Post-Harvest Preservation of Mango Using Tray and Freeze Drying Methods

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Abstract : Mango is a tropical fruit, which is often labelled as 'super-fruit' because of its unquantifiable benefits to human beings. Mango trees may live for more than 100 years and can grow up to 40 m high and are topped with a rounded canopy of foliage. There are hundreds of mango cultivars that are distributed throughout the world, of which Asia and in particular, India have over 500 and perhaps even 1000 cultivars. The mango fruit is a large, fleshy drupe, containing an edible mesocarp of varying thicknesses.

However, despite its great importance, mango is a seasonal fruit and only very few off-seasonal species are available in the market for consumption. Therefore, in order to overcome the seasonal variation and to increase the shelf-life of mango fruits, different drying methods are considered.
In this study, freeze drying and tray drying methods were used to preserve two different cultivars of mango from South Africa. Moisture content, total soluble solid, ascorbic acid, total phenol content (TPC), antioxidant activity (DPPH) and organoleptic tests were carried out on the samples before and after drying. The effects of different edible preservatives and selected packaging materials used were analyzed on each sample. The results showed that freeze drying method is the better method of preserving the selected cultivars.

Keywords: antioxidant, cultivar, mangos, Postharvest, total phenol content

Introduction

Mango (*Mangifera indica* L.) is the most important tropical fruit crop after bananas and plantains (FAO, 2011). The mango fruit is a large fleshy drupe, highly variable in size, shape, colour and taste and weighing up to 1 kg in some cultivars. More than one hundred varieties are produced globally, with almost same similar properties but specific differences peculiar to each variety (Bally et al., 2009). The fruit consists of a woody endocarp (pit), a resinous edible mesocarp (flesh) and a thick exocarp (peel).Mango is mostly consumed raw, either sliced into pieces for fruit salads or blended for juice and yogurt smoothies. The majority of mango production is consumed fresh and about 1-2% of the production is processed to make products such as juices, nectars, concentrates, jams, jelly powders, fruit bars, flakes and dried fruits (Berardini et al., 2005; Jedele et al., 2003). Mango varieties too fibrous or too soft for fresh consumption can be used for juice making (Hui, 2007; Omodamiro RM., et al.2016).

Mango is an emerging tropical export crop produced in almost 90 countries in the world with a production of over 25.1 million ton (Durrani et al,2012). The mango world market earns about 700 million dollars per year and world production in 2007 and 2008 was superior to 30X160 tons whose world export was approximately 11 million tons (FAO, 2009). Asia is the main producer of mango having 76.9% of the total world production, followed by America with 13.38%, Africa with 9% and less than 1% by Europe and Oceania (Rathore et al, 2007. In terms of production by country, India accounts for almost half of the world production, followed by China (3 million tons), Pakistan (2.25 million tons), Mexico (1.5 million tons), and Thailand (1.35 million tons) (Gundurao et al., 2011). Mango is a short seasoned fruit and highly perishable even in cold storage.

Mango fruit is an excellent source of Vitamin-A and flavonoids like beta-carotene, alpha-carotene, and beta-cryptoxanthin. The 100g of fresh fruit provides 765 IU or 25% of recommended daily levels of vitamin-A. Together; these compounds have been known to have antioxidant properties and are essential for vision. Vitamin A is also required for maintaining healthy mucus membranes and skin. Consumption of natural fruits rich in carotenes is known to protect the body from lung and oral cavity cancers. (Umesh Rudrappa et al 2015).

Mango fruit production is hampered if the frost comes too late in the season Mango trees are tolerant of drought or flooding conditions. In the subtropics, it can survive frost but young shoots and flowers are killed at temperatures ranging from 4°-12°C.

Most commonly dehydration techniques use to preserve fruits are: fluidized bed drying, solar drying; hot air drying, microwave drying, osmotic dehydration, foam-mat, spray drying, and freeze-drying (Marques et al, 2006). Freeze-drying is a technique that preserves the flavor, color and nutrients in the final product.

