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Review

Lipid oxidation in mayonnaise and the role of natural antioxidants: A review

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ABSTRACT

Background: Mayonnaise, a high-oil containing product, is susceptible to oxidation resulting in quality deterioration and the formation of undesirable components such as free radicals and reactive aldehydes. A better understanding of the factors affecting lipid oxidation and ways of retarding oxidation in mayonnaise is essential in order to improve the shelf-life of mayonnaise.
Scope and approach: This review presents up-to-date knowledge on the factors affecting lipid oxidation and strategies to retard lipid oxidation in mayonnaise, with an emphasis on natural antioxidants, and application to other similar emulsions. Eliminating possible factors, which will reduce the induction period and hasten rancidity, can increase the shelf life of mayonnaise but one of the most effective means of retarding lipid oxidation in mayonnaise is to incorporate antioxidants. Due to the negative effects and perceptions of synthetic antioxidants, there has been a growing interest in improving oxidative stability of food products with natural ingredients. Therefore, to provide a better base for food engineers to design an effective natural antioxidant system for mayonnaise, in this review the emphasis is given to using natural antioxidants in mayonnaise.
Key findings and conclusion: Recent studies showed that incorporation of natural antioxidants in mayonnaise could increase its oxidative stability. However, natural antioxidants may exert a negative effect on sensory properties and further studies are needed to identify, quantify and overcome this problem. Manipulating the interfacial layer of the oil droplet also shows promise for retarding oxidation; however, there is a lack of literature addressing this area.

1. General introduction to lipid oxidation in food emulsion systems such as mayonnaise

Oxidation of unsaturated fatty acids has been the main focus of research that targets chemical instability of emulsions. Mayonnaise is a low-pH oil in water emulsion consisting of three different components: 70–80% oil (the dispersed phase), vinegar (the continuous phase) and egg yolk as an emulsifier at the interface (Li, Kim, Li, Lee, & Rhee, 2014). As in the case of all high oil-containing foods, mayonnaise is susceptible to deterioration due to auto-oxidation of the unsaturated fats in the oil. Auto-oxidation proceeds through three steps: during the initiation step, external energy, such as light, acts on unsaturated lipid molecules or fatty acids, in the presence of catalysts such as transition metal, to generate a free radical by losing a hydrogen atom. During the propagation step, the alkyl of the unsaturated lipid (R•) reacts very fast with molecular oxygen to form peroxide radicals. This step is always much faster than the following which involves a hydrogen transfer reaction with unsaturated lipids to form hydroperoxides. At this stage, lipid peroxyl radicals (ROO•) and hydroperoxides (ROOH) are the primary oxidation products. Lipid hydroperoxides are tasteless, but they further decompose to aldehydes, ketones, alcohols, hydrocarbons, volatile organic acids and epoxy compounds known as secondary oxidation products, which are responsible for the off-flavour and off-odour of the oil. Primary oxidation products and secondary oxidation products, together with free radicals, constitute the basis for measuring the oxidative

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deterioration of food lipids (Shahidi & Zhong, 2005). In the termination step, the produced radicals from the propagation step can be terminated by self-interactions to form non-radical species, such as oxidized polar/non-polar dimers or trimers of lipids.

In emulsions formed from oil and water, lipid oxidation reactions are generally initiated at the interface between the oil and water, where pro-oxidants (transition metals) in the continuous phase are able to come into close contact with the hydroperoxides located at the droplet surface (McClements & Decker, 2000). Lipid oxidation in mayonnaise leads to the development of potentially toxic reaction products (Coupland & McClements, 1996), undesirable off-flavours and consequently decreases the shelf life of mayonnaise (Alemán et al., 2015). In order to tackle the problem of lipid oxidation, different strategies such as eliminating factors promoting lipid oxidation and using antioxidants are necessary. One of the common ways of retarding lipid oxidation is the use of antioxidants. The efficacy of an antioxidant is influenced by different factors such as its interaction with other ingredients and its ability to be located at the interface, where oxidation takes place (Coupland & McClements, 1996). Synthetic antioxidants such as butylated hydroxy toluene (BHT), butylated hydroxy anisole (BHA) and ethylene diamine tetraacetic acid (EDTA) (commercial antioxidants) are widely used in mayonnaise to prevent rancidity. However, these products suffer from a negative impression for their toxic and carcinogenic effects in high concentrations (Martínez-Tomé et al., 2001). In addition, there is a growing demand from customers for products such as mayonnaise to replace chemical ingredients with natural ingredients. Incorporation of natural antioxidants into food products has great potential for improving oxidative stability of food products and will appeal to a wider group of consumers. In addition, these compounds could also have health-promoting benefits which would enable mayonnaise producers to hit two desirable targets: health and natural (Hermund et al., 2015).

