



Impact of different processing techniques on therapeutical potential and quality parameters of pepper

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Abstract

Bell peppers are very nutritious with higher content of vitamin C and capsaicin which is used in medical departments, food and insecticides industries. Almost 11,698 pounds of bell peppers for fresh market are grown worldwide. Approximately 70% of bell pepper produced in Asia. Bell pepper production in Pakistan is 2.5 tons hectare⁻¹. Almost 40% of bell pepper waste in Pakistan. The higher antioxidant levels in bell peppers are linked with the prevention of various disorders such as Cancers and cardiovascular diseases. Moreover, Vitamin C, E and β -carotenes are also present in higher concentrations. Vitamin C plays an important role to produced collagen in the body which is essential for healing wounds and farming connective tissues. It supports the immune system and increase the absorption of non- haemoglobin iron. There is different method to control the bell pepper waste. In this review, different conventional preservation techniques used to preserve the bell peppers like freeze drying, freezing, cooling in trays, canning and hot air drying, refractive window drying, smoke dehydration, shade drying, solar drying, sun drying and osmotic dehydration. Freeze drying method is found most effective drying methods to preserve the capsaicin content.

Keywords: bell pepper, antioxidant, preservation techniques, capsaicin, dehydration

Introduction

Globally, vegetable consumption is one of the most encouraging nutrient sources for all age group. Vegetables are preferred over meat due to its cost effective and rich nutritional profile. Among various vegetables, pepper is liked most abundantly owing to its unique shape, brilliant colours, and excellent flavour. Bell pepper has been originated since the start of civilizations. The ancient ancestors of wild chilli paquin which is selected by the people for various types today. However, there are about 20 wild species that have been come into document (Nadeem *et al.*, 2011) [34].

In certain areas, plant genus capsicum whose fruit pepper is an essential component of human food. The Capsicum genus comprises a substantial community of plants, with the key economically valuable species consisting of *C. annuum L.*, *C. pubescens*, *C. baccatum L.*, *C. frutescens L.*, and *C. chinense* (Sikora *et al.*, 2014) [45]. It is used as a flavoring agent as well as health promoting agent in sauce, soups, and stew due to free cholesterol and low sodium contents. It is used as a flavoring agent as well as health promoting agent in sauce, soups and stew due to free cholesterol and low sodium contents. In all over the world pepper is 2nd important vegetable after tomatoes and provides excellent flavor and colors. African sorghum, maize porridge and different dishes would be tasteless without pepper. Flavonoids and carotenoid are vital colorants in fruits and vegetables which impart red and orange colors (Solovchenko *et al.*, 2019) [46].

Bell pepper and other members of pepper are most popularly consuming spices throughout the world (Orobiyi *et al.*, 2015) [35]. It contains higher amount of vitamin C and capsaicin. Vitamin C and capsaicin used in insecticide industries as well as in medical drugs institutes for

prevention of diseases. These two contents used to determine quality of pepper in international market. Bell pepper is cultivated all around the world for its economic and nutraceutical value (Rahman *et al.*, 2013) [38].

Mould, fungi, yeasts, and bacteria are generally growing on pepper products of various degrees, and it's therefore advisable to handle them either at start or before their usage in consumable food products. To eliminate microbial spoilage and reduce degradation reactions, different pre-treatment processes, such as chemical, dehydration, blanching and osmotic are used in processing of chilli. Physical, structural, chemical and biochemical changes occur during processing of fruits and vegetables, which influence quality characteristics such as color and texture (Di-Scala *et al.*, 2008) [17]. Fruits and vegetables are high in nutrients that aid in the prevention of a variety of illnesses. With Allah's blessings, Pakistan boasts a diverse range of fruits and vegetables that have yet to be fully explored (Atta *et al.*, 2017) [5].

