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Potential application of ultra-high pressure homogenization in the physico-chemical stabilization of tiger nuts' milk beverage

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ABSTRACT

The present study aimed to evaluate the effect of UHPH treatments (at 200 and 300 MPa and 40 °C of inlet temperature) on the physico-chemical characteristics of tiger nuts' milk beverages, in comparison with the raw beverage and the product treated by a conventional homogenization-pasteurization (18 + 4 MPa, 80 °C, 15 s) without stabilizers (H-P1) or with them (H-P2). The long term evaluation of samples showed that UHPH-treated beverages presented the highest colloidal stability, principally against creaming, due to the reduction in particle size and the new particle interactions, even if comparing with H-P2 beverage. Peroxidase activity showed the highest reduction after applying 300 MPa treatment, and regarding fat oxidation reactions, 200 MPa-treated beverage appeared to be the most stable. In this sense, the UHPH is presented as an emerging technology for obtaining tiger nuts' milk beverages free of additives with improved physico-chemical characteristics.

1. Introduction

Tiger nuts' milk beverages are complex dispersions that are obtained from the aqueous extract of tiger nuts (*Cyperus esculentus* L.) (Coşkuner, Ercan, Karababa, and Nazlican, 2002). Tiger nuts are little sweet tubers rich in starch and fat, the composition of which mainly depends on their geographical origin (Codina-Torrella, Guamis, and Trujillo, 2015a). Tiger nuts' milk beverages were traditionally produced in different Mediterranean countries, but nowadays, their consumption has been spread to all over the world (Tigernuts Traders, 2014). The nutritional profile of this product is characterized by the high content in carbohydrates (~12–17%), the amount of solids in suspension from the grinding of tubers, the moderate fat content (~2-2.5%) and the low percentage of protein (<1%). Their potential in the food market is limited by their microbial shelf-life but also by the physico-chemical reactions that occur during the storage, mainly when temperatures are >8 °C. Enzymatic activity, autoxidation of lipids and colloidal instabilities (by aggregation of particles, sedimentation of the heaviest bodies and creaming, among others) are some of the quality parameters that are involved in their loss of quality (Corrales, de Souza, Stahl, and Fernández, 2012; Selma, Valero, Fernández, and Salmerón, 2002). In order to extend the commercial shelf-life of these beverages, and facilitate their distribution, these beverages are subjected to conventional heat treatments. Regrettably, these processes compromise the quality characteristics of tiger nuts' milk beverages (loss of their sensory and nutritional properties, composition changes, etc.), which directly affects the consumer's acceptability (Corrales et al., 2012; Selma et al., 2002). Furthermore, the addition of stabilizers becomes indispensable to guarantee the physico-chemical stability of these beverages during their shelf-life.

To our knowledge, ultra-high pressure homogenization (UHPH) has demonstrated to be a promising technology for obtaining stabilized liquid foods (Cruz et al., 2007; Georget et al., 2014; Pereda, Ferragut, Quevedo, Guamis, and Trujillo, 2007; Poliseli-Scopel, Hérnández-Herrero, Guamis, and Ferragut, 2012; Toro-Funes, Bosch-Fusté, Veciana-Nogués, and Vidal-Carou, 2014).; Valencia-Flores, Hernández-Herrero, Guamis, and Ferragut, 2013). This technology is based on the same principle as the conventional homogenization, but it is capable of working at pressures up to 400 MPa. The physical phenomena that fluid suffers when it passes through the high-pressure valve gap and at the outlet, in combination with the sudden (<0.7 s) jump of temperature, involve microbiological, physico-chemical, sensorial and nutritional changes on product characteristics (Dumay et al., 2012). Since this moment, this technology has been widely studied in milk and dairy products (Amador-Espejo, Hernández-Herrero, Juan, and Trujillo, 2014; Hayes and Kelly, 2003; Pereda et al., 2007; Serra, Trujillo, Quevedo, Guamis, and Ferragut, 2007; Zamora, Ferragut, Jaramillo, Guamis,

