Effect of temperature variations on thermal properties of papaya pulp

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Abstract: The study was carried out to determine the effect of different temperatures (40, 45, 50, 55, 60, 65, 70 °C) on thermal properties of papaya pulp of three different varieties (Hawaiian, Ranchi, and Taiwan). The results showed increase in thermal conductivity with increase in temperature. Hawaiian variety showed highest thermal conductivity at 70 ^{0}C while as lowest thermal conductivity was found in Ranchi variety. Highest thermal diffusivity was found in Hawaiian variety at 45 °C and lowest thermal diffusivity was observed for Ranchi variety. There was an increase in specific heat of different varieties of papaya pulp with increase in temperature from 40 °C to 70 °C. Highest specific heat was found for Hawaiian variety at 70° C, while as lowest specific heat was observed in Taiwan variety at 40 °C.

Keywords: Papaya, thermal conductivity, thermal diffusivity, specific heat

1. Introduction

papaya fruit is one of the most popular, nutritionally rich fruit with unique flavor, fragrance, taste and heath promoting qualities making it a common ingredient in new functional foods often called "super fruits" (Wilson *et al.* 2002). Papayas are perfect to replenish salts, vitamins and energy after physical exercise. The vitamin C in the papaya enhances the absorption of iron and helps in preventing anemia. Taking papaya regularly makes the complexion fair and the skin soft and shining. Vitamin C and calcium present in papaya helps in tightening the capillary vessels and prevents bleedings of inner parts of body. It is also used as medicine for dry cough, fever and gastric problems. It is an excellent source of Vitamin-A and flavonoids like beta-carotene, alpha-carotene and beta-cryptoxanthin, 100 g of fresh fruit provides 765 mg or 25% of recommended daily levels of vitamin A.

Consumption of natural fruits rich in carotene are known to protect body from lungs and oral cavity cancers. Papaya is an excellent natural source of β-carotene; the content rises even after being picked before ripening. The content of carotenes is very high also in the dried fruit and retains high levels for at least six months after harvest. Papaya fruit is also rich in many essential B-complex vitamins such as Folic acid, pyridoxine (vitamin B-6), riboflavin and thiamin (vitamin B-1) (AOAC, 1990). These vitamins are essential in the sense that body requires them from external sources to replenish and play vital role in metabolism. Fresh papaya also contains good amount of potassium (257 mg per 100 gm) and calcium, Potassium in an important component of cell and body fluid and helps controlling heart rate and blood pressure countering effects of sodium. Papaya has been proven to be a natural remedy for many ailments. In traditional medicine, papaya seeds are anti-inflammatory, anti-parasitic, analgesic and they are used to treat stomach-ache and ringworm infections.

Knowledge of the essential thermo physical properties is of primary importance to the food industry. This information is required to make proper design of food processing equipment such as tanks, pumps, pipes, chillers and evaporators. Over the years both measured and calculated values of thermo physical properties of food have been published (Moura *et al*., 1998). However, most of the available data are for subtropical fruits, little published information is available about the thermal properties of tropical fruits. Bhumbla *et al*. (1989) described that knowledge of thermal properties like thermal conductivity (k), thermal diffusivity *(α)*, specific heat capacity (Cp) and density (*ρ*) are vital for quantitative analysis of foods undergoing thermal processing. The formulation of the product and the thermal properties of its components determine the thermal response characteristics under the applied heating conditions.

2. Materials and Methods

2.1 Sample preparation

Hawaiian, Ranchi, and Taiwan variety of fresh, sound and fully matured papaya, having good commercial quality were procured from local market. Fruits were thoroughly washed with portable water to remove any unwanted material present, manually peeled and cut into halves with stainless steel knife. The peeled and cut papaya was pressed and sieved to extract the pulp by using electric blender. The pulp from each variety was filled in pre-sterilized plastic cans, sealed and pasteurized in water bath and maintained at temperature of 100^0C for 10 minutes, cooled to room temperature and stored in a cool place for further analysis.

2.2 Determination of thermal conductivity

The thermal conductivity was also measured by differential scanning calorimeter at 40-70°C. The cylindrical sample of 6.0 mm diameter, 4 mm long was prepared from papaya pulp. The dimension and weight of the sample were determined. The lower end of the sample was touched with silicone oil before placing on the sample holder, whereas the aluminum foil slightly touched with silicone oil was used as a reference. It was calculated by using the equation given as

$$K = \alpha \times \rho \times Cp$$

Where, k is thermal conductivity, Cp is specific heat, α is thermal diffusivity and ρ is density.

2. 3 Determination of thermal diffusivity

The thermal diffusivity (*α*) of papaya pulp was calculated from experimentally determined values of thermal conductivity (K), specific heat (Cp) an bulk density (ρ) of the samples applying the equation given as

$$\alpha = k/\rho \times Cp$$

Where α is thermal diffusivity (m^2/s), k is thermal conductivity (w/m ^{0}k), Cp is specific heat (KJ/kg) and ρ is density (kg/m^3).

