reproductive tissues. Increased antioxidant activity	30-32
Turmeric	Curcumin (<100 mg)	Antioxidant, Increased hormonal activity	protect sperm and ovaries' integrity and increase blood flow to reproductive tissues. Increased antioxidant activity improves sperm count, sperm concentration, and motility. Increased antioxidant activity	33
Tomatoes, Carrots (Daily consumption)	Lycopene, L-arginine, Carnitine	Antioxidant Anti-inflammatory	enhances prostate health, protects reproductive tissues from cancer onset and progression, and boosts sexual function.	34-36
Spinach, Cabbage	Folic acid (20/40 µmol/L), lutein, zeaxanthine	Antioxidant	prevents genetic malformations in fetal cells and reverses the condition of oxidative stress in reproductive tissues.	37
Soy (61.7±7.35mg isoflavones/day)	Protein	Nutrient supply	Fortify semen with adequate nutrients required for motility and function, as well as repair weak reproductive tissues.	1,14

Functional foods	Active component	Mechanism of action	Benefits	Reference
			inactivates metal ions that aid in the generation of free radicals in reproductive cells.	
Garlic (600 mg of garlic tablets once daily for 7 days), Ginger rhizome	Organosulphur compounds, flavonoids, gingerols	Anticholesterolemic, Antimicrobial, Antioxidant	increases blood flow to reproductive tissues, mops up free radicals in tissues, regulates the female menstrual cycle, removes microbes capable of infecting reproductive tissues, especially in females, and boosts sexual health.	38-39
Oyster, Sea foods	Zinc, calcium	Nutrient supply Antioxidant Second messenger	activates the endogenous antioxidant enzyme superoxide dismutase for the breakdown of superoxide radicals, hence protecting reproductive tissues from oxidative stress-induced aberrations, enhancement of sexual function in males and females, and improved maturation of the spermatozoon and ovary.	14
Cheese, eggs (2–3 mg)	Probiotics calcium, iron, zinc, vitamin A, B6 and D, manganese	Beneficial microbes, Inducers of sex hormones	regulates hormone balance and improves ovulation	40-41
Psyllium, flaxseed (90 g/day)	Soluble fiber (13.8g fiber/day) Calcium, magnesium, iron, vitamin, omega-3-fatty acids, lignans	Cardioprotective Anti-obesity Antioxidant	improves heart health, is an estrogen booster for female reproductive health, controls inflammation and oxidative stress, and reduces hot flashes in menopausal women.	1,42-43
Red grape	Phenolics, vitamins, carnitine	Antioxidant	triggers spermatogenesis and oogenesis in males and females, respectively, and protects sex cells from free radicals and oxidative injuries.	44
Chocolate (40 g/day)	Flavonoids, procyanidins	Antioxidant	protects reproductive tissues against oxidative damage and DNA fragmentation.	44
Green/black tea (1g in 20ml water)	Epicatechins/ polyphenols	Anti-inflammatory Anticancer Antioxidant	Modulation of arginase and acetylcholinesterase activity, hence preventing erectile dysfunction in males	45-46
Cranberries (100g/day)	Proanthocyanins, vitamin E, folate, carotene manganese	antioxidant antibacterial	improves blood flow through the vessels and protects cells from oxidative damage to reproductive tissues as well as sperm and egg DNA integrity.	41,47

