Dietary Supplements: Types, Health Benefits, Industry and Regulation

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Chapter 3
Dietary Supplements: Types, Health Benefits, Industry and Regulation

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3.1 Introduction

Nowadays, diet is thought to be much richer than it used to be. The people's ignorance of the basic principles of nutrition has led a large part of the population to a non-balanced diet that is high in both calories and fat and low in proteins, vitamins and minerals (Kourkouta et al. 2016). This long-term situation has led to the emergence of various degenerative diseases. In an effort to address this concern, nutritional supplements was proposed to proffer solution to this problem (Oikonomou

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2009). *Dietary supplements are products that contain one or more concentrated nutrients with the aim of supplementing an individual's daily diet, when his or her diet is not balanced or if nutrients are lacking*. Dietary supplements do not belong to the category of common food neither medicines nor special dietary products and not intended for specific categories of people (www.nutrinews.gr).

Supplements offer the missing ingredients to the body in order for the latter to be kept in good physical and mental condition. In effect, the human system wouldn't be exhausted and at the same time injuries and fatigue are avoided (Kourkouta et al. 2016). The production as well as the consumption of dietary supplements have considerably increased in the last decade. Majority of these supplements are supplied in the form of tablets or powder. Although, the increased intake is supposed to offer health benefits, too much consumption may result in higher amounts of vitamins and minerals which the body may not be able to tolerate. As a result, consumers are exposed to health risks due to excessive consumption of dietary supplements. The problem becomes more serious if people take these supplements by themselves, without prescription or medical supervision (Beitz et al. 2004).

3.2 Dietary Supplements

Dietary supplements are products that are ingested in addition to the regular diet to provide additional health-promoting nutrients. According to the Dietary Supplement Health and Education Act (DSHEA), a dietary supplement is a product that is intended to supplement the diet; contains dietary ingredients including vitamins, minerals, amino acids, herbs, and botanicals; is intended to be ingested as a pill, capsule, tablet, or liquid; and is labeled as being a dietary supplement (ODS 2011; Ronis et al. 2018). Dietary supplements are widely used. They are generally taken to improve and maintain overall health. For women in particular, supplements are intended to support bone integrity and prevent osteoporosis. The most commonly

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used supplements are multivitamins, mineral supplements, calcium supplements, and omega-3 fatty acids or fish oil (Bailey et al. 2013). About a quarter of the supplements are used based on the advice of health-care providers. Thus, most decisions to use supplements are made by the consumers themselves. Despite their popularity, the health benefits of dietary supplements are questionable. Lack of vitamins will certainly cause deficiency diseases such as scurvy, beriberi, pellagra, and rickets. However, the vitamin content of a normal well-balanced diet is sufficient to avoid these diseases. Studies aimed at determining effects of supplements often give conflicting results. There seems to be no current scientific consensus whether vitamins or any other dietary supplements prevent disease or have health benefits in well-nourished individuals (Moyer 2014).

3.3 Historical Overview

From the beginning of human civilization, the people's diet mostly comprises of plant foods and seafoods that could be easily gathered. Hunter-gatherers later contributed meat products by big game. This was the diet of most humans until about 10,000 BC, at which time the development of agriculture and animal husbandry provided more meat and grains for the whole family. Then was little knowledge about vitamins, minerals, proteins, carbohydrates and fats and their role in human nutrition. Various people in the continents of the Earth developed nutritious cuisines with mostly local products that sustained their health. By trial and error, they chose a variety of foods and cooking methods that led to physical strength, health, and fertility. The common wisdom of native cultures knew which foods and herbs had special properties for energy, nutrition and extra health benefits for children, pregnant women and elders. Everyday diets were "supplemented" to make up for deficiencies as far back as native cultures. Native Americans, for example, knew that drinking tea made from pine bark and needles which contains high concentration of ascorbic acid could cure scurvy. This condition was later found by science to be a vitamin C deficiency disease. In 1749, Dr. James Lind discovered that citrus fruits which have high vitamin C content prevented scurvy (Shils and Shike 2006; Fraga 2009). The discovery of the role of vitamins was a major scientific achievement in understanding the association existing among nutrition, health and disease. By the 1920s and 1930s, significant strides occurred in the world of vitamin research and mass marketing of synthesized vitamin C flourished in 1935 under the brand name Redoxon. In nearly 75 years since the marketing of vitamin C pill started, large steps have been made in vitamin and other dietary supplement products (Kourkouta et al. 2016). The mainstream scientific community gradually became intrigued by the potential health benefits of dietary supplements and numerous research projects (epidemiologic, clinical, in vivo and in vitro) were initiated in the 1980s. This interest was fueled in part by studies demonstrating that nutrient antioxidants, (vitamins C, A, E, β-carotene and Selenium) have a role in protecting cells from oxidative free