Hot pepper bioactive components anti-inflammatory, analgesic and antioxidant properties, as well as their hypoglycemia and hypolipidemic potential have recently piqued attention. A variety of features, including A-biotic and biotic stresses, genotypes, cultivation techniques, maturity stages, and harvesting time, have been found to influence the nutrition, content of phytochemicals and compositional quality in different genotypes, varieties or cultivars of bell peppers. Chilli peppers are extensively consumed throughout the world and are high in vitamins A, C, E and folate, suggesting that they may help to relieve nutritional deficits in both developed and developing nations (El-Tanboly *et al.*, 2021) [19]. As a consequence, chilli fruits are in great demand round the year. Fresh chilli fruits on the other hand, are perishable and need special handling during

transportation and storage to avoid economic losses. Pepper products are often discovered to include mould, spores, yeasts and germs. Therefore, they should be treated at the manufacturer or before being used in perishable meals. To prevent microbial spoilage and minimize degradation processes, chili fruits are prepared using a variety of techniques including chemical pretreatment, hot water treatment, blanching and osmotic dehydration (Sanatombi and Rajkumari, 2020) ^[43]. Drying, on the other hand, causes nutritional, structural, physical and chemical changes in fruits and vegetables, altering qualitative characteristics including color and texture. The physical characteristics as well as the nutritional content of dried foods have been found to be affected by these pretreatment techniques. Furthermore, various cooking methods (steaming, boiling, roasting and stir-frying) may change the physical and chemical content of food. The impact of different processing methods on the biochemical or nutritional and value of different bell peppers or capsicum species has also been investigated. As the bell pepper processing technique changes, it can alter the quality of seed, physical characteristics, bioactive components, and nutritional value of the entire bell pepper (Rybak *et al.*, 2022) ^[40]. To ensure safety of food (required standards of microbiological quality) and quality of food, pepper must be treated using appropriate controlled processing techniques (aesthetic value or nutritive, rheological or texture characteristics, shelf life and preservation importance). From a dietary and nutritional standpoint, it's critical to recognize any changes that occur under various processing circumstances. As a result, the current study examines how different processing methods affect pepper quality and nutritional content (Sanatombi and Rajkumari, 2019) ^[44].

History and Classification of Bell Pepper

1. Common name of pepper

Castilian word 'pimiento' shows Capsicum species. Non pungent, thick-walled and heart moulded 'pimiento' in USA

from the species *Capsicum annuum*. In Mexico, Southwestern USA and Central America, the basic name of pepper is 'chile'. In Asia, the spelling is increasingly normal and constantly connected exceptionally sharp assortments of *Capsicum frutescens* and *Capsicum annuum*. Due to "Capsicums" family called non-pungent and sweet pepper. In American and British, it is generally called Chili Pepper and pepper. Shimla Mirch is generally known in Pakistan (Grubben and Denton, 2004) ^[26].

Capsicum annuum or Pepper is name for plants of the Capsicum genus of the Solanaceae family, whose seeds and fruits are consumed as spices and vegetables (Luna-Ruiz *et al.*, 2018) ^[31]. It may be eaten raw or cooked and is often used in pickles, sauces and pastes. In the culinary 12 industry, red ground pepper is used as a spice and flavoring component. It's prepared from dried and crushed hot red peppers. The increasing demand for shelf stable, high-quality, processed or dried veggies necessitates the modification in drying process, design and simulation in order to improve not only the process' efficiency but also the dry products quality. Vegetables lose quality after drying because of physical, structural, chemical, nutritional and organoleptic change. Although water activity is decreased (to the extent that microbe's activity and other bio-chemical reactions are inhibited) but texture, mechanical qualities, nutritional benefits, physical properties and other factors are maintained (Chenlo *et al.*, 2006) ^[11].

2. Verities of pepper in Pakistan

There are many varieties grown in Pakistan are Talhari, Narvala, Tatapuri, Ghotki, Longi and Qaisar from total area whereas, Kunri-I, Longi, Ghotki and Sanam chili production 50% is under Sindh. However, mainly famous varieties are Nageena, Dasi and Maxi grown in Kunri known as "Kunri chilli bunch". However, numerous other forms of this species are also grown on a commercial scale. Some are paprika, jalapeno and pimento jalapeno (Arin, 2019) ^[4].



