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Research financed by Polish Ministry of Science and Higher Education within founds of Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS), for scientific research

Praca finansowana przez Ministerstwo Nauki i Szkolnictwa Wyższego w ramach środków na utrzymanie potencjału badawczego Instytutu Nauk o Żywieniu Człowieka, SGGW w Warszawie

Infertility is one of the most serious medical issues and its prevalence has dramatically increased worldwide, especially in the past few decades. Recent studies have demonstrated that nutrition and lifestyle play crucial roles in the normal functioning of the reproductive system, as well as in prevention and in supportive treatment of infertility. Fruits and vegetables are a special group of foods that provide many nutrients necessary for female and male reproductive health. The paper presents current knowledge about the effects of nutrients contained in fruits and vegetables on male reproductive functions and their use in the supportive treatment of infertility. Understanding these issues can help in designing a proper diet for men of reproductive age planning parenthood, and/or those who have been diagnosed with infertility.

Key words: male, fertility, antioxidants, pro-healthy food, fruits, vegetables, nuts.

Niepłodność jest jednym z najpoważniejszych problemów medycznych, a jej rozpowszechnienie dramatycznie wzrosło na całym świecie, szczególnie w ciągu ostatnich kilku dekad. Ostatnie badania wykazały, że odżywianie i styl życia odgrywają kluczową rolę w prawidłowym funkcjonowaniu układu rozrodczego, a także w zapobieganiu i wspomaganiu leczenia niepłodności. Owoce, warzywa i orzechy to grupa żywności, która dostarcza wiele składników odżywczych niezbędnych dla zdrowia reprodukcyjnego kobiet i mężczyzn. W niniejszej pracy przedstawiono aktualną wiedzę na temat wpływu składników odżywczych zawartych w owocach, warzywach i orzechach na męskie funkcje rozrodcze i ich zastosowanie we wspomaganiu leczenia niepłodności. Zrozumienie tych problemów może pomóc w opracowaniu odpowiedniej diety dla mężczyzn w wieku rozrodczym planujących rodzicielstwo i / lub tych, u których zdiagnozowano niepłodność.

Słowa kluczowe: mężczyźni, funkcje rozrodcze, przeciwutleniacze, żywność prozdrowotna, owoce, warzywa, orzechy.

INTRODUCTION

According to the World Health Organization's (WHO) definition, infertility is the failure to achieve a clinical pregnancy after 12 months or more of regular unprotected sexual intercourse. The prevalence of this problem is increasing. Globally, about 60–80 million couples are affected by infertility, persistently or periodically; this problem concerns 10–20% of couples in the developed countries, and 15–20% of couples of reproductive age, as reported by the Polish Society of Gynaecologists and Obstetricians. Infertility has been recognized as a lifestyle disease, and was included in the International Statistical Classification of Diseases and Related Health Problems. WHO devotes a lot of attention and makes considerable efforts to promote activities aimed at the broadly understood prevention and treatment of infertility in people of reproductive age. This is a strongly justified approach, because the inability to have biological children has serious consequences for the overall mental health of individuals affected by infertility [25].

It is well known that prevention is the most effective way to reduce the incidence of many diseases. There are reliable scientific data confirming the impact of lifestyle, including diet, the use of stimulants, or physical activity, on health, including reproductive capacity. There are many nutrition-related diseases which largely result from 'wrong' irrational and unbalanced diets [9].

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A similar problem concerns infertility: more and more attention is paid to the prevention of this disease, also by means of nutritional management, and to aid its treatment with the use of foods that have a positive effect on human reproductive functions.

Reproductive capacity mainly depends on the normal functioning of glands that produce hormones regulating reproductive processes (hypothalamus, pituitary gland and gonads) and the production of gametes (spermatozoa in the testes and oocytes in the ovaries) able to survive and perform their biological role. Other hormones regulating the functions of the entire reproductive system (insulin, growth hormone, prolactin, cortisol, thyroid hormones) also play a vital role, and the ability to conceive, maintain the pregnancy and give birth to a healthy, viable child depends on the general fitness and health of both the woman and man [14].