radical damage. Furthermore, epidemiological studies suggested that a diet rich in fruits and vegetables and abundant in antioxidants, nutrients, and other substances, can reduce the risk of coronary heart disease and certain cancers (Fortmann et al. 2013; Leenders et al. 2014).

3.4 Balanced Diet and Dietary Supplements

Dietary supplement can be defined as any vitamin, mineral, chemical substance, herbal product, botanicals, amino acids, or other ingestible preparation that is added to the diet to benefit human health. Dietary supplements are used worldwide and represent a broad category of ingestible products that are distinguishable from conventional foods and drugs (Watson et al. 2010; Berginc and Kreft 2014). It is common knowledge that nutrition plays a very important role in health. However, a fundamental question that everybody asks these days that most people are very aware of is: "Will conventional and balanced diet without supplements be able to cover all the needs of the human body for a healthy lifestyle until old age?" Nutritionists and health professionals argued for years that people can get the most important food requirements for their body needs each day from a conventional, balanced and regular daily diet. Today's dietary guidelines from health and nutrition agencies all over the world cover more than 40 nutrients that are subdivided into 6 categories: carbohydrates, fats, proteins, vitamins, minerals and water. Daily nutrient recommendations are collectively known as dietary reference intakes (DRIs). A healthy diet is one that favors "real" fresh whole foods that have been sustaining people throughout the millennia. Whole foods supply the needed vitamins, minerals, protein, carbohydrates, fats, and fiber that are essential to good health. A balanced diet is a mix of food from the different food groups (vegetables, legumes, fruits, grains, protein foods, meat, and dairy). Variety involves eating different foods from all the food groups that helps to ensure that you receive all the nutrients necessary for a healthy diet. The components of the Mediterranean diet have been evaluated as substantially beneficial to human health (Katz and Meller 2014; Widmer et al. 2015). The World Health Organization (WHO) makes the following recommendations for a balanced and healthy diet: (a) eat roughly the same amount of calories that your body is using, (b) a healthy weight is a balance between energy consumed and energy that is 'burnt off', (c) limit intake of fats, and prefer unsaturated, than saturated fats and trans fats, (d) increase consumption of plant foods, particularly fruits, vegetables, legumes, whole grains and nuts, (e) limit the intake of sugar, salt/sodium consumption from all sources and ensure that salt is iodized, (f) eat a diet with essential micronutrients such as vitamins and certain minerals (WHO 2003). In contrast, many commercially prepared foods or fast foods as they are called, often lack nutrients and contain inordinate amounts of sugar, salt, saturated and trans-fats, all of which are associated with the development of diseases.

