Study Material for M.Sc. in Human Physiology of 2nd. Semester

Presented by Dilip K Nandi, Ph.D.

FUNCTIONAL FOODS

29.3 Structure

29.3.1 Introduction

"Let food be thy medicine and medicine be thy food", the age old quote by Hippocrates is the ideology of today's health conscious population. Subsequently the "Theory of Longevity" by Metchnikoff was correlated with prolonged youth and a healthy old age, observed largely in Balkan peasants of those times, who used cultured milks in their diet. Since then, the quest continues for understanding role of wide range of food components and nutrients in enhancing health or preventing chronic diseases. The research in this field has resulted in a plethora of new labels for foods that have indicated distinct benefits and such foods are termed as functional foods. The concept of Functional foods emphasizes that food not only are vital for living but also play a role in the prevention and reduction of risk factors for several diseases and are also capable of enhancing certain vital physiological functions. Functional foods also provide the

body with required amount of vitamins, fats, proteins, carbohydrates, etc. Now, we shall learn in details about the Functional Foods.

29.3.2 Definition of Functional Foods

The term functional foods was first introduced in Japan in the mid-1980s and refers to processed foods containing ingredients that aid specific bodily functions in addition to being nutritious. To date, Japan is the only country that has formulated a specific regulatory approval process for functional foods. Known as Foods for Specified Health Use (FOSHU), these foods are eligible to bear a seal of approval from the Japanese Ministry of Health and Welfare (Arai, 1996).In US and European countries functional foods are used in the different terms like nutraceuticals, desigrer foods, vitafoods, pharmafoods, medifoods, medicinal foods and foodicuticals. Overwhelming evidence from epidemiological, in vivo, in vitro, and clinical trial data indicates that a plant-based diet can reduce the risk of chronic diseases.

In 1994, the US Institute of Medicine's Food and Nutrition Board defined *functional foods* as "any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains".

29.3.3 Classification of Functional Foods

Functional foods may be classified in various ways. From the nutritional point of view, they can be categorized like Nutrients and Non-nutrients as given below:

Nutrients: Lipids---n-3 fatty acids, Conjugate linoleic acid
Vitamins---Vitamin E, Vitamin C, Folates, Carotene
Minerals--- Selenium

Non-Nutrients: Fibre--- Insoluble and soluble fibre,
Phenolic Compounds—Phenolic acids, Flavonoids, Isoflavones, Tannics
Non-digestible Oligosaccharides (NDO) ---Fructans, Galacto oligosaccharides,
Isomalto oligosaccharides, Xylo oligosaccharides, Soy oligosaccharides

Phytosterols:

Glucosinolates:

Carotenoids: Lutein, Cryptoxanthin

Lycopene:

Organosulphur Compounds:

Classification on the basis of target organs/systems benefited for clinical relevance specially to treatment and management of various diseases as follows:

Gastrointestinal Tract: Prebiotics(NDOs), Soluble & Insoluble Fibres, Probiotics, Polyphenols, Phytates, n-3 fatty acids, Miconutrients, etc.

Cardiovascular System: n-3 fatty acids, Polyphenols, Micronutrients, Soluble fibres, etc.

Immune System: Prebiotics, Probiotics, Nutrients, n-3 fatty acids, Polyphenols, etc.

Skeletal System: Fructans

Kidney: Fructans

Another classification is based on origin or sources from Plants, Animals and Microbial and some compounds/ substances are listed herein below:

Microbial: Probiotics

Plant: Fibres, Polyphenols, Fructans, n-3 fatty acids, Phytates, Carotenoids, Non-Glycerides in edible oils, etc.

Animals: Fish oils(-L-fatty acids0, Chitosan, Conjugated Linolenic acid(Dairy products), etc.