Currently, a very positive trend is being observed: people are more aware of health issues, they understand how food and diet directly or indirectly influence health, and they perceive food not only as something satisfying physiological needs, but also as a way to prevent and treat many diseases. The positive effects of food on health seem to be a feature that, along with sensory qualities and price, has the strongest impact on consumer purchasing behaviour in developed countries. Health-promoting foods include natural products of plant and animal origin with positive effects on health due to their content of certain substances, foods fortified with certain nutrients, and foods with a reduced content of undesirable components. Many recent studies have described in detail and documented the positive effects of fruits and vegetables on health. This is a group of foods characterised by a huge diversity in terms of composition. Fruits and vegetables contain nutrients and bioactive compounds that have a significant effect on the reproductive function. Therefore, it is important to characterize their role in ensuring reproductive health and supportive treatment of infertility [19, 22, 26].

MALE REPRODUCTIVE FUNCTION. THE ROLE OF ANTIOXIDANTS AND OXIDATIVE STRESS

The reproductive capacity of men depends primarily on the quality and quantity of sperm, and blood testosterone levels. Disorders in these parameters contribute to the development of male infertility. Males solely account for 20–30% of infertility cases and are responsible for 50% of all infertility cases. Semen quality and male fertility have been declining over the past few decades. One of the most common causes of male infertility is sperm dysfunction caused by many factors leading to defective spermatogenesis, like varicocele, obstructive lesions, infections, environmental factors, and deficiency of vitamins and trace elements, especially zinc and selenium [10, 39].

Free radicals, including reactive oxygen species, are necessary for normal sperm function at the stage of sperm production and maturation, and in the fertilization process. In physiological concentrations they play a vital role in maintaining the normal functioning of the cell membrane, which is associated with sperm motility, during spermatogenesis, and reactions preceding the process of fertilization and necessary for its correct course – capacitation, hyperactivation, acrosomal reaction and, finally, the fusion of reproductive cells.

Under normal conditions the main source of free radicals in the semen are leukocytes and abnormal and/or immature gametes. Free radicals are also a by-product of oxygen metabolism in cell membranes, mitochondria, peroxisomes, or in the endoplasmic reticulum [46].

The physiological level of free radicals is regulated by enzymatic and non-enzymatic antioxidants. Antioxidants are characterized by strong reducing properties. They react with free radicals and reduce their concentration, and prevent oxidant/antioxidant imbalance and the onset of oxidative stress. The cytoplasm of spermatozoa and semen contains high levels of enzymatic antioxidants: superoxide dismutase (SOD), glutathione peroxidase (GPX) and catalase (CAT), as well as non-enzymatic antioxidants, e.g. glutathione, ascorbic acid (vitamin C), alpha-tocopherol, carotenoids and ubiquinol (the reduced form of coenzyme Q10). Oxidative stress can develop when the level of free radicals is higher than the concentration and activity of antioxidants, and this has a negative effect on fertility through many mechanisms. Antioxidants neutralize free radicals by donating one of their own electrons, ending the electron-stealing reaction. The antioxidants do not themselves become free radicals by donating electrons because they are stable in either form. These act as scavengers and play the housekeeper's role by mopping up free radicals before they get a chance to create havoc in a body. Thus, they may well be defined as substances that are capable of quenching or stabilizing free radicals. These antioxidants decrease the levels of markers of oxidative stress, decrease DNA damage, prevent lipid peroxidation, and thus are associated with normal spermatogenesis, sperm maturation, and sperm motility and overall functioning [3, 46]. Selenium and zinc supplied with food are necessary for the proper functioning of enzyme-dependent antioxidative systems. Selenium is a component of glutathione peroxidase, a key enzyme that prevents oxidative stress by catalyzing the reduction of free radicals and thereby interrupting free radical reactions. Selenium has been shown to have a protective role in relation to differentiating and maturing male reproductive cells by preventing damage to genetic material (DNA) and thus ensuring the stability and motility of spermatozoa. Selenium is also an element necessary for the proper synthesis of testosterone in the testes. Moreover, a positive correlation between the plasma concentration of selenium and testosterone has been reported [34]. The importance of zinc for the normal reproductive function in men is evidenced by the high concentration of this element in all organs of the reproductive system, in semen and in spermatozoa. Moreover, zinc plays a key role in the anatomical development and maturation of the reproductive system. Studies have demonstrated that zinc is an essential element for normal testosterone synthesis and for the differentiation and maturation of spermatozoa in the testicles and in the epididymis. The concentration of zinc is decisive for the normal morphology and motility of spermatozoa, especially progressive sperm motility [27].