Fig 1: Illustrated diagram of (A) Yellow Bell Pepper and (B) Red Bell Pepper

3. Top chilli producer and exporter

India (25%), China (24%), Spain (17%), Mexico (8%), Pakistan (7.2%), Morocco (7%) and Turkey (4.5%) are the top chilli producer and exporter (Arin, 2019) ^[4].

4. Colour of pepper

Most peppers (*Capsicum annuum*) are green in colour. Yellow, red, orange, white, dark, and purple bell peppers are also present in market. While pepper utilization in the

United States has been widely used in the previous 10 years, constrained data is accessible on how their shading, retail cost, and vitamin C content impact customer inclinations (Frank *et al.*, 2001) ^[13].

5. Crop type

Peppers can be full-grown as a perennial or annually, in fields and in greenhouses, under protective covers (Bosland and Votava, 2012) ^[6]. Peppers are cultivated globally and used commercially due to their medicinal and nutritional attributes (Rahman *et al.*, 2013) ^[38]. Optimum day time temperature for growth of chili pepper is 20°C to 30°C.

The chilli cultivated is recommended from 15th March ahead, but Southern Mirpurkhas growers plant it in February. The appropriate weather for the optimal growth is dry, humid, clean and warm. Ideal day time mean temperature for better chili development is 20-25°C and evenings underneath 20°C. Chili can flourish well in warm climate in sandy topsoil type soil with a pH range of 5.5 to 8.5 (Al-Isawi *et al.*, 2016) ^[1]. Furrowing twice with form board furrow is prescribed before transplantation. For soil setting one month in front of bed making, very much decayed yard compost should be fused at the range of 25-35t/ha one month before seed bed arrangement.

Before transplantation, phosphorus, nitrogen and potash should be together mixed in the soil at the range of 70-80 kg, 35 kg and 50 kg per hectare, respectively. At the time of fruit setting 25 kg per hectare of nitrogen might be applied as valuable portion. Enormous utilization of nitrogenous manure should be evaded as it increments vegetative development and defers development, chili loves potassium. Yield obtain should began when pepper reach to completely aged, stage with red shading. Organic products dampness should be 70-75% at the time of collecting and become 8-10% in the wake of drying (Arin, 2019) ^[4].

Health benefits

Capsicum annuum is high in lipids, proteins, fibres, ash, vitamins and compound capsaicin (Chigoziri and Ekefan, 2013) ^[12]. It is used to control diseases mainly obesity, stomach and colon cancer (Rezvani *et al.*, 2013) ^[39].

Presently healthy diets are popular as many consumers enjoy the benefits of a more balance diet including numerous fruits and vegetables. In South America, pepper is very popular vegetable due to their excellent flavour and colours (Silva *et al.*, 2014) ^[45]. It is considered as a salt sensitive plant (Erel *et al.*, 2019) ^[21].

Pepper has a place with the yields that are developed all over the world for their dietary, therapeutic and monetary worth (Rahman *et al.*, 2013) ^[38]. Individual from the Solanaceae family, bell pepper is accounted to be plentiful in proteins, lipids, fibers, mineral salts, vitamins and in capsaicin. Crispy green pepper and red pepper contains higher amount of vitamin C then citrus family as well as higher amount of vitamin A as compared to carrots (Chigoziri and Ekefan, 2013) ^[12]. Bell Pepper is responsible for the weight control and is helpful in the control of malignant of the stomach and colon (Rezvani *et al.*, 2013) ^[39]. It is utilized in sauces, soups, and stews large as an enhancing flavour (Chigoziri and Ekefan, 2013) ^[12].

In brine solution the red bell paper is stripes, resulted in increased total solids, water loss and tissue softening. Furthermore, as compared to undamaged red bell pepper, PEF dealing prior to freeze-drying decreases shrinkage by

about 30%. Non-thermal processing, on the other hand, results in more than simply physical modifications. Many chemical and biological alterations in plant tissue also affect the value of the end product. The proper selection of processing parameters to better product quality which often requires considerable research to optimize the process. Hybrid drying methods, on the other hand, have been more popular in recent years as a means of enhancing material quality. Several pretreatments are often coupled with one or more subsequent drying processes in specific sequences (Wiktor *et al.*, 2018) ^[49].

