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Study on the phytochemical properties of pineapple fruit leather processed by extrusion cooking

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ABSTRACT

Extrusion cooking process was optimized for development of pineapple fruit leather product using response surface methodology (RSM). Further, image analysis was used as non-destructive quality evaluation technique for extrudate fruit leather. Rotatable central composite design (RCCD) was used to optimize the process parameter in term of total phenolic content, ascorbic acid, total flavonoid and antioxidant activity. The optimal condition of extrusion parameters was obtained as screw speed 70.30 rpm, temperature 68.10 °C and brix 18.0°. In optimal conditions, the experimental values of total phenolic content, ascorbic acid content, flavonoid content and antioxidant activity were 46.91 mg GAE/100 g 51.97 mg/100 g, 48.75 μg of quercetin/g and 95.95%, respectively. In image analysis RGB values of fruit leather were used to establish prediction model using ANN, leading to quantitative estimations of total phenolic content, ascorbic acid content, antioxidant activity and total flavonoid content with higher correlation coefficient. The predictive capability of ANN model was higher than the RSM models. The ANN model predictions lie much closer to the line of perfect prediction than the RSM model.

1. Introduction

Pineapple (*Ananas comosus*) is a tropical fruit, having good sensorial characteristics such as mouth feeling, flavor, acidity/sweetness ratio, color and nutrition. Pineapple is known to be a good source of vitamins and antioxidants. The free radical scavenging activity of pineapple is found to be much higher than the banana and is comparable to that of guava (Alothman, Bhat, & Karim, 2009). It is a perishable cash crop that grows in abundance in a short time. This necessitates protecting the perishable fruit against quality loss during storage and distribution.

Fruit leathers are an economic and convenient substitute for natural fruits with high nutritional components. Leathers are made by removing moisture from wet pulp until the desired cohesive "leathery" composition is obtained. Since, it is light and low in moisture it has minimum storage problems and is economical to ship (Moyls, 1981). Therefore, making fruit leather from fresh fruits is an effective way to preserve fruits (Maskan, Kaya, & Maskan, 2002). Furthermore, fruit leather has far fewer calories, less than 100 kcal per serving (Huang & Hsieh, 2005) and have a far greater nutritional value (e.g., especially in terms of energy, minerals, antioxidants and fiber) than the fresh fruits because all nutrients are concentrated. There are large numbers of fruit leather available in the market, such as mango leather, apricot fruit leather, grape leather, berry leather, kiwifruit leather, and jackfruit leather (Torres, Romero, & Diaz, 2015).

In general direct sun drying, solar drying, convection oven drying and electric cabinet drying are some of the drying methods that are used in fruit leather processing (Raab & Oehler, 1976). However, all the drying processes are batch processes and time consuming. In this point of view, extrusion cooking can be an effective technology for fruit leather processing. It is also known that extruders are useful for processing products with high moisture (>40%) contents (Akdogan, 1999). However, the effect of extrusion cooking on phytochemicals of pineapple fruit is not well established. Thus, indeed there will be a need of extensive research on phytochemical properties and optimization of extrusion process for pineapple fruit leather. Response surface methodology (RSM) is a widely used tool for optimizing the process; it is an efficient mathematical and statistical technique for analysis of empirical models which can describe the effect of independent variables and their interactions on responses (Myers, Montgomery, & Anderson-Cook, 2009).

Recently, the phytochemical quality of food during processing and storage has become an important problem. Therefore,

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predicting the phytochemical quality of food during processing or storage using non-destructive methods by an accurate mathematic model is important. Image analysis followed by artificial neural network (ANN) is one of most useful non-destructive quality evaluation methods, based on the acquire information from images and statistical analysis. These techniques include spectroscopy and obtaining images using digital color cameras and scanners (Fashandi, Amirshahi, Amani Tehran, & Gorji Kandi, 2010; Soponar, Catalin Mot, & Sarbu, 2008). On the basis of RGB value of images, food quality has been analyzed and predicted using ANN. Artificial neural networks (ANN) have the ability to model any linear or nonlinear relationship between the input and output data. Use of image analysis for quality evaluation of various foods such as apples (Leemans, Magein, & Destain, 2002; Li, Wang, & Gu, 2002), chicory (Zhang, De Baerdemaeker, & Schrevens, 2003), grains and seeds (Granitto, Navone, Verdes, & Ceccatto, 2002) and olives (Diaz et al., 2003) have been reported earlier. However, there have been no reports on modeling phytochemical quality of pineapple fruit leather using ANN.

The present research work is aimed to evaluate the change of phytochemical properties of fruit leather during extrusion cooking and optimized the extrusion parameters. The study also involved non-destructive quality control using image analysis.

2. Materials and methods

2.1. Raw material

Pineapples (*A. comosus*) were purchased from Kendriya Krishi Vigyan, Tezpur, India. Pineapples were sorted and stored at 5 ± 1 °C until further processing (within 24 h). The fruit was then washed under running water and manually peeled with a knife, cut into small pieces and ground in a mechanical grinder to obtain a uniform pulp.