29.3.4 Sources of Functional Foods

The different dietary sources of Functional foods with their bioactive compounds are given below:

Functional foods	**Bioactive compounds**
Nuts, seeds, and oils -	Vitamin E
Fish -	Omega-3 fatty
Legumes -	Polyphenols , Anthocyanins, catechins,
Grapes and red wines	cyanidins, and flavonols, myricetin, and quercetin
Citrus fruits and vegetables -	Vitamin C
Dark chocolate -	Flavonoid
Margarine -	Phytosterols
Whole grains -	Fiber and phytochemicals
Soy proteins -	Genistein and daidzein
Green leafy vegetables, fruits -	Carotenoids
Onion and garlic -	Quercetin
Green and black teas -	Tea polyphenols
Fruits and vegetables-	Folate, Phytochemicals
Tomatoes -	Lycopene
Vegetable oils -	Tocopherol, tocotrienols

29.3.5 Health Benefits of Functional Foods

Some functional components of foods have a major role in health enhancement. In fact, the big importance of these "bioactives" present in many foods, either naturally or added, has lead many scientists of different fields to conduct studies aimed for establishing the scientific basis that supports and validates the benefits of a particular food or component for the human health.

Soyabeans

Several classes of anticarcinogens have been identified in soyabeans, including protease inhibitors, phytosterols, saponins, phenolic acids, phytic acid and isoflavones. These, isoflavones (genistein and daidzein) are particularly noteworthy because soyabeans are the only significant dietary source of these compounds. Isoflavones are heterocyclic phenols structurally similar to the oestrogenic steroids. Because they are weak oestrogens, isoflavones may act as anti-oestrogens by competing with the naturally occurring endogenous oestrogens. This may explain why populations that consume significant amounts of soya have reduced risk of oestrogen-dependent cancer. However, more epidemiological data and clinical intervention trials are needed to investigate the role of soya in reducing cancer risk.

Soy protein, a major constituent of soybeans, is unique among the plant-based proteins and is considered a complete protein because it contains large amounts of all the essential amino acids, besides many other macronutrients with a nutritional value. It is associated with isoflavones, which have many potentially health benefits, and the replacement of animal based foods by soy proteins is furthermore advantageous, since those contain much higher amounts of fat, and particularly saturated fat. Soy protein products offer benefits to women in various life stages, including improved diet and cardiovascular status, prevention of certain types of cancer,health improvement following menopause and obesity prevention. Soy protein showed some chemo-preventive activity. The consumption of soy protein helps reducing body weight and fat mass as well as lowering plasma cholesterol and triglycerides. Since high levels of total cholesterol and LDL cholesterol constitute important risk factors for coronary heart disease, one of the most common and serious forms of cardiovascular disease, soy protein was indicated by many studies as a health promoting factor for coronary heart disease, which lead the Food and Drug

Administration (FDA) to approve in October 1999 a health claim for soy protein and coronary heart disease.

Flaxseed

Flaxseed is one of the richest sources of mammalian lignan precursors. Because enterodiol and enterolactone are structurally similar to both naturally occurring and synthetic oestrogens, and have been shown to possess weakly oestrogenic and anti-oestrogenic activities, they may also play a role in the prevention of oestrogen-dependent cancers. In rodents, flaxseed has been shown to decrease tumours of the colon, mammary gland and lung. Phipps et al. (1993) demonstrated that the ingestion of 10 g of flaxseed per day elicited several hormonal changes associated with reduced breast cancer risk. However, as is the case with soya, epidemiological data are required to support the hypothesis that enterodiol and enterolactone have anticarcinogenic properties in man.

Tomatoes

Tomatoes have received much attention in recent years because of interest in lycopene, the primary carotenoid in this fruit, and its potential role in cancer risk reduction. In a prospective cohort study of more than 47 000 men, those who consumed tomato products ten or more times per week had less than onehalf the risk of developing advanced prostate cancer. Interestingly, lycopene is the most abundant carotenoid in the prostate gland. Other cancers whose risk has been inversely associated with serum or tissue levels of lycopene include breast, digestive tract, cervix, bladder and skin. Proposed mechanisms by which lycopene could influence cancer risk are related to its antioxidant function. Lycopene is the most efficient quencher of singlet oxygen in biological systems.

