A SEMINAR PAPER

ON

Effects of Fruit Processing Techniques on Preservation of Antioxidants and Health Promotion

Course Title: Seminar

Course Code: HRT 598

Term: Summer, 2020

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Effects of Fruit Processing Techniques on Preservation of Antioxidants and Health Promotion[1]

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ABSTRACT

Fruit production and consumption both are increasing gradually because of their nutritional and health benefits. Fruits contain bioactive compounds such as antioxidants which have protective effects against cell oxidation. However, high amount of antioxidants loss of fruits can be occurred during handling after harvest, such as inappropriate fruit processing techniques and storage. Therefore, some specific processing techniques are needed to preserve the quality and quantity of antioxidant potential of fruits. Many recently invented technological strategiesshow positive and promising results to maintain antioxidant potential such as irradiation, high hydrostatic pressure (HHP), pulsed electric fields (PEFs), radiation processing,dense phase carbon dioxide (DPCD), ozone processing, edible coatings, active packaging, microencapsulation and nanoemulsion etc. By preserving antioxidants, the risk of different diseases such as obesity, diabetes,hypertension and cardiovascular disease etc. can be minimized. As antioxidants improve the immune system, they may have a great impact to tackle the present pandemic COVID-19. Finally, more analysis is needed in case of fruit processing system to maintain or even improve antioxidant status of fruits, offering options to maximize health benefits to consumers.

Key words: Fruit processing techniques, Antioxidants, Technological strategies, Human health

[1]Title of the seminar paper presented as a part of course HRT 598 during Summer 2020

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CHAPTER I

INTRODUCTION

Bangladesh is located in tropical and subtropical regions and its climate is very suitable for fruit production. The production, consumption, and trade of fruits have increased significantly in the past few years not only because of their attractive sensorial properties, but also for their nutritional and health benefits. Fruits supply an optimal mixture of biologically active components, such as natural antioxidants, fiber, and other photochemical (Yahia, 2010). Antioxidant is a bioactive substance that protects our cells from the damage caused by free radicals (Jose et al, 2013). Examples of these bioactive compounds include carotenoids and other pigments, phenolic compounds, ascorbic acid, indoles, isothiocyanates and some vitamins A, C and E etc. The antioxidant content in fruits has become an important external quality parameter such as color, shape, size, etc (Jose et al*,* 2013).

Fruits undergo different types of handling process after harvesting to preserve the color, flavor, texture and nutrition which are known as fruit processing. A huge amount of fruit loss is occurred by physiological and biochemical processes, microbial decay, high perishable nature and sub-standard postharvest handling infrastructures. The minimum requirement of fruit intake is 100 g/capita, because of fruit loss the present daily intake is only 14 g/capita (BAN-HRDB, 2007) which may cause nutritional deficiency. That's why a variety of procedures are used during the handling of fruit for long time preservation. But they have some side effects that cause unwanted changes in the physicochemical, sensory, and nutritional characteristics of fruits (Boekel et al, 2010). Antioxidant compounds such as phenolics and their biological activities in fruits may be affected by certain thermal techniques (Parmar et al, 2016). Other than these thermal heating, antioxidants from fruits are very susceptible to degradation mainly due to these handling practices such as, fungal decay, chilling injury, inadequate temperature and relative humidity, and several other types of stress (Yahia, 2010).

As main purpose of fruit processing is prolonging the self-life and maintaining the nutritional content and bioactive content of fruits, several postharvest treatments have been used now a day's including ultraviolet light, edible coatings and application of natural compounds as active packaging, microencapsulation etc. (Gonzalez-Aguilar et al, 2010).They preserve the quality of fruits and they may also influence their antioxidant potential. There are some nonthermal techniques which maintain temperature within 50^0C and provide promising alternative to thermal processing. Example of these treatments are ultra-violate treatments, high hydrostatic pressure (HHP), pulsed electric fields (PEFs), radiation processing, dense phase carbon dioxide (DPCD), ozone processing etc. which are commonly used for microbial and enzymatic inactivation of fruits (Jose et al, 2013).

Bioactive compounds are typically present in small quantities in fruits but they play important role both plant physiology and human health. Nowadays, it is well known that consumption of fruits containing antioxidants is associated with a reduced risk of developing chronic diseases (Yahia, 2010).As a health promoting agent they can inhibit biological oxidation and play a vital role in the integrity of cellular structure and biomolecules such as lipids, proteins and DNA. Antioxidants from consumed fruits are believed to offer chemo-preventive effect through various mechanisms that lead to control over cell cycle, growth and proliferation. Metabolic syndrome, including obesity, diabetes, hypertension and atherosclerotic cardiovascular disease, all of which involve oxidative stress as an important causal factor can alleviate by consuming proper amount of antioxidants (Xue et al, 2015).

