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## A comprehensive review on nutrient rich dry vegetables and fruits

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## Abstract

Nutrient rich foods are relatively good in calories or other factors, also high in nutrients like vitamins, minerals and protein, low in calories. Vegetables and fruits are regarded as the fuel for all the physiological processes in our body. In the total produce, about 25-30% is wasted from the farm production to the consumer's plates during handling. Applying appropriate methods, this wastage can be effectively reduced by processing and preservation. The importance of nutrients and drying technology for vegetables and fruits has not been well documented in earlier studies. In this regard, this study relies on the review of vegetables and fruits that have been traditionally processed to extend their storage life well beyond a few weeks. Drying vegetables and fruits make them available in off season and they also contain high fibre, carbohydrates, low in fat, making them healthy food choices. Youngsters prefer instant foods in their daily diet to maintain the time factor and their busy schedule. Dry fruits have higher carbohydrate content than fresh fruits; therefore, serving sizes of dry fruits tend to be smaller. According to USDA's Dietary guidelines half cup of dry fruits are equivalent to one cup of fresh fruits. At the time of large-scale production, vegetables and fruits are converted to value-added dry products. In most of the villages in Tamil nadu, people have been drying fruits and vegetables in summer season and using them for the winter season since ancient times. Perishable commodities like fruits and vegetables must be sold for the off - season to increase the income of the farmers. To date, there is no review on the drying of vegetables like cluster bean (*Cyamopsis tetragonoloba*), lady's fingers (*Abelmoschus esculentus*), turkey berry (*Solanum torvum*), bitter gourd, (*Momordica charantia*), ivy gourd (*Coccinia grandis*), fruits like mango (*Mangifera indica*), lemon (*Citrus limon*) and amla (*Phyllanthus emblica*). As a result of drying, the crispy brown fruits and vegetables obtained are stored in air-tight containers for a period of 6 months to one year. The process of drying to fruits and vegetables, increases storage stability, minimises losses, reduces packaging, requirements of handling and makes transportation easier and cheaper due to reduced weight and volume.

## 1. Introduction

Food dehydration removes water from fruits and vegetables which prohibits the growth of bacteria. Drying minimally affects the nutritional content of food and vitamin A is retained. Many vegetables contain cardiac glycosides, flavonoids, saponins, tannins, terpenoids, alkaloids and phlobatannins (Amarapalli Geetha *et al.*, 2024) to contribute to their therapeutic properties. Dry fruits and vegetables are rich in fibre, carbohydrates and fat is less, making them good food choices. Dry foods are nutritious, lightweight, tasty, easy to prepare and easy to store. In developing countries, home food drying remains popular as an alternative to canning (Wilhelm, 2004). Due to the high water content of about 80%, fresh fruits and vegetables are highly perishable (Kaleta, 2013). Drying fruits and vegetables not only inhibits the growth of microorganisms, but also halts the other moisture-driven deterioration reactions and browning. Thus, drying preserves the characteristics, structure and nutritional value of the original materials (Kara *et al.*, 2016). The drying of fruits and vegetables, more importantly, minimises losses, enhances storage

stability, reduces packaging and handling requirements, and makes transportation easier and cheaper because of reduced volume and weight (Kaleta *et al.*, 2013). 20% moisture content is the optimum recommended moisture level for dry fruits and vegetables. Moisture removal prevents the growth and reproduction of microorganisms to bring a substantial reduction in weight and volume, minimizing, storage, packing and transportation costs and it also enables the storability of the product under ambient temperatures. Currently, hot air drying is the most widely used method in post-harvest technology of agricultural products. Dry fruit has a higher carbohydrate concentration than fresh fruit; therefore, serving sizes of fruits tend to be smaller. Nowadays, youngsters prefer processed foods since they do not know the vegetables processing at home.