Fruits and vegetables, mango inclusive, are regarded as highly perishable food due to their high moisture content (Simal et al., 1994). Accordingly, they exhibit relatively high metabolic activity compared with other plant-derived foods such as seeds. This metabolic activity continues after harvesting, thus making most fruits highly perishable commodities (Atungulu et al., 2004). Because oxygen diffuses so much slower in water than in air, excess moisture reduces oxygen penetration. After harvest excess mango moisture content must be reduced to a level acceptable for marketing, storage and processing.

Drying is one of the most widely used primary methods of food preservation. The objective of drying is the removal of water to the level at which microbial spoilage and deterioration reactions are greatly minimized (Akpinar and Bicer, 2004). It also provides longer shelf-life, smaller space for storage and lighter weight for transportation (Ertekin and Yaldiz, 2004) Drying is used in food industry to provide microbiological stability, reduce product deterioration due to chemical reactions, facilitate storage, and lower transportation costs. Because fruits and vegetables are susceptible to heat, the selection of a suitable drying technology is a challenging task. Therefore, a compromise among all influencing factors should be made (Vega Mercado et al., 2001).

It also reduces the weight and bulk of foods which cuts down on transport and storage costs. Sun drying is the simplest and cheapest method of drying. It is used for high volume foods such as grain, rice, sultanas and raisins. The disadvantage of sun drying is that the processor has very little control over the drying conditions and the quality of the dried fruit.

Table 1: Top Ten countries Mango producer

Rank	Country	Production (MT)
1	India	1,51,88.00
2	China	43,50,000
3	Thailand	26,00,000
4	Indonesia	21,31,139
5	Pakistan	18,88,449
6	Mexico	18,27,314
7	Brazil	12,49,521
8	Bangladesh	8,89,176
9	Nigeria	8,50,000
10	Philippines	8,00,551

*Source: F FAOSTAT database, 2014

http://www.unescap.org/sites/default/files/Module%202.1%20Mango%20story_edSD.pdf

Drying is largely utilized to stabilize the product by decreasing its water activity and moisture content, and reducing quality losses Karunasena et al., (Karunasena et al., 2015; Larrosa et al., 2015 ; Law et al., 2014). Compared to fresh products which can be only kept for a few days under ambient conditions, dried products can be stored for months or even years without appreciable loss of nutrient(Ortiz-Garcia-Carrasco et al., 2016: Garcia-Alvarado et al., 2014).

Besides, drying can also create new product-forms, which add value to raw materials. Dry fruit is fruit from which the majority of the original moisture content (MC) has been removed either naturally, or through the use of hot air dryers or dehydrators. Kandala (2015)

Sample Preparation

Two mango cultivars Banganapalli and Totapuri (Figure 1) were purchased from a local market Chennai, Tamiladu. The two cultivars were ripe and fully matured at about 8 days after harvest. The mangoes were transported to food and microbiology lab of SRM University in Chennai. Selected fruits were thoroughly washed with distilled water. They were then peeled and sliced into homogenous size ranging from 6-8mm thickness.

BANGNAPALLI MANGO CULTIVAR　　TOTAPURI MANGO CULTIVAR

Figure 1: Mango cultivars used for experimentation

Citric acid (Himedia, Mumbai, India) and lime juice were used as additives, without additives mango samples was taken as control. The additive concentration and drying temperature are mentioned in Table 1. The additives were prepared into 0.5%, 1.0% and 1.5% concentration respectively. Each of the additives was later added with 50g samples. The samples were left in each concentration for 1hr. The additives were drained out of the samples in preparation for drying. 28 samples were prepared from each cultivar.