Oxidant/antioxidant imbalance can be caused by many very complex mechanisms and factors, among which the most frequently reported are environmental pollution and lifestyle-related factors, including alcohol consumption, addiction to

tobacco and food-related factors. It should be emphasized that many disorders and diseases, such as diabetes or obesity, may also lead to oxidative stress [14].

Studies conducted in various populations of healthy and infertile men have revealed that the levels of markers of oxidative stress in semen, i.e. malonyldialdehyde (MDA, product of the reaction between free radicals and polyunsaturated fatty acids, i.e. lipid peroxidation) and total antioxidant capacity (TCA), are correlated with semen parameters. There was a negative correlation between motility, morphology and sperm count, and MDA level, and a positive correlation between these parameters and TCA. In addition, men with idiopathic infertility (of unknown causes) had higher MDA levels and lower TCA in semen compared to men without infertility [4, 18].

Oxidative stress resulting in the excessive synthesis of free radicals can cause damage to DNA in reproductive cells and thus reduce not only the quality of semen (fertilization capacity), but also cause complications during pregnancy. Excessive concentration of free radicals also has a negative effect on sperm motility. The cell membrane of spermatozoa responsible for motility contains large amounts of polyunsaturated fatty acids, and their oxidative damage (lipid peroxidation) deteriorates sperm motility and thus decreases sperm quality [4, 10].

Studies also revealed that oxidative stress has a direct negative effect on male fertility by affecting sperm quality, but also an indirect effect because it influences the endocrine function of the hypothalamic-pituitary-gonadal axis. Studies investigating various factors stimulating the excessive synthesis of free radicals and thus the onset of oxidative stress have demonstrated negative effects at various levels of this axis. For example, free radicals inhibit the synthesis and release of GnRH (gonadotropin-releasing hormone) from the hypothalamus, and LH (luteinizing hormone) and FSH (*follicle-stimulating hormone*) from the pituitary gland, which is associated with the abnormal stimulation of testosterone production in gonads. Free radicals also inhibit testosterone production in the testes, mainly by decreasing the activity of the key protein StAR (Steroidogenic Acute Regulatory Protein) and finally disturb the function of Leydig cells (which produce testosterone), and Sertoli cells (sustentacular cells for spermatozoa). As a result, the blood concentration of testosterone is decreased and the negative feedback mechanism that optimizes the axis function is dysregulated [14].

Other studies revealed that the supplementation of exogenous antioxidants can minimize or even prevent oxidative damage caused by free radicals and even the onset of oxidative stress, thereby improving the quality of semen in infertile men. Supplementation of antioxidants (including alpha-tocopherol, ascorbic acid, carotenoids, e.g. lycopene, as well as selenium and zinc - components of enzymatic antioxidants) reduces the DNA damage and DNA fragmentation in reproductive cells and thus improves sperm morphology, but also lowers the peroxidation of lipids and thus counteracts the reduction of sperm motility. Therefore, it seems that the supplementation of antioxidants may be effective in the prevention and/or treatment of functional disorders of semen associated with oxidative stress [1, 3].

However, various studies have not provided conclusive evidence on the beneficial effects of antioxidant supplementation and relevant recommendations. The problem is in the huge and unlimited availability of food supplements, most often multi-component, which can easily be overdosed. Moreover, uncontrolled supplementation can be counterproductive. For example, the antioxidant paradox was described, and this problem concerns the negative effect of antioxidants taken in an uncontrolled way and in excessive doses: this supplementation strategy has no positive effects and instead stimulates the synthesis of free radicals. On the other hand, as previously mentioned, free radicals at physiological concentrations are necessary to maintain the normal function of the male reproductive system, and therefore the oversupplementation of antioxidants could unnecessarily inhibit their synthesis and lead to serious disorders. It has also been pointed out that the supplementation of antioxidants should be preceded by laboratory tests to measure the markers of the oxidant/antioxidant status in both blood and semen, and to identify individuals who would really benefit from this supplementation and improve their fertility [2, 46].

It seems more reasonable and safer to provide antioxidants with food, because the human body has mechanisms that regulate the absorption of food components as needed. Thus, the diet, as a modifiable aspect of lifestyle, can be used to both prevent and treat infertility.