According to USDA's dietary guidelines, one cup of fresh fruit is equivalent to half a cup of dry fruit. Foods intake influences the immune function, inflammation, and overall metabolic equilibrium of the body (Pidigam Saidaiiah, 2024). When planning to take dry products, diabetic persons are advised to take smaller serving sizes to avoid high blood glucose levels. During handling 25-30% of total farm products are wasted from production point to consumer's plates. It is clear that much of the carbon emission of food is contributed by the production, packaging, storage, transportation, modification, quality control, and other related logistics. Correlation between food

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consumption and carbon footprint in diets is important. The sources of carbon footprint of daily diet consumption are higher in animal based foods compared to plant-based diets. By applying processing and preservation techniques, this wastage can be effectively minimized. Hence, traditionally processing of the vegetables has

been applied to extend storage life of them well beyond a few months and make it available in the season.

## 2. Processing of vegetables and fruits

Simpler methods are adapted for the processing of vegetables and fruits as follows (Table 1 and Figure 1).

**Table 1: Processing of vegetables and fruits**

Crop	Processing methods	Dryness test
<i>Abelmoschus esculentus</i> (Dry lady's fingers)	Okra is thoroughly washed and sliced into 5 mm thicknesses. Uniform distribution of the slices in a single layer in the tray, and then it is dried in hot air dryer at 40-80°C.	Brittle, dark green to brownish.
<i>Solanum torvum</i> (Dry turkey berry)	The cleaned turkey berries are soaked in the buttermilk with salt. Shake it well until the buttermilk gets completely coated over the berries. The process is carried to reduce the bitterness and is allowed to dry until it turns completely brown for about ten days and the berries are almost dry. Once after attaining the final crispy stage, it is stored in an air-tight container. It remains fresh for 6-12 months on proper drying and under good storage conditions.	Crispy nature of berries.
<i>Cyamopsis tetragonoloba</i> (Dry cluster bean)	Custer beans are washed thoroughly. If the beans are very long, it can be chopped into halves. 4-5 cups of water is heated in a sauce pan. To the boiling water, turmeric powder and salt are added. It is boiled for 4-5 min just to make it absorb the salt and turmeric powder and it is dry in the same manner for 5-6 days or until it is completely dehydrated.	Brownish and crispy stage of beans.
<i>Momordica charantia</i> (Dry bitter gourd)	Wash and cut them into thin circles. The seeds are removed and sprinkle the salt and turmeric powder over the de-skinned slices. Mix them gently or toss them gently and close pan lid. Keep it aside for 15-30 min. and after 30 minutes, discard the water. Keep it under sun-light for 2-3 days pieces become crisp.	The greenish to brownish brittle stage is the final nature.
<i>Coccinia grandis</i> (Dry ivy gourd)	Pieces are put in a sauce pan and cooked in water along with turmeric powder and salt for 5 min, the flame is switched off and water is dried and is allowed to dry completely under sun for 2-3 days.	The crispy brown nature.
<i>Mangifera indica</i> (Dry mango)	Raw mangoes are washed well and slice them into slightly big pieces. Rock salt is added and mixed well. Toss it to coat the salt evenly. The container is closed with a lid for 2 h. Spread it in a tray to sundry.	Bone dry stage, brown.
<i>Phyllanthus emblica</i> (Dry amla)	Clean, wash and wipe water from amla chop into pieces and discard the seeds present in them and mix turmeric powder and salt. Sundry it for 5-6 days, mixing them in between is necessary.	The pieces turn crispy and dark brown.
<i>Citrus limon</i> (Dry Lemon)	Lemon is sliced up and put salt to dry it, until the lemon is dry and crispy. At night bring the lemon inside to prevent spoilage and contamination by insects. A quick way is using a dehydrator or oven to dry lemon. Before drying the lemon, wash it with warm water. The slices are arranged in a large on dehydrator trays. The trays are placed in the dehydrator for 6-8 h.	Brittle, crispy and brownish nature.
<i>Solanum nigrum</i> (Dry black nightshade)	Berries are washed and soaked in buttermilk, with salt and turmeric. The following day, the liquid is squeezed and the berries are dry in the sun. After sun drying, it is again soaked in the remaining buttermilk. This is continued till no liquid is left. After that, with a day of sun drying, it will turn dry and crisp.	The berries turn brown and crisp.