3.5 Global Market of Supplements

Globally, the nutrition and supplements market stood at over US $90 billion. Research analysis of various markets with large nutrition and dietary supplements industries show interesting sales numbers and growth projections (Nasdag 2015; CMR 2015). The global mineral supplement market is increasing due to a growing geriatric population, demand from pregnant women, and rising urban population. With the increasing population of baby boomers, spending on mineral supplements is anticipated to increase. The mineral supplement market consists of macro-minerals, calcium, phosphorous, zinc, alkaline pH booster, sodium, potassium, chlorine, sulfur, magnesium, and trace minerals: iron, boron, manganese, chromium, copper, iodine, cobalt, fluoride, selenium, colloidal silver. The global mineral supplements market was valued at $9.9 million in 2014 and was expected to grow at a rate of 7.5% during the period 2015–2020 (http://www.researchandmarkets.com/research/xjrcm6/global_mineral).

Vitamin and poly-vitamin supplements are very popular and their use as supplements, supported by commercial advertising is growing every year. The global vitamin supplements market, was estimated to be valued at US$37 billion in 2014, and is expected to grow at 6.5% annually from 2014 to 2020. This is mainly attributed to growing demand among consumer about preventative healthcare. Furthermore, increasing cost of healthcare pushes people to turn towards vitamin supplements in the hope that this could prevent disease. Vitamin supplements included vitamins C, E, B, A, β-carotene, K, niacin, folic acid, etc) (https://www.psmarketresearch.com/market-analysis/ vitamin-supplements-market). According to recent United State (US) Food Drug Administration (FDA) testimony, dietary supplements, including vitamins, were consumed by 158 million Americans in the year 2000, which is more than 50% of the US population. Surveys showed that alternative medical therapies and herbal supplements were used by over 80 million people in the USA (Kennedy 2005; Wilson et al. 2006).

3.6 Supplement Formulations

Food supplements are in various packages, sizes and types, depending on how they are taken. There are tablets, capsules, powders, oral ampoules, effervescent tablets, chocolates and mastics which is available in syrup form or otherwise. More specifically, food supplements can be taken in any of the following forms: (a) oral pills or powders for relatively quick absorption; (b) sublingual drops or oral disintegrated tablets, for ease of intake and to limit the damage of their active substance; (c) nose spray or drops to further improve their absorption; (d) injectables through intravenous and intramuscular injections for quick absorption and action; (e) bone-anchored for slow and gradual absorption and prolonged action (American Diabetes Association ADA 2001). Some supple-

ments are not well absorbed, others are almost completely destroyed by the stomach fluids and a few others irritate the mucosa of the stomach and intestine. Powders and liquid preparations are useful for those who have difficulty of swallowing the capsules or tablets. Supplements in the form of sprays can cause intense local irritation or possible lung aspiration. Injecting supplements is always done under the guidance of a physician. On the other hand, bone-anchored supplements can only be taken in hospitals due to surgical technique, monitoring and laboratory control required to prevent local inflammations and complications (Teixeira 2013). If there is intense change in color of urine when taking a supplement, this means that a large portion of the supplement is excreted because either it cannot be absorbed, or the dose is in excess. This must lead us to reflect on the effectiveness and possible harm that supplements can cause (Mulholland and Benford, 2007).

3.7 Classification of Supplements

According to the National Agency of Medicines, dietary supplements are divided into two categories depending on their intended use (EUFIC 2009):

(1) Food supplements as food product which supplements the usual diet.
(2) Foodstuff for particular nutritional uses such as beverages, which due to their special composition, are intended for certain population groups e.g. for healthy infants or children between the ages of two and five or for special categories of persons with disordered metabolism, or for categories of persons who are in a special physiological condition.

Supplements can also be distinguished depending on their origin (natural or synthetic). They are classified comparably to their texture or form in which they are available as follows: (a) Vitamin and mineral supplements, whether they are combined in the form of multivitamins or multi-minerals or not, (b) Protein supplements in the form of liquid or tablet in combination or not with carbohydrates, fats, vitamins and minerals, (c) Amino acids of every form and composition, (d) Supplements for gaining weight, (e) Meal surrogates in the form of powder, wafers or biscuits, (f) Carbohydrate supplements with or without electrolytes and vitamins, (g) Supplements which have natural anabolic effect, and which are not included in the "banned substances list", (h) "Activator" supplements of growth hormone and other hormones, (i) Supplements of basic fatty acids, (j) Foodstuffs or food ingredients such as yeast, garlic, kelp, royal jelly, (k) Herbs. There are thousands of supplements in the market. Many of them are very good, others moderate and some provide very little benefit. The main reason for their low efficiency is their manufacturing method and the source of their basic substances (Rovira et al. 2013). Some classes of supplements, their examples and contents are presented in Table 3.1.

