Mini-Review of Dehydrated Products: Nutritional Properties and Mineral Components of Freeze Dried Tropical Fruits

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Abstract: The purpose of dehydration process is to reduce moisture content to prolong shelf life, to promote convenience and at the same time to assist transportation of delicate and perishable products across long distances. Freeze drying is known as one of the best methods to retain quality compared to other dehydration processes. This is due to lower instances of rupture of the structure and minimal loss of nutrient. These parameters are important to consumers and also for the food industry. This mini-review compares methods of dehydration processes, as well as their advantages and disadvantages when used in combination with other technologies. Data compilation on nutritional properties and mineral components of tropical fruits, namely guava, pineapple, papaya and jackfruits which had underwent freeze drying technologies are also reviewed.

Keywords: Tropical fruits, preservations, freeze dried fruits, nutritional properties, minerals component.

INTRODUCTION

Consumptions of fruits are often associated with many health benefits, like reducing the risks of cardiovascular diseases and osteoporosis, lowering blood pressure, preventing hypercholesterolemia, chronic obstructive pulmonary diseases as well as respiratory problems, and so much more [1-5]. The strong antioxidants in fruits helps to protect against carcinogen and free radicals, and at the same time impedes the likeliness of chronic diseases [1,2]. Fruit is also part of daily dietary intake that is recommended for healthy human consumptions since they contain significant amount of vitamins, fibers, minerals and various phytochemicals [5,6]. Fruits are categorized as perishable since they contain high water activity, and they are heat sensitive and easily degrade [7]. High water activity of fruits results in mechanical damage, cross contamination, temperature abuse and microbial spoilage. Microorganisms favour food with high water activity, thus this parameter often stands as an indicator to predict food safety and stability [8]. Thus, fruits-processing industries often address these difficulties in their production. One of the common methods used is dehydration process; which results in prolonged shelf life and improves its convenience of consumption. However, additional specifications are needed which related to characteristics of the final product required. It is important to conserve and protect the nutrition and quality of the fruits to be safely consumed all year round, all over the world.

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This paper compares methods of dehydration processes to preserve food product, as well as their advantages and disadvantages when used in combination with other technologies. On top of that, this study also compiles and reviews the literature on the nutritional properties and mineral components for tropical fruits. Only the data of phosphorus and calcium amount are available in the freeze dried form, suggesting that there is still a lack of established data on the mineral content of freeze dried fruits. The data compilation is limited to the following fruits; guava, pineapple, papaya and jackfruits using freeze drying technologies. These fruits are rich in phytonutrients which offers opportunities for value-added products in nutraceutical and food applications. In addition, these fruits are abundant in Malaysia, as well as one of the sources that contributes to Gross Domestic Products (GDP) of Malaysia [52].

PRESERVATION OF FRUITS AND VEGETABLES

Preserving nutrients and health benefits of fruits is one of the biggest challenges in the industry due to the microbial threats. Preservation of fruits have been long practiced since centuries ago where methods like dehydration and fermentation were introduced in order to extend their shelf life and at the same time producing delicious and stable products [6,9]. Fruits and vegetables typically undergo several processes before being developed into new products. Apart from shelf life enhancement, popularity of fruits consumption has also increased due to increasing awareness of consumers on its health benefits. The extension of the fruits' lifespan would be a logistic advantage during

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transportation. With these advantages, it can sustain as an asset to the food distribution chain as this is important to commercial operations [10]. Processing during preservation could bring changes to the fruits including colour, taste, texture, physical appearance, nutritional value as well as quality. Fruits can be processed to yield a wide range of products and by-products. Some processes would depend on certain factors like the nature of the raw materials, fruits seasonality, available technology (machineries and equipment), labour and skills, packaging technology, available storage area and market demand. These factors were reported as having the potential to impact some nutritional values of the food product [6].

In general, fruits and vegetables are preserved to keep them acceptable, safe and edible once they reached the 'table' [10]. Apart from that, fruits and vegetables are preserved to retain their nutrients including carbohydrate, protein and fiber. With today's modern technology and innovation, the loss of vitamins and other nutritional values can be minimized. Table **1** below summarized the types of preservation that have been available throughout the evolution and innovation of preservation methods.