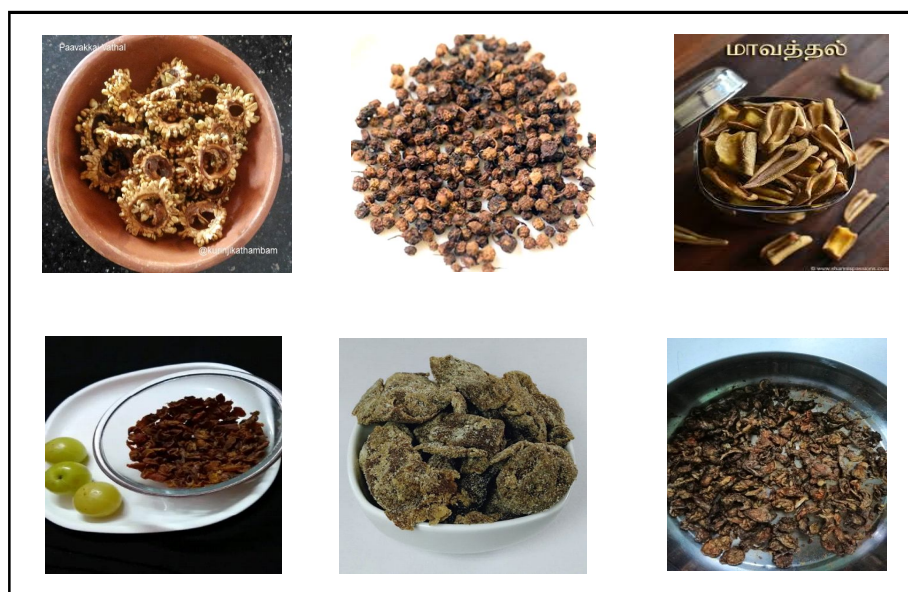


Figure 1: Dry vegetables and fruits.

### 3. Nutritional compositions of dry vegetables and fruits

#### 3.1 *Abelmoschus esculentus* (Dry lady's finger)

The young immature okra pods can be consumed in different forms (Ndunguru and Reijabee, 2004; Akintoye *et al.*, 2011) and are a good source of minerals such as potassium, magnesium, vitamin A, vitamin K, calcium and folate. Okra chips also maintain good bone strength, reducing the risk of coronary heart disease and are potent in health-boosting effects. Researches are going on to study other potential benefits and several studies have focused on the potential anti fatigue activity and remedies of okra. More research is needed on the okra seeds for antioxidants, endurance and energy levels. Several studies recorded that dehydrating okra preserves high antioxidant content and hypo cholesterol effect (Rossetto *et al.*, 2002). The presence of iodine (Ars, 2014) iron, zinc, manganese and nickel also has been reported (Moyin-Jesu *et al.*, 2007). Both pod skin (mesocarp) and seeds are excellent sources of zinc (80 mg/g) (Cook *et al.*, 2000). Dry okra sauce does not provide any beta carotene or retinol (Avallone *et al.*, 2008). However, viscous fibre content is rich in fresh okra pods, an important dietary component to low the cholesterol level (Kendall *et al.*, 2004) and are an excellent source of soluble fibres that reduce bad cholesterol levels, reduce blood sugar and have anti-inflammatory properties. These effects produce less risk of heart disease (Zaharuddin *et al.*, 2014), okra pods contain lectin, a protein may help to prevent cancer, stop the tumour growth and to kill breast cancer cells. Researches indicated that okra proteins are potential use of skin cancer treatment. It may benefit brain function and act as antioxidants, antistress and memory boosting effects in Traditional Chinese medicine and to treat anxiety disorders and dementia, antidepressant activity (Atawodi *et al.*, 2009). In some countries, *A. esculentus* is also used as an antiulcerogenic, gastroprotective, and diuretic agents in folk medicine (Gürbüz *et al.*, 2003). Further, *A. esculentus* extract may keep bacteria called *H. pylori* from attaching to the stomach, thereby guarding against gastritis, stomach inflammation due to bacterial infection. It has long been used in traditional medicine for this purpose (Messing *et al.*,

