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Cabinet Drying: a Better Method for Dehydration of Sweet Orange Slices Delivering High Quality Product With Superior Health Promoting Properties

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Abstract
The main aim of this research was to determine the best method for dehydration of sweet orange slices with peel and without peel, that will not only enhance the shelf life of sweet orange but also add value to it. Two dehydration method cabinet drying (drying at 60 ºC for 24 hours) and solar drying (drying under sunlight for 7 days) were tested. Prior to dehydration, the sweet oranges were washed with 200 ppm sodium hypochlorite solution for 1 minute to decrease the microbial population and the slices were treated with 1% sodium meta-bisulphite solution as a food preservative and enzyme inactivator. The physiochemical properties and bioactive components of the dried sweet orange slices were analyzed. The bioactive components such as ascorbic acid, polyphenol and antioxidant as well as physiochemical components such as acidity, reducing sugar, iron and phosphorous were significantly higher ($p<0.5$) in cabinet dried sweet orange slices in both cases (with and without peel) compared to solar dried sweet orange. Therefore, the cabinet drying is recommended for commercial drying of orange slices, which will deliver dried products with high quality and considerably enhance its commercial value.

Keywords: Sweet orange, Physiochemical, Bioactive components.

INTRODUCTION

One of the most common fruit crops is citrus (*citrus spp*.), whose annual production is estimated to be 115 million tons every year worldwide. Sweet oranges (*Citrus sinensis*), tangerines/mandarins (*Citrus reticulata*), lemons (*Citrus limon*), limes (many species), and grapefruits (*Citrus paradise*) are the major members of the citrus family. Citrus fruit peel contains flavonoids and limonoids, which contribute to the fruit's distinctive smell (Manthey, 2004).

The sweet orange (*Citrus sinensis*) fruit is typically round, sub-globose, or oval, with a diameter ranging from 5.7 to 9.5 cm. Its color varies from greenish yellow to orange, and it has a firm, tightly adhering skin. The fruit consists of approximately 40-50% juice, 8-10% flavedo, and 15-30% albedo. The flavedo is the outer yellow layer, rich in carotenoid pigments and containing numerous oil glands filled with aromatic essential oils. The albedo, a white, spongy inner layer, is made of parenchymatous cells and has a thickness of 0.16 to 1.43 cm. It is also high in glucosides, flavonoids, pectin, and pectic enzymes (Hashmi, 2012).

Sweet oranges are a good source of potassium and vitamin C. In terms of nutrition, one orange provides around 116.2% of the recommended daily amount of vitamin C. Citral, an aldehyde found in its peel, interferes with vitamin A's function. It contains 100g of 12.67g carbohydrate, 0.8g fiber, 1.4g protein, 0.4g fat, 198 I.U. vitamin A, 65.69 mg vitamin C, and 0.4g fat. A considerable amount of folacin, calcium, potassium, thiamine, niacin, and magnesium are also present, along with other significant phytochemicals such as synephrine, hesperidin flavonoid, polyphenols, and limonoids. Oranges include a variety of nutrients that have a wealth of health advantages. The fruit is high in pectin, a kind of dietary fiber, but low in calories, saturated fats, and cholesterol (Solanke *et al*., 2018).

Citrus fruit processing generates numerous valuable byproducts. These wastes can be repurposed to produce various phytochemicals, pharmaceuticals, food products, essential oils, seed oils, pectin, and dietary fibers. Citrus byproducts are recognized as a rich source of edible and health-promoting compounds, including polymethoxylated flavonoids, many of which are uniquely found in citrus peel (Hatamipour *et al*., 2004).

One of the oldest food preservation techniques is drying, which not only helps to preserve food and increase product shelf life but also lowers storage, packing, and transportation costs. The most used dehydration method in the food business is traditional air drying. Depending on the drying technique, dried goods may differ in terms of color, nutritional value, volatile components, texture, and ability to be rehydrated (Jayas, 2016). The Maillard reaction, also known as non-enzymatic glycosylation, plays a key role in the processing and storage of dried longan fruit. It involves the formation of a complex between amino acids and reducing sugars through covalent bonding. Maillard reaction products (MRPs) and the sugar-protein conjugates (SPC) of dried fruit products are often observed during manufacturing, warehousing, and shipping (Somjai *et al*., 2021).