In all over the world pepper is 2nd important vegetable after tomatoes and provides excellent flavour and colours. African sorghum, maize porridge and different dishes would be tasteless without pepper. Flavonoids and carotenoid are vital colorants in fruits and vegetable which impart red and orange colours. The rough concentrate of organic product was found to restrain intestinal glucose retention which might be somewhat utilized for bringing down glucose (Khalid *et al.*, 2022) ^[30]. Normal utilization of bean stew may constrict postprandial hyperinsulinemia, Alpha glucosidase and α -amylase inhibitory exercises of capsicum was assessed by researchers examined hostile to diabetic movement of *Capsicum annuum* against α -amylase, α glucosidase and angiotensin I-changing over protein inhibitors. Improvement in the biochemical boundaries, blood glucose levels and body weight of alloxan actuated diabetic Wistar rodents. Capsaicin also having anticancer property, overcome different types of tumours (Zhang *et al.*, 2020) ^[50]. High amount of Vitamin C and zinc are present in Capsicum, also some other vitamins are present like vitamin A, beta carotene, potassium and calcium. Bell pepper also contains sulfur, magnesium, sodium, B-complex nutrients and phosphorus. In clinics and hospitals capsaicin is used as a testing element. It also works as desensitizer, overcome the hypersensitive symptoms of nasal sensitivity (Parvez, 2017) ^[37].

Bell pepper fruits are sensitive to headspace gas concentrations; a carbon dioxide level indicator is required (Devgan *et al.*, 2020) ^[15]. Bell peppers are subjected to natural senescence during storage and distribution and their ripeness or over-ripeness cannot be determined without causing damage to the packaging materials. New methods are now required to determine the freshness of packaged bell pepper reliably and rapidly in a smooth manner. Pepper is a famous vegetable all over the world because of its marketability and nutritional significance. Peppers and their derivatives, are in high demand. Pepper fruits contained higher concentrations of bioactive components (antioxidants, phenols, carotenoids, and ascorbic acid) and have been discovered as one of the very important sources of these compounds (González-García *et al.*, 2021) ^[25]. In the form of ground dried bell pepper (paprika) and oleoresins, red bell pepper (*Capsicum annum*) is widely used as a natural food 29 colorant and flavoring matter. The only natural pigments present in plants are carotenoids and flavonoids (Hui, 2000) ^[27]. Calcium forms calcium pectate when it binds with pectic compounds making plants more resistant to heat softening. Drying with tempering cycles is one of the drying techniques that may be suggested for foods and other biomaterials that are mostly dried during the falling rate phase (Anaya *et al.*, 2003) ^[3]. The solid load may be removed from the dryer and placed in either a container with regulated temperature or a container at room

temperature to begin the tempering process. Tension is created in the latter by temperature gradients inside the solids, as well as humidity gradients or a mixture of both, which are created during chilling and reheating. As the number of cycle's increases this process flavors the occurrence of drying circumstances similar to those at the start of a new cycle but with progressively lower humidity content each time. This drying technique has been used to dry a variety of foods including guava (Chua *et al.*, 2003)^[14], tomato and carrots and has resulted in increased ascorbic acid, lycopene and carotenes retention as well as shorter drying times and less color variation when compared to un-tempered drying. Because food items are multicomponent systems made up of biomolecules such as proteins, carbohydrates and lipids, there is always the danger of quality degradation regardless of whether they are dried untempered or intermittently (Castro *et al.*, 2008)^[23]. Botrytis, also known as grey mould, alternaria, and fungal and bacterial soft rots are all prevalent decay microorganisms (Luo *et al.*, 2019)^[32]. Botrytis may grow at the stated storage temperatures. Although a greater CO₂ concentration (> 10%) may assist to avoid botrytis, it may also damage bell peppers (Kader 1997). As a consequence of chilling damage, Alternaria black rot develops on the stem end of bell peppers. Physical and pathological degradation induce tissue injury, increasing the risk of bacterial soft rot. Low temperatures (7-10°C) and high humidity (80–85%) may thus assist to extend the shelf life of bell peppers (Devgan *et al.*, 2019)^[16].