Drying of Slice Mango

Tray drying: Tray dryer (Rajindra Forging and Engineering, India) was loaded with the prepared samples, draying was carried out at 3 different temperatures (50^{o}C, 60^{o}C and 70^{o}C). For each drying temperature, 7 samples were used, each weighing 50g from the 3 concentrations and the last was weighed from control sample. The same procedure was carried out on the second cultivar. Drying was done in time frame of about 24 hrs for all the temperatures. Freeze draying: The prepared samples were pre-frozen at -20°C prior to freeze drying. The frozen sample were loaded into freeze dryer (Mini–Lyodel, DELVAC India), and freeze dried at -40°C at a constant low pressure of 0.4 mbar. Drying was performed for the duration of 24 hrs on both cultivars.

Determination of Total Phenolic

Total phenolic compounds were determined by Sellamuthu *et al*. method with slight modification. Dried mango sample (0.5g) was extracted with acetone–water (1:1). From the extracted sample, (9 µL) and 109 µL Folin–Ciocalteu reagent were added to the well and allowed to react for 3 min. after which 180 µL sodium carbonate (7.5%) solution was added to each well and incubated at 50 ◦C for 5 min, measurement of absorbance was taken at 760 nm (Multiskan GO microplate reader, Thermo Scientific, Finland). Gallic acid was used as standard and results were expressed as milligrams of gallic acid equivalent per gram of fruit.

$$\text{Total phenolic content} = \left(\frac{mgGAE}{g}\right) = \left(\frac{\mathrm{c} \times \mathrm{V}}{m}\right) \qquad (1)$$

where c is the concentration of gallic acid derived from calibration curve (mg/m), V is the volume of the sample solution (ml) and m is the weight of the sample.

Figure 2: Samples inside Multiskan GO microplate Reader, Thermo Scientific, Finland

Determination of Flavonoid Content

Flavonoid content was determined according to Zhishen *et al*. method with slight modification. Fruit sample (0.5g) was extracted with methanol. The extract (12.5 µL) was diluted with 112.5 µL deionized water and added to 7.5 µL of 5% $NaNO_2$ (w/v). After 5 min of equilibrium, 15 µL of 10% $AlCl_3$ (w/v) was added and finally 50 µL of 1 mol L-1 NaOH was added after 6 min and the absorbance was read at 510 nm (Multiskan GO microplate reader, Thermo Scientific, Finland). Catechin was used as the standard and results were expressed as milligrams of catechin equivalent per gram of fruit

Determination of Antioxidant By Dpph Method

2.2-Diphenyl-1-picrylhydrazyl (DPPH) was determined according to the method of Du Toit *et al*., with some slight modifications. 50g of sample was extracted with methanol–water (60:40). The extract was diluted with extraction solution to obtain different concentrations of sample. The stock solution of 250 µL DPPH (90µmol L-1) was placed in a 96-well microplate and 28 µL sample was added. The mixture was sonicated and kept for 30 min in the dark. Absorbance was read at 515 nm (Multiskan GO microplate reader, Thermo Scientific, Finland). The results were expressed as EC 50 (sample required to reduce the absorbance of the radical by 50%) in milligrams of gallic acid equivalent per gram of fruit.

Packaging

Dried samples were packaged immediately (Figure 6) after drying to prevent them absorbing moisture from the surrounding air. And stored at room temperature. After drying, the samples were packed in bulk in sealed moisture-proof polyethylene bags

Sensory Evaluation

The sensory evaluation of the dried mango samples was done with the use of 20 sensory panelists. Consisting of females and males and their age range is about of 23-35 years. They were selected from Tshwane University Technology, Pretoria West campus South Africa. The selected panelist were untrained. The dried samples were served in randomly and the attributes that were looked out for were flavour, texture and overall acceptance at different concentrations of addictive. The panelists were to assign scores to indicate their preference for the various attributes using 9 point hedonic scale from 1- 9 representing: dislike extremely, dislike very much,… liked very much and liked extremely, respectively. The responses were analyzed

