Factors that impact the stability of vitamin C at intermediate temperatures in a food matrix

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The study comprises a systematic and quantitative evaluation of potential intrinsic and extrinsic factors that impact vitamin C degradation in a real food matrix. The supernatant of centrifuged apple purée was fortified in vitamin C, and degradation was followed without stirring. Model discrimination indicated better fit for the zero order model than the first order model which was hence chosen for determination of rate constants. pH influenced strongly vitamin C degradation in citrate-phosphate buffer but not in the apple purée serum. To get an idea of the impact of the food matrix, stability in apple purée serum was compared with that in carrot purée. In the latter, stability was slightly higher. Vitamin C degradation rates were not influenced by its initial concentration. The temperature effect was only marked in the temperature range 40–60 °C. In the range 60–80 °C, filling height of tubes had the greatest impact.

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1. Introduction

Vitamin C, consisting of ascorbic acid and dehydroascorbic acid, is an important vitamin in plant foods, and is characterized by its degradability in processing and food preparation. In spite of numerous studies, its degradation is not completely understood. Impact factors are often only known for model solutions (Aka, Courtois, Louarme, Nicolas, & Billaud, 2013; Kaack & Austed, 1998; Lee & Labuza, 1975; Oey, Verlinde, Hendrickx, & Van Loey, 2006; Rojas & Gerschenson, 1997, 2001; Wilson, Beezer, & Mitchell, 1995; Yamauchi, Nimura, & Kinoshita, 1993) but their importance, especially in a quantitative way, in real food products is lacking.

The predominant pathway of vitamin C degradation in aqueous liquid systems (water activity higher than 0.980) entails oxidation of ascorbic acid to dehydroascorbic acid (Fig. 1), which itself promptly degrades to 2,3-diketogulonic acid (Washko, Welch, Dhariwal, Wang, & Levine, 1992). By the hydrolysis of dehydroascorbic acid, the molecule looses its vitamin property. With increasing water activity (aw) or moisture content, the degradation of ascorbic acid increases (Lee & Labuza, 1975). The reaction from ascorbic acid to its oxidized form dehydroascorbic acid and the following hydrolysis to 2,3-diketogulonic acid proceeds in water, without any oxidizers or reducing agents, at the same pace (Serpen & Gökmen, 2007). Fe3+ ions accelerate both reaction steps that is oxidation of ascorbic acid and following hydrolysis of dehydroascorbic acid. Cysteine in contrast enhances the reconversion of dehydroascorbic acid to ascorbic acid. During the oxidation of ascorbic acid, oxygen is not incorporated in the molecule itself but serves as acceptor of two electrons. Besides the aerobic degradation pathway via dehydroascorbic acid, ascorbic acid can also be degraded by an anaerobic pathway proceeding by hydrolysis (Schulz, Trage, Schwarz, & Kroh, 2007; Yuan & Chen, 1998). The latter is however much slower and occurs only to significant amounts over 120 °C (Dhuique-Mayer et al., 2007; Oey et al., 2006; Verbeyst, Bogaerts, Van der Plancken, Hendrickx, & Van Loey, 2013). Oxygen is therefore an indispensable reaction partner in the intermediate temperature range. When no headspace oxygen is available, degradation of ascorbic acid decelerates after an initial fast depletion of ascorbic acid which can be ascribed to consumption of oxygen as dissolved oxygen contents decrease concomitantly (Robertson & Samaniego, 1986; Verbeyst et al., 2013). However, changing initial oxygen contents in the range 0.41–3.74 mg/L does not impact the degradation rate of ascorbic acid at 36 °C (Robertson & Samaniego, 1986).

The experimental set-up concerning especially the airtightness and stirring of the system in which vitamin C degradation is followed is therefore indispensable to consider. These factors may explain the number of different models applied to describe vitamin C kinetics which range from zero, first and second order models to a biphasic and a Weibull model (Dhuique-Mayer et al., 2007; Eisonperchonok & Downes, 1982; Johnson, Braddock, & Chen, 1998).
Juice and apple juice in comparison to water (Miller & Rice-Evans, Gerschenson, 1997; Wilson et al., 1995; Yamauchi et al., 1993). The effect has been supposed to be a consequence of protective (Clegg & Morton, 1968).

In addition, an equilibrium between headspace and dissolved gases is liberated by heat, but a combination of dissolved oxygen and extrinsic factors temperature and the influence of filling height of experimental tubes. An intermediate temperature range was studied that can be encountered when food is reheated. As the bioactive form of vitamin C includes the oxidized form of ascorbic acid, dehydroascorbic acid, this concentration was incorporated in the modeling by considering the sum of these two molecules.

2. Material and methods

2.1. Chemicals

2.2. Supplementation

Apple purée was purchased at a local supermarket and carrot purée was produced by the project partner “Casamas” (Castelltercol, Spain). Both purées contained no added vitamin C. McIlvaine citrate-phosphate buffer was purchased from Sigma-Aldrich (Deisenhofen, Germany). Ortho-phosphoric acid 85%, Iron(III)chloride hexahydrate were obtained from VWR (Leuven, Belgium). Ethanol was provided by Fisher Scientific (Fair Lwan, NJ, USA).

2.3. Thermal treatment

After thawing, tubes were transferred to floating tube racks and immersed in a heated water bath ED-19 from Julabo (Seelbach, Germany). Ortho-phosphoric acid 85%, Iron(III)chloride hexahydrate were purchased from Sigma-Aldrich (Deisenhofen, Germany). Ortho-phosphoric acid 85%, Iron(III)chloride hexahydrate were obtained from VWR (Leuven, Belgium). Ethanol was provided by Fisher Scientific (Fair Lwan, NJ, USA).
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