Nutritional prospective

Pepper comprises a multifaceted assortment of various biologically active compounds in differing amounts, including carotenoids, capsaicinoids, flavonoids, polyphenols, proteins, vitamins, volatile oil, fibers, fatty oils and mineral compounds (Durucasu *et al.*, 2007). It has also been stated that pepper seeds produce 15 percent oil and have high amount of phenol containing compounds and capsicum containing acids (Guil-Guerrero *et al.*, 2006). Capsicum fruits are full of carotenoids that bring peppers various colours. Carotenoids were exposed to play a significant role in human fitness as nutrients and enhancing immune from a dietary point of view, as well as in decreasing oxidative stress, cancer cell suppression, cardiovascular disease safety, macular degeneration and cataract. Folate, an essential vitamin B decrease the menace of heart disease and cancer is also found in various pepper species to varying degrees (Ames and Gold, 2000)^[2]. Moreover, because vitamin A is safe in drying and heating, it has been shown that paprika and dried chilli contain high concentrations of this vital nutrient. Flavonoids are major phenolic acids and flavonoids identified from peppers fruits (Giuffrida *et al.*, 2013)

International products of pepper

Dried pepper, oleoresin and paprika these three significant items exchanged internationally for used in food processing. Oleoresin, a viscous fluid dissolvable extraction from ground powder of any Capsicum species, there are three types of oleoresin, first one is paprika (gives bright colour), red pepper (gives colour and spiciness) and Capsicum (gives pungency). Oleoresin and volatile compounds of Capsicum species are also essential constituents. Capsicum oleoresin is a viscous substance extracted through polar solvent

extraction from the ground powder of Capsicum fruit species and is primarily used based on the genus used for its colour and pungency. It has been shown that the quality of essential oils in pepper fruits depends on the genus, the stage of maturity, harvest period and the processes of drying. Color, shape, and nutritional content are physical properties of peppers which are important for market approval by buyers. Various reasons have been found to influence the quality of these compounds, including the ripeness level, farming practices, and various handling out methods of the fruits and ultimately certain characteristics such as pungency, colour, existence of small seeds and capacity to generate highly intense extracts. Before processing, different prior treatment techniques are often implemented to peppers (Rybak *et al.*, 2021)^[41]. The consistency of peppers may also be altered by certain pre-treatments. Therefore, in command to assess the effectiveness of the usage of these manufactured products in the human food, proper regulated processing operations are necessary to ensure the foodstuff worth as well as the food protection of the peppers (Sanatombi and Rajkumari, 2020)^[43]. Paprika, a ground non-pungent powder utilized fundamentally for its color and excellent flavor in prepared food processing. All paprika varieties are *C. annum* paprika organic products are utilized to deliver paprika oleoresin (Nadeem *et al.*, 2011)^[34]. Dietary status improvement, food security and neediness lightening developed significant distractions to create nations. In Africa, agrarian division, its escalation and broadening aid accomplish these goals (Eromosele, 2008)^[22].

The external colour of pepper is significant criterion since unwanted changes in color may occur which lead to a loss of quality and economic value (Synowiec *et al.*, 2014)^[47]. Carotenoids lose their red color due to auto-oxidation. The rate of degradation carotenoids in red bell peppers during storage has been discovered to be dependent on drying conditions, with increasing degradation rate as the drying temperature rises (Doymaz and Pala, 2002)^[18]. Peppers, which are the fruits of Capsicum plants, are a common ingredient in many people's diets all around the world. The most economically important domesticated species of the genus Capsicum include Capsicum chinense Jacq., Capsicum annum L., Capsicum baccatum, Capsicum pubescens and Capsicum frutescens L. (Vega *et al.*, 2007)^[48].