Benefits of functional foods to reproductive health: One of the most prevalent causes of reproductive health disorders is oxidative stress in the reproductive tissues. The condition is often caused by the production of free radicals that can't be stopped or by the production of free radicals that is stronger than the body's own antioxidants [6]. Dietary antioxidants present in the form of carotenoids, vitamin C, beta-carotene, and vitamin E have been shown to protect spermatozoa from reactive oxygen species' deleterious effects, which result in the production of abnormal spermatozoa. It acts by preventing DNA fragmentation, improving semen quality, and preventing the maturation of premature eggs [48]. Functional foods such as dark leafy greens, cod liver oil, eggs, spinach, papaya, etc. contain bioactive components that assist in the formation of sex hormones [41]. Bioactive compounds from dietary sources, including zinc, selenium, L-arginine, quercetin, vitamin C, and L-carnitine obtained from vegetables, whole wheat, carrots, garlic, and fruits, enhance fertility by increasing the levels of testosterone, LH, and FSH in induced infertile animals [49]. Ginger and turmeric rhizomes are used for enhancing male sexuality, regulating the female menstrual cycle, and reducing painful menstrual periods [50]. Also, antioxidants such as gallic acid, luteolin, glutathione, caffeic acid, orientin, rutin, catechin, chlorogenic acid, quercitrin, and quercetin have been implicated in the management of infertility [51]. Curcumin supplementation could increase sperm quality, including total sperm count, sperm concentration, and motility, and improve the total antioxidant capacity of plasma, malondialdehyde, C-reactive protein, and tumor necrosis factor (TNF) [52]. It is therefore important to ingest functional foods rich in antioxidants to help combat free radicals and hence reverse the oxidative stress condition in the tissues. This will enhance the proper functioning of the tissues, especially the testis in males to produce spermatozoa and the ovaries in females to produce healthy eggs. Functional foods with antioxidant properties, such as fruits and vegetables, will therefore enhance the functionality of reproductive tissues and hence increase the chances of success at conception. Other functional foods that confer anti-inflammatory effects, such as carrots, tea, and tomatoes, are useful for maintaining proper health and preventing inflammation in the reproductive tissues. This helps curb abnormal cell proliferation that may lead to benign or malignant growth in the tissues. The prostate gland, which is responsible for the nutritional enrichment of the sperm, has been shown to especially respond positively to the intake of functional foods containing lycopene [36]. Zinc- and arginine-containing foods such as oysters and fruits enhance sexual health, as arginine is required for the endogenous production of nitric oxide, which will, in turn, activate cGMP.

The accumulation of cGMP will further enhance the relaxation of the corpora cavernosum and subsequent tissue blood flow and erection in males [53]. Other functional foods have also been found to improve cardiovascular health. These foods may help lower total cholesterol levels or boost circulating levels of HDL-cholesterol [41]. This enhances blood flow through the vessels to reproductive tissues, boosting overall sexual health.

Table 2. Active components and in some natural functional foods as well as parts where they are actively involved. Source: [54]

	Organ systems	Active substance content	Functional foods
1.	Movement system: skeleton- and muscle system	Magnesium; calcium; protein	Milk and milk products; milk substitutes; fortified vegetable drinks
2.	Circulatory system	Coenzyme Q10	Special beverages enriched with Q10; beef
3.	Visceral organs: Highlights include digestive and respiratory systems	Conjugated linoleic acid; probiotics; prebiotics	Probiotic and prebiotic-enriched milk and dairy products
4.	Systems of regulatory bodies: including nervous system	Omega-3 fatty acid; colin	Sea fish enriched with active ingredients
5.	System of sensory organs	Vitamin A and E; minerals: magnesium	Vegetables and fruits; vitamin-enriched functional foods

Safety concerns about functional foods: It is noteworthy to state that despite the numerous health benefits of functional foods, caution is required to ensure moderation in consumption because nutrients or phytochemicals ingested more than body requirements may in turn pose a health risk. Furthermore, in cases of underlying health disorders, a specific patient-based prescription is required to limit drug-nutrient or drug-herb interactions. Also, safety concerns were raised recently regarding the indiscriminate enhancement of beverages, cereals, and soups, which poses a serious risk to consumers. A typical example is the hypericum present in St. John's wort, an herb utilized for the treatment of depression, which concurrently increases the metabolic activity of cytochrome P450 in the liver, thus inactivating several drugs. The consumption of this herbal medication results in a significant decrease in plasma concentrations of drugs such as warfarin, ethinylestradiol/desogestrel (oral contraceptives), cyclosporine, and theophylline when administered concomitantly [34].

CONCLUSION

Several pieces of academic research point to the beneficial effects that functional meals may have on a person's reproductive health. However, before adopting functional foods for the treatment of serious reproductive diseases, it is important to get the counsel of a nutritionist as well as other medical professionals. In addition, the organization and treatment of reproductive health issues encompass the whole spectrum of care. Considering this, it is recommended to include the intake of functional foods into a routine that also includes the conservation of a healthy weight, correct health practices, the lowering of stress, and the frequent ingestion of a balanced meal. Maintaining a healthy reproductive system may be helped by eating a well-rounded diet that is rich in foods with specific functions. It is essential to emphasize that functional meals should not be seen as individual therapies but rather as components of an all-encompassing strategy that also incorporates a healthy way of life and the direction of a physician.

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Abbreviations: FOSHU: Food for specific health use, FDA: Food and Drug Administration, GLA: gamma-linolenic acid, CLA: conjugated linolenic acid, DHA: docosahexaenoic, EPA: eicosatetraenoic, PCOS: polycystic ovary syndrome, LH: Luteinizing hormone, FSH: Follicle stimulating hormone, TNF: tumor necrosis factor, HDL: High density Lipoprotein, cGMP: Cyclic adenosine monophosphate

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