Garlic

Garlic (Allium sativum) is probably the herb most widely quoted in the literature for medicinal purposes. Allicin then decomposes spontaneously to form numerous sulfurcontaining compounds, some of which have been investigated for their chemopreventive activity. Garlic components have been shown to inhibit tumourigenesis in several experimental models. A

review of twenty epidemiological studies suggested that allium vegetables, including onions, may confer a protective effect on cancers of the gastrointestinal tract.

Tea

Catechins are the predominant and most significant of all tea polyphenols. The four major green tea catechins are epigallocatechin-3-gallate, epigallocatechin, epicatechin-3-gallate and epicatechin. Much of the work on the health effects of tea has focused on its cancer chemopreventive effects. The consumption of five or more cups of green tea per day was shown to be associated with decreased recurrence of stage I and stage II breast cancer in Japanese woman.

Broccoli and other cruciferous vegetables

The percentages of case–control studies showing an inverse association between consumption of cabbage, broccoli, cauliflower and Brussels sprouts and cancer risk were 70, 56, 67 and 29 %, respectively. The anticarcinogenic properties of cruciferous vegetables have been attributed to their relatively high content of glucosinolates. Attention has been focused on a particular isothiocyanate isolated from broccoli, i.e. sulforaphane. Sulforaphane has been shown to be a good inducer of a particular phase II enzyme, quinone reductase. Indole-3-carbinol has received attention for its cancer chemopreventive properties, particularly of the mammary gland. In addition to the induction of phase I and phase II detoxification reactions, indole-3-carbinol may reduce cancer risk by modulating oestrogen metabolism.

Citrus fruits

Several epidemiological studies have shown that citrus fruits are protective against a variety of human cancers. Although oranges, lemons, limes and grapefruits are a principal source of such important nutrients as vitamin C, folate and fibre, have suggested that another component is responsible for the anticancer activity. Citrus fruits are particularly high in a class of phytochemicals known as the limonoids. This compound to be effective against a variety of both spontaneous and chemically induced rodent tumours. However, mindful of the importance of the overall dietary pattern in cancer risk reduction.

Beef

An anticarcinogenic fatty acid known as conjugated linoleic acid was first isolated from grilled beef in 1987. Nine different isomers of conjugated linoleic acid have been reported as occurring naturally in food. Conjugated linoleic acid is unique in that it is found in highest concentrations in fat from ruminant animals (e.g. beef, dairy, lamb). In recent years, conjugated linoleic acid has been shown to be effective in suppressing forestomach tumours in mice, aberrant colonic crypt foci in rats and mammary tumours in rats (Ip & Scimeca, 1997). Functional foods from plant sources

Dietary fibers

Dietary fibers include cellulose, hemicellulose, polyfructoses, galactooligosacharides, gums, mucilages, pectins, lignin and resistant starches, and are classically divided into soluble or insoluble. The consumption of dietary and functional fibers has many potential health benefits, namely the ability to lower the incidence of constipation and irritable bowel syndrome, lower cholesterol and diminish the incidence of coronary and cardiovascular heart diseases, prevent obesity and diabetes,avoid colon cancer and increase survival in breast cancer.

However, excessive intake of dietary fiber may have some adverse effects like intestinal obstruction (in susceptible individuals), dehydration (due to a fluid imbalance), and increase in intestinal gas, resulting in distention and flatulence, and reduced absorption of vitamins, minerals, proteins, and calories from the gut.

Fatty acids riches foods

Essential fatty acids (EFAs) are long-chain polyunsaturated fatty acids, which play an important role on human health promotion, and since they cannot be synthesized by the human body they must be obtained through diet. They are “good fats” that compete with “bad fats”, such as trans fats and cholesterol, and they increase the levels of high density lipoprotein (HDL), or "good cholesterol", and decrease the levels of low density lipoprotein (LDL), the “bad cholesterol”. The omega-3 fatty acids are derived from linolenic acid, the omega-6 from linoleic acid, and the omega- 9 fatty acids from oleic acid. The three major types of omega-3 fatty acids are alpha linolenic acid (ALA), which is the basic omega-3 fatty acid, eicosapentaenoic acid (EPA) and

