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Drying and dehydration of fruits & vegetables

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Abstract
In human nutrition, fruits and vegetables play an important role towards making of a balanced diet and prevention of several chronic diseases. Fruits and vegetables provide 90% of the vitamin C and 60% vitamin A in the world. Fruits are a natural source of energy, vitamins, minerals, and dietary fiber. Typically contains between 10% and 25% carbohydrates, less than 1.0% of proteins, and a very small amount (less than 0.5%) of fat. Important fruit minerals include Ca, Mg, Na, K, P, Cl, and S and, in micro quantities, Fe, Cu, Co, Mn, Zn, I, and Mo. Potassium is the most abundant mineral in fruits followed by calcium (Kader and Barret, 1996). The minerals, vitamins, antioxidants, and dietary fiber content in fruits and vegetables might confer these health protective benefits.

Keywords: Drying, dehydration, vitamins and fruits and vegetables

Introduction
Tropics and subtropics are the stellar producers of a variety of fruits; majority if not all is perishable and prone to postharvest decay However, being perishable and highly seasonal in nature their availability becomes difficult besides it suffers from very high post-harvest losses and gluts. Value can be added to the agricultural and horticulture produce to increase the shelf life of the commodity. As India produces a variety of commodities, so there are ample of opportunity in the food processing for the entrepreneurs that includes areas like Bakery, Snacks, Beverages, Convenience, Food, Dairy, Meat and Poultry etc. Various institutions have developed technologies which has successfully adopted for entrepreneurship development especially for small and medium entrepreneurs. There are many challenges for small and Medium Enterprises in India, so innovation management in the food sector is very crucial. Food processing has been used to convert raw agricultural produce into edible, safe, healthy and nutritious food products and to preserve foods. The technologies should help in ensuring microbial and chemical safety, whilst improving nutritional quality, physical and sensory properties of food products. Food processing is an essential tool in feeding the increasing world population (Knorr and Augstin, 2021) [4].
The Food Processing Industry is pressurized to improve the quality and pace of its innovation processes. These all can be tackled by entrepreneurship in food processing (Negi, 2013) [7]. Traditionally fruits and vegetables are processed by various techniques into jam, ketchup, puree, pulp, juice, beverages and dehydrated products.
Studies indicate that the role of fruits together with their nutrients in the prevention of non-communicable diseases could be stronger than vegetables. This happens because fruits provide essential vitamins, minerals, as well as various phytochemicals that confer significant health benefits other than basic nutrition. Further, healthy eating has become one of the most important factors in food choice among governments and cultured consumers. They were conscious that more frequent consumption of fruit and vegetables should be a part of a healthy diet (Margetts *et al*., 1997) [16].
In order to develop convenient options of fruits and vegetables with enhanced functional attributed a diversified range of non-traditional products such as dehydrated slices/ fruit bar/ powder, vacuum fried, fortified, dihydro frozen, or ready-to- eat, ready to use, nutrient- dense diet are some of the new development in processed food sector. By using osmotic dehydration process, at ICAR-IIHR, Bangalore different fruits such as mango, pineapple, papaya, jackfruit, guava aonla etc has been successfully, developed and commercialized. Osmotic ally dehydrated fruit and vegetable slices and fruit bars are highly nutritious and suitable for using as snacks. Because of the growing consumer demand for healthy, natural and convenient foods, fruit and vegetable based snacks are becoming popular which would be an ideal food format for exploitation of benefits of fruits (Tiwari, 2019) [5].

Besides this, process for dehydration of other vegetables *viz*. onion, carrot, cauliflower, French bean, okra, pumpkin mushroom has also been developed. Dehydrated vegetables can be used in place of fresh vegetables in off-season and also for making vegetable soup etc.

The aim is that people should have access to a broad choice of technologies that are competitive and comply with food safety and quality standards which can be suitable employed for entrepreneurship developmental activities. A detailed account of processes/ technologies involved in development of novel kind of fruit and vegetables has been presented.

