LWT - Food Science and Technology 57 (2014) 134–140

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Comparison of direct steam injection and steam-jacketed heating in squid protein hydrolysis for energy consumption and hydrolysis performance

Panayotis D. Karayannakidis, Emmanouil Apostolidis, Chong M. Lee*

Food Science and Nutrition Research Center, Department of Nutrition and Food Sciences, University of Rhode Island, 530 Liberty Lane, West Kingston, RI 02892, USA

ARTICLE INFO

Article history:
Received 29 July 2013
Received in revised form
17 December 2013
Accepted 10 January 2014

Keywords:
Squid protein hydrolysis
Direct steam injection heating
Steam filtration
Energy consumption
Fouling formation

ABSTRACT

Direct steam injection (DSI) and conventional steam-jacketed (SJ) heating systems were compared for energy consumption and hydrolysis performance in producing squid hydrolysates (SH). Hydrolysis was carried out with endogenous enzymes at 55 °C for 90 min and native pH (6.5 ± 0.2), followed by pasteurization at 75 °C for 30 min. Hydrolysis performance was evaluated by monitoring the changes in viscosity, degree of hydrolysis (DH), and protein profile during the course of hydrolysis. The DSI heating process was more energy efficient than SJ heating with significantly less energy usage (~30% energy reduction), shorter come-up times, and total processing time. While considerable fouling was evident with SJ heating, no fouling was observed with DSI heating. No appreciable differences in hydrolysis performance were observed between DSI and SJ heating, although the DSI-treated hydrolysate exhibited slightly lower values in viscosity and DH, as well as weaker protein band intensities due to dilution caused by steam condensation. The use of a steam filtration unit in DSI not only filtered the incoming steam, but also reduced condensation. Results suggest that DSI heating with steam filtration is an energy efficient and fouling-free process for preparing SH and potentially for other type of enzymatic protein hydrolysates.

1. Introduction

The current practice of squid processing in the northeast coastal region of the United States generates large amounts of byproducts (~4500 metric tons annually), which can account for as much as 40–50% of the total squid weight (Lian, Lee, & Park, 2005). Recently, a commercially feasible bioconversion process for the production of squid hydrolysate (SH) from squid processing byproducts (SPB) has been developed (Lee & Lian, 2010), providing solution to what was previously considered a serious waste disposal problem. Briefly, the byproducts are chopped into a fine slurry and hydrolyzed by their endogenous proteolytic enzymes at 55 °C (optimum hydrolysis temperature) for 2 h (Lee & Lian, 2010).

The potential applications of SH include: (a) aquaculture feed ingredient for larval and juvenile fish (Lee, 2004; Lian, Lee, & Bengtson, 2008), (b) pet food palatant, and (c) organic fertilizer (Fetter, Brown, Görres, Lee, & Amador, 2012). In addition, the peptides formed during the course of hydrolysis are currently being examined for antioxidant activity and angiotensin-I converting enzyme (ACE) inhibitory activity for hypertension management at our lab.

So far, SH and other seafood hydrolysates, mainly for the production of seafood flavors, have been produced using the steam-jacketed heating (SJ) process, which leads to considerable fouling and subsequently to lower yields, longer processing times, increased energy consumption and intensive cleaning effort (Lee, 2012). In SJ heating systems, steam circulates in the annular space between the jacket and the vessel and, therefore, heat is transferred indirectly through the solid surface that separates the material to be heated from the heating medium (Anonymous, 2013; Das, 2005, pp. 113–124). In this case, heat is transferred by conduction through the metal wall and by natural or forced convection to the liquid food (Rao, 2010, pp. 190–200). On the other hand, in direct steam injection (DSI) heating, steam is mixed freely with the raw material and heat transfer takes place through convection, while both latent and sensible heat of steam are used to increase the temperature of the liquid food (direct heat transfer) (Anonymous, 2013; Das, 2005, pp. 113–124; Horn & Voit, 2010). Typical products processed by DSI may include milk, fresh cream and other milk-based products (Maron & Corby, 2012). However,

* Corresponding author.
E-mail address: chonglee@mail.uri.edu (C.M. Lee).

0023-6438/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.lwt.2014.01.012

steam-jacketed heating has also been employed in the dairy industry to pasteurize milk and its products. Still, one of the major disadvantages is that this process may lead to protein denaturation and subsequent fouling on the internal surface of heat exchanger due to localized heating (Tamine & Robinson, 1999, pp. 129–248). The objective of this study was to assess the direct steam injection (DSI) method, as an alternative low-cost bioconversion process for squid processing byproducts, which is expected to lead in shorter processing time, energy savings and elimination of fouling without affecting hydrolysis performance.

2. Materials and methods

2.1. Materials

Fresh squid (*Loligo pealeii*) processing byproducts (2 batches) consisting of heads, viscera, skins, fins, and small tubes along with unclaimed mantles and tentacles were obtained from a local squid processing plant (Sea Fresh USA, Inc., North Kingstown, RI, USA). The byproducts were transported to the Food Science and Nutrition Research Center of the University of Rhode Island (West Kingston, RI, USA), placed into plastic containers with 10 kg capacity, and stored with lids on at −18 °C in a walk-in freezer until used.

2.2. Reagents

A broad range protein standard was procured from Bio-Rad Laboratories (Bio-Rad, Hercules, CA, USA). L-serine, o-phthaldialdehyde (OPA), and DL-dithiothreitol (DTT) were obtained from Sigma–Aldrich (Sigma–Aldrich, St. Louis, MO, USA). All other reagents used were of analytical grade.