We are well known about the recent pandemic disease COVID-19 which threatens patients, societies and healthcare system around the world. Its lethality depends largely on its host's immunity system. The severity of the disease ranges from asymptomatic to severe lungs injury that may cause death. Deficiency of micronutrients and bioactive compounds negatively affect immune system and increase susceptibility to infections (Nathania& Andayani,2020). And we know antioxidants have immunomodulatory effects which can play important role in this case. The association of Indonesian Clinical Nutrition Specialists (PDGKI) recommends taking 1 gram of Vitamin C orally daily for COVID-19 management (Nathania & Andayani, 2020). Because vitamin C is a potent antioxidant and a cofactor for biosynthetic and gene regulating enzyme. Considering the roles of antioxidants in human health, several techniques such as plant breeding, genetic modification and postharvest treatments and strategies have been proposed. The later represents a promising means to maintain or even improve antioxidants status of fruits and offering to maximize health benefits to consumer.

Objectives

- To describe the reasons of common antioxidants loss.
- To illustrate the recently used fruit processing treatments for maintaining antioxidants content.
- To evaluate the relationship between antioxidants and human health.
- To discuss the barriers and recommendations associated with fruit processing which are used on preservation of antioxidants.

CHAPTER II

MATERIALS AND METHODS

This seminar paper is completely a review paper. Therefore, all of the information has been collected from secondary sources to prepare this paper. During the preparation of this paper, I went through various relevant books, journals, proceedings, reports, publications etc. For collecting recent information internet browsing was also being practiced. Good suggestions, valuable information and kind consideration from my honorable major professor and course instructors were taken to enrich this paper. After collecting necessary information, it has compiled and arranged chronologically for better understanding and clarification.

CHAPTER III

REVIEW OF FINDINGS

3.1. Reasons behind loss of antioxidants

3.1.1. Fruit loss

In Bangladesh, annual production of fruit is 1.95 million metric ton and post-harvest loss is 0.55 million metric tons (BBS, 2003).The range of range of post-harvest losses of fruits in Bangladesh is 25-43% (Hassan et al, 2010). Fruit wise losses are shown in Table 1. As we know that fruits

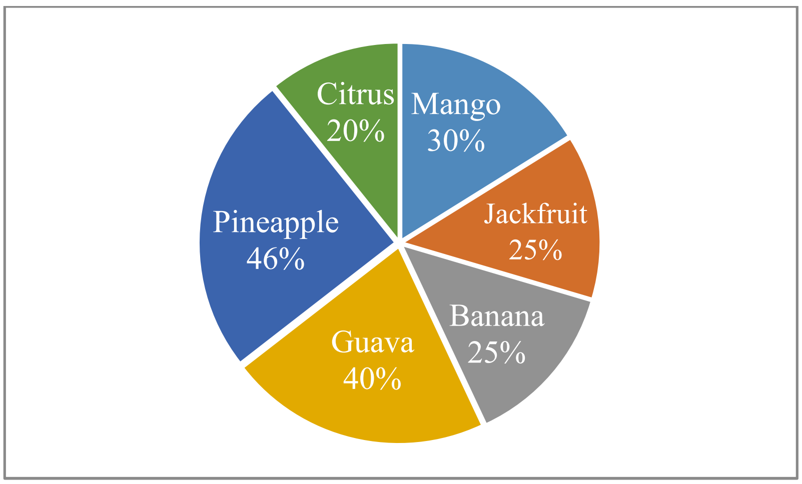

Figure 1: Estimation of post-harvest losses of fruits in Bangladesh.

(Source: Hassan et al, 2010)

Are very rich sources of micronutrients like carotene, lycopene and vitamin C (Hassan et al, 2010). The loss of these bioactive compounds is also increasing by gradual post-harvest losses.

3.1.2. Loss of antioxidants by heating

Several thermal postharvest treatments are used to inactivate microorganisms and spoilage enzymes, which are helpful for prolonging the post-harvest life of fruits. But sometimes sensorial properties and bioactive compounds of fruits are changed by these treatments. Especially, fruit processing by heating with high temperature, may reduce the bioavailability or content of several bioactive compounds by inducing some physiological and chemical changes (Kamiloglu & Capanoglu, 2015). For example, thermal techniques may affect the contents of antioxidant

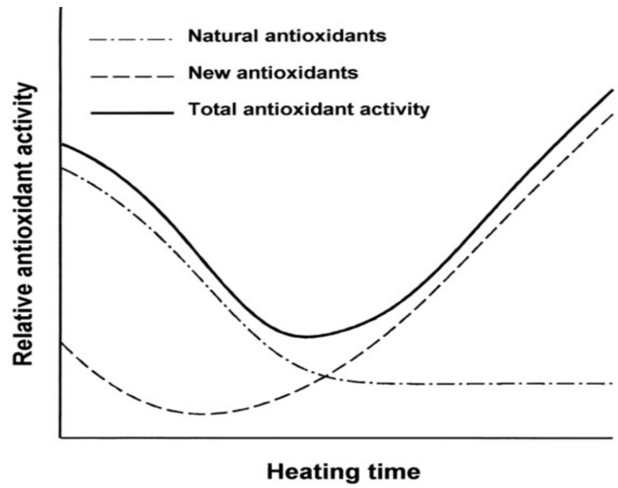

Figure 2: Changes in the overall antioxidant activity over duration of heating.