FRUITS AND VEGETABLES VERSUS MALE FERTILITY

Epidemiological studies have clearly indicated that foods rich in antioxidants play an important role in the prevention of many disorders and diseases, including cardiovascular diseases, cancer and degenerative diseases, and also have a significant anti-ageing effect. This is possible due to the fact that food can provide optimal amounts of various types of nutrients with beneficial effects on the body. Plant products, mainly fruits and vegetables, are a natural rich source of antioxidants in the everyday human diet. Fruits and vegetables contain a range of antioxidants: polyphenols (a complex group of compounds including phenolic acids, flavonoids and other compounds such as lignans, stilbenes, tannins, coumarins, and lignins), vitamins and C and E (tocopherols and tocotrienols), carotenoids (carotenes and xanthophylls), organic acids, selenium, zinc, glutathione, indoles, phytates, thiocyanates and others [24, 30]. The benefits of antioxidants have not been investigated and documented for all the above-mentioned compounds. Moreover, their mere presence in a food product, even in large quantities, is not enough to produce a positive effect. Antioxidants, like any other food components, are metabolised and modified in the human gastrointestinal tract by digestive juices, secretions (bile), as well as microorganisms forming the human microbiome. Most of these modifications do not affect the antioxidant capacity of these compounds, although in some cases can reduce it (e.g. flavonoids, including quercitin, undergo microbial degradation in the gut). In addition, antioxidants, like any other food components, undergo similar changes during processing and storage. Already at the early stage of processing, i.e. peeling, cleaning or chopping, the enzymatic decomposition of antioxidants and other compounds is activated. The most destructive processes

include oxidation, exposure to light, thermal decomposition and extraction. In order to minimize the loss of antioxidants, it is recommended that food products undergo very limited pre-treatment and further processing, and storage should be as short as possible [45].

Fruits and vegetables are a very diverse group of produce both in terms of nutrient content and in terms of organoleptic properties, cooking techniques and methods of their processing. Even with a small range of plant species and varieties, a balanced and diversified diet can be created which will provide all the necessary nutrients and bioactive ingredients. Studies have provided conclusive evidence that a large share of fruits and vegetables and their products in the diet plays a key role in preventing chronic diseases, including those related to lifestyle [24, 30, 43].

Most fruits and vegetables are rich in antioxidants. However, the actual antioxidant activity in the human body has not been documented for all of them. The concentration and type of specific antioxidants differ depending on the fruit and vegetable species and variety. Their concentration and antioxidant activity also depends on the degree of ripeness and duration of storage after harvesting [24, 46].

Particularly strong antioxidant activity resulting from high content of polyphenols has been found for soft fruits, mainly black chokeberry, bilberry, elderberry, raspberry, cranberries, black currants, gooseberries and grapes. High levels of polyphenols are also found in stone fruits, such as apples, cherries, plums, peaches, apricots, and citrus fruits. Vegetables rich in polyphenols include broccoli, cauliflower, Brussels sprouts, kale, garlic, spinach, white cabbage, beetroot and legume seeds, such as beans, soybeans, lentils, broad beans, faba beans and peas. Processing technology has a significant effect on the content of polyphenols and their antioxidant properties. Processes with the strongest negative effect are thawing, aerobic drying and rehydration, while short-term heat-treatment, blanching, freezing, and alcohol fermentation are the least destructive. Importantly, the effect of processing technology on the antioxidant activity of polyphenols contained in plant raw materials strictly depends on the type of plant material used [8, 20, 33, 46].

Among the carotenoids with a proven antioxidant effect on the human body, beta-carotene and lycopene have been the most extensively investigated. The richest source of lycopene are tomatoes, but also fruits: peach, melon, watermelon, red grapefruit, papaya and apricots. The content of lycopene in these fruits and tomatoes is higher the darker their red colour is. The highest concentration of lycopene is found in tomatoes ripening in the sun, not those from a greenhouse. Lycopene is found mainly under the skin of tomatoes, and is released during the disintegration and cooking of tomatoes. Therefore, lycopene from processed tomato products (e.g. sauce, puree or a concentrate) is much better absorbed than that from fresh tomatoes. Heating causes the chemical transformation of lycopene into *trans*-lycopene, which is better absorbed in the digestive tract [8, 20, 33, 46].

