Innovative Food Science and Emerging Technologies 28 (2015) 10–21

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

# Effect of combined high pressure–temperature treatments on color and nutritional quality attributes of pineapple (*Ananas comosus* L.) puree

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ARTICLE INFO

*Article history:*
Received 18 October 2014
Received in revised form 26 December 2014
Accepted 5 January 2015
Available online 7 February 2015

*Chemical compounds studied in this article:*
L-Ascorbic acid (PubChem CID: 54670067)
2,2-Diphenyl-1-picrylhydrazyl (PubChem CID: 2735032)
Gallic acid (PubChem: CID 370)
Aluminum chloride (PubChem: CID 24012)
Sodium bicarbonate (PubChem: CID 10340)
Quercetin (PubChem: CID 5280343)

*Keywords:*
High pressure–temperature treatment
Pineapple puree
Total color difference
Ascorbic acid
Antioxidant capacity
Response surface

ABSTRACT

High pressure processing (HPP) had a significant effect ($p < 0.05$) on the color and bioactive components in pineapple puree at 200–600 MPa/50–70 °C/10–20 min. The pH, soluble solids and titrable acidity were not significantly affected by HPP. At 50 and 60 °C, total color change ($\Delta E^*$) was in well visible range ($3 < \Delta E^* < 6$) at all pressures; whereas it was highly distinguishable ($6 < \Delta E^* < 12$) at 70 °C. The trend was true for browning indices also. The maximum loss in ascorbic acid was 20 and 25% at 60 and 70 °C, respectively. Total phenolic content increased during HPP up to 50 °C and then decreased at elevated temperatures (60 and 70 °C). Flavonoids were stable up to 50 °C at pressure levels. Response surface models developed for all the quality attributes indicated that temperature had a more detrimental effect than pressure within the domain.

*Industrial relevance:* Consumer demand for high quality pineapple puree with minimal processing explores the possibility of applying high pressure processing (HPP) as an alternative nonthermal processing to this product. On the other hand, association of moderate temperature (30–70 °C) with high pressure is necessary to inhibit the enzymatic spoilage in the product. Though HPP at moderate temperature ensures the product safety and longer shelf life, the impact on process parameters on the nutritional and other organoleptic properties of the product cannot be neglected. Detailed study on the effect of high pressure process parameters viz. pressure, temperature and treatment time on the nutritional quality attributes is needed prior to the optimization of HPP conditions. Developed RSM models to each quality attribute will quantify the changes happening during HPP combined with moderate temperatures.



## 1. Introduction

Pineapple, one of the major tropical fruits, is consumed in fresh as well as processed forms. Among the processed products, pineapple puree, normally produced from crushed pineapple, serves as the basis for preparation of juice and beverages. It also adds a fruit serving for dairy desserts, pastries, sauces, jellies and other processed foods like nutrition bars and snacks. It is a rich source of micronutrients and antioxidants such as vitamin C, polyphenols, flavonoids and phytochemicals. Besides, it contains sufficient amount of minerals especially potassium and calcium. In addition, the sucrose content in the puree is very high with a balanced ratio of acid to sugar. The specific role of ascorbic acid in disease prevention has been associated with its capacity to neutralize reactive oxygen species (Vicente, Manganaris, Sozzi, & Crisosto, 2009). The protective effects of this product have been associated with the presence of antioxidant compounds (Cao, Sofic, & Prior, 1996; Wang, Cao, & Prior, 1996) which include ascorbic acid, carotenoids, phenolic compounds and flavonoids among others (Larson, 1988). Being rich in antioxidants, pineapple puree has been proven to reduce the incidence of cardiovascular disease and some chronic and degenerative diseases associated with oxidative damage (Dragsted, 2003). Also, pineapple contains an active protease called bromelain which has numerous biological promises and therapeutic applications, those include prevention of tumor growth, blood coagulation, inflammatory changes, debridement of third degree burns and enhancement of absorption of drugs (Taussig & Batkin, 1988).