Food Processing Systems

Major aims of food processing

- Extend the shelf-life of food and serve as the surge capacity in nature's seasonal cycle. (*Supply-Demand*)
- Enhance the acceptability (flavor, color, texture) and safety of food. (*Tasty and safe*)
- Provide nutritious foods enhancing good health, strengthening bodies and empowering mind. (*Healthful diet*)
- Help build communities and generate income for the farmers and manufacturers. (*Business*)

Preservation techniques commonly used today are

Canning - by heat processing, Dehydration - by water removal, Freezing- at low temperature, Freeze-drying - Through sublimation, Pasteurizing - heat processing, Salting Pickling, Fermentation fermented product, Chemical preservation - use of chemicals like potassium metabisulphite, sodium benzoate

What fruit and vegetables can be preserved by freezing?

Practically any fruit and vegetable can be processed, but some important factors, which determine whether it is worthwhile, are:

- The demand for a particular fruit or vegetable in the frozen form;
- The quality of the raw material, i.e. whether it can withstand processing and retain nutritional qualities;
- Regular supplies of the raw material of required quality and quantities.

Even when a variety can be processed, it is not suitable unless large and regular supplies are made available. An important processing center or a factory cannot be planned just to rely on seasonal gluts; although it can take care of the gluts it will not run economically unless regular supplies are guaranteed.

Value added products from products of vegetables

Tomato: Canned whole or in form of pulp, puree, paste or juice and also in form of sauce or ketchup, dehydrated tomato slices.

Onion: Dehydrated (flakes, granules, powder), paste Peas - Canned, frozen, dehydrated

Okra: Canned, frozen, dehydrated Watermelon - Ready to serve beverage Cauliflower - Frozen, dehydrated

Carrot: Dehydrated, Frozen, juice

Beans: Canned, dehydrated, frozen

Mushroom: Canned, dried, frozen

Pickles: mixed vegetables like cucumber, cauliflower, carrot, peas

Consumer preference for Fruit & vegetable- need for the Development of diversified fruit and vegetable products

In this fast pace world, time is a factor which also affects eating habits and choice of food. Fruits and vegetables are neglected for consumption owing to the above reason, that any kind of fresh fruit and vegetable need a primary preparation which can be washing or peeling at least or for more type of fruits and vegetables operation may be many fold and it also requires specific place and instrument. One of the barriers in increasing fruit and vegetables consumption is time required to prepare them. Thus, it is not surprising that if it comes to fruit, consumers require product available in many outlets most of the year, suitable for many uses, with long shelf-life and not messy (Jesionowska *et al*., 2008) [17].

Processing

Processing of perishable has been a prime protector of food. The vegetables are processed into more stable products, that can be stored for extended period of time by canning, drying, freezing or through chemical preservation. Actually processing includes all the steps begins after harvest and ends before consumption of food. Normally handling, transportation, reception, temporary storage, washing, sorting, skin removal/peeling, size reduction i.e., dicing/slicing, blanching followed by either canning, freezing or drying.

Blanching

Blanching consists of heating the food rapidly to a predetermined temperature, holding for a specified time, then either cooling rapidly or passing immediately to the next processing stage. It can be done using hot water or steam. It is a must step before drying or freezing of vegetables to inactivate peroxidase enzymes. It helps clean the material and reduce the amount of micro-organisms present on the surface; preserves the natural colour in the dried products; it shortens the soaking and/or cooking time during reconstitution. Blanching time differs with type of vegetables.

Dehydration

Drying or dehydration is an age old technology. The removal of moisture prevents the growth and reproduction of micro-organisms causing decay and minimizes many of the moisture mediated deterioration reactions. Drying brings about substantial reduction in weight and volume minimizing packing, storage and transportation costs and enables storability of the product under ambient temperatures, features especially important for developing countries. As per requirements prepared fruits and vegetables are given different pre-treatments followed by drying using cross-flow air drier at temperature range of 55-60 °C. Different dehydration method are sun drying, solar drying, cabinet drying, vacuum drying, drum drying, spray drying, osmotic dehydration and freeze drying.