The content of beta-carotene also depends on the colour of fruits or vegetables. The richest sources of beta-carotene are apricots, peaches, watermelon, pumpkin, papaya, carrots, sweet potatoes, red peppers, tomatoes, lettuce, spinach and kale. Processing affects both the content and activity of beta-carotene. The degradation of cell walls during heat-treatment or enzymatic hydrolysis increases the bioavailability of beta-carotene. High-temperature processing (boiling, sterilization) does not cause a significant loss of beta-carotene and thus it does not reduce its antioxidant activity [8, 20, 33, 46].

Wholemeal bread, cereal products, cocoa, nuts, pumpkin seeds and legume seeds are the richest plant sources of zinc and selenium in the diet. Importantly, the bioavailability of selenium is reduced when the diet contains high levels of zinc, but increases when vitamins A, E and C are present. The bioavailability of zinc is reduced by phytic acid, oxalic acid, and dietary fibre, as well as excess intake of calcium and copper, while vitamins A, E and C, as well as magnesium, phosphorus and selenium have the opposite effect [8, 20, 33, 46].

Plant sources of vitamin E include nuts, sunflower seeds, green leafy vegetables, such as spinach and lettuce, and black currant and cranberries. Tocopherols and tocotrienols are stable even at temperatures of up to 200°C. However, they degrade during freezing, long-term storage and exposure to sunlight (particularly UVA and UVB) [8, 20, 33, 46].

The richest sources of vitamin C are blackcurrant, citrus fruits, various types of peppers, broccoli, Brussels sprouts, kale, cabbage, white cauliflower and spinach, chives and beet leaves (chard). Unfortunately, vitamin C is unstable in food products exposed to daylight and in contact with air. However, it is resistant to freezing, and thus frozen fruit and vegetables are an excellent source of this compound [8, 20, 33, 46].

It has been reported that the intake of antioxidants is associated with semen quality. Studies have shown a positive correlation between the dietary intake of several antioxidant nutrients (assessed using a semi-quantitative food frequency questionnaire (FFQ)) and selected semen parameters, like total motile sperm count, sperm concentration and morphology. Moreover, males with sperm abnormalities, or infertile subjects, had a significantly lower intake of selected antioxidants, like selenium, vitamin C and E, lycopene and beta-carotene, compared to control subjects. These antioxidants originated mainly from vegetables and fruits, and all of them have a pivotal role in improving semen quality, mainly through reduction in oxidation damage and lipid peroxidation potential [5, 17, 28, 29, 35, 36].

It is worth mentioning that nutrition is considered as a whole dietary pattern. People of reproductive age have been affected by the spread of unhealthy eating behaviours and rapid negative changes in dietary patterns, such as high intakes of saturated fatty acids, *trans* fatty acids and sodium, and low intakes of vegetables and fruits. Such unhealthy dietary patterns influence the health of the reproductive system. They also contribute to many disorders, like overweight and obesity, insulin resistance, diabetes mellitus, and dyslipidaemia, which also impairs fertility. Luckily, the negative effects of unhealthy dietary patterns may be reversible. A healthy diet for men of reproductive age includes foods which are rich in specific nutrients necessary for endocrine function, production and balance, foetal development, egg health, sperm health and much more. Several recent studies have concluded that, compared to subjects with the strongest adherence to a healthy diet, those in the lowest category of adherence had significantly poorer sperm quality. Studying dietary patterns

is a useful approach for describing the overall diet, including potential synergetic effects of food or nutrients, which are crucial determinants of nutritional status linked with normal reproductive functioning. Dietary patterns are identified by principal component analysis or factor analysis. This approach uses collinearity between nutrients or food, examining the interrelation between the diet and its health effects [13].

In general, dietary patterns are categorized as the Western-style dietary pattern and the health-promoting dietary pattern. The Western-style dietary pattern is characterized by low consumption of vegetables and fruits, frequent consumption of sweets and snacks, red and/or processed meat, animal fat, refined grain products, red meat, potatoes, high-fat dairy products, coffee, alcohol, and sugar-sweetened beverages, and is associated with lower semen quality, i.e. abnormal sperm progressive motility, count and morphology of semen. These negative effects of the Western-style dietary pattern are attributed to the high content of saturated fatty acids, natural *trans* fatty acids, and carbohydrates. This diet is low in antioxidants, which is associated with increased risk of anatomical and functional anomalies of semen.

