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Impact of three warming-up methods on the stability of vitamin C and 5-methyltetrahydrofolate supplemented to apple and carrot purée

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ABSTRACT

Two methods that are used at people's home to warm-up food namely a microwave and an Actifry® device, and a system that is usually employed in canteen kitchens to keep food warm, were examined on their impact on the stability of vitamin C and 5-methyltetrahydrofolate. The purée was heated until ebullition with the microwave, which lasted 1.5 min. Purée which was warmed-up by the Actifry® device needed around 20 min to attain 80 °C. When the purée was kept warm by a water bath, the vitamin stability was pursued for 180 min at 80 °C. During the latter, stability was examined at the surface and bottom of recipients that were filled with 600 g or 200 g of purée corresponding to a filling height of 5 cm and 1.5 cm respectively. Although vitamin C and 5-methyltetrahydrofolate are usually referred to as heat- and oxygen-susceptible molecules, none of the methods led to major vitamin losses. In terms of the warm holding method, no difference was observed between withdrawals at the surface and the bottom of vessels for neither of the two filling levels. Vitamins were also fairly stable at the surface of recipients where oxygen exposition is high.

1. Introduction

Vitamin C and vitamin B_9, the latter is also known as folate(s), are essential micronutrients which have to be ingested as they cannot be synthetized by humans' metabolism. Vitamin supplementation can be used to increase their intake. Folic acid, a synthetic folate vitamer, is predominantly used for enrichment of folates however it might mask vitamin B_{12} deficiency. Thus, the natural abundant vitamer, 5-methyltetrahydrofolate, has been proposed as alternative for supplementations (Pietrzik, Bailey, & Shane, 2010; Scaglione & Panzavolta, 2014). It is susceptible to deterioration though. To comply with the intention of enrichments, that is to supply a certain vitamin amount, the stability study of vitamin C and 5-methlytetrahydrofolate is indispensable.

Vitamin C and 5-methyltetrahydrofolate are both sensitive to oxygen and temperature (Delchier et al., 2014; Dhuique-Mayer et al., 2007). When oxygen is absent, no degradation of vitamin C and 5-methyltetrahydrofolate occurs at intermediate temperatures i.e. between 40 °C and 80 °C (Delchier et al., 2014; Herbig, Maingonnat, & Renard, 2016). Up to 100 °C, oxygen is still soluble and in dynamic equilibrium with headspace oxygen (Van Bree et al., 2012). Dissolved oxygen in supplemented apple and carrot purée is consumed entirely within 1 h at 80 °C in contrast to model solutions (Herbig et al., 2016). After the depletion, oxygen is only available in the headspace. The filling height and thus oxygen availability is the factor that influences predominantly the stability of vitamin C in apple purée serum that is heated at 80 °C in Eppendorf tubes what can be ascribed to different surface-to-volume ratios (Herbig & Renard, 2017).

Unfortunately, 5-methyltetrahydrofolate is very unstable in contrast to folic acid, and degrades rapidly in model solution (Delchier et al., 2014; Paine-Wilson & Chen, 1979). By adding ascorbic acid, complete stability of 5-methyltetrahydrofolate can be attained during heat treatments (Herbig, 2016; Oey, Verlinde, Hendrickx, & Van Loey, 2006). However, the amount of ascorbic acid which is necessary for total protection cannot be generalized, for two reasons. First, even if ascorbic acid is available in molar excess compared to the amount of dissolved oxygen or 5-methyltetrahydrofolate, degradation starts after an initial protection period (Herbig, 2016). And second, the amount can be supposed to depend on the overall oxygen availability which is influenced by the experimental set-up. The exposition to headspace oxygen, which is determined by the geometry of the recipient

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and increases when the medium is stirred, may play a crucial role. Nevertheless, the time length of complete protection of 5-methyltetrahydrofolate can be extended by increasing the vitamin C amount (Herbig, 2016).

Reheating of food exhibits other constraints than cooking in terms of temperature and time length. Temperature recommendations for hot keeping of food are very similar in different European countries with a minimum temperature of 63 °C in France (Direction de l'information légale et administrative,2013) and 65 °C in Germany (Bundesinstitut für Risikobewertung, 2008). The aim of this recommendation is to impede growth of spore-forming bacteria. In terms of heating length, it has to be distinguished between people's homes and canteen kitchens. At the latter, food is usually held warm up to several hours.

The impact of warming-up methods on the stability of vitamin C and 5-methyltetrahydrofolate has rarely been studied. Data exist for microwave heat treatments. Depending on the heating length and the type of food, vitamins are preserved or lost. For example, only 2% of vitamin C in strawberry purée were lost when the purée was treated at 90 °C for 10 s and 12% when it was heated at 120 °C for 10 s under the conditions of Marszalek, Mitek, and Skapska (2015). It was not lost in kiwi purée after a treatment at 1000 W for 340 s (Benlloch-Tinoco, Igual, Salvador, Rodrigo, & Martínez-Navarrete, 2014) and to 46% in broccoli which stayed at 1000 W for 5 min (Vallejo, Tomas-Barberan, & Garcia-Viguera, 2002). Bureau et al. (2015) observed that vitamin C and folates in 13 frozen vegetables without addition of water were well retained after microwaving them between 10 and 18 min. Johansson, Furuhagen, Frolich, and Jagerstad (2008) compared the impact of microwave heating (900 W/5.5 min), reheating in a saucepan until food reached 85 °C and warming-up in an oven (225 °C/40 min) on folates stability in 10 precooked vegetarian food products. All methods significantly influenced the stability of folates but variability of each method was high and thus no recommendation could be inferred.

