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MICROWAVE BLANCHING: AN EMERGING TREND IN FOOD ENGINEERING AND ITS EFFECTS ON *CAPSICUM ANNUUM* L

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ABSTRACT

Blanching is the most widely used processing techniques that increases the shelf life of fruits, vegetables and canned food. It softens the fruits and vegetables, aids in peeling and is vital to the canning process. This review elucidates the pros and cons of blanching – both wet and dry – on food products, with a special reference to bell peppers. Agricultural products with high nutritional value and substantial market demand need to be preserved to retain freshness and nutritional qualities till it reaches the processing industry or the consumer. In this review, we described the various attributes of the wet and dry blanching processes with the aim of providing a guide for the reader to design a blanching technique that may maximize the retention of nutrients, micronutrients and volatiles while minimizing the retention of enzymes that cause degradation of fruits and vegetables.

PRACTICAL APPLICATIONS

This study shows that microwave blanching of food products is far better approach than other blanching methods as it causes minimal/lesser damage unlike IR blanching and wet blanching methods. This can be said based on the fact that microwave blanching does not involve water as required in the process of wet blanching and, thus, reduces the chances of microbial contamination. The results found in this study can be applied in the development of an optimized blanching approach as to minimize the retention of enzymes that causes degradation and to maximize the retention of nutrients, micronutrients and volatiles.

INTRODUCTION

Nowadays, foods are not only intended to satisfy hunger but also to provide the nutrition requirements (Loureiro and Umberger 2005). To fulfill consumer demands, food industries have been exploring innovative methods of food processing by using novel technologies. The main focus of these new technologies is to ensure products' safety and shelf life while preserving, sensory and nutritional characteristics to obtain products similar to fresh foods. Various technologies for preserving food products include thermal processing, nonthermal processing, low temperature processing, chemical treatment, etc. (Juneja 2002; Tatiana *et al.* 2010).

Thermal treatment involves use of high temperature to minimize the degrading effect of enzymes and microorganisms that could potentially reduce quality and safety of food (Dennis and Richard 1997). Additionally, thermal treatment is used to fulfill many objectives including reducing compounds and enzymes responsible for off flavor development, increasing the concentration for liquid food and improving the palatability of different foods. Thermal treatment is commonly associated with loss of nutritional value and loss of sensory/organoleptic quality such as color, texture and flavor (Joy *et al.* 2007). Based on the requirements, industries are using many thermal processing techniques, e.g., sterilization, drying, pasteurization and blanching (Evans and Board 1954; Evans 1958; Sobhi *et al.* 2012). Among these, blanching is the most widely used method of heat treatment employed commonly or fruits, vegetables, frozen foods and canned foods.

Based on the consumer demand, exportability and research trends *Capsicum annuum* L. (red bell pepper) is becoming the interest to preserve and increase its shelf life. Apart from being in greater demand, bell peppers possess numerous beneficent properties, e.g., they have antioxidant properties, antibacterial properties, higher nutritional value, etc. There are also particular micronutrients, phenolic compounds and volatiles present specifically in bell peppers which impart a palatable smell and taste to them (Rose *et al.* 2012; Nesrin and Arzu 2014).

Here in this review we are highlighting different types of blanching procedure used for food processing. We also have discussed the specificity, advantage and disadvantage of several types of blanching procedure which will give a detailed inspiration for processing fruits and vegetable accordingly. We have also discussed effects of blanching on capsicum and summarized all the researches done on in this regard.

BLANCHING

As discussed earlier, blanching is a mild heat treatment unit operation prior to freezing, canning or drying where fruits or vegetables are heated so as to inactivate enzymes responsible for degradation. It helps in modifying texture while maintaining nutritional value of food (Manpreet *et al.* 2000). It also helps in preserving color and flavor, while removing trapped air (Barrett and Theerakulkait 1995; Elisabeth *et al.* 2001; Bahceci *et al.* 2004). Blanching is responsible for inactivating enzymes that cause the development of off-flavors and off-colors (Manpreet *et al.* 2000). However, it is noted that onions, leeks and peppers which have a characteristic flavor and color may lose their properties during blanching (Elisabeth *et al.* 2001). Blanching removes volatiles and metabolic gases within vegetable cells and replaces them with water, forming a semi continuous water phase that favors a more uniform crystal growth during freezing (Barrett and Theerakulkait 1995; Elisabeth *et al.* 2001; Bahceci *et al.* 2004). Gas removal by blanching before canning makes the process easier, reduces strain on the can during heating and also reduces can corrosion (Lenz and Lund 1977). Blanching may be categorized into dry and wet blanching based on requirement of water for the process (Fig. 1).