FREEZE DRYING: NUTRITIONAL VALUE AND MINERAL COMPONENT OF GUAVA, PAPAYA, PINEAPPLE AND JACKFRUITS

One of the impressive drying methods nowadays is the freeze-drying method. This method basically applies the advantage of removing water from a product through sublimation [24,50]. Sublimation is the conversion of ice directly to vapour without passing through liquid state. During the process, uniform network of ice crystal forms after sublimation which creates a dense porous matrix. A fast freezing rate creates small ice crystals [25]. Thus, freezing rate is crucial in generating the pore size of final product. This is also essential to preserve the important nutrients as well as biochemical compounds in the fruits. This method is also widely used in biopharmaceutical compounds to improve stability [26].

During drying process, some fruits may experience structural changes; some of which might be desired but some are not. The structural loss of the fruits is called collapse where it shows reduction of pore size, volumetric contraction and incapable of supporting its own weight [24]. Collapse can affect the physical, chemical and microbiology characteristics since these changes can reduce the shelf life and stability of the products [24]. Freeze dried fruits with collapse structure are sturdy with less aroma and less dehydration capacity [27]. However, only a few freeze dried tropical fruits were observed as not having collapse structures after undergoing freeze dried process. Pineapple, guava, mango, Barbados cherries and papaya are the few fruits that are thought as not experiencing collapse during the process. No specific reasons were mentioned in the report by the author with regards to these fruits. Collapse changes can be controlled by manipulating freezing speed and temperature [25]. The final structure of the freeze dried fruits either collapse, porous or sticky, may have contributed to the extension of shelf life [23].

JACKFRUIT

Jackfruit trees (*Atocarpus heterophyllus Lam*.) belong to the Moraceae family. Jackfruit is rich in phytonutrients such as vitamin A, vitamin C, vitamin B, vitamin B_3 as well as mineral components for example calcium, potassium, ion, sodium, and zinc [28]. It is also reported that the presence of isoflavones, lignans and saponin in jackfruit can act as anticancer, antihypertension, antiulcer and antiaging properties. The presence of vitamin B_3 (niacin) in jackfruit is necessary for nerve function, energy metabolism and synthesis of certain hormones; the recommended daily amount for niacin is 16 mg for males and 14 mg for females [29]. Another benefits of eating jackfruit is it is rich in vitamin C. Vitamin C is reported as antioxidant agent and helps to boost our immune systems as well as to maintain a healthy gum [29,30]. Jackfruit is also reported to be abundant in antioxidants, rich in phenolic compounds, which is essential to reduce cardiovascular diseases as well as carotenoid compounds which is vital to protect cataract disease, inflammation and age-related degeneration [31,32]. Thus, the abundance of phytonutrients in jackfruit offers opportunities for the value-added products in nutraceutical and food applications.

GUAVA

Guava tree (*Psidium guajava L.)* belong to the Myrtaceae family. Guava can be eaten raw or made into puree, chutney, juice, paste, syrup and others [33]. It is rich in sugars, minerals and vitamins; hence considered as a `super fruit´ nutritionally. Guava is reported to contain almost 6 times more vitamin C than orange [34]. Different varieties of guava exist all over the world, with ascorbic acid concentration ranges from 37 to 1160 mg/100g [35,48]. Adding sucrose and pectin to guava pulp will result in longer shelf life and more stable product after being freeze dried [37].

Table 1: Advantages and Disadvantages of Different Methods Applied in Fruit Preservation

Type of preservations	Advantages	Disadvantages	References
Sun and solar drying	Cheap method Simple and easy to use Reduction in weight and volume thus minimizing packing, transportation cost and enables storability.	Dust contamination, bird and rodent attack, fungal attacks, rainfall Loss of vitamin C Time consuming Output product quality is poor.	[11,12]
Conventional preservation Example: Sugaring Salting Canning Curing Fermentation Food additive	Easy to conduct Prevent microbial activity Economical methods for almost every background	Added attraction to the sensory taste Easy to get contaminated Long term side effect on health	[10,13,51]
Cold storage preservation	Preserve nutrient values Retain fresh taste colour and texture	Deterioration of texture, colour and flavour during thawing Damaged tissue structure when thawing Nutrient loss during pre-preservation Loss of more nutrient during storage High up-front costs and energy consumptions	[4,6,10]
Physical-based preservation Example: Pulsed electric field treatment (PEF) Ultraviolet applications Modified atmosphere packaging (MAP) Vacuum packing Electron beam irradiation (EBI)	New technology and innovation on food preservation Provide optimum temperature and relative humidity for the product Easy to ship product overseas Able to maintain quality and freshness of product Stabilize emulsion in products	Expensive and high maintenance cost Lack of expertise and literature Safety and feasibility of performing the method Public misleading questioning on the safety of product	[9,15,16]
Chemical-based preservation Example: Acidic electrolyzed water (AEW) Ozone Sodium benzoate Potassium sorbate Sodium nitrite	Strong antimicrobial activity Preserving sensory characteristic of product Effective disinfection Easy operation and relatively inexpensive	Loses antimicrobial activity when EO water is not supplied with electrolysis Lack of expertise in certain region Chlorine gas emission and metal corrosion (AEW) Ascorbic acid and antioxidant activity reduced Surface texture is damaged Long exposure to ozone associated with health effects	[9,17]
Current trend Thermal processing e.g. blanching, pasteurization Isochoric freezing Freeze drying	Inactivate microbial activity Effective and relatively up-front cost feasible Minimizing transportation cost Flavor and minerals preserve better.	Lower loss of nutrients Degrade ascorbic acid, aroma and flavour High maintenance cost Economical long term preservation Volatile compound destroyed Expensive unit operation Finished product is pricey Sterilization process is critical	[18-23]

