Multi-functional foods

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Abstract

Foods contain various biologically active substances. They exert various activities and some of them exert plural functions [1]. Thus, foods are basically multifunctional. However, contents and composition of these functional factors are fairly different with foods. Therefore, we have to take various foods to maintain our health. On the other hand, unbalanced diet may lead to the occurrence of various food style dependent diseases. To avoid such diseases, it is important to produce and afford nutritionally balanced foods. In addition, excess intake of energy and some food components induce such diseases. Among food components, excess intake of lipids, especially unsaturated fatty acids, induces various diseases. To avoid induction of such diseases, it is necessary to produce and afford multi-functional foods which prevent various diseases simultaneously. Fortunately, we can utilize multifunctional factors to produce multifunctional foods.

Keywords: Dietary fibers, Multifunctional foods, Anti-oxidative activity.

B Dietary fibers (DF) is a typical multifunctional factor presents in various plant foods and used for production of healthy foods in various countries. Though oxidized products of unsaturated fatty acids induce various diseases, they can also inhibit the occurrence of other diseases. Thus, the addition of antioxidants is important to utilize the abilities of unsaturated fatty acids. Since antioxidants suppress the oxidation of unsaturated fatty acids, they can suppress the expression of their many inconvenient effects. In addition, antioxidants exert multifunctional effects independent with their anti-oxidative activity. Effective use of these multifunctional factors may greatly enhance the ability of multifunctional foods.

In the designing of multi-functional foods, maintenance of safety is very important. Highly effective functional factors often induce side effects when they were taken excessively. To enhance the safety of multi-functional foods, simultaneous uses of biologically active factors may be effective. Some multifunctional factors are reported to have synergic effects. For example, simultaneous use of a-tocoferal and sesamin exert their biological effect at lower doses. Such decrease of dosage may attribute to the maintenance of safety of multifunctional foods, as well as reduction of production cost.

Biologically Active Food Components

Biologically active food components are given below (Table 1).

Table 1: Biologically active food components.

<table>
<thead>
<tr>
<th>Food components</th>
<th>Functions</th>
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<tbody>
<tr>
<td>Saccharides</td>
<td>Monosaccharides Glucose is a major energy source of body, especially of brain. Fructose and galactose are also available for energy source. Sugar alcohols are hardly absorbable, and used as low-calorie sweetener.</td>
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<tr>
<td>Oligosaccharides</td>
<td>Digestive ones such as sucrose are utilized as an energy source. Hardly digestive ones are used as low-calorie sweetener. Some of them enhance the growth of lactic acid bacteria.</td>
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<tr>
<td>Polysaccharides</td>
<td>Digestive ones such as starch are utilized for energy source. Hardly digestive ones called dietary fibers exert various biological effects.</td>
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<tr>
<td>Proteins</td>
<td>Amino acids Essential amino acids should be taken from foods. Nonessential amino acids can be synthesized via TCA cycle. These amino acids can be converted to various biologically substances such as nucleic acid bases via TCA cycle</td>
</tr>
<tr>
<td></td>
<td>Peptides Degraded products of proteins. Some of them exert biological activities such as enhancement of mineral absorption, inhibition of blood pressure elevation, anti-oxidative activity etc.</td>
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<tr>
<td></td>
<td>Proteins Digestive ones afford essential and nonessential amino acids. Some of hardly digestive one act as dietary fibers. Most functional proteins lose their activities through their digestion. The ones exert their activities in the digestive truck such as digestive enzymes are useful for our health.</td>
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Metabolism improving activities. Thus, hardly digestive polysaccharides and lipids. This leads to the expression of anti-cancer and lipid-lowering active substances. Digestive polysaccharides and sugars are important energy source for animals. However, persistent elevation of serum glucose level lead to the occurrence of diabetes. Extrinsically, hardly digestible polysaccharides suppress the degradation of digestive polysaccharides and incorporation of glucose. This leads to the prevention of diabetes.

In addition, hardly digestive polysaccharides can bind lipid-soluble components such as carcinogenic components and lipids. This leads to the expression of anti-cancer and lipid-lipid metabolism improving activities. Thus, hardly digestive polysaccharides are called DF and widely used for the production of health-oriented foods. Some oligosaccharides are also hardly digestive. In addition, such oligosaccharides enhance the growth Lactobacillus and Bifidus bacteria which improve the circumstance of gut. Thus, these saccharides are also widely used as low-calorie biologically active components.

Proteins are polymers composed of about 20 amino acids. Since human cannot synthesize some amino acids sufficiently, they are called essential fatty acids (EFA) which should be taken from various foods. Balanced intake of EFA is important to keep health, because they are necessary for in vivo synthesis of various regulatory proteins.