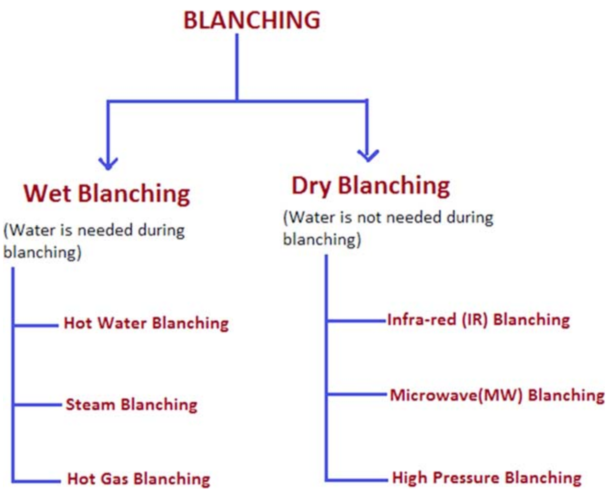

FIG. 1. TYPES OF BLANCHING BASED ON REQUIREMENT OF WATER DURING PROCESSING

WET BLANCHING

When water or steam is used to blanch samples then the technique is referred to as wet blanching. Furthermore, based on the type of water used, wet blanching again can be categorized as hot water blanching, steam blanching and hot gas blanching (Fig. 1). Hot water blanching is performed at temperatures ranging typically from 70 to 100C. Techniques used for hot water blanching are: LTLT (low temperature for longer time), HTST (high temperature for shorter time) or a combination of both (Agblor and Scanlon 2000).

Steam blanching is recommended for a few vegetables like broccoli, pumpkin, sweet potatoes and winter squash. Both steaming and boiling are satisfactory methods. Steam blanching, however, takes about 1.5 times longer duration than hot water blanching. A combination of steam and hot water blanching is also in practice (Sheetal *et al.* 2008). Another technology called individual quick blanching (IQB) was developed to maintain the uniformity of the process throughout the sample. In IQB, a single layer of product is conveyed through the steam chamber and each "individual" piece of product immediately comes in contact with the steam (Jose *et al.* 2010). In hot gas blanching, combustion of flue gases and steam is used to increase humidity and prevent product dehydration. It has the advantage of reducing waste production and is comparable to conventional blanching with respect to nutrient retention. However, this often results in product weight loss. This approach is not currently used in industries and need to be further investigated and optimized (Jack *et al.* 1973).

There are many disadvantages of wet blanching. It requires longer processing time and a large amount of energy. As a result of this there is a more leaching of minerals, nutrients, phytochemicals and flavor. Additionally, wet blanching creates high temperature gradients between the center and the surface of the food product increasing chances of "over-blanching" or "under-blanching." Also, wet blanching may cause undesirable changes in product texture and produce effluents with large biological oxygen demand (BOD). In order to overcome these disadvantages, dry blanching may be an alternative (Castro *et al.* 2008).

DRY BLANCHING

Dry blanching is achieved using microwaves (MW) (Chung *et al.* 1981; Gunes and Bayindirli 1993; Cano *et al.* 1998; Devece *et al.* 1999; Ramesh *et al.* 2002), Infra-red (IR) radiation (Ponne *et al.* 1994; Zhu and Pan 2009; Kalathur *et al.* 2013) and high pressure (Matser *et al.* 2000; Castro *et al.* 2008). It has been reported that dry blanching has many advantages over conventional blanching. These primarily include lower time required for the inactivation of enzyme complexes that cause degradation in quality and little or no leaching of vitamins, volatiles, pigments, carbohydrates and other water soluble components (Ancos *et al.* 1999).