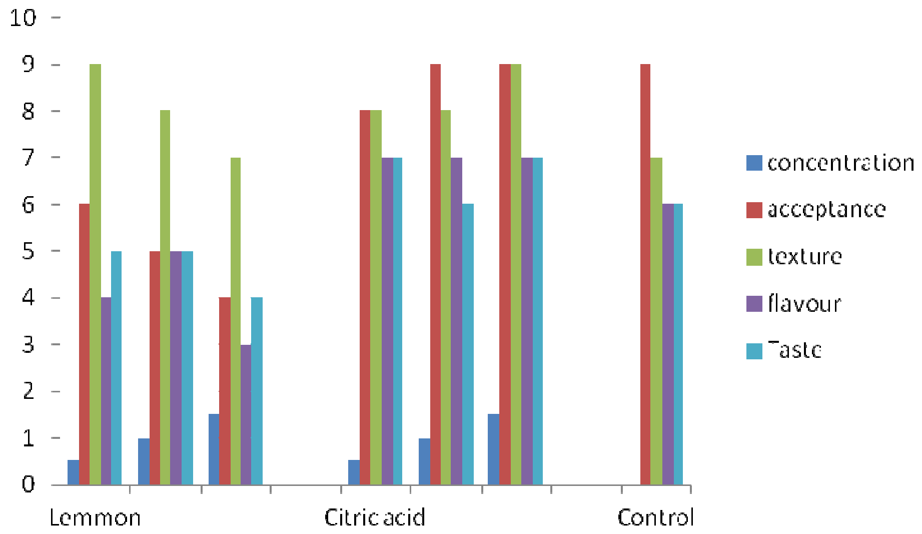

Figure 1 Sensory Evaluation of freeze dried samples

Results and Discussion

Drying Effect

This study examined effects of drying (freeze & try) on mango samples and some edible addictive. Tray drying method at 50^{o}C, 60^{o}C and 70^{o}C temperature level at with three level of concentration, dry rate and physical qualities for market acceptance and storage were evaluated.

The initial moisture content of the sample s ranged from 57% to 63% after 6hr of drying of drying. The fastest drying rate was observed in sample treated with 1.5% lemon juice and the control sample between 12hrs-18hrof during at 700c.the same trend were observed by (Ong and Law, 2011; Doymaz and Ismail, 2011) drying rate increased as temperature decreased
with time from (12hrs-24hrs).

Figure 4: Samples in Freeze Dryer

Table 2: showing drying rate at different temperature and time

Treatment	Concentration	Drying temperature at (50°C)				Drying temperature (60°C)				Drying temperature (70°C)			
			Weight/Time (hr)			Weight/Time (hr)				Weight/Time (hr)			
		6hrs	12hrs	18hrs	24hrs	6hrs	12hrs	8hrs	24hrs	6hrs	12hrs	18hrs	24hrs
Citric acid	0.5	29.0	14.0	9.0	7.0	25.0	18.0	9.0	8.0	20	18.0	5.0	5.0
	1.0	26.0	12.0	10.0	8.0	24.0	18.0	14.0	12.0	22	16.0	6.0	6.0
	1.5	27.0	17.0	11.0	7.0	23.0	16.0	12.0	9.0	21	13.0	7.0	7.0
Control		21.0	15.0	12.0	6.0	20.0	16.0	14.0	11.0	19	7.0	6.0	6.0
Lemon	0.5	29.0	15.0	12.0	10.0	26.0	18.0	14.0	10.0	21	17.0	10.0	9.0
	1.0	22.0	17.0	12.0	10.0	22.0	19.0	19.0	9.0	18	15.0	8.0	7.0
	1.5	20.0	19.0	11.0	9.0	20.0	16.0	14.0	9.0	19	17.0	8.0	7.0

