Water-Soluble Vitamins

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Contributor: Berta Maria Abreu Nogueiro Estevinho, Sílvia Castro Coelho, Fernando Rocha

Vitamins are essential micronutrients in diets that ensure the biochemical functions of the human body and prevent diseases. They act as antioxidants, hormones, and mediators for cell signaling, cell/tissues regulators, and differentiation. They are sensitive compounds that are degraded during cooking and storage processes by factors such as light, heat, oxygen, moisture, pH, time, and reducing agents. Consequently, vitamin encapsulation can overcome limitations associated with external agents such as oxidants, heat, and low solubility, and promotes effective delivery into the body. Water-soluble and fat-soluble vitamins are two main groups of this type of micronutrient. Water-soluble vitamins are important for growth, development, and human body function.

Keywords: Vitamins ; Water-Soluble Vitamins ; diets ; Microencapsulation

1. Water-Soluble Vitamins

Vitamins are essential micronutrients in diets that ensure the biochemical functions of the human body and prevent diseases [1]. They act as antioxidants, hormones, and mediators for cell signaling, cell/tissues regulators, and differentiation [2]. They are sensitive compounds that are degraded during cooking and storage processes by factors such as light, heat, oxygen, moisture, pH, time, and reducing agents [3]. Consequently, vitamin encapsulation can overcome limitations associated with external agents such as oxidants, heat, and low solubility, and promotes effective delivery into the body.

Water-soluble and fat-soluble vitamins are two main groups of this type of micronutrient. Water-soluble vitamins are important for growth, development, and human body function. However, due to physiological conditions, it is not possible to keep them for a long period of time in the body [4]. B-complex group and vitamin C are the main compounds with degradation activity from food processes. Therefore, factors such as bioavailability and bioaccessibility should be considered in current research. Commonly, water-soluble vitamins show a pH sensitivity with bioaccessibility reduction when exposed to small intestine pH values [5].

Microencapsulation techniques such as electrospinning have been the focus of investigation for these types of vitamins. In fact, the non-use of high temperature appeared as a crucial alternative to overcome these limitations associated with these compounds. Another important factor to be considered is the effect of the hydrophobicity/hydrophilicity of the wall materials on the encapsulation method. In fact, the protection of water-soluble vitamins is more efficient for a hydrophobic shell preventing the diffusion of vitamins into food until the desired timepoint [6].

New approaches have been investigated in order to achieve processes with lower temperature and duration [4].

2. B-Complex Group

The B-complex group comprises micronutrients that act as cofactors for enzymatic reactions in metabolism processes. These compounds are vitamin B1 (thiamine), vitamin B2 (riboflavin), vitamin B3 (niacin), vitamin B5 (pantothenic acid), vitamin B_6 (pyridoxine, pyridoxal, and pyridoxamine), vitamin B9 (folic acid), and vitamin B12 (cobalamin). They cannot be stored in the human body and should be consumed daily [7]. These vitamins present high sensitivity to light, pH conditions, and temperature. Therefore, encapsulation is an important step in minimizing vitamins' bioavailability and increasing their effectiveness in situ [8].

2.1. Vitamin B1

Vitamin B1 (vitB1), also known as thiamine, is a coenzyme precursor [9]. It is essential for carbohydrate metabolism and plays a vital function in the cardiovascular system as well as in the nervous, immune, and muscular systems [7]. As an essential micronutrient, vitB1 needs to be consumed daily due to the incapacity of the human body to store B12 [10]. VitB1 is found in yeast, grains, and meat and in lower amounts in vegetables and fruits. VitB1 presents reduced stability against environmental conditions such as temperature, pH, humidity, oxygen, and metal ions [10]. Carlan et al., reported the successful encapsulation of vitB1 using different encapsulating agents by a spray-drying method [10]. In terms of achieved stability, the best results were developed for chitosan and modified chitosan presenting low vitB1 loss.

2.2. Vitamin B2

Riboflavin, also known as vitamin B2 (vitB2), is a coenzyme in several redox reactions [9]. VitB2 is present in the liver, milk, dark-green leafy vegetables, enriched bread, and cereal. VitB2 is a photosensitive vitamin that converts amino acids into niacin [7]. VitB2 has functions in oxidation–reduction reactions in the body and the cellular system; regeneration and growth of tissues [7][11].

2.3. Vitamin B3

Niacin is the generic name of the active form of vitamin B3 (vitB3), also known as nicotinic acid or nicotinamide. It is a water-soluble vitamin present in food products such as meat, poultry, and fish, being accessible as a supplement. Niacin is synthesized in the body and is converted to NAD+ [12]. NAD+ is crucial in different phases, namely its reduction to NADH. NAD and NADH are essential for the production of energy, cholesterol, and fats; and the synthesis/repair of DNA [9]. This vitamin is sensitive and loses its activity with shelf life and storage. VitB3 deficiency in the diet is the cause of pellagra nutritional disease [13].