docosahexaenoic acid (DHA). The primary omega-6 fatty acid is linoleic acid (LA), which is converted by the human body into gamma linolenic acid (GLA), being latter broken down into arachidonic acid (AA). EFA deficiency and omega 6/3 imbalance is linked with serious health conditions, such as heart attacks, cancer, insulin resistance, asthma, lupus, schizophrenia, depression, postpartum depression, accelerated aging, stroke, obesity, diabetes, arthritis, attention deficit hyperactivity disorder (ADHD), and Alzheimer's disease, among others. Omega-3 deficiencies are linked to decreased memory and mental abilities, tingling sensation of the nerves, poor vision, increased tendency to form blood clots, diminished immune function, increased triglycerides and "bad" cholesterol (LDL) levels, impaired membrane function, hypertension, irregular heartbeat, learning disorders, menopausal discomfort, itchiness on the front of the lower legs, and growth retardation in infants, children, and pregnant women. Some omega-6 fatty acids improve diabetic neuropathy, rheumatoid arthritis, premenstrual syndrome (PMS), skin disorders (e.g. psoriasis and eczema), and aid in cancer treatment. Monounsaturated oleic acid (omega-9) lowers heart attack risk and arteriosclerosis, and aids in cancer prevention. EFAs help in the absorption of essential nutrients and expelling of harmful waste products, support the cardiovascular, reproductive, immune, and nervous systems, and are important for proper growth in children, particularly for neural development and maturation of sensory systems. The importance of EFAs has also been proved to many diseases: asthma,attention deficit disorder (ADD) or attention deficit hyperactivity disorder, burns, photodermatitis, acne or psoriasis,obesity, insulin sensitivity, depression, bipolar disorder, schizophrenia, hypertension , osteoporosis, age-related macular degeneration (AMD), dry-eye conditions, such as Sjögren's syndrome. Besides, consuming significant amounts of foods rich in omega-3 fatty acids appears to reduce the risk of colorectal, breast and prostate cancer.

The others health benefits of functional foods are discussed in SLM no. 29.2 and 29.5 chapters.

29.3.6 Development Biomarkers

There are so many biomarkers for specific diseases and to influence by different bioactive compounds present in various functional foods. Very few examples are given below:

Functional foods	**Bioactive compounds**	**Potential mechanism with biomarkers**
Fish -	Omega-3 fatty acids	Inhibition of LDL-C oxidation
Green leafy vegetables, fruits	Carotenoids	
Citrus fruits and vegetables -	Vitamin C	

Tomato - Lycopene
Extravirgin olive oil - Polyphenolics and oleic acid
Green tea - Tea polyphenolics
Soy proteins Genistein, daidzein, and glycitein
Dark chocolate - Flavonoid
Pomegranate - Polyphenols

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Fish - Omega-3 fatty acids Lowering blood triglycerides

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Fruits and vegetables Folate,Phytochemicals Lowering blood homocysteine
Whole grains - Fiber and phytochemicals
Citrus fruits and vegetables - Vitamin C
Nuts, seeds, and oils - Vitamin E

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Tomatoes - Lycopene Antioxidant action
Green leafy vegetables, fruits - Carotenoids lowering SOD,catalage,etc.
Vegetable oils - Tocopherol, tocotrienols
Citrus fruits and vegetables - Vitamin C
Soy proteins - Genistein and daidzein
Green and black teas - Tea polyphenols
Grapes and red wines- Anthocyanins, catechins,cyanidins, Flavonols , myricetin and quercetin

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There are a large number of biomarkers available for assessing colon cancer risk in dietary intervention studies, which are validated to varying degrees. These include colonic mucosal markers, faecal water markers and immunological markers.

Colon mucosa biomarkers

1. Adhesion of Gram-negative bacteria,2. Modulation of cyclo-oxygenase-2 (COX-2),
3. Proliferation, 4. K-ras, 5. Genetic instability, 6. Apoptosis, 7. DNA-repair integrity,
8. Metastasis markers, 9. Microsatellite instability, 10. Oxidative DNA damage
11. Gene-specific damage

Faecal water markers

In recent years, there has been considerable interest in the role of the aqueous phase of human faeces (faecal water) in studies examining the mechanisms underlying the dietary aetiology of

colon cancer. The motivation is that components of this faecal fraction are more likely to be able to exert untoward effects on the cells of the colonic epithelium than components bound to food residues and the bacterial mass.