2.2. Extrusion

The extrusion cooking was carried out using a single screw extruder (vented extruder with L/D ratio 30:1 and 22 mm × 3 mm die opening, developed in Tezpur University). In the present study, to prevent the phytochemical losses during extrusion cooking, the pineapple fruit pulp was extruded at lower temperature and screw speed. The extrusion cooking was carried out with a barrel temperature of 60–100 °C and with screw speed from 50 to 150 rpm (Table 1). On the other hand, the moisture content of raw pineapple fruit pulp was 85.79 ± 0.5 (% db) which was quit high for extrusion. Moreover, to vary the moisture content in pineapple fruit pulp needs further unit operation which may cause phytochemical loses. Therefore, soluble solids of feed was used as independent parameter and varied in term of °brix from 10–20 during extrusion cooking. The total soluble solid of the sample was measured using refractometer in term of brix. Starch (thickening agent) content was kept as constant at 2% level. After addition of starch in pineapple fruit pulp, the total soluble solids of pulp were maintained from 10 to 20 °brix using sugar. After extrusion cooking, pineapple fruit leather was dried at 60 °C for 1 h to maintain 20% moisture content in final product.

2.3. Sample preparation

For the phytochemical analysis, the sample was prepared according to the method proposed by Franke, Custer, Arakakib, and Murphy (2004) and Chun, Kim, Moon, Kang, and Lee (2003) was modified and adapted. Approximately, 1 g of fruit leather was taken and extracted in 20 mL of the solution (16:4 v/v, methanol: water).

Table 1
Experimental design of independent variables during extrusion process.

Run	Screw speed (X_1) (rpm)	Temperature (X_2) (°C)	Brix (X_3) (°)
1	100.00 (0)	80.00 (0)	10.00 (−1.682)
2	100.00 (0)	80.00 (0)	15.00 (0)
3	100.00 (0)	100.00 (+1.682)	15.00 (0)
4	50.00 (−1.682)	80.00 (0)	15.00 (0)
5	129.73 (+1)	91.89 (+1)	12.03 (−1)
6	70.27 (−1)	91.89 (+1)	12.03 (−1)
7	100.00 (0)	80.00 (0)	20.00 (+1.682)
8	70.27 (−1)	68.11 (−1)	12.03 (−1)
9	100.00 (0)	80.00 (0)	15.00 (0)
10	129.73 (+1)	68.11 (−1)	17.97 (+1)
11	70.27 (−1)	91.89 (+1)	17.97 (+1)
12	100.00 (0)	60.00 (−1.682)	15.00 (0)
13	100.00 (0)	80.00 (0)	15.00 (0)
14	100.00 (0)	80.00 (0)	15.00 (0)
15	150.00 (+1.682)	80.00 (0)	15.00 (0)
16	70.27 (−1)	68.11 (−1)	17.97 (+1)
17	129.73 (+1)	68.11 (−1)	12.03 (−1)
18	100.00 (0)	80.00 (0)	15.00 (0)
19	129.73 (+1)	91.89 (+1)	17.97 (+1)
20	100.00 (0)	80.00 (0)	15.00 (0)

The extract was placed in an incubator shaker at 30 °C for 5 h. The extracts were then centrifuged at 10,000 rpm for 10 min. After centrifugation, the supernatants were stored at −4 °C for further analysis.

2.4. Phytochemical properties

2.4.1. Total phenolic content

A modified version of the Folin–Ciocalteu assay as described by Singleton and Rossi (1965) was used to determine the total phenolic content in the extrudate. Gallic acid was used for the preparation of standard curve at various concentrations. Independently, extract (20 μL each), gallic acid and blank were prepared and mixed with 1.58 mL distilled water then Folin–Ciocalteu reagent (100 μL) and 300 μL of sodium carbonate were added to the mixture. The samples were vortexed immediately and incubated for 30 min at 40 °C. The absorbance was measured at 765 nm in UV-VIS spectrophotometer (Spectrascan UV-2600, Thermo Fisher Scientific, Nasik, India). The phenolic content was expressed in mg GAE/100 g.

2.4.2. Ascorbic acid content

The method of Lee and Labuza (1975) was followed to determine the ascorbic acid content of pineapple fruit leather. 10 mL aliquot of each sample was placed into a 100 mL volumetric flask and brought to volume with 0.4% oxalic acid solution. The solution was filtered through a Whatman No. 4 filter paper. 10 mL of the filtered solution was pipetted into a conical flask along with 15 mL of 0.4% oxalic acid solution. The obtained solution was titrated using a microburette, with 0.04% aqueous sodium dichlorophenolindophenol solution to first pink shade. The sodium dichlorophenolindophenol solution was standardized with sodium thiosulfate 0.01 N, in a matrix of potassium iodide (50%) and HCl 1 N, using starch as indicator.

The following equation was used to calculate the ascorbic acid content:

$$\text{Ascorbic acid}\left(\frac{\text{mg}}{\text{100g sample}}\right) = \frac{0.5\text{mg}}{V_1} \times \frac{V_2}{15\text{mL}} \times \frac{100\text{mL}}{\text{Weight of sample}} \times 100$$