In IR blanching, infrared radiation energy with specific wavelengths penetrates the food product and directly heats the water and moisture in foods to achieve blanching effect and drying. Water in food absorbs heat energy very efficiently in the range of medium and far infrared wavelengths with peak wavelengths at 3, 4.7 and 6 μm (Zhongli and Griffith 2010). It is highly efficient for energy transfer to food since the medium IR and far IR energy does not heat the air and surrounding environment.

MW blanching causes heating of materials which have a dielectric medium. Alignment of dielectric materials towards the oscillating electromagnetic (EM) field causes heating effects. Molecular rotation occurs in materials containing polar molecules having an electric dipole moment, which will align them in an electromagnetic field. Due to this, kinetic energy increases which causes temperature of the material to increase. Thus, dipole rotation is a mechanism by which energy in the form of electromagnetic radiation is converted to heat energy in matter. MW blanching is a method for dry blanching but in 1971 researchers have used water as a coolant during MW blanching. However, this modification was discarded because there was evidence of nutrient loss (Chen *et al.* 1971).

MW is located between radio waves and infrared in the electromagnetic spectrum with a wavelength range of 1 mm–30 cm. Lower wavelength microwaves have higher energy (Mudgett 1986; Mudgett 1982). In MW blanching, heat is uniformly distributed in the material, leading to faster heating rates compared to conventional heating where heat is usually transferred from the surface to the interior. The main advantage of MW blanching system is that it is capable of producing heat internally and it has greater penetration depth too; because of which "retention" of thermo labile constituents is improved. In a nut shell, MW blanching can be regarded as one of the best HTST systems for thermal treatment (Collins and McCarty 1969; Dietrich *et al.* 1970).

High pressure (HP) blanching is yet another alternative available for wet blanching techniques. It involves high pressure treatment of food products, normally contained in heat sealed packages. The pressure range is varied between 50 and 700 MPa, depending on the product characteristics, but generally between 100 and 200 MPa is recommended (Castro *et al.* 2008). Some high pressure blanching procedures also incorporate dipping the food product into liquids like citric acid. High pressure blanching has shown to be an efficient technique for inactivation of enzymes that can cause degradation, as shown in the case of inactivation of peach polyphenoloxidase enzymes when peach slices were treated with high pressure. In the same study, Kingsly *et al.* (2009) also showed that this high pressure treatment of peach slices could be exploited as a potential pre-treatment for drying because it reduced the drying time and increasing rate of drying of the product.

BELL PEPPER

Bell pepper (*Capsicum annuum* L.) is an angiosperm belonging to the Solanaceae family. Today, they are cultivated worldwide and have become a key element in many regional cuisines (Gil-Jurado 2006). Bell peppers can be used raw or cooked; they are suitable for stuffing with fillings such as cheese, meat or rice. They can be preserved in the form of jams and pickles or by drying or freezing. They have very good antibacterial activity when mixed in ground beef (Sulaiman *et al.* 2012). Dried peppers may be consumed as a whole or processed into flakes or powders. Pickled or marinated peppers are frequently added to sandwiches and salads. Frozen peppers are used in stews, soups and salsas. Extracts can be incorporated into hot sauces. The Maya and Aztec people of Central America used *Capsicum* fruit in cocoa drinks as a flavoring agent (Bosland 1996).

Different varieties of bell peppers are available possessing myriad tastes and colors. Some commonly found colors of bell peppers are green, red, yellow, orange and rarely even, brown, white, rainbow, lavender and dark purple. Most typically, the unripe fruits are green or less commonly, pale yellow or purple. One variety, permagreen, retains its green color even when fully ripe. The taste of ripe peppers can also vary with growing conditions and post-harvest storage treatment; they are the sweetest when the fruits are allowed to ripen fully on the plant in full sunshine, whereas fruit harvested while green and consequently ripened in storage are less sweet (Manpreet *et al.* 2000; Rose *et al.* 2012; Nesrin and Arzu 2014).

TABLE 1. GENERAL DETAILS OF PROCESS PARAMETERS – WAVELENGTH, RUN TIME, AND RADIATION INTENSITY – FOR DIFFERENT BLANCHING TECHNIQUES.