(Source: Nicoli et al, 1999)

Compounds such asphenolics and their biological activities of fruits (Parmar et al,2016). (Nicoli et al, 1999) has shown that antioxidant properties may reduce during short heat treatments (Fig. 2). But this loss can be reduced by prolonging the heating time.

3.1.3. Loss of antioxidants during storage

In maximum cases, antioxidant compounds are lost after harvesting because of microbial action and long-time preservation. There is an evidence of sharp declination of vitamin C with the

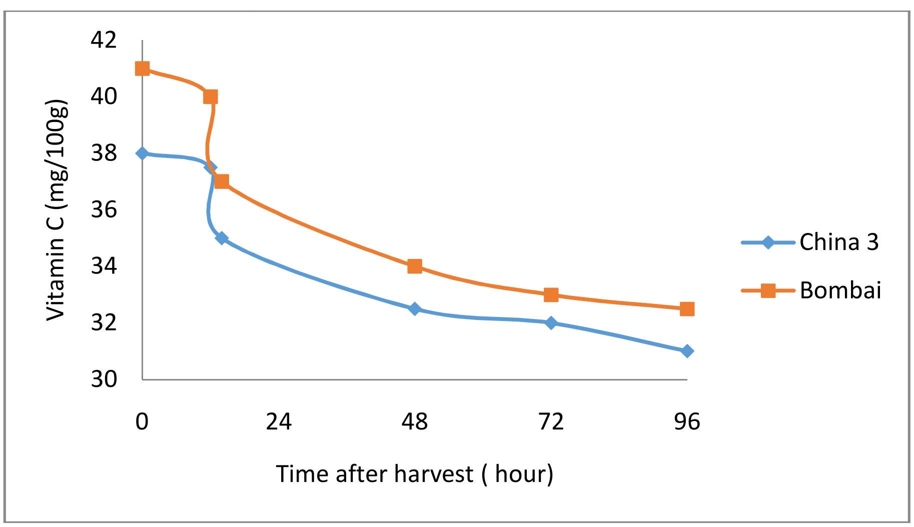

Figure 3: Loss of vitamin C in litchi fruit with the progress of storage duration.
(Source: Hassan et al, 2010)

progress of storage duration after harvest (Fig. 3). (Maity & Mitra, 2001) and has shown that freshly harvested China 3 litchi contained 38 mg/100 g vitamin C when harvested, but after 96 hours sharply declined to 31 mg/100 g. It was also found in Bombai variety.

3.2. Promising fruit processing techniques on preservation of antioxidants

3.2.1. Irradiation

A number of studies have suggested that the effects of irradiation on the antioxidant status of fruits is depended on the function of the radiation source, dose, time of exposure, storage conditions, treated produce and antioxidant sensitivity (Jimenez et al, 2011). Some of the current studies on the effects of ionizing and non-ionizing radiation on the antioxidant content in fruits are shown in table 1.

Table 1: Effects of irradiation and ultraviolet treatments on natural antioxidants from various sources

Sample	Irradiation treatment	Results
Pomegranate	γ -Irradiation (0–20 kGy)	Total phenolic content increased from 16.1 to 16.8 g GAE/100 g
Navel orange fruits	γ -Irradiation of 100–700 Gy Followed by 3 weeks of storage at 5 _C	Total phenolics, vitamin C, and oxygen radical absorbance capacity were unaffected by irradiation
Watermelon juice	UVC irradiation between 2.7 and 37.5 J/mL in a coiled reactor	Lycopene and total phenolic content was consistent with that of untreated fresh samples
Sun-dried apricot	γ -Irradiation of 3 kGy	Irradiation increased DPPH radical ferric ion reducing power and enhance overall antioxidant capacity
Blueberries	Use UV-C and after treating samples were stored at 80 °C	The optimum doses of UV-C for enhancing TP and anthocyanins were 2.15 and 4.30 kJ m2.

(Source: Al-juhaimi et al, 2018; Jose et al, 2013)

Electron beam and γ-irradiation are mostly used ionizing radiation to increase the antioxidant content in the fruits (Table 1). Gamma (γ) radiation has showed a positive effect on the antioxidant content, increasing the content of phenolics in pomegranate peels (Table 1). The application of electron beam irradiation has resulted in a negligible effect on antioxidants such as phenolics, carotenoids and vitamin C shown in navel orange (Girennavar *et al*. 2008). An increment of antioxidants content by UV radiation is shown in blueberries and watermelon juice in table 1.

