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Mechanical Size Reduction and Solar Drying of Fresh Mango Slices for Amchur Production

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Abstract:

Fruits play a vital role in human nutrition, but their highly perishable nature limits their storage duration. As drying is an ancient preservation method, a study was conducted to evaluate the impact of solar tunnel drying on the physio-chemical properties and antioxidant activity of mango fruits. Fresh mango slices were subjected to solar tunnel drying at a temperature of 60 ± 2°C for 6 hours. The drying process led to a decrease in moisture content, which in turn enhanced the physio-chemical characteristics, including total soluble solids, acidity, reducing and total sugars. While heat-sensitive vitamin C decreased, the antioxidant compounds, such as total phenols and total carotenoids, increased. Moreover, the antioxidant activity improved significantly, from 68.6% to 86.3% in mango. In conclusion, solar tunnel drying is a cost-effective method for preserving fruits efficiently and effectively for extended periods.

Key words: Raw Mango, Slicing, Solar drying, Amchur Powder

1. INTRODUCTION

Mangoes are a widely consumed tropical fruit with diverse industrial applications. One such application is the production of amchur, a dried powder made from unripe mango slices. The mechanical size reduction and solar drying of fresh mango slices are critical steps in the amchur manufacturing process. This study aims to investigate the efficacy of various size reduction techniques and solar drying for the production of amchur-ready mango slices(Abano, 2016). Mango drying is a complex process that involves the removal of moisture to extend the shelf life of the fruit. Conventional drying methods, such as sun drying and hot-air drying, have limitations in terms of long drying times and potential loss of nutritional and sensorial properties (Andrés et al., 2007).

To overcome these challenges, the study evaluated the use of mechanical size reduction methods, including slicing, chopping, and grating, to prepare mango slices for solar drying. The influence of these size reduction techniques on the drying rate, moisture content, and quality attributes of the dried mango slices were assessed. (Méndez et al., 2016)

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The mango industry generates a significant amount of byproducts, such as seeds and peels, which can be converted into value-added products to minimize environmental pollution (Alvarez-Fischer et al., 2013). This study will explore the potential of utilizing mango seed flour in the formulation of a body scrub, further contributing to the sustainable utilization of mango byproducts.

India produces 54.7 and 41.28% of mango output in developing Asia and the developing globe, respectively, with 10,800,000 Mt/year. The absence of mechanical equipment for peeling ripe mangoes is a major impediment to expanding mango processing output(Evans et al., 2017).Many processed items needed peeled or sliced fruit . Manufacturers now provide similar devices (biz.com). Fruits used for drying should be clean, healthy, and virtually free of insect or fungal assault. Permitted preservatives may be present in the dehydrated or dried fruits. There should be no apparent mold, insects, or larvae on the products. Fruits that have been sun-dried or dehydrated shall have a moisture level of no more than 20% (w/w) (FPO 1955, revised 1996).

2. Literature Review

Several studies have explored the processing and utilization of mangoes and their byproducts. (Siddiq et al., 2017) provides an overview of mango processing and the diverse range of mango-based products, including pickles, chutneys, and amchur (Jahurul et al., 2015) suggests that mango peels and seeds can be valorized through the recovery of valuable phytochemicals, such as flavanol glycosides, monoterpenes, and mango pectin.

It emphasizes the importance of understanding the chemical and biochemical changes that occur during the drying process, as they can significantly impact the antioxidant activity and overall quality of mango byproducts. The mechanical size reduction of fresh fruits and vegetables is a crucial step in various food processing operations, such as juicing, puree production, and drying.(Andrés et al., 2007)

The findings of this study suggest that the choice of size reduction method can significantly impact the drying rate and quality of the dried mango slices (Link et al., 2017)(Pu & Sun, 2015). Proper selection and optimization of the size reduction technique can lead to the development of high-quality, shelf-stable mango products, such as amchur, with enhanced nutritional and sensorial properties.

The choice of size reduction method can significantly affect the physical and chemical properties of the final product. Researchshows that the development of a vertical axis wind turbine for small-scale power generation, which could potentially be utilized in the drying process for mango byproducts (Pu & Sun, 2015).

Solar drying is a cost-effective and environmentally friendly method for preserving and processing agricultural commodities.

3. Materials and Methods

3.1. Mango Processing

The fresh mango slices were procured from a local supplier and subjected to various size reduction techniques, including slicing, chopping, and pulverization. Amchur is made from unripe mango slices that are processed as shown in chart 1before the fruit ripens. First, the peeled mangoes are dipped in a saline brine solution and then treated with a preservative. This involves exposing the slices to a potassium metabisulphite solution at a maximum of 2000 rpm for 5 minutes. Next, the treated slices are drained and dried either in the sun or using a solar dehydrator. Finally, the dried mango slices are ground to produce the amchur powder, which is then stored in HDPE packets. (Fageria & Choudhary, 2003).