The healthy dietary pattern is characterized by frequent consumption of fish, fruits, vegetables, legumes, soups, mixed dishes, whole-grain products, juices and nuts rich in antioxidants (beta-carotene, vitamin E and vitamin C and polyphenols), fibre, folate, vitamin B6, and omega-3 fatty acids, which play an important role in ensuring the quality of semen. It has been suggested that the possible effect of antioxidants may consist in reducing oxidative stress and chronic inflammation while improving the function of semen, reducing the amount of damaged DNA, participating in steroid hormone synthesis, inhibiting sperm agglutination, and most probably protecting against the toxic effect of heavy metals. A healthy diet, according to specific components, is also divided into the following patterns: health-conscious (fruits, vegetables, fish, legumes and whole grains are the main foods consumed in this pattern), prudent (fruits, vegetables, legumes, poultry and whole grains are the main foods consumed in this pattern), and Mediterranean (high consumption of olive oil, nuts, fruits, vegetables, legumes and whole cereals, and fish, poultry and wine consumed in moderate amounts) [7, 13, 16, 40].

The Mediterranean diet is well known for its positive effects on longevity by preventing cardiovascular disease. Studies have also demonstrated its beneficial effects on preventing lifestyle diseases, such as diabetes, obesity, cancer, infertility, and neurodegenerative and autoimmune disorders. The positive effect of this diet is most likely due to the high content of monounsaturated and polyunsaturated fatty acids from the omega-3 group, and antioxidants such as vitamin C, E, carotenoids and flavonoids [12].

In addition to antioxidants, vegetables and fruits also contain other compounds important for male fertility. Particularly noteworthy is dietary fibre, whose content in fruit and vegetables is significant, and in fact they are its main source in the human diet. A diet rich in fibre is recommended, for example, to prevent overweight and obesity, and carbohydrate metabolism disorders such as hyperinsulinaemia, insulin resistance and diabetes. These medical conditions have a strong negative effect on male fertility. Excess of body fat disturbs the hormonal axis regulating gonadal function, which leads to abnormal testosterone synthesis and the differentiation and maturation of spermatozoa. In addition, overweight and obesity significantly disrupt the secretion of leptin, resistin and adiponectin, which are also hormones essential for normal gonadal function. Consequently, the quality of sperm and its fertilization capacity are reduced. It has been demonstrated that obese men have a decreased count of spermatozoa with normal morphology and their concentration in ejaculate, and are at very high risk of oligozoospermia and azoospermia. Hyperinsulinaemia, usually associated with states of overweight and obesity, affects the conversion of testosterone to oestrogen in adipose tissue, thus leading to abnormal testosterone to oestrogen ratios. In addition, it is associated with the inhibited hepatic synthesis of SHBG (sex hormone binding globulin), a protein that also binds testosterone. This increases the risk of developing hypogonadism, which is a direct cause of male infertility. Thus, a higher intake of fruits and vegetables in the diet, especially those rich in fibre, helps to prevent infertility and supports its treatment [9, 15, 44].

Legume seeds, including soybeans, are particularly noteworthy in terms of their impact on male reproductive capacity. Legume seeds are rich in nutrients, including dietary fibre and antioxidants, mainly represented by isoflavones. Soy isoflavones have strong antioxidant properties with documented positive effects on the human body [45]. However, their oestrogenic and anti-oestrogenic properties in the aspect of male fertility raise considerable concerns. Isoflavones, such as genistein, daidzein and glycitin, contained in soy and soy products, can bind to oestrogen receptors and thus influence hormonal metabolism. It should be emphasized that studies on humans and animals have not provided conclusive evidence on the negative effects of soy and soy products consumption on male hormonal balance, testicular mass or sperm properties, and thus on fertility. The richness of nutrients and bioactive ingredients in soy should be considered, as well as the basic principle of proper diet, which is moderation, to balance potential negative effects [21, 31, 39, 47].