3.2.2. Pulsed electric field (PEF) treatment

Different studies support that PEF treatments modify enzymatic activities and reduce microbial populations without reducing the quality and taste of fruits. PEF exhibited higher vitamin C contents than thermally processed juices during storage in different juices, such as strawberry, tomato, and orange juice (Corte´set al, 2008). Total anthocyanin stability in sour cherries was retained well after PEF treatments (17–30 kV/cm for 131 ms) compared to untreated cherries (Altuntaset al, 2010).Carotenoids such as lycopene and b-carotene have found in high concentration in PEF-processed tomato juices than in untreated juices (Odriozola-Serrano et al, 2009). Lycopene and total antioxidant capacity of watermelon juice was increased by applying

Table 2: Effects of PEF on the antioxidant activity of fruits and their products

Product	Treatment conditions	Major findings
Watermelon juice	35 kV/cm at 200 Hz for bipolar pulses	Lycopene increased by 13%, total antioxidant capacity was unchanged
Tomatoes	1 kV/cm at 0.1 Hz for 16 ms with 4 msmonopolar pulses	Total polyphenol, lycopene, and anti oxidant capacity increased by 36.58, 20.10, and 20%, respectively
Sour cherry juice	17–30 kV/cm, at 131 ms pulse	Total anthocyanin stability was retained
Strawberry juice	35 kV/cm at 100 Hz for 1700 ms with 4 msbiopolar pulses	Flavonols content were stable compared to untreated sample

(Source: Xuiet al, 2015)

PEF (Oms-Oliu etal, 2009)(Table 2). Antioxidants contents can preserve long time when fruits are treated with PEF method.There isan evidance that in pineapple juice the concentration of β carotene was lower in PEF treated juice (with 13KV/cm) than in untreated juice at day 0 but the

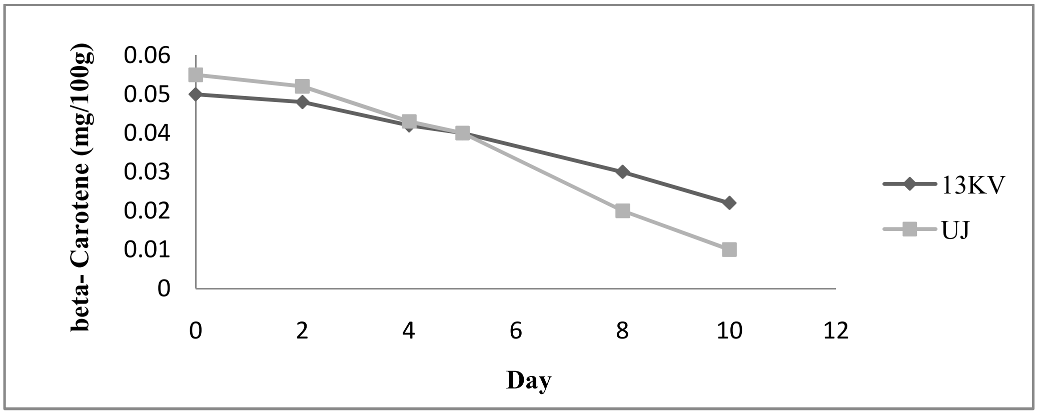

Figure 4: β-carotene content of PEF treated pineapple juice and untreated juice at different day.
(Source: Yousuf et al, 2020)

rate of β carotene depletion was higher in untreated juice (UJ) in Figure 4. As the activity of some enzymes is inhibited which are responsible for oxidation of β carotene, the untreated juice lost its antioxidant capacity at a higher speed than the treated one (Yousuf et al, 2020).

3.2.3. Dense Phase Carbon Dioxide (DPCD)

Several studies have already reported that DPCD plays positive impact on preservation of antioxidants (Table 3) and microbial inactivation. The effects of DPCD treatments in apple juice showed a statistically significant increase on antioxidant activity comparison with untreated samples (Porto et al, 2010). There is an evidence that when red grapefruit juice was treated by

Table 3: Effects of DPCD on the antioxidant activity of fruits and their products

Product	Treatment conditions	Major findings
Apple juice	15 MPa, 35 C, 15 min	Antioxidant activity increased significantly (2.4-fold)
Red grapefruit juice	13.8, 24.1, and 34.5 MPa, 5.7% CO2, 40 C for 5, 7, and 9 min	Decreasing losses of antioxidant capacity from 12.8% to 10.3% and ascorbic acid content from 15.3% to 9.4%
Hami melon juice	35 MPa, 55 C, 60 min	Ascorbic acid content was 6.4 times higher than untreated one in storage condition
Grape juice	34.5 MPa, 8 and 16% CO_2,	Enhanced anthocyanin and phenolics stability

	6.25 min, 30 C	
Guava puree	30.6 MPa, 6.8 min, 35 C	Antioxidant capacity and ascorbic acid content were increased.