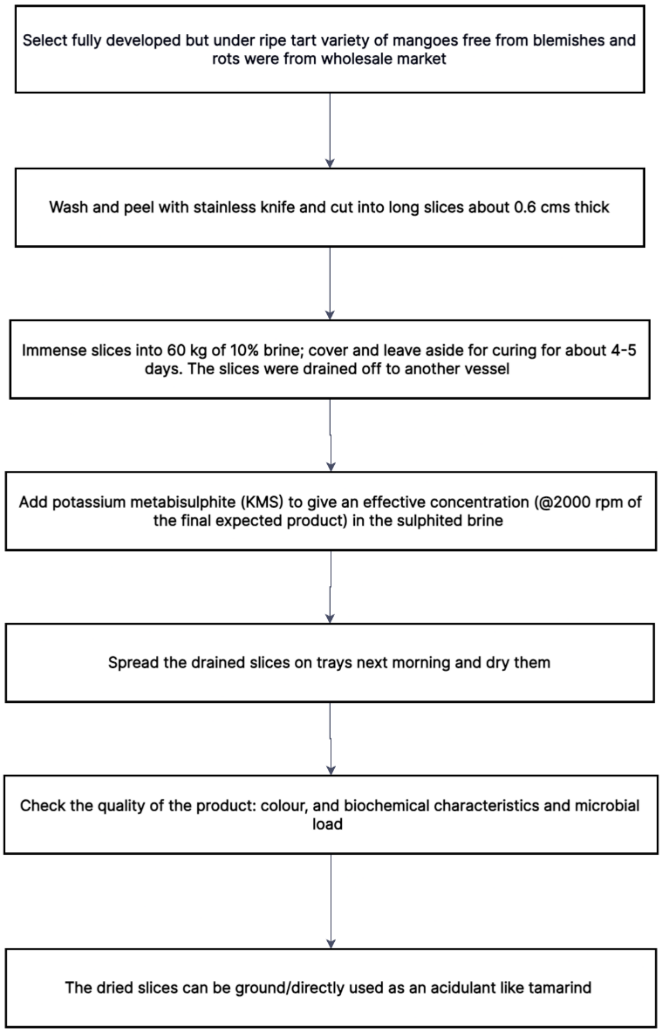

Chart 1: Process for dehydration of Green Mango Slices

3.2. Size Reduction Techniques:

The fresh mango slices were procured from a local supplier and subjected to various size reduction techniques, including slicing, chopping, and pulverization. Amchur is made from unripe mango slices that are processed before the fruit ripens. First, the peeled mangoes are dipped in a saline brine solution and then treated with a preservative. Thereafter, the mangoes are subjected to mechanical size reduction, such as slicing, chopping, or grating, to increase the surface area for efficient drying. (Link et al., 2017)

Creating mango powder involves several size reduction techniques to process the fruit efficiently. Here are some commonly used methods (Caparino et al., 2012):

3.2.1. **Washing and Peeling**: Before size reduction, mangoes should be washed and peeled to remove dirt and skin as shown in Fig 1.

Fig 1: Washed and Peeled Mangoes

3.2.2. **Slicing**: The mango flesh is sliced into thin pieces as shown in Fig 2 to facilitate drying. This can be done using a manual or mechanical slicer.

Fig 2: Sliced Raw Mangoes

3.2.3. **Blanching**: Briefly boiling the slices can help preserve color and flavor, and it can soften the mango, making it easier to grind.

3.2.4. **Drying**: After slicing, the mangos pieces are dried using methods like sun drying, dehydrators, or ovens. The goal is to remove moisture, which helps prevent spoilage.

3.2.5. **Grinding**: Once dried, the mango slices are ground into a fine powder using a grinder or mill. The type of mill (e.g., hammer mill, pin mill) can affect the particle size and quality of the powder as shown in Fig 3.