2.4 Determination of specific heat

The specific heat was measured by differential scanning calorimeter (DSC model Q100, TA instrument) at 40-70^{0}C. A disc of 4.2 × 1 mm sample was prepared from papaya pulp. The sample disc was placed in a hermetic aluminum pan and the sample weight was determined by a micro-balance (Sartorius MC5) and was sealed with the DSC sample sealer. The encapsulated test sample was then placed on the sample holder, using an empty hermetic aluminum pan as reference. It was calculated by the following formula

$$Cp = k/\alpha \times \rho$$

Where, Cp is specific heat, k is thermal conductivity, α is thermal diffusivity and ρ is density.

3. Results and discussions

3.1 Thermal conductivity

Thermal conductivity of Hawaiian, Ranchi, and Taiwan variety of papaya pulp at different temperature variations ranged from 0.59 to 0.65, 0.583 to 0.583 and 0.60 to 0.63 W/m ^{o}C respectively as shown in Table 3.1. There was a slight increase in thermal conductivity of different papaya pulp samples with respect to temperature variations. Highest thermal conductivity was observed for Hawaiian variety at 70 ^{0}C. Lowest thermal conductivity was found in Ranchi variety. Similar results were observed by Dithfield *et al*., 2005 for banana puree.

Table 3.1 Effect of temperature variations on thermal conductivity (W/m ^{o}k) of different papaya pulp samples

Temperature	Sample 1	Sample 2	Sample 3
40	0.59±0.01	0.58±0.024	0.60±0.006
45	0.60±0.00	0.58±0.006	0.61±0.005
50	0.60±0.00	0.59±0.002	0.61±0.006
55	0.61±0.00	0.62±0.002	0.62±0.007
60	0.62±0.00	0.62±0.000	0.62±0.008
65	0.62±0.00	0.63±0.002	0.63±0.009
70	0.65±0.04	0.64±0.01	0.63±0.008

Sample 1 = Hawaiian Variety, Sample 2 = Ranchi variety, Sample 3 = Taiwan Variety

3.2 Thermal diffusivity

Thermal diffusivity of all test samples of papaya pulp is presented in Table 3.2. It was revealed from the results that the sample 2 depicted low thermal diffusivity (1.6×10^{-7} m^2/s) at 40 °C as compared to sample 1 and 3. There was not a clear trend in thermal diffusivity of all the samples with increase in temperature. Highest thermal diffusivity of 1.80×10^{-7} m^2/s was found in sample 1 at 45 °C. On the other hand, lowest thermal diffusivity (1.50×10^{-7} m^2/s) was observed for sample 2. Similar results were demonstrated by Bird *et al.* (2002) for thermal diffusivity of papaya pulp at different temperature variations. Thermal diffusivity of papaya pulp was 1.7, 1.6 and 1.7×10^{-7} m^2/s at 40, 50 and 60^{o}C respectively.

Table 3.2 Effect of temperature variations on thermal diffusivity (10^{-7} m^2/s) of different papaya pulp samples

Temperature	Sample 1	Sample 2	Sample 3
40	1.73±0.05	1.6±0.05	1.70±0.05
45	1.80±0.17	1.7±0.00	1.76±0.05
50	1.70±0.00	1.6±0.11	1.73±0.05
55	1.73±0.05	1.6±0.11	1.73±0.05
60	1.70±0.00	1.5±0.00	1.66±0.05
65	1.66±0.05	1.5±0.00	1.66±0.05
70	1.73±0.11	1.5±0.10	1.63±0.05

Sample 1 = Hawaiian Variety, Sample 2 = Ranchi variety, Sample 3 = Taiwan Variety

3.3 Specific heat

The average experimental values for specific heat of papaya pulp are shown in Table 3.3. The specific heat of different varieties of papaya pulp increased with increase in temperature from 40 °C to 70 °C. Specific heat of sample 1, 2 and 3 varied between 32.99 and 37.07 Kj/kg, 32.39 and 36.2 Kj/kg and 31.80 and 33.53 Kj/kg, respectively. Highest specific heat was found for sample 1 at 70° C, while as lowest specific heat was observed in sample 3 at 40 °C. Similar results were found by Achi and Akomas (2006) that specific heat of papaya pulp increased with temperature variations. Specific heat of papaya pulp was found to be 31.80, 32.0 and 34.20 at 40, 50 and 60 ^{o}C.

Table 4.3 Effect of temperature variations on specific heat (Kj/kg) of different papaya pulp samples

Temperature	Sample 1	Sample 2	Sample 3
40	32.99±0.19	32.39±0.90	31.80±0.54

45	33.83±0.15	33.03±0.40	31.98±0.60
50	34.28±0.24	33.6±0.34	32.41±0.63
55	34.81±0.35	34.22±0.24	32.65±0.63
60	35.48±0.47	35.16±0.46	32.85±0.69
65	36.36±0.38	35.4±0.34	33.18±0.87
70	37.07±0.21	36.2±0.43	33.53±1.12

Sample 1 = Hawaiian Variety, Sample 2 = Ranchi variety, Sample 3 = Taiwan Variety

4 Conclusion

In order to manufacture the equipments and machines for the processing of fruits thermal properties like thermal conductivity, thermal diffusivity, and specific heat of fruits render vital information and data. Papaya was selected for this study because it is not widely processed in India. Thus, the aim of this study was to provide valuable information for the design and manufacture of equipments for papaya processing. The results depicted that thermal conductivity and specific heat increased with increase in temperature while as thermal diffusivity showed no clear trend.

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