(Source: Xue et al, 2015)

DPCD (13.8, 24.1, and 34.5 MPa, 5.7% CO_2, 40 C for 5, 7, and 9 min) treatments over six weeks of storage at 4 C, total antioxidant activity, ascorbic acid, and phenolic contents were influenced greatly (Ferrentino et al, 2009) and same result was found in guava puree (Plaza et al, 2010).Ascorbic acid is easily oxidized when oxygen is present in the environment, but a satisfactory retention of Ascorbic acid was achieved in DPCD-treated Hami melon juice (Zhang et al, 2010). Antioxidant compounds such as anthocyanin and Phenolics were enhanced in DPCD treated grape (Pozo-Insfran et al, 2007) respectively.

3.2.4. Ozone Processing

FDA (Food and Drug Administration) has recently approved ozone as a direct food additive that can prolong storage life and delay ripening and senescence in various fruit (Miller et al, 2013). The amount of ascorbic acid, carotinoids, phenolic compounds content was significantly

Table 4: Effects of ozone on the antioxidant activity of fruits and their products

Product	Treatment conditions	Results
Pineapple, banana	8 0.2 ml/s, 20 min	Polyphenol and flavonoid content increased by 15.7 and 32% in pineapple, by 8.2% and 14.7% in banana,
Papaya	3.5 ppm, 96h	Increased ascorbic acid (28.4%), total phenolic (14.3%), beta-carotene (82.2%), and lycopene (52.8%) contents and enhanced antioxidant activity (21.9%) were observed.
Kiwifruit	0.3 ppm, 144 h	Total carotenoid content was increased.
Tomato	10 ppm, 10 min, 20 C	The accumulation of phenolic compounds increased by 50%.

Strawberries	0.35 ppm, three days,2 C	Ascorbic acid content was three times than that of control fruits at the end of treatment.

(Source: Xue et al, 2015)

increased in papaya after 10 days of storage upon exposure to ozone in comparison with untreated (Ali et al, 2014). The same result was also found in ozone-treated strawberries and kiwifruits (Minas et al, 2010). Accumulation of phenolic compounds with 50% increment was found in tomato (Rodoni et al, 2010). It is observed that ozonized strawberries (0.3 ppm in aqueous phase at 15 2 C) preserved 82% of the anthocyanins after 13 days of storage at 4 1 C (when compared with fresh samples), but untreated and water-washed samples preserved only 55% (Alexandre et al, 2012).

3.2.5. High hydrostatic pressure (HHP) treatment

HHP is basically used to inactivate microbes and enzymes in foods in the range of 300-700 MPa (Chawla et al, 2011). There are some reports that have described the retention of carotenoids and ascorbic acid after HHP treatment (Figure 5). A gradual increase in the content of total

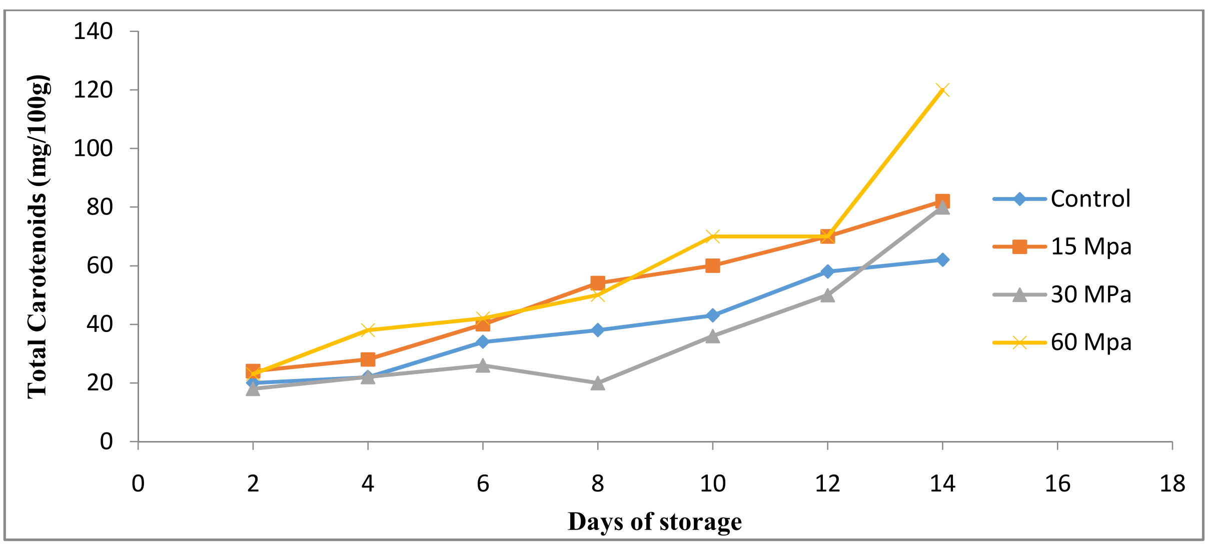

Figure 5(a): Effets of HPP treatment on total conc. of carotenoids.
(Source : Ortega et al, 2013)