Table 3.1 Classification of supplements, examples and contents

Class	Example	Contents
Activator	Amino acids	Contains growth hormone and other hormones
Carbohydrate	Dextrose	May contain vitamins and electrolytes
Food and Food stuff	Fish oils, mineral and vitamins	Contain garlic, kelp, royal jelly, yeast
Herbs	Ginseng, Fiber	Contains amino acids, other plant source
Minerals	Selenium, multimineral tablets	Contains only minerals
Multivitamins and multiminerals	Vitamin D, calcium supplement	Contains both mineral and vitamins
Oil supplements	Cod liver oil, primrose oil	Contains oil base, with vitamins, minerals
Vitamins	Vitamin C, vitamin B	Contains only vitamins

3.7.1 Vitamins and Minerals as Supplements

Today, multivitamin, multimineral, vitamin, and mineral supplements are the most widely used dietary supplements (Bailey et al. 2013). Although adequate intake of these micronutrients is required to maintain optimal health, the possibility of toxicity increases with increasing dose (Mulholland and Benford 2007). Because dietary micronutrient deficiency is increasingly rare in developed countries, most supplement consumers actually have excess vitamin and mineral intake. Despite the widespread belief that vitamin and mineral supplements are beneficial to health, recent reviews of vitamin and mineral supplement trials in community-dwelling adults with no nutritional deficiencies have concluded that there is no clear evidence of beneficial health effects. These include primary or secondary prevention of chronic diseases including cardiovascular disease, cancer, and cognitive decline, as well as effects on overall mortality (Guallar et al. 2013; Fortmann et al. 2013). Indeed, there is evidence for possible harm from consumption of individual vitamins and mineral in excess. Toxicity following consumption of water-soluble vitamins is rare. However, photosensitivity and neurotoxicity have been reported at doses higher than 500 mg/day of pyridoxine (vitamin B6) (Ziegler and Filer 1996), and cases of pyridoxine-associated chronic sensory polyneuropathy have been reported in elderly patients consuming multivitamin supplements (De Kruijk and Notermans 2005). Reports of toxicity associated with overconsumption of supplemental antioxidant fat-soluble vitamins are more prevalent. Vitamin E is a family of eight related tocopherols and tocotrienols, of which α-tocopherol is the form generally used in supplements. Doses of 800–1200 mg/day can result in bleeding associated with antiplatelet action, and doses above 1200 mg/day can result in diarrhea, weakness, blurred vision, and gonadal dysfunction (Ziegler and Filer 1996). Moreover, vitamin E supplementation following radiation therapy in a randomized trial of head

and neck cancer patients was associated with increased cancer recurrence in the first 3.5 years of follow-up (Bairati et al. 2005), and meta-analysis has suggested an increase in all-cause mortality after high-dose vitamin E supplementation (Miller et al. 2005). Toxicity has also been associated with consumption of supplemental vitamin A and its provitamin carotenoid precursors. Excess vitamin A supplementation has been suggested to be associated with adverse effects on bone health, including low bone mineral density and increased fracture risk (Melhus et al. 1998). In addition, women consuming large amounts of vitamin A supplements during pregnancy have been reported to have increased incidence of congenital abnormalities (Rothman et al. 1995). There is also a case report of intrahepatic cholestasis in a patient with chronic hypervitaminosis A after 12 years of supplement consumption, which resolved after supplements were ceased (Ramanathan et al. 2010). Toxicity can arise from excess consumption of minerals as well as vitamins. In particular, there is an increased risk of hyperchromatosis, an iron storage disease associated with liver injury after excess consumption of iron or multimineral supplements (Barton et al. 2006).