Typical consumption

From 1986 to 1995 intake of fruit and vegetables is recorded per capita an improvement of 0.38 % for fresh fruits and 0.92% for vegetables. The maximum usage of fresh fruit was reported in China (6.4%), as the apparent consumption of vegetables in China rose from 68.7 kg per capita in 1986 to 146 kg per capita in 1995 (53.8 5% growth rate), whereas the demand for fresh fruit in the African and Near East Asian countries decreased. Sub-Saharan Africa has reported the lowest intake of vegetables per capita (29 kg of vegetables consumed both in 1986 and 1995). Chinese consumers have bought much of their fresh fruit in street retail stores and marketplaces where imported fresh fruits are affordable, according to trade reports, and have gained praise from U.S. and European brand names. Highly common sold fruits and vegetables are items such as Red Delightful apples and Sunkist oranges. Sunkist is one of the only orange labels that buyers know. One indicator of the

population's quality of living is the shift towards fresh vegetable consumption in developed countries. It is possible to process several vegetables into canned goods that appeal to local tastes. They can be processed for a long period, easy to transport and comfortable to serve, eliminating losses suffered from the migratory supply of excess vegetables sold annually at the similar time. In developed countries, the metropolitan population is exploding, increasing from 35% of the overall population in 1990 to 54% in 2020. With growing metropolitan populations, an improvement in the availability of fresh fruits and vegetables would involve more open markets and wholesale markets. For instance, consumption growth in the U.S. has been led in part by growing need for tropical and seasonal fruits and vegetables (Joint, 2003) [24].

Effect of various methods on pepper quality

Product preservation under regulated temperatures and conditions of relative humidity can improve its perishability and decrease decay. The packaging of products with the required content increases the appearance and marketability of colour. In rural regions, a number of alternate methods may be used to store fruits and vegetables, such as sun drying, fermentation, and refrigeration. Fruit and vegetable fermentation is a form of storage common in rural regions and there is little need for expensive machinery because of the ease of the procedure; pickled vegetables, wine is example of this process. Brushing and washing are sometimes the only preservation methods available for minimally handling fresh fruits and vegetables. Cleaning includes the reduction of foreign materials such as twigs, stalks, gravel, sand, soil, insects, chemicals and nutrient contaminants from fruits and vegetables as well as from containers and machinery, as the first stage of production. The cleaning method often includes removing light by gravity, flotation, picking, filtering, dewatering and others from hard materials. Usually, washing is achieved with chlorinated water (i.e., 200 ppm allowed in the USA) (Joint, 2003) [24].

Quality changes

For washing, water must be of optimum quality. Washing of fruits and vegetables, three parameters are controlled:

1. Volume of water consumed: 5-10 L/kg of substance
2. Water temperature: 4°C to cool the product
3. Active chlorine concentration: 100 mg/L

Washing and Cleaning

Two examples of specifically built devices for washing fruit and vegetables include:

(i) Rotary drums

Rotary drums utilized for cleaning strawberries, beets; water sprayed high-pressure on a substance that never meets dirty water.

(ii) Wire rotary leafy crop washers

Wire rotary leafy crop washers with medium pressure sprays of fresh water that never meets dirty water. Dirty water should be withdrawn from the tanks and packed with chlorinated water for fruit or vegetable re-washing and disinfection.

Sucrose solution NaCl, CaCl₂ or sodium metabisulphite, are frequently used as prior processing treatments for pepper

prior to drying. It has been reported that such pre-treated peppers result in relatively enhanced vitamin-C maintenance, color, and decisiveness (Zhao *et al.*, 2013). This decreases microbial load, remove dust particles and help to dry pepper more quickly. A highly suitable canned pepper manufactured goods with favoured physical and chemical properties and emergence has been shown to produce amalgamation, blanching with reaction of Na metabisulphite (Mensah-Brown *et al.*, 2014) [33]. Similarly, various blanching techniques have also been shown to improve drying kinetics pepper comparative to un-blanching peppers, such as hot water, infrared, microwave, and high-humidity warm air impingement blanching. However, the results of pressure treatments at 100 or 200Mpa for 10 or 20 min, respectively, followed by decompression for approximately 45 seconds by means of a cylindrical pressure chamber autoclave packed with medium containing of 2% hydraulic fluid water and thermal blanching on sweet green and red bell peppers have been considered (Castro *et al.*, 2008) [9]. The various cleaning techniques can be utilized to reduce the contamination levels.