As per requirements prepared, vegetables are given different pre-treatments before they are subjected for dehydration. Vegetables are dried using cross-flow air drier at temperature range of 55- 60 °C. Examples of dehydrated products are dried onion flakes/onion powder, dried carrot slices, dried bean, cauliflower and dehydrated mushroom.

Open Sun Drying

Open sun drying has a profitable activity, but it has some associated problems like: damage due to rain, insect, dust and

dirt contamination. This results not only in deterioration in quality of produce but also affects appearance, nutrient quality and shelf life adversely

Solar drying

Solar drying is a continuous process where moisture content, air and product temperature change simultaneously by the solar radiation. The drying rate is affected by ambient climatic condition- temperature, relative humidity, sunshine hours, available solar radiation, wind velocity, frequency and duration of rain showers during the drying period. The hybrid solar drying has great potential to be incorporated into family agriculture, increasing the income and productivity of small farmers. The system is an excellent alternative for tropical regions with high solar incidence (Roratto *et al*., 2021) [9].

Raisins (Dried Grapes)

Raisins are used in food preparation and considered as delicacies. Manufacturing of raisins has been an important preservation industry in the grape growing areas of Maharashtra and Karnataka. Grapes with high TSS are found better for raisin making. Fresh grapes bunches are wished, sulphited, and then berries are dried under shade for making raisin. Thompson seed less and Arkawati varieties have been found to be suitable for raisin making.

Anardana

Dried seeds of sour var. of pomegranate are called anardana. It is used as an acidulant and also in the other industries. Acidic hybrid `***Amlidana***' has been developed at IIHR, which is suitable for anardana making.

Dehydrated French beans

`Dehydrated French bean is used in place of fresh vegetables and also in noodle and vegetable soups. Green colour, long, straight, tender pods of medium size, thick wall and small seed, lack of fiber or string are the desired qualities in varieties for dehydration. French bean varieties Arka Komal and Arka Suvidha released by ICAR-IIHR Bangalore are best suited for dehydration. The optimum maturity indices for these varieties are 17 days old pods weighing 6-7 g and 16 days old pods with weight of 5-6 g. The various steps in the dehydration process are given in the flow chart.

Chart for dehydration of French bean

1. Selection of suitable variety and harvesting at optimum maturity
2. Sorting, grading and washing
3. String removal, trimming and transverse cutting (2-3 cm)
4. Dipping in aqueous alkali solution for 30 min
5. Draining and thorough washing with clean water
6. Blanching in boiling water containing additives for chlorophyll fixation
7. Drying in cabinet drier at 55-60 °C to < 10 per cent moisture content
8. Packing in laminated pouches
9. Storage

Dehydrated onion:

Dehydrated onion flakes and powder are highly valued products in the international market and in great demand. Dried flakes, the major processed product of onion are derived by the process of dehydration in which the moisture content is reduced to a minimum optimum level of 5 per cent to prevent the growth of spoilage microorganisms. The reduction in weight and volume and also minimization of packaging, storage and transportation cost brings value addition. White variety of onion with high TSS (15-20 Brix) such as Arka Pitamber, RHR White, Pusa White Round are most desirable for dehydration. Since dehydration process results in the loss of some pungency and the product is mainly used as flavour enhancer, the onion meant for dehydration should possess high pungency. Dried onion slices, coarse powders and fine onion powders has extensive application in convenience foods as flavouring for meats, sausages, pickles, ketchup, chutney, bread, biscuits, snacks, salad dishes etc.