3.7.2 Fish Oil and Omega-3 Fatty Acids as Supplements

Omega-3 fatty acids are essential fatty acids that cannot be synthesized de novo in humans and therefore must be provided through the diet (Spector and Kim 2015). A link between fish oil and ischemic heart disease was suggested by a widely publicized study from 1971 involving Eskimos (Greenlanders) from the west coast of Greenland (Bang et al. 1971). Greenlanders eating a traditional meat and fish diet rich in polyunsaturated omega-3 fatty acids had significantly lower levels of plasma total lipids, plasma cholesterol, plasma triglycerides, and pre β-lipoprotein (equaling very low-density lipoprotein) than both Danes and Greenlanders living in Denmark. The authors hypothesized that this diet contributed to the low incidence of ischemic heart disease and diabetes among Greenlanders. Since then, polyunsaturated omega-3 fatty acids taken in the form of fish oils, krill oil, or mixtures of docosahexaenoic and eicosapentaenoic acids, also known as DHA and EPA, purified from fish oils have become widely used dietary supplements. These fatty acids have metabolites with anti-inflammatory properties and have electrical stabilizing effects on ion channels in cardiac myocytes (Sierra et al. 2004; Leaf et al. 2008). They have been linked to anti-cancer and cardio-protective effects (Gogos et al. 2000; Harris and Isley 2001). However, the therapeutic benefits on cardiovascular diseases are still controversial owing to disparate findings from different clinical trials (Glück and Alter 2016). It appears that fish oil and omega-3 fatty acids are well tolerated, even at doses of 1000–2000 mg/day, and there is little evidence of toxicity. However, simultaneous consumption of fish liver oils that also contain vitamin A and multivitamin supplements could result in hypervitaminosis A. Furthermore, fish oils and omega-3 fatty acid supplements may exacerbate

anticoagulation and promote bleeding in patients taking anticoagulant medications such as warfarin (Gross et al. 2017).

3.7.3 Protein Powders and Infant Formula as Supplements

Protein powders consisting of the dairy proteins casein and whey and of vegetable proteins in soy protein isolate (SPI) are popular supplements among athletes and body builders. These proteins are also the basis of infant formulas. The dairy proteins appear to have little toxicity except in individuals with allergies to cow's milk protein, although excessive consumption may result in ketosis. In contrast, there is an ongoing debate with regard to the potential safety of SPI. This debate is related primarily to the presence of weakly estrogenic compounds—the isoflavones: genistein and daidzein, which are among the 100 phytochemicals that remain bound to the protein isolate (Fang et al. 2004). These compounds can reach potentially estrogenic levels after SPI consumption in soy formula–fed infants and in children, men, and postmenopausal women taking soy protein supplements. Concerns have focused on potential estrogenic effects in early development resulting in reproductive toxicity, infertility, demasculinization, and increased promotion of estrogen-responsive cancers such as breast and endometrial cancer (Messina,2016). Animal studies of SPI and soy formula toxicity have however been contradictory. Akingbemi et al. (2007) reported that perinatal exposure to diets made with soy resulted in suppressed steroidogenesis, decreased testosterone secretion, and increased Leydig cell proliferation in rats. Similarly, marmoset monkeys fed soy infant formula had suppressed serum testosterone concentrations (Tan et al. 2006). Increased testis size and increased Leydig cell numbers per testis were also observed in these monkeys at adulthood, consistent with compensated Leydig cell failure. In adult female ovariectomized mice, feeding SPI increased growth of human breast cancer cell xenografts, consistent with an estrogenic effect (Allred et al. 2001). In contrast to the small number of animal studies with SPI suggesting estrogenicity, lifetime feeding studies in rats fed with SPI revealed that the sole protein source in soy formulas had no effects on sex organ weights, serum sex steroids concentrations, or fertility (Badger et al. 2009).