1. Cytotoxicity, 2. COX-2 induction, 3. Caspase induction, 4. Calprotectin levels, 5. Activator protein-1 activation, 6. Bile acid levels, 7. Effects on metastasis, 8. Genotoxicity, 9. Effects on cell metabolism, 10. Gene induction

Immunological and inflammatory response markers

In the colon:

1. Suppression of COX-2 induction by pro-inflammatory cytokines

In blood:

1. Natural killer cells, 2. Lymphocyte proliferation
3. Cytokines (interleukin-2, interleukin-b, tumour necrosis factor)

29.3.7 Effect of Food Processing and Storage

There are many changes mainly chemical, physical, and nutritional occurred during food processing and storage. The several advantages occurred after food processing as follows:

- Increased shelf-life.
- Decreased hazards from microbial pathogen.
- Prevents qualitative and quantitative losses of nutrients.
- Prevents spoilage (microbial, enzymatic, etc.).
- Inactivation of anti-nutritional factors.
- Ensured round the year availability of seasonal foods.
- Facilitates production of easy to handle and transport food items.
- Saves time and labour.
- Makes food distribution easy.
- Makes foods more acceptable through the incorporation of variety,colour,texture and tastes…….etc.

However, there are certain **disadvantages** of food processing and storage. The very few are discussed below:

- Damage of colour.
- Changes of flower.
- Changes of functional properties of the food.
- Damage of texture of the foods.
- Development of toxic constituents……etc.

In case of cereals, husk or bran are often losses of dietary fibrer, Vitamins etc. Antioxidants are destroyed as parboiled rice is more susceptible to lipid peroxidation. Refining process of fat &

oil comprises of lecithin, free fatty acids removal. In processing fruits & vegetables are losses of carotenoids and other pigments into cooking as well as canning.

29.3.8 Summary

In this SLM, we studied about the different types of functional foods apart from the basic nutritive values with sources and classification. The specific health benefits for each functional component in the various foods are also studied. Subsequently we learnt about the development of different biomarkers to indicate efficacy of functional ingredients present in food items. We have learnt about the effects of processing and storage on functional components of food stuff.

29.3.9 Glossary

Nutraceutical: The term combines with 'nutrition' and 'pharmaceutical' to mean that food extracts can be used as preventive drug or food supplements and has added the knowledge about the preventing phytonutrients present in food stuffs.

Texture: It is refer to structure, appearance, and consistency of foods.

Cancer: The word 'Cancer' comes from the Latin for crab. It refers to malignant growth or tumor cased by abnormal and uncontrolled cell devision.

Carcinogen: The substance / agents which are producing any cancer.

Food Processing: The process in which the perishable food materials are given a suitable physical or chemical treatment.

Canning: A process of preserving foods by sealing them in an air-tight vacuum containers for future use.

Gelation: Process of formation of gel from a solution, solidification, solidifying of a liquid matrix due to internal bonding.

Gelatinisation: The change in texture,colour, and physical state ,when starch is heated in water.

29.3.10 Self Assessment Questions

1. Define functional foods.
2. What are the functions of functional foods, as per 'FOSHU'?
3. What are non-nutrients foods?
4. What are the bioactive substances in protein foods?
5. What are the different ways by which foods can be made functional?
6. Define non-glycerides in edible oils.
7. What are CVD biomarkers?
8. Distinguish between soluble and insoluble dietary fibers.
9. What are the criteria of 'FUFOSE' as per Europe?

29.3.11 References

1. Food Science By B.Srilashmi
2. Food and Nutrition by Mahindra Deshpande and Dr. Nikhilesh Kulkarni
3. A textbook of food, Nutrition and Dietitics by Raheena Begum
4. Food Theory and Applications by B.E.Brooker.
5. Foods: Facts and Principles by Shakuntala and Shadaksharaswami
6. Essentials of Food and Nutrition by M.Swaminathan.
7. The Science of Food, OXFORD by Gaman and Sherrington.