PAPAYA

Carica papaya trees belong to Caricaceae family. Papaya is low in calories and rich in different types of enzyme such as papain, lipase and chymopapain. Papain is abundant in unripe papaya which helps to digest the protein in food at acid, alkaline and neutral medium. Papain is generally used for tenderizing while lipase acts as natural immobilized biocatalyst [38]. Papaya is also a rich source of vitamins such as provitamin A, carotenoids, vitamin C, vitamin B, lycopene, dietary minerals and dietary fiber [38]. The folic acid in papaya helps the conversion of homocysteine into amino acids such as cysteine and methionine; unconverted homocysteine give significant impact for stroke [38,40]. As papaya offers exceptional nutritional and medicinal properties, appropriate drying process are vital to preserve the important nutrients. In addition, papaya also contains high moisture content; therefore it is important to find an appropriate method to dry the pulp. This is due to the significant physical changes in volume, shape, porosity and density that can cause structural collapse; which will impact the quality of the end product [37,39].

PINEAPPLE

Pineapples (*Ananas comusus*) belongs to the Bromeliaceae family. Pineapple can be consumed fresh, canned, as juices and can be used in dessert, fruit salad, ice cream and others. Pineapple is rich in dietary fiber, as well as low in fat and cholesterol. It is also a good source of vitamins and minerals such as potassium, manganese and copper. Bromelain in papaya helps to aid digestion, clear bronchial passages and fight infections [40]. The anti-inflammatory properties, specifically bromelain, is reported to be able to reduce the symptoms of arthritis and treat sports injuries such as healing of bruises, ease joint aches, tendonitis and bursitis. To obtain the most nutritional value from pineapple, it is best to eat it raw; however, since pineapple is highly perishable and seasonal, it is vital to preserve the fruits through appropriate dehydration method to prolong its shelf life with minimal degradation of nutrient.

Fruit dehydration may cause some changes to nutritional values and chemical composition. Thus, a few component groups were examined to determine the quality index of the fruits. The components include vitamin C, carotenoids and total phenolic compounds [23,41]. The stability of vitamin C (ascorbic acid) is often used as indicator and estimation for the overall nutrient retention in the product since vitamin C is the least stable during processing [42]. Some researchers assume that if vitamin C content is reduced after processing, other nutrients are also reduced because vitamin C is extremely sensitive to heat, oxygen, pH, light, moisture content, and heavy metallic ions (Cu^{2+}, Ag^{+}, Fe^{3+}) [23]. Some studies may have reported different values of vitamin C for the same fruit because every fruit have various factors influencing the vitamin C content such as genotype difference, climatic conditions, soil state, maturity at harvest, and harvesting method. Generally, quick drying retains quite a significant quantity of vitamin C than slow drying [23]. A few studies also reported some losses of vitamin C after freeze drying process; however, the deficit were considered small compared to reduction of vitamin C where thermal drying was applied.

