LWT - Food Science and Technology 59 (2014) 504–509

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Iron enrichment of whole potato tuber by vacuum impregnation

Erihemu [a], K. Hironaka [a,*], Y. Oda [b], H. Koaze [b]

[a] University of the Ryukyus, Okinawa 903-0213, Japan
[b] Obihiro University of Agriculture and Veterinary Medicine, Obihiro 080-8555, Japan

ARTICLE INFO

Article history:
Received 23 May 2012
Received in revised form
28 March 2014
Accepted 24 April 2014
Available online 4 May 2014

Keywords:
Whole potatoes
Vacuum impregnation
Iron enrichment
Steam-cooking
Storage

ABSTRACT

The effect of vacuum time, restoration time, steam-cooking and storage at 4 °C on the iron content of vacuum-impregnated (VI) whole potato was evaluated. Whole potato tubers were immersed in a 0.4 g/100 g iron (ferric pyrophosphate) solution. Vacuum pressure of 1000 Pa was applied for 0–120 min, and atmospheric pressure restoration for 0–4 h. The result indicated that the iron content of VI potatoes increased with vacuum and restoration time; 1 h vacuum-treatment potatoes provided 6.4 times higher iron content compared to raw potatoes, and 3 h restoration time supplied 6.4 times higher iron content (>4.1 mg/100 g fr.wt.) compared to raw potatoes. Moreover, VI-cooked unpeeled or peeled potatoes had 6 times higher iron content than un-VI-cooked unpeeled or peeled potatoes. European daily potato consumption (260 g) of the VI-cooked unpeeled and peeled potatoes provided adult men with 93–104% and 67–90% of the recommended daily allowance (RDA) of iron, respectively. Also, the daily potato consumption of the unpeeled and peeled potatoes could supply adult women with 43–48% and 31–41% of the RDA, respectively. This study indicated that VI treatment of whole potato was useful for enriching the iron content.

1. Introduction

Health benefits are one of the specific issues that will greatly influence the food industry in the coming years (Mazza, 1998). Food industry companies have rather high expectations for food products that meet consumer demands for a healthy lifestyle (Menrad et al., 2000). Functional foods move beyond necessity to provide additional health benefits that may reduce disease risk and/or promote optimal health. They include conventional foods, modified foods, medical foods and foods for special dietary needs (ADA, 2009). Experts like Sloan (2000, 2002) have reckoned the global functional food market to be 47.6 billion US$; the United States is the largest market segment, followed by Europe and Japan. Moreover, in many countries around the world, functional foods represent an important growth category for the commercial sector (Sibbel, 2007). Functional foods are associated with various benefits, and involve vitamin and mineral fortification, cholesterol reduction, antioxidants, phytochemicals, dietary fibre, herbs and botanicals, and probiotics, prebiotics and symbiotics (Alzamora et al., 2000).

The recent publications by FAO (2004) have shown the importance of the potato (*Solanum tuberosum*, L.) as a global food crop, ranking fourth among other crops with an overall annual production of nearly 327 million tons and about 19 million ha planted. The potato is a versatile, carbohydrate-rich food highly popular worldwide and prepared and served in a variety of ways. Freshly harvested, it contains about 80 percent water and 20 percent dry matter. About 60-80 percent of the dry matter is starch (Burlingame, Mouillé, & Charrondiére, 2009). Moreover, potato tubers are rich in several nutrients of minerals (FAO, 2008).

Iron is required for haemoglobin production in the cell precursors, and thus insufficient iron delivery to the red cell precursors results in impaired erythropoiesis and an iron-deficient anaemia (Domanski et al., 2011). Iron is not actively excreted from the body in urine or in the intestines. Iron is only lost with cells from the skin and interior surfaces of the body-intestines, urinary tract, and airways. The total amount lost is estimated at 14 μg/kg body weight/day (Green, Charlton, Settle, & Bothwell, 1968). Iron deficiency (ID) is the most widely distributed nutrient deficiency state, affecting some 2 billion people worldwide (DeMaeyer & Adiels-Tegman, 1985) and impairing the function of iron-dependent enzymes and proteins (Beard & Dawson, 1997). USDA (2000) reports that 62% of women aged 20 and older are ID. FAO/WHO indicated that the recommended daily allowance (RDA) of iron for adult men and women amounted to 9.1 and 19.6 mg/day, respectively (Schümann, Ettle, Szegner, Elsenhans, & Solomons, 2007).