Hot air (convective/ cabinet) drying is more common than other most significant approaches because of the new techniques researchers have developed to prevent the loss of nutrients during drying. According to data from the literature, it uses little energy and produces dried goods of significantly inferior quality (Azadbakht *et al*., 2018; Bozkir, 2020). The degree to which consumers will accept dehydrated products depends on factors such as their structural, textural, sensory, microbiological, and rehydration capabilities. Food processing frequently modifies, degrades, or eliminates fragrance and phenolic compounds, especially during drying, which lowers the quality of the final product and may cause customers to reject it. The quality of dried agricultural goods has been reported to be impacted by drying techniques and drying parameters, particularly drying temperature. On

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the storage stability of the dried orange slices, there is, nevertheless, a dearth of literature-based information (Giri & Prasad, 2013).

MATERIALS AND METHOD

Sweet orange samples were brought from Sindhuli, Nepal. The crystallized sugar was bought from Satdobato, Lalitpur. Sodium hypochlorite was used to disinfect the sweet orange and potassium metabisulphite was used as food preservative.

Preparation of dried sweet orange slices

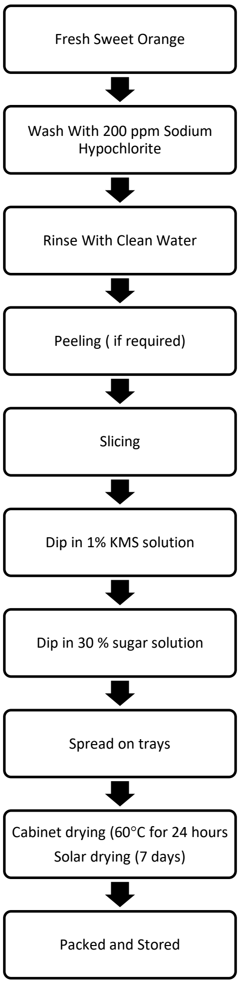

Figure 1: Flowchart for preparation of dried Sweet orange slices

Sweet orange samples were collected from Sindhuli, Nepal which were cleaned thoroughly with water and was washed with sodium hypochlorite solution (200 ppm) for 1 minute in the ratio of 1 part fruit and 2 parts sodium hypochlorite solution. Further, the sweet oranges were rinsed properly with clean water. For the preparation of dried sweet oranges without peel, the peel was removed with the help of peeler. Then, the sweet oranges were sliced with the thickness of about 0.3 cm. The slices were dipped in 1% KMS solution in the ratio of 1 part fruit and 2 part KMS solution for 30 minutes. After 30 minutes, the orange slices were removed from the KMS solution and then dipped in 30% sugar solution for 4 hours at room temperature. The weighed amount of orange slices were then spread on the trays for cabinet drying and solar drying. For cabinet drying, the sweet orange slices were dried at 60°C for 24 hours, whereas for solar drying the sweet orange slices were dried using solar drier for 7 days.

Analysis of dried sweet orange slices

For the analysis of the dried sweet orange slices, the moisture content was determined by using hot air oven at 105 ± 2°C (FSSAI, 2016). The moisture, acidity, reducing sugar, ash, iron, calcium, and phosphorus content were determined as described by (Ranganna, 2008). The acidity was determined by titrimetric method with 0.1 N NaOH using phenolphthalein as indicator, reducing sugar was determined by DNS method.The total phenol content of the sample extracts was measured using the Folin-Ciocalteu method, as described by (Mahdavi *et al.*, 2010). A 1 ml aliquot of the extract or a standard gallic acid solution (100–1000 µg/ml) was placed into a 25 ml volumetric flask containing 9 ml of distilled water. Then, 1 ml of Folin-Ciocalteu reagent was added, and the mixture was shaken. After 5 minutes, 10 ml of 7% Na_2CO_3 solution was added, and the solution was diluted to the final volume with distilled water and mixed thoroughly. The mixture was incubated for 90 minutes at room temperature, and the absorbance was measured at 765 nm using an automated UV-VIS spectrophotometer against a reagent blank (distilled water). A standard curve was prepared using gallic acid, and the results were expressed as milligrams of gallic acid equivalents (GAE) per 100 grams of sample. According to Brand-Williams *et al.* (1995), the total antioxidant was determined by DPPH as a free radical.