Wavelength	Radiation intensity	Heating time	Reference
Infrared blanching			
Medium IR (peak): 3,4.7 μm	3,000–4,000 W/m^2	20 min	Zhu and Pan (2009)
Far IR (peak): 6 μm			
Microwave blanching			
Frequency	Temperature	Time	Reference
2,450–50 MHz	85–87C	10–11 min	Boyes *et al*. (1997)
High pressure blanching			
Pressure	Temperature	Time	Reference
100 and 200 MPa	22–24C (100 MPa) 24–26C (200 MPa)	10 min (100 MPa) 20 min (200 MPa)	Castro *et al*. (2008)
Hot water blanching			
Temperature	Time		Reference
70, 80 and 90C	1 min (70, 80C) 2.5 min (90C)		Castro *et al*. (2008)
Steam blanching			
Temperature	Time		Reference
100C	15–20 s		Wang et al. (1997)
Hot gas blanching			
Steam usage	Time		Reference
1.9–2.9 kg/min	14–25 min		United States Environmental Protection Agency (1974)

Capsicum annuum is composed of soluble carbohydrates, pectins, capsaicinoids and volatiles. Sucrose, glucose and fructose are the major components of the soluble neutral sugars found in *Capsicum annuum* (Barrett and Theerakulkait 1995). Additionally, bell peppers have many vitamins and nutrients and contain the antioxidant compound, lycopene, as one of their active constituents. The level of carotene, like lycopene, is nine times higher in red peppers than other bell peppers. Red peppers have twice the vitamin A and vitamin C content than present in green peppers (Manpreet *et al.* 2000). Also, one large red bell pepper contains 209 mg of vitamin C, which is three times of an average orange (70 mg). Red and green bell peppers are high in p-coumaric acid.

The characteristic aroma of green peppers is caused by 3-isoButyl-2-methoxypyrazine. Its detection threshold in water is estimated to be 2 ng/L (Elisabeth *et al.* 2001; Bahceci *et al.* 2004). It should also be noted that more than 60 volatiles have been identified in red bell pepper, out of which some major volatiles are hexanal, linalool, 3-carene, trans-2-hexenal, 2,3-butanedione, etc. (Ranjan *et al.* 2013) have enlisted the enzymes that cause degradation in bell peppers using bioinformatics and online databases like Swissprot, Uniprot, ExPAsy and BRENDA enzyme database. Detailed information on many degrading enzymes has been provided along with the mechanism of action (Table 1). Such enzymes include peroxidase, polyphenol oxidase, tyrosinase, catechol, catalase, 9-lipoxygenase, L-asparaginase, capsanthin synthase and ribulase-phosphate-3-epimerase.

EFFECTS OF BLANCHING ON NUTRITIONAL VALUE OF CAPSICUM

Castro *et al.* (2008) have compared the effect of pressure treatments at 100 and 200 MPa (10 and 20 min) and of thermal blanching at 70, 80 and 98C (1 and 2.5 min) on sweet green and red bell peppers. Pressure treated peppers showed a lesser reduction on soluble protein and ascorbic acid contents when compared to the peppers that were blanched. Treated bell peppers even showed an increased content of ascorbic acid (15–20%), compared to the untreated peppers. POD and pectin methylesterase were highly stable to pressure treatments, particularly the latter enzyme, while PPO was inactivated by the thermal blanching and pressure treatments. These findings indicate that pressure treatments at 100 and 200 MPa can be used to produce frozen peppers with similar or better nutritional values and texture characteristics. Kinetic characterization and thermal inactivation studies for partially purified red pepper (*Capsicum annuum* L.) POD showed that thermal inactivation causes a first-order inactivation kinetic, and the Arrhenius plot yielded a straight line with a slope equivalent to an activation energy of 151 kJ/mol. Significant inactivation occurred at temperature >40C and the *D* value for 5 min was 44.5C (Serrano-Martíneza *et al.* 2008). Earlier, inactivation of bell pepper pectin methylesterase by combined high-pressure and temperature treatments were studied by Castro *et al.* (2006). Pressure and temperature dependence of the inactivation rate constants on the labile fraction was quantified using the

Eyring and Arrhenius relations, respectively. A third-degree polynomial model (derived from the thermodynamic model) was successfully applied to describe the temperature/pressure dependence of the inactivation rate constants of the labile pepper pectin methylesterase fraction (Castro *et al.* 2006).