The basic steps involved in onion dehydration are selection of raw material, sorting, grading, peeling, washing, cutting into rings after topping and tailing, pre-treatment of slices in 6 per cent salt or 0.25 per cent potassium metabisulphite solution for 10 min followed by drying at 50-60 °C to a final moisture content below 5 per cent. Dehydrated onion deteriorates rapidly under open condition with high humidity. Hence, packaging with 400 guage LDPE pouches or air tight pet jars is essential.

Dehydrated carrot

Large size, fully matured carrots with high solids and carotenoid are preferred for dehydration. The carrot roots contain farm soil and needs thorough washing in clean water before peeling. The different steps of dehydration process are washing, lye peeling for 2 min, washing with water, slicing (5 cm), low temperature long time (LTLT) blanching in water containing sugar for better carotene retention, drying at 55-60oC to less than 10 per cent moisture content and packing in polythene bags or pet jars. The shelf life is one year under ambient conditions.

Dehydrated cauliflower

For dehydration, selected cauliflower heads are cut into individual florets (2.5 cm thick), washed thoroughly, blanched for 5 min. in boiling water (95 °C) to inactivate enzymes, reduce microbial load and to improve colour and texture dipped in solution containing preservatives and sugar. Pre-treated florets are dried at 50-60 °C to a moisture content of below 10 per cent. The hygroscopic nature of dried cauliflower necessitates its packing in pet jars or in polythene bags having moisture and light barrier properties. The shelf life is one year under ambient conditions.

Dehydrated Okra

Okra pods with bright green colour, less fiber and mucilage, straight type having medium length are preferred for dehydration. IIHR released varieties Arka Abhay and Arka Anamika have been found suitable for dehydration. In dehydration process different steps involved are washing, trimming of pedicel ends, blanching in an aqueous medium containing additives and preservatives for 2 min at boiling temperature, air cooling, drying in cabinet driers at 55-60 oC and packing in polythene bags or pet jars.

General applications of dehydrated vegetables

Commonly used Spice blends, Rice blends, Soup, Salad dressings, Sauces, Gravies, Salsas, Condiments,
Canned foods, Frozen foods, Snack foods, processed foods,

Dried fruits

Dried fruits, which serve as important healthful snacks worldwide, provide a concentrated form of fresh fruits. They are nutritionally equivalent to fresh fruits in smaller serving sizes, ranging from 30 to 43 g depending on the fruit, in current dietary recommendation in different countries. Fresh fruits are processed by various techniques to become dried fruits to prolong their shelf life. Dried fruits are a concentrated form of fresh fruits, albeit with lower moisture content than that of their fresh counterparts since a large proportion of their moisture content has been removed through sun-drying or various modern drying techniques, such as mechanical devices, solar drying, vacuum drying, spray drying etc. Fruits can be dried whole (e.g., grapes, berries, apricots, and plums), in halves, or as slices (e.g., mangoes, papayas, and kiwis). Dried fruits are important healthy snacks worldwide.

They also have the advantage of being easy to store and distribute, available throughout the year, and healthier alternative to salty or sugary snacks. Apples, apricots, dates, figs, peaches, pears, prunes, and raisins are referred to as ''conventional'' or ''traditional'' dried fruits. Meanwhile, some fruits, such as blueberries, cranberries, cherries, strawberries, and mangoes are usually infused with sugar solutions or fruit juice concentrate before drying the process is popularly known as osmotic dehydration through which various products have been standardised as well as reported (Tiwari, 2005) [15] in fruit like guava (Anitha *et al*. 2014) [1] banana (Thippanna and Tiwari, 2015) [14], aonla (Sumitha at al. 2015) [13] as well as vegetables such as carrot (Selvakumar and Tiwari, 2018ab) [11-12].