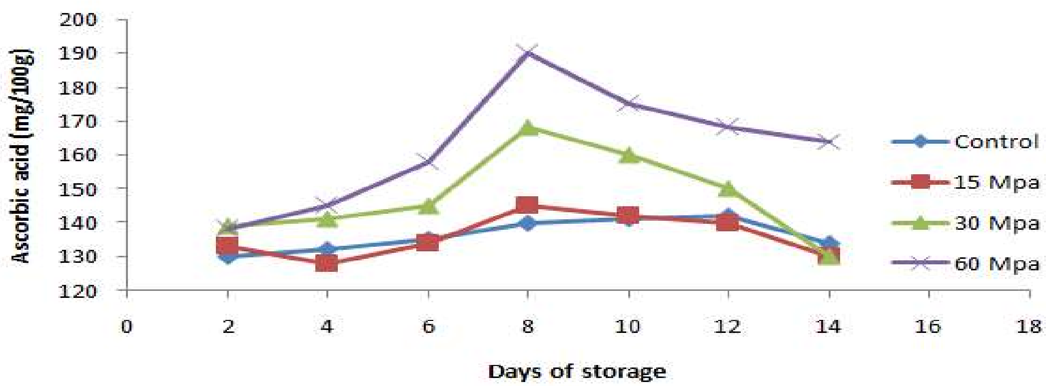

Figure 5(b): Effets of HPP treatment on total conc. of ascorbic acid.

(Source : Ortega et al, 2013)

carotenoids related to control fruits when treated for 10 minutes. In case of ascorbic acid, pressurized mango at 60 MPa (10 or 20 minutes) showed lower respiration rate and ethylene production rate than control mango.

3.2.6. Use of edible coating

By incorporating natural bioactive compounds, such as antimicrobials, probiotics, flavors, and antioxidants, coating is mostly used to increase the nutritional and health potential of fruits. Recent studies show that edible coatings enhance the antioxidant value of fruits by carrying

Table 5: Quality improvement and antioxidant activity changes in fruits with edible coating

Fruit	Treatment	Major findings
Melon	Alginate, pectin, gellan	Antioxidant capacity increased by 13.6 and 57.1%.
Sweet cherry	Sodium alginate	Total phenolic content and antioxidant capacity increased by 48 and 31.3%.
Apple	Calcium ascorbate	Antioxidant capacity and content of vitamin C were 16 times and 20 times more than untreated fruits.
Pomegranate	Aloe vera gel	Total phenolic and anthocyanins increased by 54.1 and 69.8%.

(Source: Xue et al, 2015)

basic nutrients that are lacking or present in low amounts in fruits, has shown in table 5. Polysaccharide based coating such as chitosan has been used as the principal edible coating nowadays to improve the antioxidant potential of fruits. Combination of bioactive compounds

Control 1% citric acid

Figure 6: Appearance of tomatoes treated with chitosan coating.

(Source: Zhang et al, 2017)

with chitosans have been used to enhance quality of fruits by enhancing the shelf life and nutritional quality, increasing consumer acceptance and other factors. For example, tomatoes treated with citric acid and chitosan coating increased the self-life significantly, which may be related to the higher anthocyanin content in pericarp (Zhang et al, 2017) (Fig. 6).

3.2.7: Micro and nanoencapsulation

Micro and nanoencapsulation is a very useful method to enhance the stability of antioxidants by the spray drying technique. This encapsulation technology is mainly used during storage which may provide final fruit product functionality (including controlled release of the core) (Fig. 7). It is reported that bioactivity and bioavailability can be enhanced by encapsulation of antioxidants which may prevent degradation of antioxidants during digestion in the stomach (Takahashi et al, 2009). Microencapsulation by fruit products have been demonstrated and implemented with

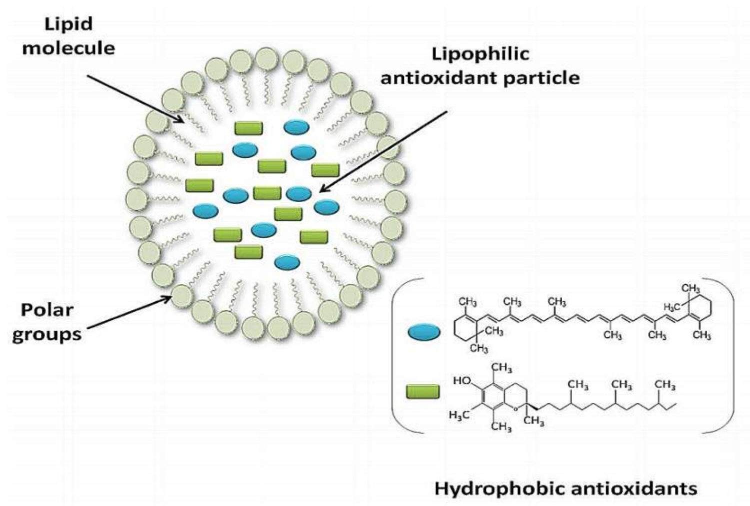

Figure 7: Mechanism of encapsulations.