Table **2** shows the vitamin C, minerals and moisture content of four fruits namely, papaya, guava, pineapple and jackfruit. The values of vitamin C varies due to multiple factors including method of analysis, genotype difference of the fruits, climatic conditions and maturity of the fruit [23]. Despite the various factors affecting the amount of vitamin C, the freeze dried papaya contained the highest amount of vitamin C compared to the freeze dried guava, the freeze dried pineapple and the freeze dried jackfruit. It is worth noting that due to the highly porous structure of freeze-dried products, the loss of vitamin C will increase due to the oxidative reaction when stored in an inadequate storage. Therefore, the metal packaging, polyethylene and polyethylene double layer packaging must be used to reduce the oxidative reactions to retain the vitamin C in the final product [23]. On the other hand, the loss of vitamin C is also related to the glass transition temperature (Tg) and depletion of oxygen by vacuum during the freeze drying activity [23].

Although they exist in small amounts, minerals content is important because they assist the synergy activity and metabolism in our body [43]. Phosphorus is vital in bone development while calcium is required for muscle contraction, nerve impulse transmission and other metabolic processes. In general, deficiencies of both calcium and phosphorus component will lead to an abnormal bone development [44]. Values obtained in Table **2** were in a range of 6.6 to 13.9 ppm for both phosphorus and calcium. Amongst the freeze dried fruits, papaya and pineapple contained higher amount of calcium (13.97 ± 0.01 and 12.49 ± 0.03 respectively) while guava contained higher amount of phosphorus (12.13 ± 0.02). Moisture content is reported because it is important to maintain the moisture within a certain range, because residual moisture can affect the chemical and physical stability of the product. On the other hand, moisture content values will give variation in data when one reports in wet weight versus dried weight such as reporting nutritional values. Reporting data in dried weight values are more precise than reporting data in wet weight values; however it also depends on the objective of the research. Table **3** shows nutritional values of four fruits namely papaya, guava, pineapple and jackfruit. These data provide

Table 2: Vitamin C, Mineral and Moisture Content of Freeze Dried Papaya, Guava, Pineapple and Jackfruit

Freeze dried papaya		
Vitamin C (mg/100g)	**Minerals (ppm)**	**Moisture content (%)**
66.13±0.03 [36] 16.84±2.31** 3.80±0.03 [23] 54.07±0.83 [46] 49.00±0.00**	Phosphorus: 6.6±0.01 [36] Calcium: 13.97±0.01 [36]	15.29±0.01 [46] 18.70±0.50 [47] 6.90±0.01**
Freeze dried guava		
Vitamin C (mg/100g)	**Minerals**	**Moisture content (%)**
59.00±0.01 [48] 5.08±0.01 [23] 53.00±0.00**	Phosphorus: 12.13±0.02 [36] Calcium: 7.21±0.01 [36]	3.80±0.01**
Freeze dried pineapple		
Vitamin C (mg/100g)	**Minerals**	**Moisture content (%)**
1.80±0.01 [23] 14.00±0.01**	Phosphorus: 9.69±0.01 [36] Calcium: 12.49±0.03 [36]	3.4%±0.03**
Freeze dried jackfruit		
Vitamin C (mg/100g)	**Minerals**	**Moisture content (%)**
13.70±0.00**	Data not available	4.9% ± 0.5 [49] 3.3%± 0.5**

**, Laboratory results of this study, (IBD-UTM, Malaysia).

Table 3: Nutritional Values of Freeze Dried Jackfruit, Guava, Pineapple, and Papaya (Laboratory Results of this Study, IBD-UTM, Malaysia)

	Jackfruit	**Guava**	**Pineapple**	**Papaya**
Protein	3.6 %	5.2 %	4.4 %	6.5 %
Ash	3.4 %	3.2 %	3.3 %	3.9 %
Total carbohydrate	91 %	86%	89 %	82 %
Fat	0.7 %	2.0%	0.4 %	0.9 %

overall info for the purpose of labeling; however, nutrition labels do not impart the significant degradation of nutrients that may occur during storage.

Less scientific evidences were reported on the total phenolic compounds and carotenoids of the freeze dried fruits. Perhaps these can be the future research analysis to comprehend the physicochemical as well as the overall nutritional properties for the freeze dried fruits especially papaya, guava, pineapple and jackfruit.

CONCLUSION

In general, freeze drying causes minimal destruction of nutritional compound and also retains the original flavour and aroma of the fruits pulp. Nutritional characteristics of dehydrated fruits can be a marker to evaluate the quality of the products. In general, vitamin C, phosphorus and calcium retained in the freeze dried guava, papaya, jackfruit and pineapples characterize these products, which can be a valuable source of vitamin C and mineral contents. However, understanding nutrient data is quite complex, thus a complete physicochemical analysis is required to support the data and provide specific information.

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