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Evaluation of quality attributes of papaya dried by infrared drying

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Abstract
Use of infrared radiation for drying of agricultural produce is a novel technology in drying of foods. The effects of process variables such as infrared power, air temperature and air velocity on colour, vitamin C, water activity and rehydration ratio were studied. Infrared convective drying of papaya is the best drying technique i.e. retains high quality parameters than convective drying methods. The final dried product was much firmer and quality losses are less compared to other drying methods. The product was found superior quality by using this method.

Keywords: infrared; colour; vitamin; osmosis

1. Introduction
Papaya (*Carica papaya*) is an important fruit of tropical and subtropical regions. Papaya is highly perishable in nature and cannot be stored for longer periods in ambient condition. Therefore it is required to develop suitable process technology through which value added products could be prepared from the papaya fruits. Processing of the papaya into processed products can alleviate these problems to some extent. Attempts were made to produce canned, dehydrated, liquid form and concentrated papaya products. Papaya skin, pulp and seeds also contain a variety of photochemical, including natural phenols.

Papaya fruits are primarily used in three segments namely, fresh fruit, canning and juice concentrate with characteristic requirements of size, shape, colour, aroma and flavor. It is a wonderful tropical fruit having exceptional juiciness, vibrant tropical flavor and immense health benefits. In summer, it gives freshness and coolness to the body. Its juice helps in digestion of high protein foods. In addition to being eaten fresh, the fruit can also be canned and processed into different forms. The relatively short shelf life of fresh fruit after harvest is one of the main factors that demonstrate the necessity of developing an efficient and cheap preservation process. Also, the growing search for products with similar sensory and nutritional properties to fresh fruits, such as minimally processed fruits and vegetables, and for products enriched with some compounds, such as functional foods, also stimulates the food industry to look for new food preservation techniques.

At present, the quality attributes have become much more important to the consumer. Quality includes safety of dried food and its sensory properties. Many food properties can help to evaluate the quality of dried products, such as color, texture, flavour, nutritional content, ability to absorb water, mechanical properties, microstructure and others. There are most important two variables the rate of drying and material final temperature. High drying rate damages tissue and the material becomes fragile.

IR radiation penetrates directly into the inner layer of the material without heating the surrounding air; the energy consumption of infrared drying is lower compared to other techniques. IR drying is known as a means of dehydration that allows a high rate of water evaporation without much quality losses, such as changes in color, shrinkage, surface hardening, sample deformation, loss of aroma, the gap between the surface and bottom moisture content, and loss of ascorbic acid.

The objective of this research was to evaluate the quality of dried papaya cubes using infrared-convective dryer, with the help of different operational variables such as infrared power, air temperature and air velocity.

2. Materials and Methods
A laboratory scale infrared-convective drier was used for studying the infrared-convective drying behavior of osmosed papaya cubes. The dryer consisted mainly of drying chamber equipped with infrared heater of 1000 W, an air supply cum heating unit and a sample tray. The dryer was equipped with the proper control for variation of air flow rate, infrared power

and air velocity. Constructional details of the dryer are given elsewhere (Sharma, Verma, & Pathare, 2005) [10].
Papaya cubes were weighed and suspended in the vessel containing the sugar solution at the concentration of 60%, temperature 37 ºC and 4.25 hours immersion time (Jain, 2011) [6]. Osmosed papaya cubes were dried initial moisture content of 2.33 g water/ g dry matter to a safe level about 0.06 g water/g dry matter. The experiments were conducted at infrared power of 300, 400 and 500 W, air temperatures of 40, 50 and 60ºC and air velocities of 1.0, 1.5 and 2.0 m/s.
Food quality is the sum of all important desirable characteristics in food processing which make a food acceptable to eat. The quality of osmo-infrared convective dried papaya samples had been evaluated on the basis of several parameters such as colour determination, water activity, ascorbic acid, and rehydration ratio.