Dehnad *et al* (2016) in a recent review stated that drying is a complex process frequent in most of the food processing industries. The functional properties of food components, highly affected by the drying processes. It not only outlines the effect of drying/heating treatments on diverse biopolymers, but also compares the effect of each one (oven, sun, shade, solar, tray/cabinet, vacuum, freeze, fluidized bed, drum, and spray drying. High drying temperatures decrease the swelling capacity of carbohydrates and increase their susceptibility to breakdown during hydrothermal processes. For drying of carbohydrate sources, fluidized bed, especially at low temperatures, oven and freeze drying could yield final powders with higher functional qualities. Foam-mat, sun and freeze drying could yield better final functional properties of dried flours than oven, solar, cabinet/tray and hot air drying approaches. With microwave drying, functional properties, as opposed to nutritional qualities, could be maintained more effectively than other drying techniques, e.g. freeze drying. While application of infrared, as a novel dehydration technique, might not improve functional properties of food powders in comparison with other superior drying techniques, vacuum impregnation, another novel drying approach, could result in high saving of functional ingredients in food powders, higher anthocyanin content and better antioxidant properties of the final product.

Artificial type of drying of fruits and vegetables

is an important method of preservation and production of a wide variety of products such as slices, powder, chips, bar etc. Although, drying changes the physical and biochemical form of fruit and vegetable leading to shrinkage and change of colour, texture, taste etc. By use of suitable pre-treatments and drying methods, it could be possible to minimize these changes and make highly convenient products. One of such treatment is osmotic dehydration process. It improves product quality, needs less energy, helps in retention of nutritional characteristics, flavour and final product is of longer shelf-life.

The drying process may also cause changes in the physicochemical properties that could influence the final quality of the product. These modifications are changes in

- Optical properties (colour, appearance),
- Sensory properties (odour, taste, flavour),
- Structural properties (density, porosity, specific volume),
- Textural properties
- Rehydration properties (rehydration rate, rehydration capacity) and
- Nutritional characteristics (vitamins, minerals).

Osmotic ally dehydrated fruits and vegetable products

Demand for healthy, natural and tasty processed fruits is continuously increasing not only for finished product but also for ingredients to be included in complex foods such as ice creams, cereals, dairy, confectionary and bakery products. Osmo-air dried fruits are the dehydrated fruit products based on the novel approach towards dehydration. By using osmotic dehydration process, at ICAR-IIHR, Bangalore different fruits such as mango, pineapple, papaya, banana, *aonla*, jackfruit, guava, sapota and vegetables *viz*. carrot, pumpkin, beetroot, muskmelon has been successfully dehydrated in to shelf stable slices which can be stored at room temperature for one year. The quality of osmotic ally dehydrated product is near to the fresh fruit in terms of colour, flavour and texture. It can be consumed as a snack. Such product can be used in ready to eat type of foods, ice creams, fruit salad, kheer, cakes, bakery products etc.

Osmotic dehydration process

Osmotic dehydration has received greater attention in recent years as intermediate step in drying of several fruits and vegetables. Being a simple process, it has potential advantages for the processing industry for dehydration of tropical fruits with longer shelf-life. Osmotic dehydration process involves water –rich solid products being soaked in concentrated aqueous solutions (mainly sugar or salt solutions) which creates three types of counter current mass transfer: an important water out flow from product to solution; a solute transfer, from the solution to the product; it is thus possible to introduce the desired amount of an active principal, a preservative agent, any solute of nutritional interest, or a sensory quality improvement in the product; a leaching out of the product's own solutes (sugars, organic acids, minerals, vitamins etc.) in negligible quantity affecting composition of the final product.

Therefore, compared to single drying process, osmotic dehydration achieves a twofold transformation of the food items, by both a decrease in water content and a solute incorporation which may result in a subsequent weight reduction. Solute uptake during osmotic dehydration modifies the composition and taste of the final product. In many cases, however, extensive solute uptake is undesirable, because of its negative impact on the taste and nutritional profile of the product. Leaching of natural acids out of osmotic ally dehydrated fruit also affects the taste due to change in sugar

acid ratio. Further partial dehydration and solute uptake protect fruit slices against structural collapse during terminal drying.

