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Effect of iron and ascorbic acid addition on dry infusion process and final color of pumpkin tissue

C. Genevois [a,b], S. Flores [a,b], M. de Escalada Pla [a,b,*]

[a] Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires (UBA), Ciudad Universitaria, 1428 CABA, Argentina
[b] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

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A B S T R A C T

In the present study, pumpkin (*Cucurbita moschata* Duchesne ex Poiret) was used as raw material to produce sweet food fortified with iron (Fe) and ascorbic acid (AA). A dry infusion process with a subsequent air drying was applied. Response surface methodology was performed in order to analyze the effect of Fe and AA incorporation into the formulation on: water loss (WL) and solid gain (SG) during the dry infusion process, color changes (ΔE) and the dehydration percentage during subsequent air drying process. The results showed that the presence of Fe and/or AA promoted SG and WL during the dry infusion and also, weight changes during the air drying process (PP). An increase of the color changes was also observed. In turn, it was possible to obtain predictive equations for the parameters studied. The application of edible coating based on tapioca starch on pumpkin product was also tested showing a protective effect from the pumpkin color view point.

1. Introduction

The micronutrient malnutrition (MM) is widespread over the world, but developing regions are the most affected. From a public health point of view, MM is a concern not only for the large number of people affected, but also because it remains a risk factor for many diseases (Ashwell, 2004). Iron (Fe) deficiency is considered the most prevalent of the MM, showing a continuous increase in its prevalence, representing the main nutritional deficiency problem in terms of magnitude and spatial distribution (Allen, Benoist, Dary, & Hurrell, 2006; Souto de Olivera, 2009). At present, it is estimated that 2 billion people, or over 30% of the world population, are anemic, mainly due to Fe deficiency and this situation is further magnified in low-income areas with a high incidence of infectious diseases that contribute to the high prevalence of anemia according to World Health Organization (WHO, 2013). Both Fe deficiency and anemia, even in its moderate form, have serious health consequences for the population, including stunted growth and cognitive development (WHO, 2013; Zimmermann & Hurrell, 2007).

By the moment, food fortification with Fe is considered the strategy most sustainable and cost-effective against iron deficiency (Laxmi Narayan, Mills, & Berman, 2006; Tripathi & Platel, 2013). Nevertheless, there are some technological difficulties to be solved like changes and unpleasant sensory characteristics of the food matrix due to this fortification. The Fe compounds that are very soluble in water, for example ferrous sulfate, provide Fe of high bioavailability and, therefore, would be the primary choice in food fortification. However, in this type of compounds, Fe is highly reactive, causing oxidation of fats, vitamins and several amino acids in the food that is fortified (Boccio & Monteiro, 2004; Gaucheron, 2000) and, consequently, undesirable color and flavor changes in the food matrix could appear. Rao and Kawamura (2008) reported that the major technological problems caused by soluble salts of Fe in the production of food and beverages are the color and flavor alterations.

At the same time, there are dietary compounds which positively affect the Fe absorption, as is the case of ascorbic acid (AA). The presence of this hydrosoluble vitamin at the intestinal level promotes absorption of non-heminic Fe by means of its reduction to ferrous ion (Fe^{+2}). In foods, the AA acts as a reducing agent keeping the Fe in its soluble reduced form (de Escalada Pla, Campos, & Gerchenson, 2009; Souto de Olivera, 2009), and also acts as an antioxidant through the free radicals neutralization at the cellular level (Rojas, 1995). Some studies have also shown that vitamin A

Abbreviations: Fe, Iron; AA, Ascorbic acid; WL, Water loss; SG, Solid gain; ΔE, Color changes; PP, Weight changes due to air drying process; MM, Micronutrient malnutrition; WHO, World Health Organization; CCD, Central composite design; rpm, Revolutions per minute; RDI, Recommended Daily Intake; RDA, Recommended Dietary Allowance; NEB, Non-enzymatic browning.

* Corresponding author. Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina. Tel.: +54 11 45 76 33 66.
E-mail address: marina@di.fcen.uba.ar (M. de Escalada Pla).

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and, even more the β-carotene, significantly increase the bioavailability of Fe (Binaghi, Greco, López, Ronayne, & Valencia, 2005).

The policy adopted by some countries was to select as a carrier, those foods widely consumed by the risk groups. Vegetable and fruit matrices have widely been used to support vitamins and minerals like Ca^{2+} and Zn^{2+}, applying impregnation or vacuum impregnation technology for their enrichment (Gras, Vidal, Betoret, Chiralt, & Fito, 2003). This processing has been proposed by Zhao and Xie (2004) as a pre-treatment before the final drying step with the purpose of achieving two goals: decreasing moisture content before final air drying to save energy and incorporating functional solutes, such as nutrients, antimicrobial, antioxidant, and anti-browning agents to improve product quality. The impregnation processes of fruits and vegetables with hypertonic solutions were widely studied and well reported (Gras et al., 2003; Moreno et al., 2012; Spiazzia & Mascheroni, 1997; Zhao & Xie, 2004). Dry infusion was recommended as a practical tool for small producers as fruit preservation process that could be performed in rural areas (Alzamora, Guerrero, Nieto, & Vidales, 2003).

Edible coatings can have an additive or synergistic effect with other stress factors in the task of improving the overall quality of foods. The application of coatings on fruits and vegetables improved color and flavor retention during storage, extending the shelf life of the product, retarding moisture and/or firmness loss and product senescence (Campos, Gerschenson, & Flores, 2011).