2.1 Colour measurement
Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value and food is no exemption. The overall objective of colour to the food is to make it appealing and recognizable. Colour of the dried papaya samples was measured using a Hunter Lab Colorimeter. A cylindrical glass sample cup (6.35 cm dia. x 4 cm deep) was placed at the light port (3.175 cm dia). Each sample was measured for colour values three times. The instrument was initially calibrated with a black as well as with standard white plate. The colour values are obtained on L*, a* and b* scale.
From these values croma (C) was calculated according to following relation as suggested by (Pomeranz and Meloan, 1971) [8].

$$C = \sqrt{(a^*)^2 + (b^*)^2}$$

2.2 Vitamin C
Ascorbic acid is oxidized by colored dye 2,6-dichlorophenolindophenol to dehydroascorbic acid. At the same time dye is reduced to colourless compound so that end point is easily determined. Other compounds also oxidized by dye, to prevent this acid medium are used for the reaction (Ranganna, 1986) [9].

2.2.1 Reagents
1. 2, 6 –Dichlorophenol indophenol Solution
2. 4 % Oxalic Acid
3. Standard Ascorbic acid Solution 0.1 % (1mg/ml) in 4 % oxalic acid
4. Working standard: Dilute to 10 times (100 µg/ml)

Extract the sample 0.5-5 g with known volume of 4 % oxalic acid, centrifuge and collect the supernatant. Take 5 ml of working standard solution and add 10 ml of oxalic acid. Titrate against the dye till appearance of pink colour which persists for a few minutes. The amount of dye consumed is equivalent to the amount of ascorbic acid. Similarly take 5 ml of the test sample adds 10 ml of oxalic acid and titrate with dye.

$$\text{Amount of ascorbic acid mg/100g sample} = \frac{0.5\ mg}{V_1 ml} \times \frac{V_2}{5\ ml} \times \frac{100\ ml}{wt. of\ sample} \times 100$$

Where,
V1 = Volume of dye consumed for standard solution
V2 = Volume of dye consumed for test solution

2.3 Rehydration ratio
Every dried product cannot be consumed directly. Most need to rehydrate by soaking in water prior to consumption. There are several factors affecting rehydration, such as soaking period, temperature of water and rehydration capacity of the product.
The rehydration capacity can be influenced by drying process. Drying processes that change the product consumption to lesser extent is supposed to offer better rehydration characteristics of finished product. Due to drying process collapsing of cellular structure and shrinkage, rehydration is may eventually affected the rehydration characteristics. Rehydration of dried fruits implies to restoration of water in them. Rehydration study was carried out by adding dried papaya cubes with distilled water in a beaker at room temperature. After about 6 h, sample was taken out from distilled water surface moisture was absorbed carefully with tissue paper and then weighed (Ranganna, 1986) [9].

$$\text{Rehydration ratio} = \frac{W_r}{w_d}$$

Where,
Wr = Weight after rehydration, g
W_d = Weight of dried papaya, g

2.4 Water activity
Water plays an important role in the stability of fresh, frozen and dried foods. It acts as a solvent for chemical, microbiological and enzymatic reactions. Water activity, a_w, is a measure of the availability of water to participate in such reactions. Water in a food will exert a vapour pressure. The extent of this pressure will depend on the amount of water present, the temperature and the composition of the food. Different food components will lower the water vapour pressure to different extents, with salts and sugars being more effective than starches or proteins. Thus two different foods with similar moisture contents may not necessarily have the same a_w.
Water activity can be defined as the ratio of the vapour pressure exerted by the food to the saturated vapour pressure of water at the same temperature.

$$a_w = \frac{P_A}{P_{Asat}}$$

Where
a_w= Water activity
PA = Vapour pressure of water exerted by food.
P_{Asat}= Saturated vapour pressure of water at the same temperature

Water activity is a function of moisture content in the food and the temperature. Bound molecule of water in food can be defined by water activity (Barbosa-Cánovas and Vega-Mercado, 1996) [3]:

- Tightly bound water a_w < 0.3
- Moderately bound water 0.3 < a_w < 0.7
- Loosely bound water a_w> 0.7
- Free water a_w = 1.0.

Most bacteria do not grow at water activities below 0.91, and most molds cease to grow at water activities below 0.80 (Leung, 1986) [7]. By measuring water activity, it is possible to predict which micro-organisms will or will not be potential sources of spoilage. Lower water activity of a dried product implies better potential for storage.

3. Result and Discussion

Fresh, infrared-convective dried papaya cubes were further evaluated for their quality aspects such as colour value, vitamin C and rehydration ratio, water activity.

