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Review

Review of the effects of food processing and formulation on flavonol and anthocyanin behaviour

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ABSTRACT

In spite of the growing interest over the last few years in flavonoids and their antioxidant capacity, little work has been devoted to investigate the effect of the processes on the structure and the activities of these molecules during processing and storage steps. Most of the studies concern the characterization and analyses of these compounds in raw materials before their processing. Flavonoids are sensitive to heat and to the physico-chemical environment; thus the steps of processing (heating, mechanical and domestic processes), of formulation (food matrix) and the storage period and conditions may lead to a degradation of the flavonoids and an alteration of their antioxidant properties. In this paper, we review the main studies describing the effects of processing, formulation and storage on flavonol and anthocyan content and we also report the models describing the degradation kinetics under a wide range of temperature and operating conditions.

Contents

1. Introduction

Over the last few decades, links between diet and general well-being have been investigated. Beneficial health effects are attributed to dietary intake of some bioactive compounds. Among these, phenolic compounds and particularly flavonoids have gained attention due to their antioxidant properties and their natural abundance in the human diet. Numerous epidemiological studies have provided evidence of a potential role of flavonoid-rich foods in the lowering the risk of specific diseases (cancers, coronary heart diseases or neurodegenerative diseases) (Tomás-Barberán et al., 2000). Due to these benefit properties many studies have dealt with the identification of the dietary sources of flavonoids and their antioxidant capacity (Tomás-Barberán et al., 2000). However, most of these studies have essentially focused on raw foods while the human diet includes mainly cooked and processed foods. In fact, the processing and the formulation can drastically affect

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flavonoid content and by consequence the antioxidant capacity of convenience foods formulated from these raw materials (Nicoli et al., 1999). Processes applied to raw materials also affect the behaviour of phenols (Paixão et al., 2007; Seruga et al., 2011), the analysis of these effects will be useful to optimize processes. Antioxidant capacity of foods depends on the flavonoid structure, thus study the effects of food processes on the flavonoid degradation seems to be relevant to ensure to consumers functional foods with antioxidant properties. The environment of the flavonoid is therefore a key factor. Depending on this environment, synergies between antioxidant compounds and the food matrix can occur. In some cases, the antioxidant capacity of flavonoids in a food matrix is enhanced (Freeman et al., 2010), while in other cases, the antioxidant capacity is reduced (Hidalgo et al., 2010). These two last factors are very important and must be studied in order to have a clear vision of the antioxidant potential of flavonoids in the human diet. The study of the effects of process and formulation leads to the establishment of flavonoid degradation kinetics. Thus, modelling these kinetics is relevant to predict the influence of processing on the food product quality, particularly nutrients losses. Modelling of degradation kinetics includes calculating the reaction order, the rate constant and activation energy, which are essential data to minimize undesired changes and optimize process design and food formulation.

Flavonoids are categorized into seven classes (flavanols, flavanones, flavones, flavonols, isoflavonoids, anthocyanins, and flavans) (Peterson and Dwyer, 1998). Only the effect of processes and formulation on anthocyanins has been recently reviewed (Patras et al., 2010). Thus, the first aim of this review is to summarize recent findings about the effects of different processes (thermal, mechanical and domestic reheating), food matrix and storage conditions on the degradation of flavonol and anthocyanin. The second objective is to summarise models developed to describe the effect of heat treatment on flavonoids.

2. Effect of processes

Processes used in food engineering are numerous. They can be studied individually or as a manufacturing process. Some authors dealt with the manufacturing of food products such as raspberry jam (Zafrilla et al., 2001), blackberry juice (Gancel et al., 2010) and cocoa cake (Stahl et al., 2009). In the case of the strawberry jam and cocoa cake, no flavonoid degradation is observed, whereas losses of about 23% of flavonoids were reported in the blackberry juice. Others studies dealt with unit operations -either thermal such as pasteurization, baking, cooling, freezing, or mechanical such as peeling or mixing. Moreover, the effects of some domestic processes by means preparation of the convenience foods at consumers home are also investigated.

2.1. Thermal processes

Thermal processes have a large influence in flavonoid availability in foods which depends on their magnitude and duration. Different heating methods (drying, microwaving, heating by an autoclave, roasting, water immersion, pasteurization, pressured-steam heating, blanching) were used and their effects were analyzed (Table 1). These treatments were applied on both flavonoid-rich foods and on flavonoid solutions as food models.