Low pH and high fat content of mayonnaise makes it resistant to microbial spoilage (Depree & Savage, 2001). Therefore, the objective of the present paper is to review current understanding of factors affecting lipid oxidation and antioxidative strategies to retard lipid oxidation in mayonnaise with a particular focus on current knowledge on the efficacy of natural antioxidants in retarding lipid oxidation in mayonnaise. The aim is to provide important information based on available literature reports concerning lipid oxidation in mayonnaise to control lipid oxidation and facilitate the replacement of synthetic antioxidants with natural ones.

2. Factors affecting lipid oxidation in mayonnaise

Lipid oxidation in a complex food system such as mayonnaise, is not simple, so the mechanism of lipid oxidation in mayonnaise is more complex than in bulk oil systems. Although the basic oxidation reactions of lipids in mayonnaise are the same as those of lipids in bulk oil systems, factors affecting lipid oxidation are significantly different in mayonnaise and bulk oil systems (Jacobsen, Let, Nielsen, & Meyer, 2008). In this section, data from previous studies of factors influencing lipid oxidation in mayonnaise, from intrinsic to extrinsic, will be presented in order to highlight not only the most important factors affecting lipid oxidation in mayonnaise, but also to provide a general view of ways to lessen these factors and control lipid oxidation in mayonnaise.

2.1. Metals

The presence of even small amounts of transition metals in mayonnaise can accelerate oxidation by decreasing the induction period of the oil and making it more susceptible to oxidation. Iron and copper are known initiators of lipid oxidation. Mayonnaise is an acidic product; during manufacturing and packaging, it contacts utensils and machinery. The acid of mayonnaise dissolves out the iron from a tin-lined tank and may become contaminated with metals, which accelerate rancidity and shorten the shelf life of the finished product (Epstein, 1929b; Reynolds, 1927). Epstein (1929a) pointed out that the presence of metals in mayonnaise products not only causes rancidity but also it decreases nutritional value of ingredients present in the product. However, with proper care and precautions it is possible to lessen the risk of contamination of products, for instance, using aluminium utensils.

2.2. Temperature

We know from lipid oxidation theory that high temperature increases lipid oxidation (Frankel, 1998, pp. 129–160). Findings from experiments with mayonnaise have shown the increase in oxidation at higher temperatures which are in agreement with lipid oxidation theory. A study investigating the effect of temperature on the oxidation of fish oil mayonnaise, showed that fish oil mayonnaise is more stable at refrigerator temperatures (2 °C) than at higher temperatures (30 °C) (Hsieh & Regenstein, 1991). In addition, a study on the oxidative stability of cholesterol in commercial mayonnaise demonstrated that temperature and time are important factors in oxidation of cholesterol in mayonnaise. They proposed that total formation of cholesterol oxides during 165 days was 20.3 μg/g at 4 °C and 30.2 μg/g at 25 °C. Hence, decreasing storage temperature could be a good way of suppressing the oxidation of cholesterol in mayonnaise (Morales-Aizpurúa & Tenuta-Filho, 2005). Based on another study, light mayonnaise (40% oil), even those without fish oil, cannot be stored at 20 °C for 4 months because of significant lipid oxidation (Sørensen, Nielsen, Hyldig, & Jacobsen, 2010). Consistent with previous studies, higher totox values and peroxide values were recorded for mayonnaises stored at 25 °C compared with samples stored at 4 °C (Li et al., 2014).

2.3. Light

Lipid oxidation caused by light exposure can be due to either photolytic auto-oxidation or photosensitized oxidation. Photolytic auto-oxidation occurs when lipids are exposed to ultraviolet radiation and consequently, free radicals are produced. On the other hand, in the presence of photosensitisers and visible light, unsaturated fatty acids undergo photosensitized oxidation. Natural pigments present in foods, such as riboflavin and chlorophylls, are known to be efficient photosensitisers due to their conjugated double-bond system (Bradley & Min, 1992). Light, with a wavelength of 365 nm, promotes the oxidation of unsaturated fats due to photosynthesised oxidation but light of wavelengths above 470 nm has no effect. Hence, it is important to protect mayonnaise from wavelengths shorter than 470 nm (Lennersten & Lingnert, 2000). The visible light in the blue range also increases oxidation in mayonnaise. Considering lights used in supermarkets (significant source of light at 365 nm and in the 410–450 nm range) avoiding intensive lighting can help preserving the fresh taste of mayonnaise (Lagunes-Galvez, Cuvelier, Odonnaud, & Berset, 2002).

2.4. Packaging

In addition to processing, mayonnaise quality during storage depends on the chosen packaging material. Some substances used in these materials may migrate to the food matrices and cause off-flavours. In some cases, gas may permeate the packaging material