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Review

Review of the effects of different processing technologies on cooked and convenience rice quality

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ABSTRACT

Background: Commercially available convenience rice such as retorted, quick cooking or frozen rice suffers from sensory deficiencies compared to home cooked rice. The mechanisms causing deterioration in texture and flavour during convenience rice processing are, in many cases, poorly understood.
Scope and approach: This review describes pre-cooking methods including washing and soaking, cooking methods including cooking in excess water, by absorption and by high pressure, and post-cooking technologies including cooling, freezing, retorting, canning, drying and storage, as well as the influence of each process on physical properties and sensory attributes of cooked rice.
Key findings and conclusions: Water diffusion and starch leaching, which occur in many processing steps, are important factors affecting cooked rice quality. Soaking saves energy by reducing cooking time. Cooking by absorption increases stickiness, but does not ensure uniform moisture distribution compared to cooking in excess water, thus is not applicable for rice manufacturers. Amylose leaching during soaking and cooking affects hardness and stickiness of cooked rice significantly. Non-thermal treatments such as high pressure soaking and cooking have potential to improve rice sensory properties compared to high temperature treatments, which change colour and flavour of convenience rice. Drying and freezing results in a porous structure resulting in spongy texture after rehydration and thawing, respectively. During storage, starch retrogradation deteriorates texture, but can be retarded by high pressure processing or storage below the glass transition temperature. Much is known about processing factors that affect freshly cooked rice, but more substantial knowledge of how processing steps affect the structure property relationships and sensory properties of convenience rice will assist manufacturers to specifically design products to meet the ever growing consumer demands for convenience food.

1. Introduction

Rice is cooked in a variety of ways in the home with the method used usually relating to the cultural background of the consumer. Some cultures soak rice before cooking while others cook rice directly by boiling it in excess water or by cooking it with an absorption method (Crowhurst & Creed, 2001; Son et al., 2013; Tian et al., 2014; Tsugita, Ohta, & Kato, 1983). Other methods involve steaming (Metcalf & Lund, 1985) or cooking in a pressure cooker (Leelayuthsoontorn & Thipayarat, 2006; Son et al., 2013). Rice can also be cooked in a microwave or under very high pressure (Boluda-Aguilar, Taboada-Rodríguez, López-Gómez, Marín-Iniesta, & Barbosa-Cánovas, 2013).

Rice is a staple food in many countries and is relatively easy to cook because it simply requires water and heat, especially with an automatic rice cooker, but the standard home cooking processes usually take in excess of 15 min. Manufacturers provide consumers with a pre-processed alternative for convenience, and which is favourable for those occasions where only single portions are required (Gofton & Ness, 1991). Convenience food saves the consumer time and energy use in acquisition, consumption and disposal in the process of food consumption (Brown & McEnally, 1992). Convenient rice dishes that include meat and vegetables provide a very attractive option as a 'ready meal', and the market for these is expanding rapidly, underpinned by microwave cooking

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and new packaging technologies. The Asian market for convenience rice was established 20 years ago and has grown exponentially (Byun et al., 2010). Globally, the convenience meals market is expected to grow by 3.2% from $ 1.1 trillion in 2011 to $ 1.3 trillion in 2016 and much of this growth is predicted to occur in China (Schmidt Rivera, Espinoza Orias, & Azapagic, 2014).

Several studies have been performed on determining the effect of processing variables on the sensory quality and morphology of the cooked rice. This includes studies that showed how the shape and volume of rice was affected by the presence and absence of a soaking stage prior to cooking, and variations in cooking time (Bhattacharya, 2011; Mohapatra & Bal, 2006; Sabularse, Liuzzo, Rao, & Grodner, 1991) as well as studies that focused on how sensory quality is affected by temperature, cooking time and water-to-rice ratio (W/R) (Bett-Garber, Champagne, Ingram, & McClung, 2007; Leelayuthsoontorn & Thipayarat, 2006; Srisawas & Jindal, 2007). In comparison, relatively little is published on the effect of process variables on the sensory quality of convenience rice. Recent advances have focused on extending the shelf life of convenience rice via additional post-cooking processing steps such as high temperature, high pressure, freezing or drying that seek to destroy bacteria and their spores and/or prevent spore germination and bacterial growth. These additional processes alter both the flavour and overall quality aspects of the convenience rice and result in a product considered to be inferior to freshly cooked rice (Kwak et al., 2013). If the cooked rice is eaten without any sauce or seasoning the unacceptable change in aroma is perceived more strongly (Tsugita, 1985). As consumers judge food quality mainly in terms of its sensory and nutritional characteristics (Steptoe, Pollard, & Wardle, 1995), the food industry faces the challenge of developing new technologies to produce shelf-stable convenience rice that tastes homemade despite the many processing steps. To unlock potentially large international markets for convenience rice products and meals, it is imperative to understand how cooked rice quality is influenced by each processing step before, during and after cooking, and how the mechanical, structural and sensory properties are affected. This knowledge will assist food manufacturers to design high quality, shelf-stable, convenience rice. Therefore, the most commonly used pre-cooking, cooking and post-cooking processing technologies applied to freshly cooked and convenience rice and their effect on eating quality will be discussed in this review.