Spoilage in pineapple products is not only encountered by microbial contamination but also by enzymatic degradation which is generally not accepted by the consumer (Chakraborty, Rao, & Mishra, 2014). Conventional processing of pineapple puree refers to thermal treatment which leads to the quality degradation in the product. High pressure processing (HPP), the common nonthermal technology, has the ability to

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http://dx.doi.org/10.1016/j.ifset.2015.01.004
1466-8564/

inactivate enzymes (Guerrero-Beltrán, Barbosa-Cánovas, & Swanson, 2005) along with a minimal effect on the nutritional quality (Oey, Van der Plancken, Van Loey, & Hendrickx, 2008). This is the major driving force for applying HPP on fruit products specifically due to their high nutritional benefit. HPP treatment also has the potential for sterilization of food products if applied at elevated temperatures (60 to 90 °C) along with the temperature increase due to adiabatic compression. By choosing the appropriate process conditions, it is possible to completely inactivate both vegetative cells as well as microbial spores in order to obtain food products that are shelf-stable (Black et al., 2007; Matser, Krebbers, van den Berg, & Bartels, 2004). In any case, the chances of degradation of the thermosensitive compounds cannot be neglected. The evaluation of the sensory and nutritional quality of foods processed by HPP is a very important factor because it is contingent on the consumer acceptance of the product.

Applications of HPP on pineapple and its products have been investigated before like fresh cut pineapple (Alemán et al., 1998), pineapple juice (Alemán et al., 1996), osmodehydrated pineapple (Rastogi, Angersbach, & Knorr, 2000) and pineapple puree (Barros et al., 2005). In these studies, HPP has been applied at lower temperatures (below 40 °C). HPP at room temperature (<30 °C) can reduce the microbial load to a desired level but the inactivation of spoilage enzymes need the assistance of moderate temperature (Chakraborty, Rao, & Mishra, 2014). Fulfillment of consumer demand for minimally processed pineapple puree needs an optimized HPP condition considering enzyme inactivation, microbial destruction and nutritional degradation in the product.

Several literatures have described the effect of HPP combined with/without temperature on nutritional and physico-chemical properties of fruit juices and purees (Dede, Alpas, & Bayindirli, 2007; Fernández Garcia, Butz, & Tauscher, 2000; Kaushik, Kaur, Rao, & Mishra, 2014; Oey, Loey, & Hendrick, 2004; Sampedro, Geveke, Fan, & Zhang, 2009; Sánchez-Moreno, Plaza, De Ancos, & Cano, 2006; Sánchez-Moreno et al., 2005). Among the available research, the information on pineapple puree as a food product is very scarce. Therefore, the objective of the present work was to investigate and develop models describing the effect of combined high pressure–temperature treatments on color and other nutritional properties of pineapple puree.

## 2. Material and methods

### 2.1. Reagents and chemicals

The reagents and chemicals used in the study were purchased either from Merck, India or from Sigma-Aldrich, Germany.

### 2.2. Sample preparation

Matured pineapples (*Ananas comosus* L. Cv. Queen) available in the local market near the Indian Institute of Technology Kharagpur, India were used for the study. The whole fruit was washed thoroughly by soft water and the surface was disinfected by dipping them in 100 ppm sodium hypochlorite solution for 3 min. After surface disinfection the fruit was washed again in distilled water and blotted to ensure zero residual chlorine on the surface (Marrero & Kader, 2006). Further, the skin was removed manually along with the core. The puree was made by blending the cut pieces of pineapple in a house-hold fruit juicer at 6000 rpm for 5 min. The uniformity was maintained by homogenizing at 6000 rpm for 4 min at 4 °C with the help of a disperser (R01-127, Remi Lab-Technique, India). The samples were packed in LDPE (80 μm) pouches containing 20 mL each and kept at −35 °C until the HPP treatment. The biochemical properties of the resultant puree have been summarized in Table 1 (Chakraborty, Rao, & Mishra, 2015).