(i) Scalding or blanching in hot water

Fresh vegetables, root vegetables, and fruits are put into bath having hot water at 91-99°C for 1-10 minutes, to minimize microbial count and partially decrease peroxidase and polyphenoloxylase (PPO) function.

(ii) Sulphiting

Pepper slices soaked in solution of sodium bisulphite (200 ppm) during this procedure in order to reduce unwanted colour variations, any further microbial and enzyme development and to maintain a remaining concentration in end product of 100 ppm (Joint, 2003) [24].

Processing treatments

1. Drying of food

Foods are dried to prevent microbial growth and quality deterioration. The amount of drying, on the other side, is determined by the product's planned usage. After processing, cereals and oilseeds are dried to a moisture content that allows for microbial stability during storage. Blanching vegetables until drying eliminates fast darkening and drying is achieved not only to discourage microbial growth but also to prevent browning (Chávez-Servín *et al.*, 2020) [10].

2. Conventional drying method

The convective process of drying is used to remove water from food products. Hot air is forced to flow through the substance, transmitting heat to the food thus removing moisture.

3. Sun drying and Osmotic dehydration:

Dehydration perhaps most important strategy for storing fruits and vegetables in countryside zones. Then dehydrated fruit and vegetable items wrapped in plastic containers, bottles or cans with fruit slices. The fruit is retained during osmotic dehydration and crystallization by heating the substance in the sugar solution, accompanied by washing and drying to reduce the accumulation of sugar on the surface of the fruit. Depending on the consistency of the commodity obtained. The benefit of this approach is that the fruit produced by enzymatic reactions avoids discoloration

and browning. The large concentration of sugar in the fruit creates a dehydrated product with strong coloring (Joint, 2003). By using either sunlight or drying with solar collectors, pepper drying is more widely carried out worldwide. Its lengthy procedure that requires 10 days to decrease the moisture 9.9 percent on a weight basis. Outdated methods of sun drying are also considered to be linked to microbial growth, contamination of mycotoxins, infestations of insects and fungi and thus contribute to consistency deterioration in peppers (El-Hamzy *et al.*, 2016) [20]. Samples dried by sun drying or mechanically at 37°C have higher nutrient and seed quality as compared to chilli dried in shaded spaces (O'Neill *et al.*, 2012) [29].

4. Shade drying

Shade-dried samples have been shown to be frequently associated with fungal infection, which is known to be the primary cause for condition degradation.

5. Solar drying

Drying utilizing theoretically suitable and commercially viable solar dryers is mostly desirable and successful uses of solar energy system to efficiently minimize pepper's moisture (Owusu-Kwarteng *et al.*, 2017) [36]. To decrease moisture substance 500 kg chili in 3 days, a greenhouse style solar dryer, parabolic form, polycarbonate roof, concrete base, a small air inlet, and fitted with nine DC fans operated by 350W solar cell modules, was used effectively, while traditional sun drying looked-for 5 days to dry the samples. These solar dryers used to dry pepper samples effectively on a wide scale (Owusu-Kwarteng *et al.*, 2017) [36].

6. Smoke dehydration

Smoke dehydration includes aeration chilli fruit using smoke created by flaming firewood, is another popular form of conventional dehydration processing chilli. Jalapeno rayado (*C. annuum*) smoke-dried peppers created by conventional smoke dehydration utilizing smoke created by burning *Quercus* sp. smoke-dried pepper contained higher concentrations of flavonoids, phenolic compounds and antioxidants as compared to the bell peppers dried through the convective dehydrations. However, Maillard compounds can produce in smoke-dehydrated peppers responsible for their brown color (Campos-Hernández *et al.*, 2018) [7].