Pumpkin *Cucurbita moschata* is one of the most consumed vegetables in Argentina. Furthermore, an increasing interest in this vegetable has also been reported in other countries (Gwanama, Botha, & Labuschagne, 2008). Tissue from this kind of pumpkin was characterized previously (de Escalada Pla et al., 2005; de Escalada Pla, Delbon, Rojas, & Gerschenson, 2006; de Escalada Pla, Ponce, Stortz, Gerschenson, & Rojas, 2007). More recently, the adequacy of pumpkin mesocarp tissue as a food matrix for Fe supply was reported (de Escalada Pla et al., 2009). The iron was incorporated after blanching and during the cooling step. Then, a hypertonic osmotic covering solution was added to storage bags.

The aim of the present work was to study: 1) the possibility of fortifying *C. moschata* Duchesne ex Poiret tissues with iron through a process of dry infusion, thus avoiding the use of huge amounts of hypertonic osmotic solutions; 2) the effect of the joint presence of Fe and AA on process parameters, physical and quality characteristics in the final product; and 3) the application of an edible coating based on tapioca starch for protecting pumpkin tissue from possible color detriments due to Fe/AA contents during the process and food storage.

2. Material and methods

2.1. Chemicals

Food grade sucrose and tapioca starch were employed. The additives: $FeSO_4.7H_2O$ (Merck, Argentina); potassium sorbate (Sigma, USA); L-(+)-ascorbic acid (Merck, Argentina); citric acid and glycerol (Sintorgan, Argentina) and other chemicals used were of analytical grade.

2.2. Preparation of the pumpkin fortified with Fe and AA

Pumpkin (*C. moschata* Duchesne ex Poiret) obtained in a local supermarket was carefully washed and rinsed with distilled water. Then, cylinders of 15 mm diameter and 10 mm thickness were cut from the mesocarp using a stainless steel cork borer. The cylinders were blanched with water vapor for 8 min and then rapidly cooled for 1 min by immersion in water at 0 °C. Finally, they were impregnated with sucrose (900 g/kg of pumpkin), citric acid (1.5 g/kg of pumpkin) and potassium sorbate (1.9 g/kg) following a dry infusion process described by Alzamora et al. (2003). Briefly, pumpkin cylinders were placed in a plastic bowl and sprinkled with powdered sucrose. Water from vegetal tissue began to flow from the pumpkin cylinder to the surrounding sucrose concentrate. In that moment, citric acid, potassium sorbate, AA and Fe salt were added to the liquid solution and the orbital agitation started up. Citric acid was added in order to decrease pH values below 5; since sorbate and sorbic acid as an antimicrobial are more effective in this range of pH (Lindsay, 1996). In order to evaluate the effect of AA and Fe during the preparation process and on the final color quality, different amounts of AA and $FeSO_4.7H_2O$ were added to the systems according to a central composite design (CCD) of two factors (independent variables) and five levels (Table 1). Pumpkin used in all the systems came from a same single lot of raw product.

The dry infusion was carried out at 20 °C up to equilibrium on an orbital shaker (Vicking S.A., Argentina) at 35 revolutions per minute (rpm) to assure good contact of tissue and the impregnating system. Equilibrium was reached at 72 h when pumpkin cylinders and the surrounding solution achieved the same a_w and pH values. Once the dry infusion was concluded, the cylinders were drained through a stainless steel strainer and dried under forced air convection at 40 °C for 3 h, in order to achieve a water activity (a_w) value below 0.85 (Fontana, 2008).

Finally, the pumpkin cylinders were introduced into low density polyethylene bags of 80 μm thickness, provided with a Ziploc® type closure. Each bag was filled with 5 mesocarp pieces (10 g) and stored in a chamber at 18–20 °C.

2.3. Preparation of the pumpkin fortified and coated

From the results obtained with CCD (see Section 3.2), one formulation was chosen and one additional batch was performed. A dry infusion process, as previously described, was carried out and after draining, the cylinders were separated into two parts. One part was dipped into a solution of gelatinized starch in order to generate an edible coating on pumpkin cylinders, and the other part, pumpkin without coating was also prepared for comparing purposes in subsequent testing assays. Impregnated pumpkins with or without coating application were submitted to a drying process with force air convection at 40 °C for 3 h in order to achieve the following purposes: (1) to constitute the coating, in the case of coated cylinders and (2) to obtain an additional reduction of a_w in both cases (Fontana, 2008).

The edible coating was prepared with native tapioca starch (50 g/kg), glycerol (20 g/kg) as a plasticizer and potassium sorbate

Table 1
Treatments performed according central composite design for optimization of pumpkin fortification with iron (Fe) and ascorbic acid (AA). The control system (C) is also included.

System	Coded		Uncoded	
	Fe[a]	AA[a]	Fe[b]	AA[b]
1	1	1	0.288	15.2
2	1	−1	0.288	5.6
3	−1	1	0.144	15.2
4	−1	−1	0.144	5.6
5	0	0	0.216	10.4
6	0	−2	0.216	0.8
7	0	2	0.216	20
8	−2	0	0.072	10.4
9	2	0	0.360	10.4
10	0	0	0.216	10.4
11	0	0	0.216	10.4
C	NA	NA	NA	NA

NA: not added.
[a] Coded levels for Fe and AA.
[b] Real values for Fe and AA (g/kg pumpkin).