3.1 Colour

Colour is often used as a parameter to indicate quality and freshness of for food products. Hence it has become important for food processor to be able to evaluate quality of their products based on colour. Colour values measured using a colour flex hunter lab colorimeter, were relative to absolute values of perfect reflecting diffuser as measured under the same geometric conditions (ASTM method).

The colour values of infrared-convective dried osmosed papaya cubes increased ranged between 24.3 and 36.4 shown in Table 1. At IR power of 400 W and at air temperature of 40ºC, the colour value at air velocity 1.0 m/s was observed to be 33.86which reduced to 29.5 when air velocity was increased to 2.0 m/s. It indicates that red colour in the papaya powder decreased when the air velocity was increased. The reason could be that drying time at a velocity of 2.0 m/s was more as compare to at an air velocity 1.0 m/s. They observed that by increasing the drying time, the color of the papaya cube became darker.

3.2 Ascorbic acid (Vitamin C)

Vitamin C determination in osmotically pre-treated papaya cubes was done before and after drying to determine the extent of vitamin C degradation in dried papaya cubes. Determination of vitamin C was done according to titration method as described in 2.2 section. It is an established fact that vitamin C is heat sensitive vitamin and it was not therefore surprising to observe that the dried fruit pieces registered a decline in vitamin C after the drying process. Vitamin C of infrared-convectively dried papaya cubes ranged between 29.55 and 41.3 mg/g dry matter shown in Table 1. The significant effect of IR power, temperature and air velocity had observed on vitamin C.

3.3 Rehydration ratio

The rehydration ratio was considered as one of the important quality attribute for the dried cubes in the present study. The rehydration ratio values of dried osmosed papaya cubes were estimated as discussed in earlier sections, using standard procedure. It varied between 2.05 and 3.02, under different drying conditions shown in Table.

3.4 Water activity

The water activities of all samples were measured by using a Hygrolab water activity meter at room temperature. The water activity ranged between 0.195 to 0.255 which is safe limit to avoid microbial growth and enzymatic reactions. Thus, it can be seen that infrared convectively dried papaya cubes prepared in this study were found to be reach safe level of final moisture content. As regards to individual effect of temperature it revealed that as temperature increased water activity decreased. This was related to water loss during drying process. At higher temperature, the water evaporation rate was higher, influencing the moisture and content consequently water activity of the product

Table 1: Quality of dehydrated papaya cubes dried by infrared-convective drying process

Treatment number	Drying conditions			Quality attributes		
	P (W)	T (ºC)	V (m/s)	Colour value	Ascorbic acid (mg/100mg)	Rehydration ratio
1	300	40	1	27.45	43.10	2.59
2	300	40	1.5	33.83	35.71	2.72
3	300	40	2	33.22	29.55	2.71
4	300	50	1	34.95	35.20	3.02
5	300	50	1.5	35.23	34.09	2.67
6	300	50	2	33.27	28.79	2.62
7	300	60	1	30.71	30.47	2.57
8	300	60	1.5	33.53	41.63	2.46
9	300	60	2	29.73	37.11	2.34
10	400	40	1	33.86	37.71	2.41
11	400	40	1.5	33.36	32.10	2.46
12	400	40	2	29.5	34.15	2.57
13	400	50	1	30.37	35.89	2.81
14	400	50	1.5	36.41	40.77	2.73
15	400	50	2	32.57	34.86	2.71
16	400	60	1	30.37	35.45	2.77
17	400	60	1.5	32.57	31.72	2.34
18	400	60	2	29.19	35.07	2.13
19	500	40	1	24.22	41.42	2.14
20	500	40	1.5	27.30	32.72	2.76
21	500	40	2	28.29	29.78	2.31
22	500	50	1	25.95	30.25	2.67
23	500	50	1.5	29.79	33.14	2.62
24	500	50	2	25.26	34.28	2.34
25	500	60	1	29.73	31.50	2.46
26	500	60	1.5	30.47	34.27	2.53
27	500	60	2	24.35	36.36	2.14

4. Conclusion
Infrared drying is a novel drying technology with numerous benefits from a food quality, safety and energy efficiency standpoint that can achieve simultaneous drying and deactivation of fungal and bacterial spores. The electromagnetic wave energy is absorbed directly at the surface of food and resulted into heating the material. These radiations have significant advantages over convection drying such as significant energy savings and uniformly radiation distribution resulting into better quality products.

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