Vacuum impregnation (VI) is the application of low pressure to a solid–liquid system, followed by the restoration of atmospheric

* Corresponding author. Tel./fax: +81 98 895 8768.
E-mail address: kazuhiro@agr.u-ryukyu.ac.jp (K. Hironaka).

http://dx.doi.org/10.1016/j.lwt.2014.04.043
0023-6438/

pressure (Fito, 1994; Fito & Chiralt, 1997). Different applications of food VI have been developed recently in numerous studies (Chiralt et al., 1999; Fito & Chiralt, 2000; Fito, Chiralt, Barat, & Martínez-Monzó, 2000; Gras, Vidal-Brotóns, Betoret, Chiralt, & Fito, 2002). These studies have validated the model which describes the coupling of the hydrodynamic mechanism (HDM) and the deformation-relaxation phenomena (DRP) of the viscoelastic product (Fito, Andrés, Chiralt, & Pardo, 1996) when they are immersed in an external liquid phase and submitted to pressure changes. These studies are mainly devoted to fruit product development (Fito et al., 2000; Fito & Chiralt, 2000; Tapia, López-Malo, Consuegra, Corte, & Welti-Chanes, 1999) through osmotic treatments, and to improve salting processes of cheese (Chiralt & Fito, 1997; González, Fuentes, Andrés, Chiralt, & Fito, 1999), meat and fish (Chiralt et al., 2001).

Gras et al. (2002) studied the response of several sliced vegetables (beetroot, carrot, eggplant, zucchini, mushroom and oyster mushroom) to vacuum impregnation treatments, in terms of sample volume deformation and impregnation levels. They evaluated changes in the microstructure of different vegetables by cryo-scanning electron microscopy observation, and found that VI could be used to fill intercellular air spaces (ICAS) in the vegetable matrix. VI of porous food matrices with adequate solutions/suspensions of physiologically active compounds (PAC) has been claimed as a useful way to obtain this kind of product, without destroying the initial food matrix, but only occupying its initial porous fraction with a liquid phase (Fito et al., 2001). Derossi, De Pilli, and Severini (2010) found that the VI on slices of peppers (15 cm in length and 1 cm in width) with lactic acid solution increased the acidification degree to a greater extent than processing carried out under atmospheric pressure. Results proved that the vacuum impregnation process is a useful technique to improve acidification treatments of vegetables.

Concerning VI of potato, only one report was found regarding enrichment of ascorbic acid content of whole potatoes (Hironaka et al., 2011). However, no studies exist on vacuum impregnation of iron for whole potatoes.

In this paper, we first evaluated the effect of vacuum time and restoration time on the iron content of VI potato tubers. Moreover, the effects of steam-cooking and storage at 4 °C on iron content of VI potato tubers were also evaluated.

2. Materials and methods

2.1. Materials

Two cultivars of processing potatoes were used: Toyoshiro and Snowden. They were harvested in September, late in 2010. After harvesting, tubers approximately 150–200 g in size were selected, then washed with tap water to remove the attached soil. Tubers were then dried with tissue papers, and provided for the VI treatment.

Ferric pyrophosphate and hydrochloric acid were purchased from Kanto chemical Co., Inc. (Tokyo, Japan).