2.4. Vitamin B5

Vitamin B5 (vitB5) is a water-soluble B-complex vitamin, also known as pantothenic acid or pantothenate [2]. VitB5 is a component of an important coenzyme A and an essential vitamin for energy metabolism that allows the conversion of carbohydrates, fats, and proteins into energy [2]. Moreover, vitB5 is necessary for the production of the brain neurotransmitter acetylcholine, responsible for memory and reducing anxiety [14].

2.5. Vitamin B6

Vitamin B6 (vitB6) is a water-soluble vitamin necessary in several reactions including amino acid metabolism, glycogen, and different enzymatic reactions concerning immune and growth functions [7]. VitB6 also has an important function in the synthesis of neurotransmitters [15]. It appears in several forms such as pyridoxine, pyridoxal, and pyridoxamine. VitB6 is present in meats, poultry, fish, grain products, fruits, and vegetables [15]. This vitamin is thermally unstable [16]. Modifications to the digestive system, depression, marks of skin aging, and eczema are related to its deficiency [17].

2.6. Folic Acid (Vitamin B9)

Folic acid is an essential water-soluble micronutrient that is crucial for several physiological functions in the human body. Also known as vitamin B9 (vitB9), it presents an important function in preventing neural tube defects in children and can decrease the probability of developing vascular diseases, cancer, and Alzheimer's disease [18]. Folic acid acts on DNA, RNA, and amino acids, supporting rapid cell division [18]. It is not synthesized in the human body but is found in small quantities in fruits, vegetables, and cereals [18]. Nevertheless, the degradation of these vitamins occurs when exposed to light, temperature, oxygen, and acid/alkaline conditions. In fact, this vitamin is one of the most sensitive to losses during food storage and processing due to its chemical reactivity [19]. The microencapsulation of folic acid is a solution to avoid its degradation and maintain its stability and bioactivity in different food matrices. Different matrix materials have been developed for encapsulation of this micronutrient, e.g., spray-drying and electrohydrodynamic techniques, in order to be used as a supplement or food fortification [20].

2.7. Vitamin B12

Vitamin B12 (vitB12), or cyanocobalamin, is a cobalt-containing compound (corrinoid) [21]. VitB12 is a stable compound in an aqueous solution of pH 4–7 and does not lose activity when heated at 120 °C [22]. VitB12 is synthesized by bacteria and is found in foods derived from animals such as meats, milk and derivates, and eggs. VitB12 is fundamental in human growth and development. This vitamin plays an important role in the metabolism of fatty acids and aliphatic amino acids; in the brain and nervous system activity; and in blood formation [23]. VitB12 deficiency can lead to anemia, Alzheimer's disease, neural tube defects, and ulcers [24].

3. Vitamin C

Vitamin C (vit C), also known as ascorbic acid, is a very common water-soluble vitamin present in fruits and vegetables such as broccoli, citrus fruits, strawberries, tomatoes, raw cabbage, and leafy greens [25]. It cannot be stored in the human body and is not synthetized in it [12]. This micronutrient is a food supplement and a powerful antioxidant [26]. VitC herewith vitamin E, vitamin A, and selenium are four of the main antioxidants recognized by the US Food and Drug Administration [3]. It acts on the synthesis of collagen protein, wound healing, healthy immune and nervous system, quenching or stabilizing the free radicals involved in degenerative diseases, cardiovascular cancer, cataracts, and the immune system [27].

Vit C has the capacity to donate hydrogen atoms to neutralize free radicals and reactive oxygen species that can damage the DNA [1][27]. This vitamin can also prevent the adverse effects of chemotherapeutic agents [28]. However, it is a thermolabile compound [29]. The environmental factors and dissolution in water contribute to minimizing its stability; for example, vitamin degradation at room temperature [1]. This micronutrient is extremely sensitive and can interact with other food ingredients. It is highly reactive and oxidases in the presence of metals such as copper and iron [27]. The microencapsulation technique allows increasing its stability, preserving it from thermo-oxidative degradation. The encapsulation of this vitamin is essential for industry, in order to improve its applicability in food processes. Uddin et al., reported the successful use of several polymers to coat vitC by the spray-drying technique, masking the color and taste changes and controlling its release [30]. Trindade et al., suggested the stability of vitC encapsulated by spray drying, using rice starch and GA encapsulation agents [31].

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