3.7.4 Botanical Supplements

Traditional herbal medicine can be said to be the precursor both for drugs used in modern medicine that are based on plant compounds (such as aspirin and morphine) and for contemporary botanical dietary supplements. Herbal and botanical products have sustained popularity given the fact that these natural (i.e., derived from plant root, leaves, or bark) substances were among the oldest therapeutics. Estimates published by the CDC as part of the National Health and Nutrition Examination Survey

2003–2006 reported that 20% of adults use a supplement containing at least one botanical ingredient (Bailey et al. 2010). A common motivation for taking these substances is to "improve overall health". Accordingly, the FDA regulates the majority of botanicals as dietary supplements and not as drugs developed for the treatment or prevention of specific maladies (FDA 2016). Botanical use is correlated with non-smoking and higher self-reported health (Bailey et al. 2013). Alarmingly, patients frequently do not report herbal supplement use to primary care physicians (Wu et al. 2011), a concern because many botanical supplements may interact with prescribed medications. On their own, bioactive constituents of botanicals can have acute adverse effects that require hospitalization. This review describes acute adverse effects and herb-drug interactions of the most common botanical and herbal supplements. As a result of their plant-based derivation, botanical supplements consist of a mixture of organic compounds. Only a fraction of these compounds is biologically active, with a small subset of the active compounds having therapeutic and/or toxic mechanisms of action. Table 3.2 presents a list of commonly used and researched botanical supplements, their primary active constituents and typical use. Concurrent exposure to other compounds (e.g., pharmaceuticals, smoking) and the heterogeneity of herbal supplements often obfuscates the determination of toxic mechanisms in clinical cases, even when doses of the supplement are reported. As such, reports of adverse effects directly attributable to botanicals are generally rare (Di Lorenzo et al. 2015). In most such cases, effects are mild (e.g., nausea, fatigue, and headache). However, more serious clinical cases have appeared, most often relating to adverse effects falling under the general category of drug-induced liver injury and its associated mechanisms, namely mitochondrial dysfunction, oxidative stress, and alteration of bile acid homeostasis.

3.8 Advantages and Limitations

The advantages that nutritional supplements generally offer includes high content of nutrients in small volumes; special nutrient compositions; lack of undesirable accompanying substances such as fats, cholesterol and purines; and complete coverage of specialized sporting needs. Nevertheless, these formulations should be treated as a supplement of basic healthy diet and not as a replacement. Users of dietary supplements often increase the dosage or frequency. As a result, doses become less and less effective. Thus, the human organism is forced to work harder to eliminate the extra amounts of supplements taken in (Thomas 2001). All these factors lead to the appearance of side effects due to toxicity of dietary supplements, which depends on the factors including (a) The dosage, because exceeding the recommended dosage may cause side effects; (b) The duration of intake which is related to the fact that the human organism is overloaded, owing to specific substances that the supplement contains, till the substance is eliminated; (c) The special chemical properties of some substances and their interactions with other foods and substances; (d) The person's weight who takes those supplements; (e) Age, because

Table 3.2 Commonly used botanical supplements, their primary active constituents and typical uses

