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Comparison of free/bi-axial, fixed axial, end-over-end and static thermal processing effects on process lethality and quality changes in canned potatoes

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A B S T R A C T

Thermal processing as the most prevalent food preservation technique has been extensively studied and used for years. Different modes of agitation that can be employed in the canning process are characterized by relatively different, heat impacts and their associated quality changes. Hence, the main objective of this study was to evaluate the impact of different retort conditions on lethality (F_o), color and textural changes in potato cubes. Process variables employed were: retort temperature: 115, 120, 125 °C; agitation orientations: vertical (end-over-end) and horizontal (fixed and bi-axial); agitation speed: 0 (static), 10, 20 rpm. A water immersion single basket rotary retort was retrofitted to simultaneously accommodate agitating modes of rotation. Accumulated process lethality values were calculated for each experimental run. Color quality in terms of parameters such as, yellowness (b-value), total color difference (ΔE values) and textural quality in terms of hardness values were compared for the particles processed under each condition. All process variables had a significant *($p < 0.05$)* influence on F_o, color and texture parameters of potato particles. The quality changes were found to correlate well with the accumulated F_o values achieved during processing. As can be expected, the quality loss increased with an increase in F_o and vice versa.

1. Introduction

Thermal treatments imparted during the canning of vegetables have to meet the criterion of commercial sterility. The desired lethal effect can be provided over the wide range of temperature–time combinations; however, the heat process also results in physical, chemical and various organoleptic quality degradations which depend on the process severity. Rapid heating processes have been generally credited with lower damage to product quality. Rapid and uniform heating contributes to achieving the target lethality in shorter time which consequently results in lesser degradation of texture, color and nutrients in foods. Moreover, rapid heating techniques also contribute to improving process efficiency and/or outputs and reduced energy consumption (Dwivedi & Ramaswamy, 2010).

Texture softening which occurs during thermal processing of foods (such as chick peas, beans etc.) may be a useful cooking attribute because it softens the food tissues and makes the food consumable and to reduce the cooking time at the consumer level as well. However, for most canned vegetables, the product texture is often too soft; hence it is desirable to reduce the degree of cooking during processing to better preserve the product texture. While process is established based on lethality values, its effect on quality is generally measured using a “Cook Value”. The cook value (C_o) represents equivalent minutes of cooking at 100 °C. The equivalent minutes are accumulated through integration of time temperature data, the same as process lethality, but a reference temperature of 100 °C and z value of 30 °C are used instead of 121.1 °C and a z value of 10 °C for process lethality (Abbatemarco & Ramaswamy, 1994). The z value of 30 °C used for cook value generally represents that of quality factors. The cook value gives a relative measure of the degree of cooking associated with the different processes. Hence, in process optimization studies, the objective is set to minimize the C_o values in addition to satisfying the commercial sterility restrictions.

Few studies have also demonstrated positive influence of thermal treatments on nutritional attributes of few vegetables as well.

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Roy, Takenaka, and Isobe (2007) reported an increase in antioxidant activity due to thermal processing of selected vegetables. Dewanto, Wu, Adom, and Liu (2002) found that, thermal processing enhances the nutritional value of tomatoes by increasing lycopene content and hence, the antioxidant activity as well. The food processing industry therefore aims at achieving a balance between the conducive and harmful effects of the thermal processing (Balsa-Canto, Banga, & Alonso, 2002). Hence, for designing an optimal thermal process, different temperature–time combinations which deliver the target microbial lethality are screened to minimize the thermal damage on color, texture and nutritional attributes.

Visual appearance of the food is the first thing that influences buying behavior of customers. Color changes during thermal processing of vegetables have been studied by many researchers: peas (Garrote, Silva, Roa, & Bertone, 2008; Rao, Lee, Katz, & Cooley, 1981; Shin & Bhowmik, 1995; Smout, Banadda, Van Loey, & Hendrickx, 2003); green vegetables (Gnanasekharan, Shewfelt, & Chinnan, 1992); potato, carrot and beans (Abbatemarco & Ramaswamy, 1994; Nourian & Ramaswamy, 2003a, 2003b); red and green chilli purees (Ahmed, Shivhare, & Debnath, 2002; Ahmed, Shivhare, & Ramaswamy, 2002). These studies have concluded that there is aggravation in color quality of vegetables due to thermal processing; hence, it is imperative to evaluate the color changes incurring during thermal processing. The texture of vegetables is mainly due to the properties of pectic substances that provide adhesion and keep the cells together (Loh & Breene, 1982). During thermal processing, pectic substances undergo chemical changes which result in dispersal of the plant cells, thereby causing softening of vegetable tissues (Huang & Bourne, 1983). Thermal softening of potato tissues have been studied by several researchers (Alvarez & Canet, 2002; Lebovka, Praporscic, & Vorobiev, 2004; Solomon & Jindal, 2003). Moyano, Troncoso, and Pedreschi (2007) have also studied the textural changes in potato products as influenced by different types of thermal treatments. The two mechanisms that are responsible for the softening of potato tissue are: due to changes in pectic substances in cell wall in the inter-lamellar region and due to gelatinization of potato starch (Alvarez, Canet, & Tortosa, 2001).