Food proteins are digested to peptide or amino acids in the digestive tract and incorporated into our body. Some peptides are reported to exert biological effects such as enhancement of Ca absorption and inhibition of anegetensin-inducing enzyme activity. The former is useful for the prevention of osteoporosis and the latter for the inhibition of blood pressure elevation.

Lipids are lipid-soluble components present in foods. Major component is neutral lipid in which glycerol is bound to three fatty acids. The function of neutral lipid is highly dependent on the composition of fatty acids. Animal fats are rich in saturated fatty acids and oleic acid (OA18:1n-9). Most plant oils are rich in polyunsaturated fatty acids (PUFA) belongs to n-6 series. On the other hand, fish oils are rich in PUFA belongs to n-3 series.

PUFA with 20 carbons were oxidized by lipoygenase or cyclooxygenase to give various eicosanoids which have diverse biological effects. Leucotrienes (LT) produced from arachidonic acid (AA, 20:4n-6) are one of inducers of food allergy, but the activity of LT produced from eicosapentaenoic acid (EPA, 20:5n-3) is very low. In addition, EPA-derived LT suppress the expression of allergic effect of AA-derived LT, through a competition with AA-derived LT. Thus, the composition of PUFA in diets is highly important in the prevention of food allergy.

PUFA is easily oxidized in vivo and the oxidized products induce various diseases. To prevent the oxidation of PUFA in vivo, intake of antioxidants is important. Vitamins are low molecular regulatory factors present in various foods, and balanced intake of vitamins is important to maintain healthy condition. Among them, vitamin E is a lipid-soluble antioxidant which efficiently suppresses the oxidation of unsaturated fatty acids in lipophilic circumstance such as cell membrane.

On the other hand, vitamin C is a water-soluble antioxidant which is effective in the prevention of oxidation in foods or in body fluids. In addition, various types of antioxidants are present in foods. These antioxidants prevent the occurrence of food-style depending diseases via suppression of oxidation of unsaturated fatty acids. In addition, some antioxidants induce various biological effect independent with their anti-oxidative activity. This means that antioxidants are important multi-functional factors as well as DF and PUFA.
Most popular multifunctional factor is DF. DF is polysaccharides which are not digestive or hardly digestive by human digestive enzymes. Some of them are water-insoluble and the others are water-soluble. Typical water-insoluble DF is cellulose. Because of its hydrophobic surface, it adsorbs lipophilic food components, such as dietary fats or carcinogenic compounds. Since DF cannot be absorbed in our body, it inhibits the absorption of these lipophilic components. This leads to the expression of its lipid metabolism regulating and anti-cancer activities.

On the other hand, water-soluble DF (WSDF) is partially digested by intestinal bacteria to give short-chain fatty acids (SCFA), such as acetic, propionic and butyric acids. Since acetic acid is absorbed at intestinal wall and used as an energy source, WSDF afford some amounts of energy. On the contrary WSDF, the rats fed glucomannan (GM) or pectin (P) gave higher serum IgA and IgG levels and a lower serum IgE level than those fed cellulose, when aged eight-month-old Sprague-Dawley (SD) rats were fed the diets containing the above DFs for 3 weeks [5]. On the other hand, these results were not obtained in 8-month old aged SD rats [6]. This suggests that the dietary effects of WSDF are age-dependent. Similarly, the young SD rats fed GG, GM or P gave significantly higher serum IgA levels than those fed cellulose, but the effect was not observed in aged rats.

In the feeding experiments, lymphocytes were isolated from spleen and mesenteric lymph node (MLN), and cultured for 24 h in the absence of DF to determine the effect on Ig productivity of these lymphocytes. In this experiment, lymphocytes isolated from MLN of young SD rats fed WSDF gave higher IgA, IgG, and IgM productivities than those isolated from the rats fed cellulose.

In the case of splenocytes, the stimulating effects were weaker than those observed in MLN. In aged rats, the stimulating effect was observed only in MLN lymphocytes, but not in splenocytes. These results suggest that the feeding effect of WSDF is dependent on immune tissue, as well as age of rats.

As shown above, feeding experiments using experimental animals afford an excellent system to study multi-functional activity of food components. When some biological effects were observed in animal experiment, cultured cells are often used to clarify the regulatory mechanism food components. However, the in vitro system was not effective in WSDF. When established cells or lymphocytes with Ig-producing activity were cultured in the presence of WSDF or SCFA, such changes in Ig productivity were not induced. This suggests that...
the effect of WSDF was not induced through the direct interaction of WSDF with immune cells.