2014). Lastly, isoquercitrin in okra is believed to protect against oxidative stress, help prevent chronic inflammation, and slow muscle loss in mice treated for denervated muscle atrophy. Fruit mucilage of *A. esculentus* is a protective food additive against inflammatory gastric and irritating diseases.

#### 3.2 *Solanum torvum* (Dry Turkey berry)

*S. torvum* contains highly nutrients with various components such as proteins, carbohydrates, fats. Minerals like potassium, sodium, iron, magnesium and copper and phenols, alkaloids, antioxidants, sterols and triterpenes are also present in it (Cuda *et al.*, 2002). Potassium is recommended to maintain proper fluid balance and heart muscle function (Tomita *et al.*, 2002). After drying, potassium content in turkey berry ranges from 695 mg/100 g to 1660 mg/100g to manage pain and inflammation and to treat conditions like arthritis; dry seeds are commercially used for medicine. Vitamin C in turkey berries, which converts iron into a more readily absorbable form, may enhance immunity to fight against infections (Lu *et al.*, 2009). Dry turkey berries might help reduce blood glucose levels in various researches and it might be due to the phenols in turkey berries that lower the blood glucose level to managing diabetes. It may inhibit the progression of cancer cells and have the potential to reduce blood pressure by relaxing the blood vessels which may positively impact on blood pressure.

#### 3.3 *Cyamopsis tetragonolobus* (Dry cluster bean)

*C. tetragonolobus* is a good source of fibre, protein, carbohydrates, calcium, and iron. Hence, incorporating cluster beans provides a balanced diet that can support weight management efforts (McCrory *et al.*, 2010). The high fibre and protein content in these beans promote satiety, keeping feeling fuller for longer periods and reducing overall calories and fat, making them a nutritious choice for those looking to maintain a healthy weight (McCrory *et al.*, 2010). For individuals managing diabetes or seeking to regulate blood sugar levels, incorporating cluster beans into their diet may prove beneficial. These beans have a low glycaemia index (Jenkins *et al.*, 2012) meaning they

cause a gradual rise in blood sugar levels, which can help prevent spikes and crashes. The soluble fibre found in cluster beans slows down the glucose absorption, contributing to improved glycaemia control (Pascale *et al.*, 2018). Dietary fibre is essential for good gut health and acts as a laxative to become bulky and helps in regulating bowel movements and protects colon mucous membrane from cancer causing chemicals (Somraj *et al.*, 2024). Fruits like lasoda, jamun are rich source of dietary fibre. The high fibre and potassium content aids in lowering cholesterol levels and regulating blood pressure. Thereby reducing the risk of heart disease and stroke (Hermsdorff *et al.*, 2011) and beans are packed with calcium, an essential mineral in

bolstering bone strength and reducing the risk of bone thinning. Additionally, these beans are rich in phosphorus, and vitamin K and vitamin C (Table 2), promoting overall bone wellness (Messina *et al.*, 2014). Making dry cluster beans is a part of our daily diet can make our immune system stronger (Rebello *et al.*, 2014) and researchers found that extracts from dry cluster beans can fight against harmful bacteria such as *S. typhimurium* and *E.coli*. It might also boost the strength of the stomach's protective layer, offering a shield for the inner surface of the stomach. Additionally, dry cluster beans might assist in lowering the swelling linked to ulcers, potentially aiding in the healing process (McNabney *et al.*, 2017).