Most of the quality studies in vegetables have been performed during thermal processing in either static retorts (Alvarez & Canet, 2002; Huang & Bourne, 1983; Rao et al., 1981; Shin & Bhowmik, 1995) or in end-over-end rotary retorts (Abbatemarco & Ramaswamy, 1994; Garrote et al., 2008; Jobe, 2003). No literature on the quality evaluation studies has been reported with thermal processing under bi-axial or free axial mode of agitation. Hence, the objective of this study was to evaluate the quality changes taking place in potato particles suspended in non-Newtonian fluid and subjected to different thermal processing conditions (rotation mode, rotation speed and process temperature). Non-Newtonian fluid was chosen as the can liquid because of its viscosity property which allows similar heating behavior like that of canned soups which contain suspended food particles.

2. Materials and methods

Potatoes (*Solanum tuberosum*) of Goldrush variety were obtained from a local market and stored under refrigerated conditions (4 °C) until use (about one week). Refrigerated potatoes were peeled, cut manually with sharp knife into cubes of sizes 1.6 cm^3 and kept dipped in cold water (∼10 °C) so as to reduce the browning until filling.

2.1. Liquid and particulate system

For thermal processing, the prepared potato cubes were blanched in boiling water for 1 min, cooled and filled in to 307×409 sized cans. Aqueous solution of carboxy methyl cellulose (1 g/100 mL) was used as the covering liquid. The headspace was fixed at 10 mm and filling density was kept 23 g potato cubes per 100 mL

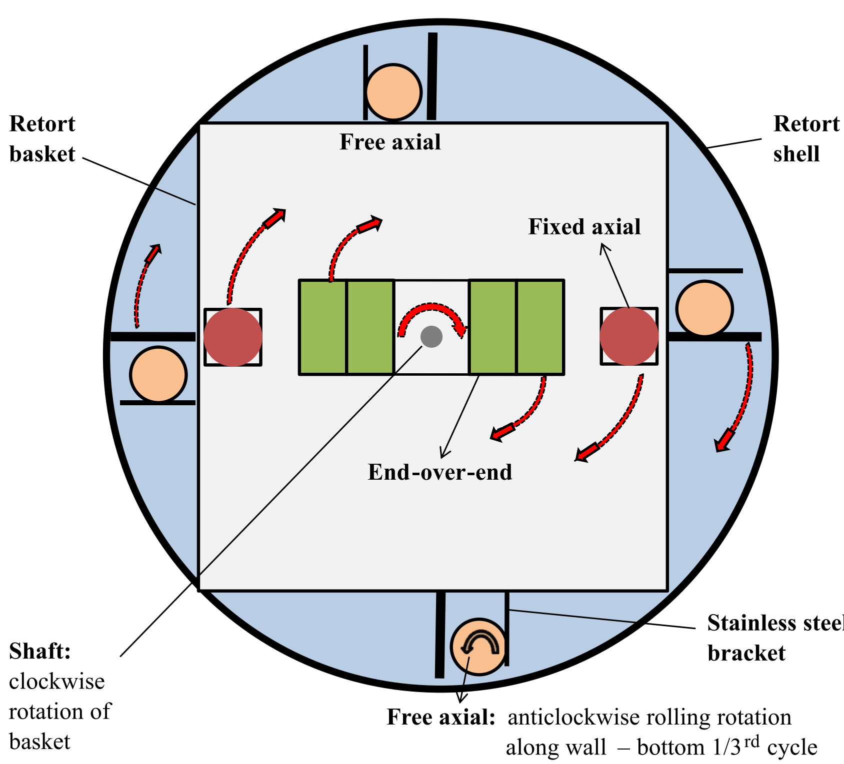

Fig. 1. Schematic of retort rack showing the different modes of rotation.