2.3. Production of squid hydrolysate (SH)

SH was produced using two different heating processes: direct steam injection (DSI) and conventional steam-jacketed (SJ) heating. For the production of SH using SJ or DSI heating, three containers (10 kg each) of squid processing byproducts (SPB) were taken from each frozen batch (60 kg in total for each process) and thawed overnight (~18 h) at 25 °C. Thawed SPB, was put into a Hobart VCM 40 mixer (The Hobart Manufacturing Co., Troy, OH, USA) and chopped at high speed for 2 min. The resulting SPB homogenate (SPBH) was then placed in a 113.6 L floor-mounted steam-jacketed tilting kettle (60 cm width × 50 cm depth) (VDLT30; Crown Food Service Equipment, North York, ON, Canada) and subjected to SJ or DSI heating for producing SH. The experimental set up for the production of SH using DSI and SJ heating is shown in Fig. 1. For the DSI heating experiment, a devised steam sparger unit (48 cm height × 124 cm loop length) was installed into the kettle prior to placing SPBH. Small holes (2 mm diameter), equally spaced (27 holes, 4.43 cm apart), were drilled down inward along the sparger's perimeter at an angle of 45°, which allowed the steam injected to condense into the SPBH as intended. In both heating processes, the SPBH was subjected to the following heating schedule based on the previous study of Lian et al. (2005) and Pappas (1995): initial SPBH temperature 6.5 ± 1.0 °C, heating to reach optimum hydrolysis temperature (55 °C), holding for 90 min, additional heating to reach pasteurization temperature (75 °C), and holding for 30 min. The temperature of SPBH was controlled by regulating steam flow with a Toho automatic temperature controller (TTM-J4; TTI Instruments, Williston, VT, USA) and recorded by inserting three thermocouples at different spots of the kettle. Steam was supplied by a steam generator (LB-60; Electro-Steam Generator Corp., Alexandria, VA, USA). Mixing throughout each heating process was carried out with a Stir-Pak mixer (Cole-Parmer Instruments Co., Chicago, IL, USA) fitted with a dual cross propeller (4 cm width × 9 cm length).

2.4. Steam filtration

A steam filtration unit (Balston SR; Parker Hannifin Corp., Haverhill, MA, USA) was installed with stainless steel pipes and joints to assess its steam condensate reducibility (Fig. 1). The unit is

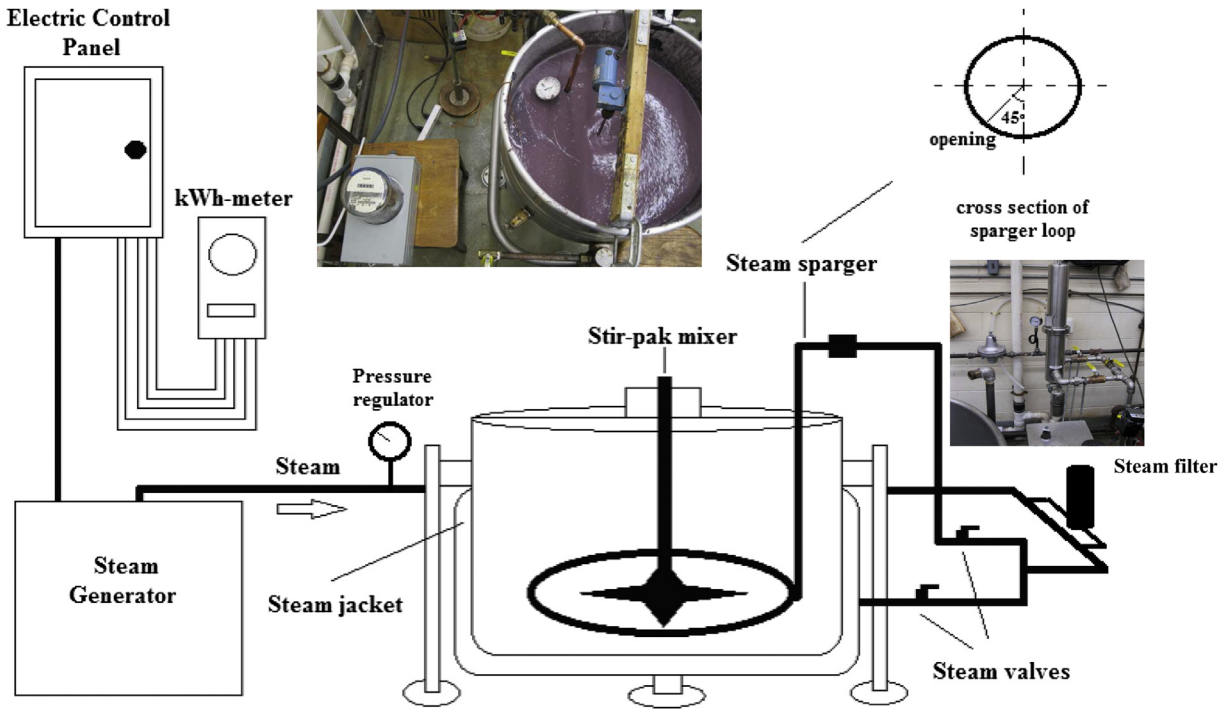

Fig. 1. Experimental set-up for the production of squid hydrolysate using DSI and SJ heating. Steam filtration unit was used only for the DSI experiments.