Statistical Analysis

The analysis was carried out in triplicate for each parameter. For statistical analysis and data interpretation, IBM SPSS (Statistical Package for the Social Sciences) Statistics version 23 and Microsoft Office Excel 2019 were used. The data obtained were analyzed by one-way analysis of variance (ANOVA) and the significant differences among them were studied by using Tukey HSD at 5% level of significance.

RESULTS AND DISCUSSION

Physiochemical composition of dried sweet orange slices

The physiochemical compositions of dried sweet orange slices were analyzed, and the obtained result are shown in

. The moisture content of solar-dried sweet orange slices was found to be significantly higher in comparison to cabinet-dried slices. The size, shape, and stacking arrangement of the fruit during the drying process along with the temperature, time, relative humidity and velocity of air in the drying chamber affects the moisture content in the final product. During solar drying, the drying process completely depends on the moisture level of the environment no lower than 15-20 % (Phalak & Banerjee, 2022). The acidity, reducing sugar and phosphorus of cabinet dried sweet orange were found to be significantly higher ($p<0.05$). According to Gallali *et al.* (2000), the drying process can increase the amount of reducing sugar in dried product by converting total sugar into simple sugars and increasing the concentration of sliced fruit. The increase in acidity might be due to removal of moisture content and hence concentration effect resulted in increase in acidity. Further the increase in acidity might have been due to formation of acids because of inter-conversion of sugars and other chemical reactions. During storage, the de-esterification of pectin molecules occurs, leading to a reduction in jelly grade

Table 2 Physiochemical properties of dried sweet orange slices

S. No.	Parameters	Cabinet Dried Sweet Orange Slices		Solar Dried Sweet Orange Slices	
		With Peel	**Without Peel**	**With Peel**	**Without peel**
1.	Moisture (%)	7.61 ± 0.79^{a}	5.87 ± 0.33^{a}	10.45 ± 3.66^{b}	8.92 ± 0.76^{b}
2.	Acidity (g %)	1.10 ± 0.06^{ab}	1.46 ± 0.20^{b}	0.74 ± 0.03^{b}	1.12 ± 0.03^{ab}
3.	Reducing Sugar (g/100g)	6.66 ± 0.02^{a}	5.55 ± 0.31^{ab}	2.55 ± 0.29^{c}	4.83 ± 0.39^{b}
4.	Ash (g %)	1.51 ± 0.04^{a}	1.47 ± 0.06^{a}	2.16 ± 0.08^{b}	1.69 ± 0.14^{a}
5.	Iron (mg/100g)	1.52 ± 0.07^{a}	1.37 ± 0.06^{a}	2.29 ± 0.13^{a}	4.41 ± 0.49^{b}
6.	Phosphorus (mg/100g)	61.72 ± 2.04^{ab}	71.42 ± 0.41^{b}	48.71 ± 3.06^{c}	59.96 ± 2.92^{a}

Note: Values are the mean ± standard error of mean obtained from the triplicate data. Superscript(s) indicates significant difference ($p < 0.05$) from each other. All the data are in dry basis except moisture content.

This process results in a gradual decrease in the methoxyl content of the pectin and an increase in titratable acidity (Pareek & Kaushik, 2012).