**Multi-functional activity of polyunsaturated fatty acids**

Biological activities of unsaturated fatty acids are dependent on their structures. Linoleic acid (18:2n-6) has a double bond at the 6th position from its methyl terminal and metabolized to dihomo-γ-linolenic acid (20:3n-6) and finally to arachidonic acid (AA, 20:4n-6) via γ-linolenic acid (18:3n-6) and dihomo-g-linolenic acid (20:3n-6). The AA in membrane phospholipids (PL) is cut out by phospholipase and then oxidized with lipoxygenase to 4-series leukotrienes (LT) which induce type I allergy. On the other hand, α-linolenic acid (18:3n-3) has a double bond at the 3rd position from its methyl terminal and metabolized to lipoygenase to 5-series LT which induce type I allergy. Hence, AA exerts no activity. In addition, tea polyphenol administration exerts anti-allergic effects at the doses where each component is expressed in the tissues where T3 are not present. Thus, T3 derivatives are detectable only in small number of tissues, when their tissue levels are determined without fasting. Though α-Toc is detected in various tissues and the levels are fairly stable, the levels of α-T3 and γ-T3 are usually much lower than that of α-Toc. In the adipose tissues, small amounts of α-T3 and γ-T3 are detected at 0 hr and the levels are increased with the elongation of ingestion time.

Detection of T3 derivatives without T3 administration and the increase of T3 levels after T3 administration suggest that T3 derivatives are accumulative in the adipose tissues. In other tissues, T3 derivatives are not detectable at 0 h and accumulated with the elongation of ingestion time in some tissues. In the liver and MLN, the levels of T3 derivatives were highest at 8 h after ingestion and decreased at 24 h.

In these tissues, T3 may be incorporated quickly and then released or metabolized thereafter. The quickness of disappearance in some tissues may be the reason why T3’s is detectable only in limited tissues. T3 derivatives often exert stronger biological effects than Toc derivative in cell culture assays [18]. However, such biological effects cannot be expressed in the tissues where T3 are not present. Thus, clarification of tissue distribution is essential for the determination of target tissue of biologically active substances.

**Multi-functional activity of antioxidants**

There are various types of natural and synthesized antioxidants which are used for the inhibition of oxidation of food component in vitro or in vivo. They exert various physiological activities in addition to the anti-oxidative activity. Among them, biological effects of polyphenolic compounds were widely studied. Diphenols with two OH groups on a benzene ring at ortho or para position exert strong anti-oxidative activity, as well as anti-allergic effect [13,14]. These polyphenols may exert the activities through the binding to cell surface or through the interaction with intracellular components after their incorporation into cells. In general, triphenol compounds exert stronger activity than diphenol compounds on cell surface [13,14] probably due to stronger interaction with cell surface [15].

Among tea polyphenols, epigallocatechin gallate (EGCg) with 2 triphenol groups exerts strong biological activities. For example, it exerts much stronger toxicity against rat 3Y1 diploid fibroblasts transformed by E1A than other tea polyphenols, but their toxicities against normal 3Y1 cells are unchanged [16]. This means that EGCg is more effective anti-cancer compound with low toxicity against normal cells than other catechins. Since it strongly suppresses both histamine and LTB4 release from rat peritoneal exudates cells stimulated with a calcium ionophore A23187 [14], EGCg may also be useful for prevention of type I allergy.

In the case of vitamin E derivatives, clarification of their tissue distribution is important [17]. Tocopherol (Toc) derivatives are distributed to various tissues, but the presence of tocotrienol (T3) derivatives is limited in several tissues. When a mixture of Toc and T3 is administrated into the stomach of SD rats and their tissue contents are determined after around 16-hr fasting, T3 can be detected only in small number of tissues. On the other hand, T3 derivatives are detected in various tissues, when their tissue levels are determined without fasting. Though α-Toc is detected in various tissues and the levels are fairly stable, the levels of α-T3 and γ-T3 are usually much lower than that of α-Toc. In the adipose tissues, small amounts of α-T3 and γ-T3 are detected at 0 hr and the levels are increased with the elongation of ingestion time.

Some biologically active substances interact with other substances. For example, two anti-oxidative components, such as α-Toc and sesamin, exert a synergic effect [19]. When rats were fed these compounds simultaneously, these components exert anti-allergic effects at the doses where each component exerts no activity. In addition, tea polyphenol administration...
enhances the anti-allergic effect of n-3 PUFA. Though LTB4 productivity of peritoneal exudates cells isolated from the rats fed perilla oil rich in n-3 PUFA was significantly lower than that from the rats fed safflower oil rich in n-6 PUFA, administration tea polyphenol further decreased LTB4 of the cells [20]. In the case of EGCg, coexistence of phosphodiesterase inhibitor strongly enhanced the expression of its biological activity [21]. Such combinational use of biologically active components allows us to decrease the dose of these components [22]. This leads to the improvement of safety and reduction production costs. Thus, the studies on the interaction of biologically active substances are also important to produce multifunctional foods with a high safety.

References


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