Total phenol content

Prolonged temperature applications have negative effect on the quality of dried fruits and bring about degradation of bio-functional food constituents (F.M. Yılmaz et al., 2015). In our study, nutritional quality degradation was assessed in terms of total phenolic, Drying temperature and time have no statistically significant effect on the final total phenolic ($p > 0.05$). Total phenolic content was higher in freeze dried Totapuri samples when compared to Banganapalli sample, when subjected to different treatments before, which then reduced gradually. Furthermore, the application of lemon treatment helped to maintain the total phenolic content in tray dried mango sample than citric acid–treated samples during drying period. Citric acid also maintained the total phenolic content in tray drying when compared to untreated control fruits. Phenolic compounds play a significant role in scavenging free radicals. Thus, these compounds may help to protect cells against the oxidative damage caused by free radicals (Zhang et al. 2008).

Sensory Evaluation

Consumers choice of agricultural products depend upon their sensory properties i.e., color, taste, texture and aroma. The shape, size, gloss, and vibrant color of a fruit or vegetable attract consumers and influence decision picking it up by hand or fork. Once attracted by the appearance and color of a produce it goes to mouths, where the aroma and taste take over. Freshness, spiciness, sweetness, and other flavor attributes are critical to consumers eating pleasure. Aroma refers to the smell of a fruit or vegetable product, whereas flavor includes both aroma and taste. Once the product is placed in the mouth, one can perceive the smoothness, thickness, firmness, Sensory measurement are very useful in the development of new products and determining product standards while instrumental methods are superior in measuring quality on a routine basis (D. M. Barrett et al.,2010). Consumers' sensory evaluation varies depending on the fruit one is dealing with. For example a dried mango should give a yellow-brown color. In this study, drying with both techniques significantly affected the sensory evaluation of the product. Controlled-freeze dried samples were most accepted by the panelist (Figure 2). The lemon treated sample were found to be the least accepted in both cultivar. Tray dried samples at 70^0c were generally given least score, this may be caused by the effects of prolong drying at high temperature.

Figure 5: Packed dried samples

Figure 6: Packed dried samples

Table 3: effects of various drying temperatures on total phenol content of Banganapalli Mango

Treatment	temperature ^{0}c	% concentration	Total Phenol content (mg/g)
Lemon	70	0.5	3.12 ± 0.508
		1.0	3.05 ± 0.244
		1.5	2.03±0.262
	60	0.5	2.68 ± 0.031
		1.0	2.92 ± 0.511
		1.5	1.54±0.610
	50	0.5	1.82 ± 0.101
		1.0	1.89 ± 0.599
		1.5	2.55±0.077
Critic Acid	70	0.5	1.41 ± 0.623
		1.0	1.01± 0.631
		1.5	1.83±0.041
	60	0.5	2.55 ± 0.040
		1.0	1.54 ± 0.259
		1.5	2.61 ± 0.021
	50	0.5	2.66 ± 0.301
		1.0	2.40 ± 0.531
		1.5	1.83 ±0.041
Control	70		1.03 ± 0.918
	60		2.32 ± 0.532
	50		1.68 ±0.0482

Conclusion

This study confirms that drying methods, drying conditions and treatment strongly influence the quality of final product. From an engineering view, drying operations should be handled by considering many aspects such as economy, final quality of product, consumer and preference and acceptability. Drying at high temperature should be done with lesser time, and if more time is required for dry, it should be done at low temperature. The efficiency of the process can be improved by optimizing drying conditions. Mango fruit has been found to protect against colon, breast, leukemia and prostate cancers. Many trial studies suggest that polyphenolic anti-oxidant compounds in mango help in protection against breast and colon cancers. The fastest drying of mango samples was completed in tray drier with final moisture content ranging from 11% to 15% in the two cultivars examined. This is in line with FAO recommendation on dried mango. The freeze dried samples were highly favored by the panelist. Lemon treated sample with 1.0% concentration had the highest Total Phenol Content. Drying helped to maintain the phenol content in the mango samples

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