The effect of different cooking methods on the antioxidant properties of colored peppers was investigated. Six varieties of peppers were subjected to different cooking methods, such as microwave heating, stir-frying and boiling, for 5 min individually. The cooked and raw peppers were analyzed for radical-scavenging activity (RSA) and total polyphenol content (TP) using 1,1-diphenyl-2-picrylhydrazyl–high-pressure liquid chromatography (DPPH)–HPLC and Folin–Ciocalteu methods, respectively. The samples were also evaluated for ascorbic acid content (AsA) by using HPLC. Total carotenoid content was determined spectrophotometrically. Results suggested that there was no significant ($P > 0.05$) difference in RSA, TP, AsA and total carotenoid contents between the cooked and raw peppers after being processed for 5 min. However, the cooked peppers show a marked difference ($P < 0.05$) in the RSA, TP and AsA content when cooked for 5 min in boiling water with further reduction observed after boiling for 30 min. This may be due to the leaching of antioxidant compounds from the pepper into the cooking water during the prolonged exposure to water and heat. Therefore, it is vital to use less water and reduce the cooking time and also utilize the water used for boiling so as to obtain the optimum benefits of bioactive compounds present in peppers. It is concluded that microwave heating and stir-frying without using water are better suited to cook pepper, so as to ensure the maximum retention of antioxidant molecules (Chuah *et al.* 2008). This result supports the findings of Nihal *et al.* (2005) in terms of the antioxidant activity (Nihal *et al.* 2005). For rehydrated dried red bell pepper (*var.* Lamuyo) the rehydration ratio, water retention capacity, color, firmness, vitamin C content and microstructure level were analyzed and the results showed that the best quality product was obtained when samples were pre-treated before drying. Microscopic examination of the rehydrated pepper samples suggested that damage to cellular structure was minimized by pretreatment of samples; the resulting rehydrated peppers displayed comparatively improved vitamin C retention, color and firmness.

Effects of mild pressure treatments and thermal blanching on bell peppers were analyzed by Castro *et al.* (2011) found that pressure treatments reduced peroxidase activity only by 5–10% (Castro *et al.* 2011). Activity of pectin methylesterase was undetectable in both fresh as well as thermally and pressure processed peppers. Firmness of peppers measured from the skin side was about 2.5-fold higher than from the flesh side. After the thermal blanching and the pressure treatments, firmness of peppers was better retained when measured from the flesh side. On the other hand, in pressure treated and thermally blanched peppers, a relative decrease in firmness has been noted (Castro *et al.* 2011). In a recent analysis, dry blanching of red bell pepper (*Capsicum annuum* L.) slices using infrared (IR) and microwave (MW) radiations was attempted and the performance was compared with conventional water and steam blanching methods. Processing conditions (time and temperature) were standardized on the basis of the degree of enzyme inactivation (POD and PPO). Effect of blanching on retention of micronutrients such as ascorbic acid, β-carotene and protein, along with product shrinkage, structure and texture (shearing force) were analyzed. Water and steam blanching were observed to require lower processing time (1.0 and 1.5 min, respectively) compared to IR (6.0 min) and MW blanching (3.0 min). However, microwave-blanched samples retained higher amounts of ascorbic acid (94.7%). Dry blanching with IR (15C) and MW (17.5 W/g) resulted in higher retention of β-carotene (103.2 and 118.6%, respectively) compared to water (60.3%) and steam blanching (88.3%). Dry blanching resulted in moisture loss (1–6%) and shrinkage, perhaps resulting due to higher shearing force observed. This study explored the possibilities of dry blanching red bell pepper using infrared and microwave radiation as a potential alternative to water and steam blanching. The dry blanching is expected to retain higher amount of nutrients, reduce solid loss and eliminate effluent generation besides being convenient to operate (Jeevitha *et al.* 2013). In another similar study involving blanching of peppers using microwaves, it was found that phenolic compounds were reduced from 9.6 to 7.6 mg/g peppers (dry weight basis) and antioxidant activity was enhanced from 29 to 42 μM trolox/g in the peppers (dry weight basis) with thermal microwave blanching. Changes in the content of phenolic compounds were confirmed using HPLC and the emergence of other phenol derivatives with enhanced antioxidant activity was detected in blanched samples. It may be concluded that blanching bell peppers with microwaves may induce the formation of derivatives of phenolics with enhanced antioxidant activity (Lidia *et al.* 2011).