7. Refractance window drying

One more modern film drying system with a reasonably small cycle period, low energy expense and enhanced product consistency is refractance window drying (RWD) (Nindo *et al.*, 2006). It utilizes circulating water under atmospheric pressure at 95-97°C to provide thermal energy to a thin layer of wet substance on the film through a clear plastic film. The belt holding the dry commodity then travels before being scrapped off the belt with a cold water wash. Due to the decreased heat transfer during the final step of drying, deterioration is eliminated and the procedure does not have any detrimental impact on the consistency characteristics of the dried pepper (Topuz *et al.*, 2009).

8. Hot air drying

Pepper dehydration is also widely done by hot air drying or oven drying, enabling rapid and major processing by Nasiroglu *et al.*, 2009. While higher drying temperatures

have been seen to contribute to improved shelf life, some serious problems have been posed by the maintenance of nutritional and commercial quality of pepper through the process, including reduced pepper length, retained macronutrients and deteriorated micronutrients, active total polyphenols, flavonoid concentration, antioxidants and spicy hotness (Salima *et al.*, 2014). In addition to modifying the quality of capsaicinoids, it has been proposed that the plant digestibility, attributes of cell-wall polysaccharides and capsaicinoids intracellular attachment to different micromolecules and macromolecules and the release rate of capsaicinoids can also alter the strength and length of the capsaicinoids and thus the bioavailability and bioaccessibility and of various components (Campos-Vega *et al.*, 2013) [8].

9. Canning

It is also potential method of food production for the preservation of food materials. Purposely, the food materials are enclosed in airtight jar and warmed to reduce food spoilage-causing micro-organisms. In order to preserve the physicochemical attributes of canned foods, different processing factors, such as processing medium blanching, heat and the time-temperature mix used for processing, have an effect on the consistency of the packaged foods and improve the processing conditions. In this respect, 0min blanching, 10min processing period and 0.2% sodium metabisulphite therapy have been documented to be sufficient for preserving the physicochemical attributes and appealing appearance of canned pepper (Campos-Vega *et al.*, 2013) [8].

10. Cooling in trays:

This procedure is conducted in metal trays in which cold air is moved in order to cool the fruits and vegetables before being wrapped in sterile plastic bags, unless there is a further step to consider (Joint, 2003) [24].

11. Freeze drying

Freeze drying, also known as lyophilisation or cryodesiccation, is a low-temperature dehydration method that involves freezing the product, lowering the pressure and then sublimating the ice. This is in contrast to most traditional methods of dehydration, which use heat to evaporate water. The quality of the rehydrated product is excellent, and the original shape of the product is maintained. Biological (e.g., bacteria and yeasts), biomedical (e.g., surgical transplants), food processing (e.g., coffee) and preservation are the most common uses for freeze drying. Another low-temperature dehydration system used in food production is freeze drying, often known as lyophilisation, in which the samples are frozen, accompanied by reducing pressure and sublimation to extract water from ice crystals. There is minimal research on the impact of freeze drying on the content of capsaicinoids and other metabolites, while freeze drying is a popular processing technique for vegetables. Freeze drying did not induce any change in the volatile component profiles of the peppers when the effects of freezing (deep frozen at -22°C) and freeze drying on the volatile components of parden peppers were examined, although deep freezing resulted in little improvement in the volatile component profiles of the peppers (<https://en.wikipedia.org/wiki/Freeze-drying>).

Conclusion

The FD method was found to be the most effective drying method for preserving capsaicin content over other drying methods while for nearly all pepper cultivars tested. The fresh samples maintain higher concentrations of β -carotene, antioxidants and TPC relative to the dried samples of each variety tested. As the pepper cultivars differed, hunter colour parameters were often observed to differ in correlation with the drying methods subjected. However, the maximum colour parameter values were noted in fresh samples rather than in any of the dried samples of the cultivars tested.

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