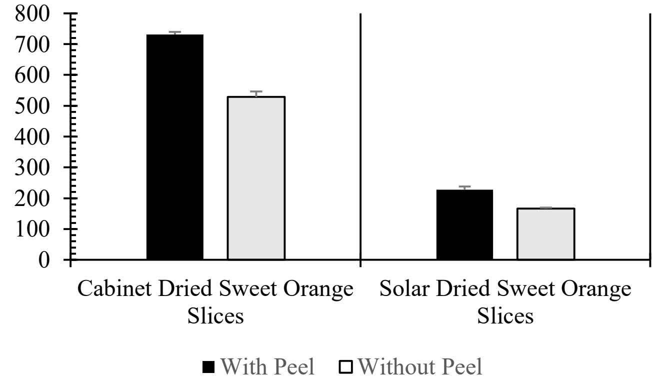

Figure 4: Ascorbic acid (mg/100g)

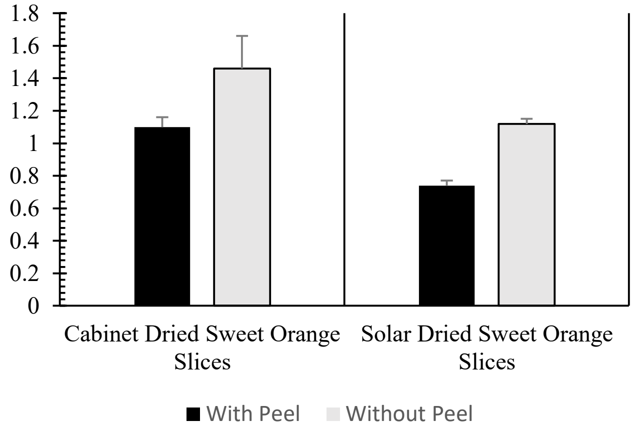

Figure 5: Antioxidant (mg/100g)

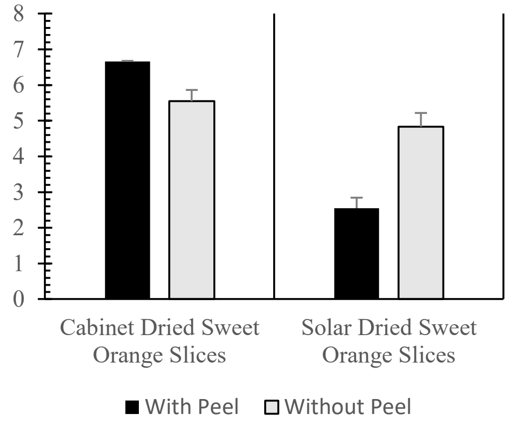

Figure 6: Polyphenol (mg as per GAE/100g)

Result reported by Giovanelli *et al*., (2002) that the reduction in ascorbic acid content was mainly due to the temperature, exposure to direct sun light and the presence of air. Similarly, Demiray *et al*., (2013) mentioned that the ascorbic acid degradation was mainly due to the temperature at which the tomato products were heated in the presence of air. In a similar line, Zerdin *et al*., (2003) mentioned that the loss of ascorbic acid was primarily due to chemical degradation involving oxidation of ascorbic acid in the presence of heat, light, oxygen, enzymes, moisture, and metal ions. According to Que *et al*., (2008) and Yu *et al*., (2005), the increase in total phenols after solar drying in fruits might be due to the formation of Maillard reaction products leading to formation of new phenolic compounds from their pre- cursor at high temperature. Moreover, it can be presumed that bound phenolics with larger molecular weight, in samples might have been liberated into simple free forms by heat treatment leading to enhancing total phenolic contents (Sultana *et al*., 2012).

CONCLUSION

Most dried fruits preserve the nutritional value of fresh ones and supply the main nutrients and a set of preventive bioactive components that makes them valuable resources for improving food quality and reducing the risk for chronic diseases. From ages, dried fruits have been recognized as a healthful food due to their unique blend of flavor and nutritional value. They need very little maintenance, are naturally resistant to deterioration, and are simple to carry and store. Cabinet drying technique can be implemented in domestic and semi-industrial conditions to preserve the nutritional and bioactive components as well as the plant pigmentation of sweet orange.

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