**Table 2: Nutrient content in dry fruits and vegetables of 100 g**

Nutrient content (Value per 100 g)	Dry Turkey bean berry	Dry Cluster guard	Dry bitter guard	Dry Ivy gourd	Dry Mango	Dry Amla	Dry Lemon	Dry Black night shade
Protein (g)	2.4	3	0.84	-	1	-	1	5
Carbohydrates (g)	10.7	5.31	4.32	0.0064	33	80	70	68
Fibre (g)	6.1	3.7	2	-	1	3.3	8	-
Fat (g)	0.4	0.31	0.18	0.1	-	-	-	1
Potassium (g)	1.6	-	-	3.1	11.7	-	-	-
Calcium (mg)	104	156	-	40	-	133	-	410
Phosphorus (mg)	70	-	-	-	-	-	-	70
Magnesium (mg)	61.1	-	-	-	-	-	-	-
Iron (mg)	4.6	3.96	-	1.75	0.5	0.6	0.17	20.5
Ascorbic acid (mg)	4	2.3	-	1.56	3	-	4	-

### 3.4 *Momordica charantia* (Dry bitter gourd)

Indigenous tribes utilised the energy value, fats, carbohydrates content, fibre, protein, salt and sodium in bitter gourd for a very long time. In all over the world bitter gourd help to cure issues related to diabetes due to its strong therapeutic potential (Leung *et al.*, 2009). Charantin alkaloids in a bitter gourd imitate insulin hormone controls unexpected blood sugar surges. It is high in soluble fibre to consider it as a best vegetable for diabetics with strong hypoglycaemic effect (Snee *et al.*, 2011). The lipid metabolism is also influenced by bitter gourd for an antiobesity impact to lower fat build up. Dry bitter gourd target adipocytes specifically which may leads to decrease the body's fat reserves (Alam, 2015). Vitamins A and C, are both good for the skin, are abundant in *M.charantia* (Apak *et al.*, 2004). Proliferation of cancer cells and formation of tumours prevention (Cadenas *et al.*, 2002) are done by bitter gourd due to antioxidants profile, to treat cancer, hair, and skin issues. It enhances blood circulation, to promote better health efficiently. It is the ideal supplement for respiratory health because of its antihistamine, antiinflammatory, expectorant, suppressant and antiviral characteristics. It also improves liver enzymes and advantageous for the bladder and intestines functions. Consuming bitter gourd juice instantly relieves haemorrhoids (Kagan *et al.*, 2002) and a therapeutic agent for tissue regeneration, wound-healing properties and proliferation of dermal fibroblasts in humans (Tan, 2016). Malignancies of blood, cervix, nose, and pharynx are inhibited. Seeds, fruit, and leaves contain alpha and beta-momorcharin proteins to show anti-HIV activity *in vitro* (Au *et al.*, 2000) and also suppress of HIV-1 integrase (Au *et al.*, 2000). MRK29 protein also

found in bitter gourd is able to inhibit the viral reverse transcriptase (Wang *et al.*, 2001).

### 3.5 *Coccinia grandis* (Dry ivy gourd)

The nutrients, total fat, carbohydrate, potassium, calcium, vitamin C and iron content of dry ivy gourd are represented in Table 2. It increases glucose tolerance (Medagama *et al.*, 2014) and has antiobesity properties, hypoglycaemic effect. In many Indian recipes, it is used because of minerals, nutrients, vitamins and anti oxidants for immune boosters. It is a healthy energy boosting vegetable to cure some nerve and genetic diseases (Hosseini *et al.*, 2015; Zaini *et al.*, 2011). The calcium content can be combined with other vegetables to treat kidney stones (Yadav *et al.*, 2010). For ageing, the antioxidant properties of ivy gourd scavenge the free radicals and other degenerative illnesses (Kurutas *et al.*, 2015). High content of alkaloids, steroids, tannins, terpenoids, saponins, and flavonoids in ivy gourd make it as a natural remedy for diabetes, leprosy, bacterial infections and other allergic conditions (Wasantwisut *et al.*, 2003). Flavonoids present in fruits of ivy gourd acts as a good antioxidant (Ramachandran *et al.*, 2014; Sims *et al.*, 2003).