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and Trujillo, 2007), but there is still few references in the bibliography about its application in vegetable beverages (Briviba, Gräf, Walz, Guamis, and Butz, 2016; Ferragut et al., 2014). Different authors have demonstrated that UHPH can be considered as an alternative treatment to the conventional heat pasteurization and/or sterilization in the obtaining hygienic soymilk and almond milk beverages, by inactivation of microorganisms (Cruz et al., 2007; Poliseli-Scopel et al., 2012; Valencia-Flores et al., 2013). These studies have also pointed that UHPH improves the colloidal stabilization of these beverages, through the particle size reduction and the induced changes on the functional properties of their proteins as emulsifiers. Regarding the chemical stability of UHPH-treated beverages, Poliseli-Scopel, Hernández-Herrero, Guamis, and Ferragut (2014) showed that UHPH treatment (300 MPa, 80 °C inlet temperature) caused stable levels of primary oxidation in soymilk, in comparison to conventional heat treatment of ultra high temperature (UHT) (142 °C for 6 s), which was attributed to the protective effect of proteins by covering oil droplet surface, and also to the existence of new interactions between proteins and fat droplets during the first days of storage, which may result in a less reactivity of these compounds. This new interactions might be attributed to the presence of unfolding and denatured proteins due to the UHPH treatment, which interact with other proteins and fat droplets in suspension (Thiebaud, Dumay, Picart, Guiraud, and Cheftel, 2003; Cruz et al., 2007). In this study, these authors also reported an important decrease of advanced levels of oxidation in UHPH-treated soymilk over time, in comparison to the heat-sterilized beverage. Besides of the physico-chemical and microbiological improvements observed in UHPH-treated vegetable beverages, these treatment may lead also to changes in the nutritional value. In line with this, Briviba et al. (2016) demonstrated that UHPH treatment at 350 MPa and 85 °C inlet temperature preserved B_1 and B_2 vitamins of almond milk and also decreased the antigenicity of the untreated beverage. Toro-Funes et al. (2014) also showed that UHPH treatments at the higher combination of pressure and temperature (300 MPa, 75 °C inlet temperature) lead to obtain a soymilk with increased amounts of bioactive compounds (total phytosterols and isoflavones), in comparison to raw product. Nevertheless, results obtained in these studies demonstrated that the effect of this technology depends to some extend on the characteristics of the food matrix. For this reason, it is interesting for food industry to investigate the application of UHPH in other vegetable beverages, in order to extend its application within this group of products.

Considering that the application of UHPH in the physico-chemical stabilization of tiger nuts' milk beverages have not been studied yet, the purpose of this work was to evaluate the effect of this technology for improving the physico-chemical stability of these vegetable beverages during their shelf-life, in comparison to the conventional heat treatment of homogenization-pasteurization.

2. Materials and methods

2.1. Tiger nuts' milk beverage making

Tiger nuts' milk beverages were produced and processed at the Pilot Plant of Universitat Autònoma de Barcelona (UAB, Bellaterra, Spain). Tubers were under the geographical origin C*hufa de Valencia* and they were provided by Horchata Lider, S.L. (Polinyà, Spain) from the province of Valencia (Alboraya, Spain). Their general composition (as % dry matter) corresponded to 8.66 ± 0.04 moisture, 35.21 ± 3.07 fat, 8.45 ± 0.20 protein and 45.05 ± 3.13 nitrogen free material, according to Codina-Torrella et al. (2015a). Tubers were washed, hydrated (12 h at room temperature) and disinfected according to Gallart (1999) (by immersion tiger nuts in a solution of 0.1% NaClO for 30 min). Then, their skin was mechanically removed (Mejisa Mectufry Mecanica Jijonenca S.A., Jijona, Spain). Liquid extract was obtained with a specific machine for tiger nuts' milk beverage making (Group-Model T0, Mainox, Valencia, Spain), which flow rate corresponds to 150 L/h of liquid extract. Peeled tubers were put into the mill hopper and then, they were ground in the hammer mill with decalcified water at the proportion of water:tubers 1:8 (w:w). The ground product was separated by pressing and filtering (100 μm) and finally, 8% (w/w) of sucrose was mixed with the liquid extract. This mixture was considered the raw product (RP), and its composition (%) corresponded to: 12.99 ± 0.18 total solids, 10.30 ± 0.60 nitrogen free materials, 2.01 ± 0.02 fat, 0.54 ± 0.02 protein and 0.13 ± 0.01 ash. The pH value of the RP corresponded to 7.02 ± 0.19.