Fruits and vegetables are recommended as the basic components of a healthy diet promoting both general and reproductive human health. However, the presence of pesticide residues in these products is of concern. In fact, fruits and vegetables are the main source of exposure to pesticides in the human diet. Considering this, it is important to distinguish between fruits and vegetables that accumulate small to medium amounts of pesticide residues and those that accumulate large amounts. The lowest levels of these residues are found, for example, in avocado, sweet corn, pineapple, cabbage, sugar peas, onion, asparagus, mango, papaya, kiwi, eggplant and cauliflower. The highest levels of pesticide residues are accumulated in strawberries, apples, celery, grapes, cherries, spinach, tomatoes, red peppers, cucumber and lettuce [32, 48]. It has been demonstrated that the consumption of fruits and vegetables containing small to medium amounts of pesticide residues is associated with better sperm parameters in young men, i.e. the count and morphology of spermatozoa, compared to men consuming fruits and vegetables containing large amounts of residues. This implies that the content of pesticide residues can modify the beneficial effects of fruits and vegetables on male fertility [11, 31]. Therefore, it is important to make conscious choices of individual types of vegetables and fruit available on the market.

Another healthy food that plays an important role in human nutrition and health due to their nutrient profile and bioactivities are nuts. Nuts (tree nuts and peanuts) are nutrient-rich foods that contain plenty of compounds such as: unsaturated fatty acids, B-vitamins, fibre, microelements (copper, magnesium, potassium, zinc, selenium, calcium), nutrient and non-nutrient antioxidants (e.g. phenolic compounds and tocopherols), and numerous bioactive components which have beneficial effects on human health. These components can be acquired provided that nuts are not roasted. Different kinds of nuts have characteristic compositions, thanks to which they influence particular diseases, such as cardiovascular diseases, atherosclerosis, obesity, and inflammatory disorders. They also have neuroprotective activity and reduce stress. The most popular edible tree nuts are almonds, hazelnuts, walnuts and pistachios. Other common edible nuts are pine nuts, cashews, pecans, macadamias and Brazil nuts [6, 38, 49]. Many studies have aimed to investigate the role of different nuts in human fertility, especially in male fertility. Nut supplementation improves semen quality and functioning in healthy men and in animal studies. A hazelnut supplemented diet improves plasma testosterone levels, plasma and testicular oxidant-antioxidant status, and semen quality markers [23]. Moreover, the inclusion of a mixture of nuts in the Western-style diet significantly improves the total sperm count and the viability, motility, and morphology of sperm. These findings could be partly explained by a reduction in sperm DNA fragmentation, and this beneficial effect is probably attributed to the nuts' components, i.e. microelements – zinc, selenium and other antioxidants [37, 41]. Additionally, compliance with a healthy diet supplemented with mixed nuts may help to improve erectile function and sexual drive in healthy males [42].

In conclusion, nuts, beyond their basic nutritional functions, offer an excellent choice as a reproductive-healthy snack food and food additive. Nuts should be consumed with their skin (pellicles) whenever possible, because of their high phytochemical content as well as antioxidant activity.

CONCLUSIONS

Human infertility could be induced by free radicals through occupational activities and the uncontrolled growth of industrialization, civilization and malnutrition. However, dietary supplementation with functional food components can prevent this abnormality. Therefore, the consumption of functional foods to ensure reproductive health and capacity should be advocated for the proper management of infertility among concerned couples.

Vegetables, fruits and nuts rich in unique nutrients, sometimes referred to as superfoods, should be basic components of the diversified and balanced diet of men of reproductive age planning parenthood and those treated for infertility.

PODSUMOWANIE

Niepłodność u mężczyzn może być skutkiem uszkadzającego działania wolnych rodników związanego z narażeniem zawodowym, industrializacją, rozwojem cywilizacji i niewłaściwym sposobem żywienia. Uzupełnienie diety w produkty żywnościowe korzystnie wpływające na męskie funkcje rozrodcze może temu zapobiec. Dlatego zbilansowana dieta bogata w produkty prozdrowotne powinna być zalecana w postępowaniu w przypadku niepłodności.

Warzywa i owoce oraz orzechy, ze względu na bogactwo i unikatowość składu, określane jako produkty prozdrowotne o wysokiej wartości odżywczej, powinny stanowić podstawowy element zróżnicowanej i zbilansowanej diety dla mężczyzn w wieku reprodukcyjnym zarówno planujących rodzicielstwo, jak i leczonych z powodu niepłodności.

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