At people's homes, microwaves are often employed. Warming-up with an Actifry® device, which is usually used to cook French fries with a reduced amount of oil, could be an alternative. The Actifry® device is equipped with a scoop which automatically stirs the food product. Heating is carried out via conduction and additionally by ventilation of hot air in the headspace. Each heating method has its own, critical parameter for vitamin losses. When food is warmed-up by a microwave, heating until ebullition is necessary to ensure food safety. When using an Actifry® device, the product is heated at a lower temperature but is stirred and thus more exposed to headspace oxygen. In canteen kitchens, duration can be a critical factor as food is usually kept warm up to several hours.

The objective of the present work consisted in assessing the stability of vitamin C and 5-methyltetrahydrofolate after a warming-up treatment carried out by three different systems. It was envisaged to optimize the heating protocols in case that vitamins are lost. Apple and carrot purée was therefore supplemented with the two vitamins on a pilot scale. The impact of a microwave and an Actifry® device, and that of a warm holding method which is usually used in canteen kitchens, was studied. When examining the impact of the latter method, special attention was paid on the effect of filling height of recipients and degradation at the bottom and surface of vessels.

2. Material and methods

2.1. Production and supplementation of apple and carrot purée

Supplemented apple and carrot purée (25 kg respectively) were produced by the "Centre Technique de la Conservation des Produits Agricoles" (CTCPA) in Avignon/France. In Fig. 1, production steps are shown. For the preparation of apple purée, apples of the type "Golden" were washed and cut into pieces. Afterwards, apple pieces were chopped at 80 °C for 1 h in a "Stephan" (Stephan, Hameln, Germany) which is a combination of a mixer and a cooker. The apple mix was passed through a "Parmentière" (Eillert, Ulft, Netherlands) that is a filter, to discard apple cores and seeds. An amount of 25 kg of the purée was weighed, let cool down for 30 min and subsequently homogenized for 10 min in the "Stephan". For the production of enriched carrot purée, the same procedure as for apple purée was applied except that the washing and cutting step, and filtration by the "Parmentière" were omitted since deep-frozen carrot pieces were used.

Afterwards, ascorbic acid and 5-methyltetrahydrofolate were supplemented. Therefore, ascorbic acid (12.625 g) and 5-methyltetrahydrofolate (50.5 mg) were dissolved in 250 mL ultrapure water. The aimed ascorbic acid concentration in the purée was 50 mg/100 g and of 5-methyltetrahydrofolate 0.2 mg/100 g. The solution with the two vitamins was poured in the purée. Afterwards, the mixture was stirred for homogenization during 10 min in the "Stephan". The supplemented purée was transferred into cans which were deep-frozen (≤−18 °C) until experimentation.

2.2. Reheating experiments

Purées were thawed overnight in a cold room (8 °C) before each heat treatment. Temperature in the reheating vessels and after microwave was monitored using a digital thermometer (EU 620-0916NA82020-744, VWR, Fontenay-sous-bois, France).

2.2.1. Microwave warming-up

Thawed purée (250 g, corresponding to one can) was poured in a deep plate. A domestic microwave of the type Crisp FT439 Whirlpool (Whirlpool Corporation, Michigan, USA) was used for the heat

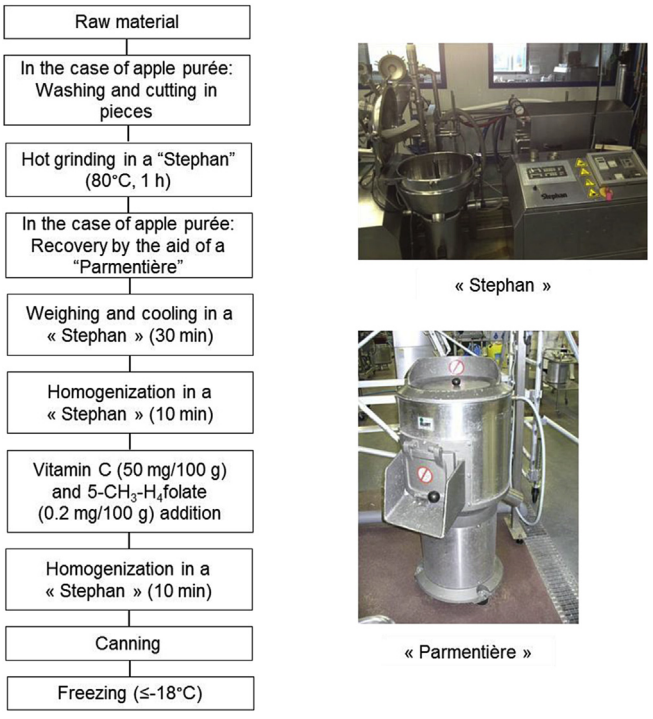

Fig. 1. Processing steps of supplemented apple and carrot purée.