**Table 1**
Biochemical characterization of fresh pineapple puree.
Chakraborty, Rao, & Mishra, 2015

| Attributes | Value ± standard error |
|---|---|
| Color values | |
| $L^*$ | 54.06 ± 1.3 |
| $a^*$ | −2.21 ± 0.7 |
| $b^*$ | 20.15 ± 0.43 |
| pH | 3.48 ± 0.03 |
| Total soluble solid (°Brix at 20 °C) | 12.8 ± 0.8 |
| Titrable acidity (g citric acid per 100 g sample) | 0.56 ± 0.07 |
| Total phenolic content (mg GAE per 100 g sample) | 39.2 ± 1.7 |
| Total antioxidant capacity (mg GAEAC per 100 g sample) | 12.4 ± 2.7 |
| Total flavonoid content (mg QE per 100 g sample) | 8.67 ± 0.54 |
| Ascorbic acid (mg per 100 g sample) | 54.0 ± 5.6 |

Values are presented as mean ± standard error (N ≥ 10).
GAE, gallic acid equivalent; GAEAC, gallic acid equivalent antioxidant capacity; QE, quercetin equivalent.

### 2.3. Experimental

#### 2.3.1. Experimental design

A full factorial design was employed for HPP treatment taking pressure ($P$ in MPa), temperature ($T$ in °C) and dwell time ($t$ in min) as three independent variables. Each of these three parameters was varied at five equidistant levels within the domain resulting in 125 ($5 \times 5 \times 5$) experimental runs. For instance, the selected pressure levels were 200, 300, 400, 500 and 600 MPa; whereas the process temperature was varied at 30, 40, 50, 60 and 70 °C. The dwell time for a HPP cycle was considered as the isobaric holding period excluding pressure CUT and decompression time. It was ranged from 1 s to 20 min where single second dwell time was meant for the pulse treatment. All the treatments were performed in duplicate and analyzed in triplicate.

A quadratic polynomial (Eq. (1)) model was developed by regression analysis for each quality attribute ($Y$, the response variable significantly affected by the process parameters) as a function of $P$, $T$ and $t$, where different $c_i$ ($i = 0$ to 9) are the regression coefficients.

$$Y = c_0 + c_1P + c_2T + c_3t + c_4P^2 + c_5T^2 + c_6t^2 + c_7PT + c_8Tt + c_9Pt. \quad (1)$$

The response surfaces were plotted further to visualize the interaction effect of $P$–$T$ on $Y$ within the domain.

#### 2.3.2. Combined high pressure–temperature treatment

The double packed sample pouches were treated in a batch mode high-pressure vessel (model: S-IL-100-250-09-W; maker: Stansted Fluid Power, UK). The pressurization was accomplished by compressing 30% mono-propylene glycol which served as the transmitting medium. The pressurizing rate was fixed at 300 MPa·min$^{-1}$ and a rapid decompression was achieved (<10 s). The maximum target pressure (600 MPa) was reached within 133 s after the cycle starts; whereas for 200 MPa, the corresponding figure was 45 s. The target temperature near the sample was maintained by the circulating fluid in the jacket surrounding the vessel. The hysteresis set for pressure and temperature was 5 MPa and 1 °C, respectively. After the treatment, a refrigerated condition (2–4 °C) was ensured for the samples prior to biochemical analysis.

#### 2.3.3. Measurement of pH, total soluble solid and titrable acidity

The pH, total soluble solid (TSS) and titrable acidity (TA) of the sample were measured according to the methods described in Ranganna (2007). A digital pH meter (model: CL 46+; maker: Toshcon, India) and a digital refractometer (model: PAL-1; maker: Atago, Japan) were used to measure the pH and TSS of the samples, respectively. Acidity of the puree sample was determined by titrating the sample against a standard alkali (sodium hydroxide solution) and quantified as g citric