(Source: Jose et al, 2013)

promising result such as, for preventing grape seed oil oxidation, it was microencapsulated with soybean protein isolates and malt dextrin (Xiaomei & Yuefeng, 2009).

3.2.8. Active packaging

This technology ensures product safety and quality by antimicrobial properties such as application of essential oils or polyphenols as antimicrobial agents or additives (Wang et al, 2011) as well as it can increase the antioxidant potential in fruits (Fig. 8). This mechanisms or

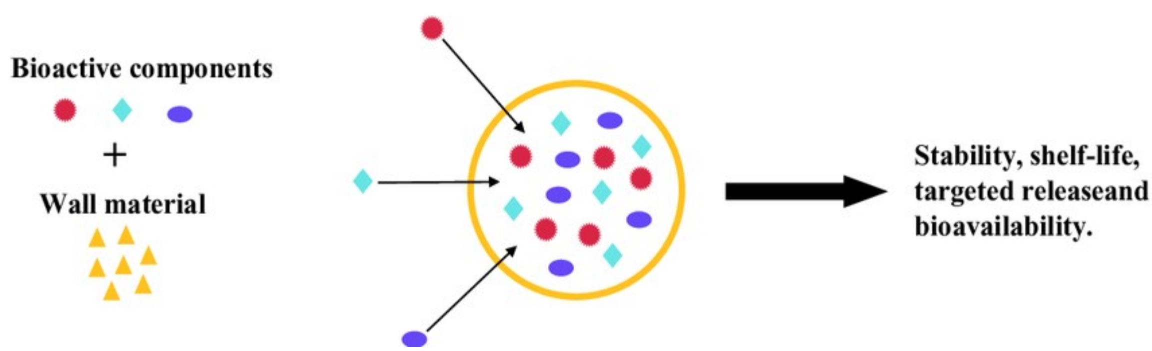

Figure 8: Active packaging system.

(Source: Chawda et al, 2017)

principles may be applied to increase the antioxidant potential in fruits and vegetables contained in the package.

3.3. Relationship between antioxidants and human health

3.3.1. Fruit source of antioxidatns

Fruits are common source of natural antioxidants, the most common of which being vitamin C (ascorbic acid), vitamin E, vitamin A (carotenoids and their derivatives), various polyphenols including flavonoids, anthocyanins, lycopene (a type of carotenoid) etc. (Table 7) (Yadav et al, 2016).

Table 6: Major antioxidants in some common fruits

Source	Major antioxidants
Apple	Benzoic acid, cinnamic acid, flavan-3-ols, anthocyanidin, flavonols, dihydrochalcones
Berry	Anthocyanins, flavonols, flavanols, proanthocyanidins, ellagitannins, gallotannins, stilbenoinds, phenolic acids
Grape	Resveratol, catechin, anthocyanins, gallic acid
Grapefruit	Narirulin, hesperetin, hesperidin, ascorbic acid
Citrus	Carotenois, ascorbic acids
Tomato, papaya	Lycopene, carotenoids, flavonoids

(Source: Nayak et al, 2015)

3.3.2. Minimizing risk of different diseases

Most of chronic diseases in human body are generically occurred by oxidative damage which produce reactive oxygen species (ROS) (Harman, 1972). Free radical reactions can be suppressed by incorporating antioxidant enzymes and various antioxidant molecules and minerals (Blasa et al, 2010). The concentration of phytochemical antioxidants in the biological fluids depends on diet and they change from one person to another. The bioavailable antioxidants are able to prevent or retard chronic diseases and it has become a discipline called chemoprevention (Sporn, 1980). They have different kind of identical mechanisms of potential disease-preventive action, including novel antioxidant, antibacterial, antiviral, and enhanced