2.2. VI treatment of potatoes

Ferric pyrophosphate was used for iron fortification in this study; it can be used as a food additive to prevent iron deficiency in humans without colour and palatability changes (Hurrell, 2002; IMNA, 2004; Navas-Carretero, Pérez-Granados, Sarriá, & Vaquero, 2009; Zimmermann & Hurrell, 2007). However, this salt is hardly soluble in water (Navas-Carretero et al., 2009), and a maximum concentration of 0.4 g/100 g (Kishi, 1972) was used in this study. The mass ratio of the solution to the potato of 3% W/W was used to ensure adequate immersion and minimize the dilution effect (leaching of intercellular sap) on the concentration of VI solution (Sormani, Maffi, Bertolo, & Torreggiani, 1999). A whole potato tuber was placed into a 5 L beaker containing the ferric pyrophosphate solution in a 30 L vacuum chamber (VO-32D, Advantec, Tokyo, Japan). A vacuum meter (PM-12, Shimadzu Corporation, Kyoto, Japan) was used to measure pressure and placed between the vacuum pump (GDH-362, Shimadzu Corporation, Kyoto, Japan) and vacuum chamber (Fig. 1).

The experimental designs of VI treatment for vacuum time and restoration time experiments were expressed in Tables 1 and 2, respectively. In Table 1, a vacuum pressure of 1000 Pa was applied to the system for 0, 15, 30, 60 and 120 min (t_1). After the vacuum period, the atmospheric pressure was restored, and the potato tuber was maintained in the iron solution for a restoration time (t_2) of 3 h. In Table 2, a vacuum pressure of 1000 Pa was applied for 1 h (t_1), and afterwards the atmospheric pressure was restored and the system remained at this pressure condition for 0, 1, 2, 3 and 4 h (t_2).

VI-treated whole potatoes were drained, rinsed with ion-exchange water to remove the attached solution, and gently wiped with tissue papers. Iron contents of VI-treated samples, and non-VI (NV) treated sample (control; immersion in the iron solution without vacuum treatment) potatoes were analysed immediately.

2.3. Cooking

Cooking experiments were done to investigate the effect of steam-cooking on iron content of VI potatoes. The VI potatoes were divided into two sections: (1) unpeeled, and (2) peeled. Peeled potatoes were obtained by peeling to a depth of 0.5 mm using a hand peeler (Mondy, Munshi, & Seetharaman, 1992). Unpeeled or peeled whole potatoes were placed in a stainless steam cooker, which was covered with a lid and steamed over boiling water at atmospheric pressure until easily penetrated with a fork (25 min) (Faller & Fialho, 2009; Weaver, Timm, & Ng, 1983).

2.4. Storage

The storage experiment was done to study the effect of storage at 4 °C on iron content of VI potatoes. Potatoes for domestic consumption are stored at 5 °C in order to avoid serious sprout growth (Burton, van Es, & Hartmans, 1991). The VI treatment potatoes were stored at 4 °C and 90% relative humidity for up to 30 days. The iron contents of the samples were measured at 5, 10, 20 and 30 days.

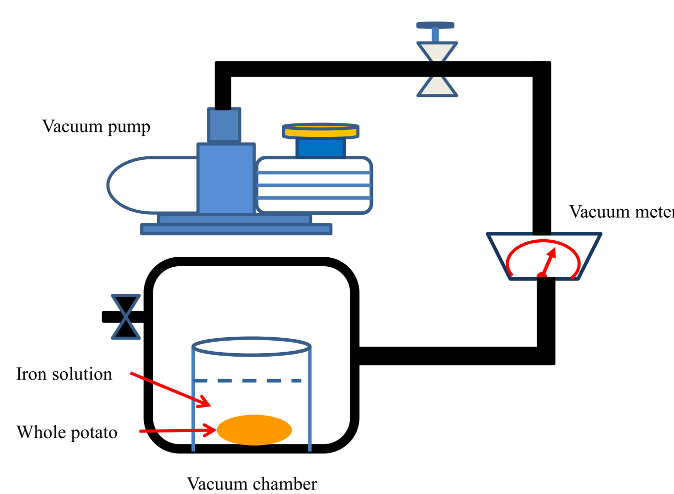

Fig. 1. Schematic representation of the vacuum impregnation system.