2. Processing technology and influences on cooked and convenience rice quality

This section reviews processing technologies for home cooking and large scale production of cooked rice that includes pre-cooking, cooking and post-cooking stages, and reviews how these influence the rice physical properties and sensory attributes. The pre-cooking stage includes washing and soaking of rice; various cooking methods include cooking in excess water, using limited water absorption and by utilising high pressure; and the post-cooking stage includes treatments such as retorting, canning, cooling, freezing, drying and storage of cooked rice. A block flow diagram highlighting each stage with the various methods utilised is given in Fig. 1, whereby different combinations are possible to produce freshly cooked and convenience rice with certain properties. Table 1 provides a summary of the main processes used within each stage and highlights their most important impact on cooked rice quality.

2.1. Pre-cooking

2.1.1. Washing

Washing raw rice with water before cooking is common to remove milling dust and any remaining hull or bran with washing repetitions varying from 2 to 5, depending on the rice variety and the cooking method used (Champagne, Bett-Garber, Fitzgerald, Grimm, Lea, Ohtsubo, Jongdee, Xie, Bassinello, Resurreccion, Ahmad, Habibi, & Reinke, 2010). Rice varieties such as Basmati with a high amylose content from Pakistan, India or Iran are washed 3 to 5 times before they are cooked in excess water, whereas rice with a medium amylose content from Thailand, China, Philippines, Japan or Australia are washed 2 to 3 times and cooked in a rice cooker with the absorption method (Champagne et al., 2010). This study however does not state why these number of repetitions were chosen. Rice washed three times has been shown to cause less deterioration in flavour and colour after the cooked rice was stored for up to 24 h than rice washed only once (Fukai & Tukada, 2006). This is because around 60–80% of total surface lipids were removed by one washing step for 5 or 10 min, with a reduction of free fatty acid and conjugated dienes relative to unwashed control samples (Monsoor & Proctor, 2002). The decomposition of lipids on the surface of rice from residual rice bran, which is hydrolysed to free fatty acids via lipase and subsequently oxidised, produces a rancid and stale flavour (Takano, Kamoi, & Obara, 1989). Therefore washing may be a practical means to reduce free fatty acids and off-flavour development in cooked milled rice from lipid oxidation (Monsoor & Proctor, 2002). The washing procedure will also remove free starch produced by the milling process which may alter rice texture by changing grain-grain and grain-surface adhesion in a similar way to starch/amylose leaching, though this hypothesis requires greater investigation.

2.1.2. Soaking before cooking

Soaking rice in excess water before cooking is a traditional practice in Japan, Korea, and other Asian countries, and is a factor affecting cooking quality, with the soaking typically done below gelatinisation temperature of rice starch, at different pressure levels, and with soaking times varying between 15 and 120 min (Champagne, 2008; Champagne et al., 2010; Horigane, Takahashi, Maruyama, Ohtsubo, & Yoshida, 2006; Tian et al., 2014; Yamakura, Okadome, Suzuki, Tran, Homma, Sasagawa, Yamazaki, & Ohtsubo, 2005). Soaking rice under various conditions is also a common pre-treatment for several convenience rice products such as frozen rice or quick cooking rice, as it distributes water evenly within the grain, leading to a reduction in cooking time and energy consumption (Chakkaravarthi, Lakshmi, Subramanian, & Hegde, 2008; Das et al., 2006).

Water diffuses into rice grains due to the moisture gradient between the surface and the centre of the grain, and diffuses more rapidly into milled grains through cracks and chalky areas before diffusing to the outer layer (Horigane et al., 2006). The moisture content reaches a plateau after 30–60 min (Boluda-Aguilar et al., 2013; Das et al., 2006) and a positive correlation between temperature and the rate of water diffusivity has been shown (Bello, Tolaba, & Suarez, 2004; Chakkaravarthi et al., 2008; Muramatsu, Tagawa, Sakaguchi, & Kasai, 2006; Suzuki, Kubota, Omichi, & Hosaka, 1976). Starch granules swell and expand during soaking, which has been found to cause more complete starch gelatinisation after cooking compared to unsoaked rice. The initial moisture content of the raw rice influences the hydration homogeneity, degree of gelatinisation, percentage of broken kernels and degree of starch leaching (Genkawa, Tanaka, Hamanaka, & Uchino, 2011; Han & Lim, 2009; Prasert & Suwannaporn, 2009; Seki & Kainuma, 1982).

A soaking temperature of 15 °C, compared to 35 °C, leads to more cracks in the outer layer of the rice grain (Genkawa et al., 2011) and consequently, the grain is expected to break more easily during cooking. Lower soaking temperature decreases the rate of water diffusion, producing a difference in the specific