The process is simple and involves operations like selection of fruits, cleaning, washing, peeling, curing and slicing/dicing. The prepared fruit slices are soaked in sugar solution to remove water by osmotic pressures. Then the slices are drained and dried in hot air drier. The dried fruit is packed in flexible pouches.

Parameters influencing osmotic dehydration

The process variables such as pre-treatments, temperature, nature and concentration of the dehydration solutions, agitation, additives, has been found to influence the osmotic process (Tiwari, 2005).

1. Composition -nature and molecular weight of the osmotic solute
2. Concentration of osmotic solution
3. Process temperature
4. Duration- immersion time
5. Pre-treatment
6. Agitation/circulation of osmotic solution
7. Food to osmotic solution ratio
8. Shape, size and thickness of fruit pieces (surface area)
9. Variety and maturity of fruits used.
10. Food structure (porosity etc.)
11. Pressure (high pressure, ambient or vacuum)

Advantages of Osmotic dehydration

Though many advantages have been attributed to osmotic dehydration, important ones are as follows:

1. Minimum lose of colour and flavour.
2. Flavour retention is more when sugar or sugar syrup is used as an osmotic agent.
3. Enzymatic and oxidative browning is presented.
4. Sweetening of the product.
5. Reduces the water removal lead at the dryer
6. Increases the solid density of the product, which can be subsequently freeze dried.
7. Textural quality will be better After seen situation.
8. Simple facility and equipments are required
9. Energy consumption is very less.
10. The process is less expensive.

Freeze-drying

Freeze-drying is the process of dehydrating frozen foods under a vacuum so the moisture content changes directly from a solid to a gaseous form without having to undergo the intermediate liquid state through sublimation. In this process, the product maintains its original size and shape with a minimum of cell rupture. Removing moisture prevents a product from deteriorating at room temperature. The process is used for drying and preserving a number of food products, including meats, vegetables, fruits, and instant coffee products. The dried product will be the same size and shape as the original frozen material and will be found to have excellent stability and convenient reconstitution when placed in water. Freeze-dried products will maintain nutrients, colour, flavour, and texture often indistinguishable from the original product.

Depending on the product and the packaging environment, freeze-dried foods are shelf-stable at room temperature for up to ten years or more, if canned, and between 6 months to 3 years if stored in a poly-bag container. The main determinant of degradation is the amount and type of fat content and the degree to which oxygen is kept away from the product. The Benefits of Freeze-Drying are it retains original characteristics of the product, including: colour, form, size, taste, texture, nutrients; cold storage not required; reconstitutes to original state when placed in water; Shelf stable at room temperature; the weight of the freeze-dried products is reduced by 70 to 90 percent, with no change in volume; the product is light weight and easy to handle; offers highest quality in a dry product compared to other drying methods.

Conclusion

Dehydration is widely used to preserve fruits and vegetables since the reduction of both their moisture content and water activity increases their shelf-lives significantly. For that, fresh foods are dried to reach a water activity that prevents microorganisms' growth and considerably reduces chemical and enzymatic reactions. Besides, drying adds value to fruits and vegetables and reduces storage and transportation costs, which is very important in countries with deficient transport systems. Therefore, food drying can be an opportunity to add value to products from small producers. If fruits and vegetables are dried where they are produced, this may reduce food losses and help small farmers to have a higher income. Food drying can be performed by different processes, such as convective drying, vacuum drying, freeze-drying and solar drying etc. However, during processing, undesirable changes in the sensory and nutritional properties of the food commonly occur which may be minimized by applying suitable pre-treatments. Convective drying is relatively cheap and is extensively used for the dehydration of fruits and vegetables. Application of osmotic dehydration will be useful for making fruits and vegetables based snack fruit. Fruit pulps can me dried to nutritional fruit bar. Solar drying has great potential to be incorporated into family agriculture, increasing the income and productivity of small farmers

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