Scientific name	Common name	Uses	Active components	References
Genus *Echinacea*	Echinacea	Imuno-stimulant	Chicoric acid, alkylamides	(Hermann and von Richter 2012)
Allium sativum	Garlic	Antioxidant; antihypertension	Allicin, adenosine	(Hermann and von Richter 2012)
Ginkgo biloba	Ginkgo biloba	Memory improvement; lowering blood pressure	Terpenoids (ginkgolides)	(Mayo Clinic 2013a)
Panax ginseng	Ginseng	Overall health; antistress	Ginsenosides	(Hermann and von Richter 2012)
Camellia sinensis	Green tea extract	Antiproliferative; antioxidant	Catechins (ECGC, ECG)	(Chen et al. 2016)
Serenoa repens	Saw palmetto	Treatment of benign prostatic hypertrophy	Various phytosterols	(Mayo Clinic 2013b)
Hypericum perforatum	St. John's wort	Antidepressant	Hyperforin, hypericin	(Mayo Clinic 2013c)
Silybum marianum	Milk thistle	DILI; high cholesterol	Silymarin	(Mayo Clinic 2013d)
Piper methysticum	Kava kava	Reducing anxiety	Kavalactones	(Teschke 2010)
Cimicifuga racemosa, Actaea racemose	Black cohosh	Alleviating postmenopausal symptoms	Triterpene glycosides	(Mayo Clinic 2013e)
Valeriana officinalis	Valerian	Reducing anxiety	Valepotriates (terpene alcohols)	(Gharib et al. 2015)
Pausinystalia yohimbe	Yohimbe	Stimulant; erectile dysfunction treatment	Yohimbine	(Hermann and von Richter 2012)
Hydrastis canadensis	Goldenseal	Treatment of cold/ respiratory infection; alleviate menstrual complications	Hydrastine, berberine	(Hermann and von Richter 2012)

lots of supplements are not recommended for underaged persons or the elderly; and (f) The individual capacity, because each person reacts differently in the face of various substances (Oikonomou 2009). No supplement is innocent. For instance, some overdose of fat-soluble vitamins causes hypervitaminosis. Protein overdose damages kidneys and the liver. A lot of carbohydrate intake in the form of powder can cause fat increase. A large dose of fatty acids may lead to some inability of the organism to form some muscle proteins. Last but not least, performance-enhancing drugs may cause endocrine disorders (Troesch et al. 2012).

3.9 Future Perspectives

Attitudes toward safety, efficacy, and values about what is important in food and life will be important in determining future needs involving supplement science in the countries we have discussed and perhaps elsewhere in the world. Safety is critical and requires better chains of custody and product characterization that exists at present for these products, particularly those involving global markets. Efficacy/health promotion claims for the product as being true and not misleading is also critical. Demonstrating efficacy requires clinical studies with well-defined products and rigorous experimental designs, and the studies must be replicable (NCCIH 2017). Finally, there are issues of personal choice and values, sometimes involving the efficacy of supplements as complementary and alternative therapies that are part of larger philosophical or religious world views and systems (Sebastian et al. 2017; González-Sarrías et al. 2017). Supplements intended to enhance sports performance (Kuhman et al. 2015) botanicals used for disease treatment (Costello et al. 2016) and those ingredients thought to slow aging (Delmas 2015) all require identification of valid biomarkers of efficacy as well as of exposure. The associations between supplement ingredients and health outcomes in chronic degenerative diseases must be clarified (Yetley et al. 2016; Pérez-Cano and Castell 2016). Collaborations among scientists in a number of countries are needed to drive supplement science forward. Irrespective of the type of health product, high quality science is fundamental to the success of any regulatory framework. Assessments of the safety, quality and efficacy of nutrients and other bioactive compounds are needed to provide the scientific information that regulators need (Taylor and Yetley 2008).

3.10 Conclusion

Scientists and health professionals agree that dietary supplements can be under certain conditions beneficial to human health but should not replace complete and balanced daily meals of food substances. The market for dietary supplements taken to improve the health or well-being of the customer is enormous. However, these products are not necessarily safe for everybody. Like regular drugs, supplements with active ingredients that provide a physiological or pharmacological effect are likely to also cause adverse effects in susceptible individuals. More attention to adverse effects and potential interactions is needed to avoid serious medical outcomes. Users and physicians alike should consult updated literature before beginning or advising a regimen involving these substances. Medical providers should be aware that a large fraction of the general population takes dietary supplements. They should therefore request information from patients about their supplement intake to provide optimal medical care. Self-prescription of dietary supplements should be avoided and patients, older people, pregnant women, young persons and people liv-

ing with disabilities should be informed and advised by their doctors or pharmacists on dietary supplementation.

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