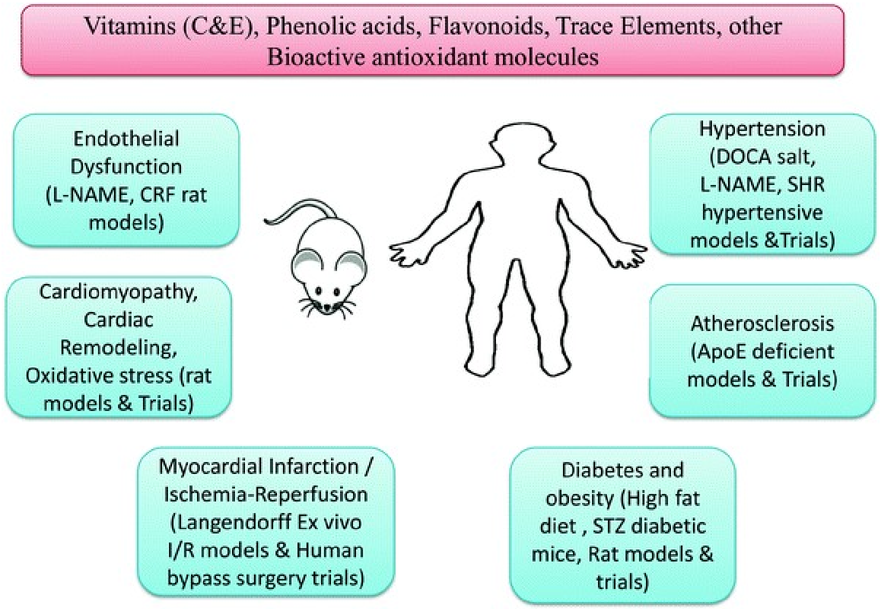

Figure 9: Role of Antioxidants in minimizing the risk of different diseases.
(Source: Manivannan et al, 2016)

production of detoxification enzymes, enhancing immune health, reduction of different diseases which are shown in figure 9.

3.3.3. COVID-19 Vs antioxidants

Pattanayak (2020) has tried to show probabilities of using effective medicinal plants to stimulate the immunity of individuals against that virus. Many antioxidants are present in the food items, among them efficient use of fruit biomedicines listed in Table 7. Pattanayak (2020) also

Table 7: Fruit plants having related reports to act against viral infections like COVID-19

Fruit source	Related reported use as/in
Indian bael	The fruit juice has anticancer, cardio protective, antibacterial, antifungal, **antiviral**, antioxidant, anti-inflammatory. radio protective, analgesic properties.
Lemon	Anti-cancer activity, prevents kidney stones, **bring down fever**, balance body pH.
Pomelo	Use in **treatment of cough, fever** and in all kinds of liver problems.

Indian gooseberry	**Immune- stimulant** during recovery from chronic diseases, **antimicrobial**, in septic **fever**.
Tamarind	Fruits protective to arteriosclerosis, having antimicrobial, antiparasitic, antifungal, **antiviral**, anti-inflammatory, **antioxidant**, anti-diabetic, wound healing properties.

(Source: Pattanayak, 2020)

predicted that dilatory intake of a few medicinal herbs and fruits prepared without addition of any synthetic material or chemical stimulate body immunity to prevent catching of viral infections like COVID - 19 and may be a very efficient alternative to the present systems followed to prevent or treat such infections.

3.4. Limitations behind referenced fruit processing techniques

The future challenge in near decades will be to ensure the availability of sufficient safe, nutritious, tasty and convenient food with achieving sustainability to the rapidly expanding and more affluent population (Fresco, 2009). Therefore, in the few last decades, much research has been conducted to retain or increase the quality of fruits such as non-thermal technologies, using different types of coating, active packaging etc. But the cost of these processing techniques is so high as the energy prices is increasing day by day. Most of the cases there is limitation 0f expert human source. Using processes are responsible for the highest contribution to the emissions of organic water pollutants because ~25% of water consumption worldwide was attributed to food processing (Ölmez, 2013). In addition, there are some indirect impact of non-thermal processing such as food losses, suboptimal utilization of by-products/processing residues, sometimes unexpected loss of antioxidant and unnecessary quality decay within the supply chain etc.

3.5. Possible schemes of overcoming barriers

Additional research on bioactive compounds should be conducted with minimal cost. Future research should focus on developing new methods for fabricating and refining or adapting current methods for their application to fresh produce. It should be ensured that only food-grade ingredients will be used and they should be economical process. As for the development of new techniques, need to develop skilled employee in this area will have fundamental understanding of biopolymer structure and interactions with antioxidants (Jose et al, 2013).

CHAPTER V

CONCLUSIONS

Fruits are highly valued for their vitamins and minerals in the human diet. But the desired level of requirement has not yet been achieved because of a number of constraints. Due to absence of proper postharvest management system, antioxidant loss is occurred and a huge quantity of the harvested fruit is damaged every year.

During conventional fruit processing, antioxidants are subjected to qualitative and quantitative changes which in some cases are negative. Fruit processing technological strategies (ultraviolet light, PEE, DPCD, HHP, ozone processing, application of the natural compounds edible coatings, active packaging, microencapsulation and nanoemulsion etc.) show positive and promising results to protect the antioxidant stability and ensure fruit antioxidant potential.

The application of this knowledge is also important for delivering health benefits to consumer because antioxidants help to prevent different kind of degenerative diseases. Different researchers suggest to intake optimum amount of antioxidant for stimulating immunity system of individuals to tackle the present pandemic caused by COVID-19 virus.

More research on fruits is still needed to obtain data on the overall effect of postharvest treatments on the nutritional value. The factors that modulate plant tissue stress response should be identified to get better results. Finally, it is recommended to investigate the interaction and combination of fruit processing techniques with those technological strategies that stable or promote the antioxidant potential of fresh fruit and ensure human health promotion.

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