### 3.6 *Mangifera indica* (Dry mango)

Dehydrated mangoes are good for health (Sadler *et al.*, 2019) as dry mangoes are a good source of iron, it is highly recommended for pregnant women and anaemia people (Pardo-Andreu *et al.*, 2006). People suffering from acidity should also have at least one serving of dry mangoes every day as it helps in combating acidity (Carvalho *et al.*



*al.*, 2007). Dry mangoes are a rich source of vitamin A and vitamin E, selenium which helps in various heart related issues. The active ingredients and antioxidants with the soothing inflammation on skin, improve regrowth, and reduce the chances of early ageing (Jain *et al.*, 2013). They are also a good source of dietary fibre and carbohydrates to satisfy appetite. It helps in balancing the level of bacteria in the gut (Koubala *et al.*, 2013). The assorted minerals and vitamins present in dry mangoes are good for boosting bone mineral density and lessening the risk of suffering from osteoporosis (Wang, 2015). Beta-carotene in dry mangoes acts as an antioxidant that reduces macular degeneration and slows the onset of cataracts (Khalid, 2020). Mangiferin has anticancer properties (Gold-Smith *et al.*, 2016) to eradicate *Helicobacter pylori* that are responsible for chronic gastritis, ulcer and gastric cancer (Zhang *et al.*, 2017).

### 3.7 *Phyllanthus emblica* (Dry Indian goose berry)

According to studies, dry amla are used for different types of skin disorders and effective in treating scabies, dry skin, and wrinkled skin. Hypocholeretic effect of dry amla reduces triglyceride levels to pose the risk of heart health (Zhao *et al.*, 2015) and photo protective effects to protect skin from harmful UVB radiations (Zanwar *et al.*, 2013). Amla extracts have shown anticancer properties according to several studies and are used to prevent cancer. Amla is rich in antioxidants to reduce cell damage and to control the cancer risk (Zhao *et al.*, 2015). Another significant benefit is to regular bowel movement and to avoid constipation. Dry amla fruit works as a gastro protective agent (Zanwar *et al.*, 2013), enhances blood circulation in the scalp stimulate hair growth, manage dandruff problems and to prevent premature greying (Hashem-Dabaghian *et al.*, 2018).

### 3.8 *Citrus lemon* (Dry lemon)

Dry lemons are an excellent source of the antioxidant (Gattuso *et al.*, 2007) to prevent free radicals from causing cell damage and cancer. People with bronchial hypersensitivity with a common cold are benefitted by dry amla (Gattuso *et al.*, 2007). High intake of vitamin C can trigger collagen formation, GI tract problems and C may boost immunity in people who are undergoing extreme physical activity (Han *et al.*, 2017).

### 3.9 *Solanum nigrum* (Dry black nightshade)

Solanigrines, saponin, riboflavin, nicotinic acid and vitamin C present in black nightshade (Stephen *et al.*, 2015) and contains solanine, solasonine, solamargine, solasodine, diosgenin, tigogenin, and vitamins A and C of *S. nigrum* has been used in traditional folk medicine to treat different cancers. Black nightshade is a hepatoprotective, antiinflammatory agent (Manivannan *et al.*, 2022) and it has calcium availability up to 40% to reduce urinary infections and also clears constipation.

## 4. Conclusion

Enormous amount of seasonal fruits and vegetables produced are wasted due to lack of storage facilities. Since, the commodities are highly perishable, they cannot be stored for a longer period, are preserved by post-harvest drying. During large scale production, vegetables are converted to value added dry products to minimise losses, enhance storage stability, reduce packaging and handling requirements, make transportation easier and cheaper because of reduced weight and volume. To increase the shelf life of these produce,

drying technology may be followed by farmers to make vegetables and fruits availability even during the off season. This technology leads to an increase in income generation to self help groups and it is an industry for farmers to foreign export of dry vegetables and fruits. More research is needed on new crops and foods that can withstand adverse environmental conditions.

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## Conflict of interest

The authors declare no conflict of interest relevant to this article.

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