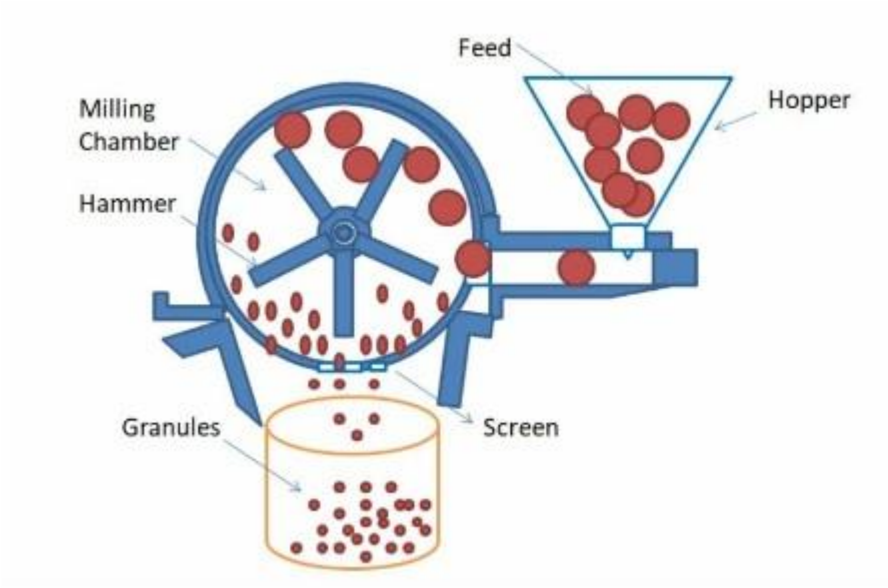

Fig 3: Hammer mill for grinding dried sliced mangoes

3.2.6. **Sieving**: The ground mango powder is sieved to ensure uniform particle size. This can help remove larger particles and achieve the desired texture.

3.2.7. **Packaging:** Finally, the mango powder is packaged in airtight containers to preserve its quality and extend shelf life.

Using these techniques effectively can produce high-quality mango powder suitable for various culinary uses.(Link et al., 2017)

3.3. Solar Drying

The size-reduced mango slices were dried using a cabinet-type solar dryer. The dryer was designed to maximize the absorption of solar energy while minimizing heat losses. The drying process was carried out under controlled temperature and humidity conditions until the desired moisture content was achieved. The corresponding drying period and quality attributes of the dried mango slices were recorded and reported for solar intensity regime.(Méndez et al., 2016) The drying in solar dehydrator may not be significantly lower for drying of fruits and vegetables but the final products definitely were are hygienic and marketable. The average solar intensity in the drying period is as shown (Fig 4). The solar tunnel dryer environment monitored, showed changing temperature & relative humidity regimes also.

Fig 4: Drying of mango slices

Drying in this solar tunnel dryer developed at CIAE was studied under no-load and for drying unripe peeled mangoes. It was a batch type dryer (80-90 Kg wet product/batch), of modular construction to facilitate transport, installation and capacity enhancement. Cut mango pieces were uniformly spread over the drying trays at the rate of 4.5 kg/ . Initial moisture content of mango was around 79%. The mango pieces could be dried in the solar dryer in about 3 days to a moisture level of 4.2% as compared to 10 days in the open drying to moisture content of 4.7% (Thanvi & Pande, 1987). The final moisture was 1.1% after 92h (4days). If there was rain during the period of drying however the tunnel dryer was totally protected. The tunnel dryer had solar supplemented fans so the excess heat and humidity was removed from the drying chamber where the slices were placed in it.

3.4. Physical and biochemical Parameters

The texture of raw mangoes and dried mango slices was evaluated using a TA-XT2i texture analyzer from Stable Micro Systems, UK. A P/5 cylindrical probe was used to measure the compressive force. A trigger force of 20 g, a load cell of 5 kg, and a pre-test speed of 5 mm/s, test speed of 2 mm/s, and post-speed of 10 mm/s were employed. The probe penetrated the samples to a depth of 2.00 mm, and the average of three readings was recorded (Penchaiya et al., 2015).

The color of fresh mangoes, raw mango slices, dried mango slices, and different particle sizes of ground mango powder was measured using a Hunter Color Lab spectrophotometer with Universal V3.71 software. The color readings were obtained on the CIE-L*ab** scale, with an illuminant of D65 and a 10-degree observer. The 'L' values ranged from 0 to 100, representing the lightness or darkness of the color. The 'a' value indicated the degree of redness or greenness, while the 'b' value represented the yellowness or blueness.

The moisture content of the dried samples was determined using the standard gravimetric method, which involves measuring the loss in weight of the sample upon drying.

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1) Moisture Content (% wb) = $\frac{\textit{intial wt.of sample} - \textit{wt.of dried sample}}{\textit{Intial wt.of sample}} * 100$

Other biochemical parameters, including total solids, water insoluble solids, soluble solids, titrable acidity, reducing sugars, total carbohydrates, and ascorbic acid, were analyzed during the drying period of the product in a solar tunnel dehydrator. The various formulae used for these analyses are briefly described below:

2) Solids: % solids = $\frac{\textit{Total fr wt} - \textit{moistue wt}}{\textit{total fr wt}} * 100$

Water Insoluble Solids:

% water insoluble solids = weight of dry insoluble solids × 4

3) Titrable acidity

$$\%\text{Titrable acidity} = \frac{Titre \times 75.05 \times Normality(0.1N)}{Wt\ of\ sample\ for\ estimation \times 1000} \times 100$$