Representative samples of the RP were bottled in sterile glass bottles (1 L of capacity) with twist-off caps (Apiglass Envases y Material Apícola, S.L., Sant Fost de Campsentelles, Barcelona, Spain) and stored at refrigeration (4 °C) until their analysis.

Just before the application of the hygienizing treatments of UHPH and conventional pasteurization, 0.05% of α-amylase enzyme (Bialfa, Biocon Española, S.A., Les Franqueses del Vallès, Spain) was added to the RP, in order to hydrolyze the starch granules and avoid their subsequent gelatinization during the treatments. The holding time of the enzyme in RP before applying the technological treatments corresponded to 10 min. After the treatments, a qualitative determination of starch in all samples was performed by using the Total Starch Assay Procedure kit (Amyloglucosidase/α-amylase method, K-TSTA 404-2009, Megazyme International Ireland Ltd., Wicklow, Ireland). Results demonstrated that this component was totally hydrolyzed in all treated beverages.

2.2. Beverage treatments: UHPH, homogenization-pasteurization

Two different UHPH treatments were performed by using an ultra-high pressure homogenizer at a flow rate of 120 L/h (Model: DRG No. FPG11300:400 Hygienic Homogenizer, Stansted Fluid Power Ltd., Harlow, UK) at two different pressures, 200 and 300 MPa, and at the same inlet temperature (T_i) of 40 °C. The high-pressure homogenizer system consisted of two intensifiers driven by an hydraulic pump, a high-pressure homogenization valve and two spiral type heat exchangers located before the machine entrance and after the high-pressure valve (Garvía, Barcelona, Spain), respectively (Poliseli-Scopel et al., 2012). T_i, the temperatures before and after the UHPH valve (T_1 and T_2, respectively) and the outlet temperature (T_o) of all beverages were monitored during the treatments. In the current study, T_1 corresponded to 55.9 ± 2.1 and 58.5 ± 3.1 °C, for the 200 and 300 MPa treatments, respectively. T_2 corresponded to 92.1 ± 1.7 and 116.3 ± 4.3 °C, for the 200 and 300 MPa treatments, respectively, in which the product remained for <0.7 s (Poliseli-Scopel et al., 2012). T_o corresponded to 15.3 ± 1.1 and 17.1 ± 1.6 °C in 200 and 300 MPa treatments, respectively.

A conventional treatment of Homogenization-Pasteurization (H-P) were also applied to the RP (H-P1), using an indirect system composed by a double stage homogenizer positioned upstream (LAB type: 22.51, Rannie, Copenhagen, Denmark) and a multitube tubular heat exchanger at a flow rate of 1000 L/h (laminar flow) (6500/010, GEA Finnah GmbH, Ahaus, Germany). Beverages were homogenized at 18 + 4 MPa at 65 °C and subsequently pasteurized at 80 °C for a holding time of 15 s.

Previously to the H-P treatment, a second batch of the RP was mixed with 0.2% (w/v) of a mixture of emulsifiers (citric acid esters of mono- and diglycerides of fatty acids and sucrose esters of fatty acids) commercialized as Base HC9 (Cargill, S. L., Barcelona, Spain) (H-P2).

All samples (RP, H-P1, H-P2, 200 MPa and 300 MPa) were collected in sterile glass bottles of 1 L of capacity with twist-off caps (Apiglass Envases y Material Apícola, S.L.) inside a laminar flow cabin (Mini-V cabin, Telstar Technologies, S.L., Terrassa, Spain) and were stored at refrigeration temperature (4 °C) until their analyses. The overall experiment was performed in triplicate (on three different days), which consisted on three independent batches of 200 L of tiger nuts' milk beverage that were produced and processed in the Pilot Plant as described.