For flavonoid- rich foods, the effect of heat treatment was quantified either by evaluating the evolution of the total flavonoid concentration or by the determination of the behaviour of each individual flavonoid.

As shown in Table 1, most of heat processes lead to a degradation of flavonoids. A loss of about 22% in total flavonoids has been observed in water cooked products at a temperature of 50 °C during 90 s (Viña and Chaves, 2008). For the roasting process at 120 °C, 20 min provokes a decrease of 12% of total flavonoid content (Zhang et al., 2010) and 15.9% for 160 °C, 30 min (Zielinski et al., 2009). Steam heating at 0.2 MPa during 40 min induces a decrease of 25% in flavonoid content (Huang et al., 2006; Zhang et al., 2010). Similar findings were reported with microwaving at 700 W during 10 min (Zhang et al., 2010) and autoclaving at 100 °C, 15 min (Choi et al., 2006). However, one blanching per immersion in water at 100 °C during 4 min does not deteriorate flavonoids (Viña et al., 2007). Drying processes lead also to flavonoids degradation. The proportion lost depends on the drying method. Freeze-drying is the less aggressive method whereas hot air drying leads to major losses. As intermediate solutions microwave and vacuum drying can be used (Dong et al., 2011; Viña and Chaves, 2008; Zainol et al., 2009; Zhang et al., 2009).

Individual flavonoids are also subject to heat degradation. The identification and quantification of flavonoid degradation were performed with high performance liquid chromatography. Rutin in buckwheat groats is reported to be more stable to heat then vitexin, isovitexin, homoorientin and orientin during roasting at 160 °C for 30 min (Zielinski et al., 2009). However, an increase of the dehulling time (10–130 min) leads to greater losses of rutin in the same product grains (Dietrych-Szostak and Oleszek, 1999). Boiling including soaking (100 °C/121 °C) with/or without draining stages induces 1–90% losses of quercetin and kaempferol in Brazilian beans (Ranilla et al., 2009). Thermal pasteurization treatment (90 °C, 60 s) for strawberry juices has no effect on quercetin and kaempferol contents (Odriozola-Serrano et al., 2008), whereas it reduces naringin, narirutin, quercetin, naringenin content for grapefruit juices (Igual et al., 2011) and procyanidins in canned peach (Asami et al., 2003). For Fuleki and Ricardo-Da-Silva (2003), pasteurization of grape juice increased the concentration of catechins in cold-pressed juices, but it decreased concentrations in hot-pressed juices. The concentration of most procyanidins was also increased by pasteurization.

However, the above results may not be comparable, because on the one hand, the food matrix is different from one assay to another and on the other hand, the food matrix can act as a barrier to heat effect or induce the degradation. It is not easy then to dissociate the thermal processing effect from the food matrix effects. When innovative processes are used instead of thermal treatments, the importance of food matrix is lower because the flavonoid degradations are limited. Indeed, several studies showed the capacity of innovative processes (microwave, infra-red, high-pressure processing) to enhance the flavonoid extraction (Périno-Issartier et al., 2010; Shao et al., 2011; Srinivas et al., 2011; Xi and Shouqin, 2007; Zill et al., 2011). Odriozola-Serrano et al. (2008) studied the effect of high-intensity pulsed electric fields (HIPEF) process on quercetin and kaempferol contents of strawberry juices and reported that such a process caused no damage on these compounds.

For model solutions, few studies have examined the effect of thermal processing on flavonoid behaviour. The data indicated that flavonoids in aqueous solutions show different sensitivity to heat treatment depending on their structures. However, whatever their structure a significant degradation is observed for temperature above 100 °C. For rutin, a higher stability compared to its aglycon form (quercetin) is observed (Buchner et al., 2006; Friedman, 1997; Makris and Rossiter, 2000; Takahama, 1986). These findings are attributed to the prevention of carbanion formation because of the glycosylation of the 3-hydroxyl group in the C-ring (Buchner et al., 2006; Friedman, 1997; Takahama, 1986). Authors reported also that luteolin was more stable to heat than rutin and luteolin-7-glucoside when heated at 180 °C for 180 min (Murakami et al., 2004).