Where, Equivalent weight of Titrant acid = 75.05

4) Reducing sugar (by Lane and Eynon method 'Personal communication', 2001):

$$\%\ \text{Reducing sugar} = \frac{Factor \times Final\ volume \times 100}{Titer \times W \times 1000}$$

Where, W= the wt. of sample present in the final sample volume

*Sample wt. = in g; Final volume= of sample used in ml

Total carbohydrates by colorimetric Dubois method after dissolving the sample in required HCl

5) Ascorbic acid: a = $\frac{bcd}{ef} \times 100$

Where a = Ascorbic acid; b = Titer; c = dye factor; d = Volume made up; e = aliquot of extract; f = Wt. or vol of sample

4. RESULTS

4.1. Physical Properties

Texture of raw mangoes and dry raw mango-slices as checked using a textures analyzer (Probe used needle 2N) were recorded. The increase in hardness can be easily seen.

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Colour of raw mangoes, fresh raw mango slices, and dried raw mango slices and different sized particulates of ground raw mango powder of raw mango are shown (Table 1, 2)

Table 1: Colour of Mangoes in the Cycle of Processing to Dried Raw Mango Powder

Raw Mango Powder	L	a	b	Y1 D1925 (2/C)	WI CIE
Coarse grade particulates (left on ISI 70 sieve)	48.52	7.23	19.23	62.87	-126.47
Middle grade particulates (passed ISI 70 sieve	55.55	9.21	25.80	72.80	-148.04
Fine grade particulates (passed ISI-115 sieve)	61.72	8.19	26.98	69.61	-136.56

*Colour scale values observed D65 as illuminant; Observer 10degree observer angle; Lightness 'L'= 0-100 scale

The product after drying was darker than the fresh mangoes used for drying (see L values). The redness increased and yellowness reduced (a, b values respectively) (Table 1). Similarly the colours of particulate sizes of raw processed mango powder were different in different grades (Table 2).

Table 2: Colour of Different Particulate Sizes of Raw Mango Powder Processed

Color Values	Raw mangoes	Raw Mango Slices	Dried Raw Mango Slices	Raw Mango Powder Ground (grades)
L	41.01	69.70	30.53	48.52 to 61.72
a	-12.43	-1.03	9.55	7.23 to 9.21
b	27.41	32.21	16.85	19.23 to 26.98
Y1 D1925(2/C)	53.37	60.39	81.48	62.87 to 72.80
WI CIE	-233.78	-145.47	-161.92	-126.47 to 148.04

The powder of good quality so obtained contained 55% particulates if ~125 micron fine size. The fine mess can be increased by changing the sieve; however that may reduce the yield of the product in the hammer mill.

4.2. Other Biochemical Parameters

Moisture Content vs Total Solids:

The moisture content of drying slices of raw mangoes reduced with drying 92h (1.1% mc) with a corresponding increase in solids in the dried product (98.9% solids) due to evaporation of the moisture from the drying mango slices.

Titrable Acidity: The final acidity of the dried product was 10.35% after 92h of drying the slices.

Ascorbic Acid: This vitamin is heat labile and the reduction in dehydration process is logical due to heat in the process. The final Ascorbic acid content in the product was 710mg/100 g after 92h drying.

The final dried product Fig 5 yield was 18% of the raw mangoes processed. It contained moisture as low as 1.1%, solids 98.9%, water insoluble solids 89.56 %, total acidity of 10.35%, reducing sugars 1.74%, ascorbic acid 710 mg/100 g, total carbohydrates 64.23%.

Fig 5: Processed Mango Powder (Amchur)

5. CONCLUSION

The study found that the Amchur product did not contain any hazardous microorganisms, and the total microbial load was within the specified Agmark standards. The mango powder contained different particle size fractions, which could be further refined by adjusting the sieve size of the hammer mill. The solar tunnel drying process was deemed feasible for large-scale amchur production, as it reduced the operational costs compared to using electrical energy for drying. The hammer mill used was easy to operate and reduced labor costs by efficiently reducing the particle size of the dried, hard mango product. The technical know-how of the processing methods and equipment can be demonstrated for entrepreneurs at the Agro Processing Division of the institute, with associated charges.

The study found that solar tunnel drying of mangoes led to increases in things like total soluble solids, acidity, and sugars. While drying reduced the bulk, it maintained the fruit's quality without drastically changing its functional properties. Solar drying also boosted total phenols and carotenoids, though it decreased ascorbic acid. Overall, the antioxidant and free radical scavenging activity increased. So in conclusion, solar tunnel drying is an affordable and safe way to preserve the quality of these fruits.

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