Residual activities of lipoxygenase (LOX), POD, PPO were determined in paprika and chili powder after immediate thermal treatment of the fresh plant material by Schweiggert *et al.* (2005) and PPO showed the lowest heat stability and was completely inactivated by heating at 80C for 10 min. Inactivation of LOX was also largely accomplished by heating at 90C for 5 min and at 100C for 5 min, whereas up to 3.5% (paprika) and 3.3% (chili) of the initial POD activities were retained even when applying rigorous time–temperature regimes. The results demonstrated that substantial inactivation of deteriorative enzymes was ensured by the recently suggested process, thus facilitating the production of high quality spice powders (Schweiggert *et al.* 2005; Ranjan *et al.* 2013).

In a recent study, a central composite design (CCD) with three variables was used to analyze the response pattern and to determine the optimum combination of the variables. CCD combines vertices of the hypercube whose co-ordinates are given by a 2n factorial design and two star points (outsider points) to provide for the estimation of curvature of the model. Microwave conditions were optimized by using RSM. Four conditions optimized using overlaid contour plot, response optimizer and based on similarity only two conditions were considered for validation (W: 524, W/g: 19.371, time: 191 s; W: 540.02, W/g: 19.343, time: 194 s). After validation ascorbic acid and capsaicin were analyzed by using HPLC which are as $90.062 \pm 0.023\%$ and $92.34 \pm 0.027\%$, respectively. For capsaicin standard, the retention time is 4.538 min, but no peaks we observed close to this retention time in either raw or blanched red bell peppers, therefore leading to the conclusion that capsaicin is absent in red bell peppers (Ranjan and Hebbar 2013), a deduction consistent with earlier findings (Zeid *et al.* 2011). The β-carotene retention content in slices blanched at optimized MW blanching conditions was also estimated and found to be 0.04 ± 0.0039 mg/g (dry weight) for raw, 0.0249 ± 0.0047 mg/g (dry weight) and 0.0318 ± 0.0033 mg/g (dry weight) for blanched samples at optimized conditions, respectively. From gas chromatograms, it can be concluded that the volatile linalool retention time is approximately 36 min. When estimated in raw bell peppers, the linalool content was considerably lesser than the linalool observed in blanched bell peppers. This can be attributed to the fact that the raw bell peppers were not exposed to MW like the blanched red peppers and hence the volatiles emitted in them were lower. Maximum area was observed for the blanched sample at 524 W, 19.371 W/g for 191 s, thus concluding that blanching causes loss in volatiles. From this research, we have optimized blanching condition for red capsicum, and these optimized conditions may be used for other vegetables as well, facilitating greatly increased shelf life and minimal loss of nutrients (Ranjan and Hebbar 2013). Jeevitha *et al.* (2014) have evaluated the effect of electromagnetic radiation (microwave and infrared) based dry blanching and superheated steam enzyme inactivation on product quality of green bell pepper. They have concluded that the time taken in MW blanching and super-heated steam blanching is comparatively lesser than the conventional methods for blanching. They have also comparatively evaluated the retention of ascorbic acid and soluble protein and found that the retention was higher in microwave and superheated steam-blanched slices of bell peppers (Jeevitha *et al.* 2014).

CONCLUSION

Blanching is a processing step mainly employed to increase the shelf life of the food by decreasing the microbial load and lowering the concentration of enzymes that causes degradation. Blanching has its own merits and demerits. It is used for preserving color, removing trapped air and maintaining nutritional value. However, blanching also has some disadvantages which can be optimized for minimal loss. Wet blanching decreases the nutritional value because of leaching; also, due to higher water activity, chances of microbial contamination are high. Dry blanching can be a better alternative to wet blanching to overcome these drawbacks. Leaching of the nutrients and micronutrients can be prevented by dry blanching and further microbial growth can also be prevented since water is not being used during the process. IR blanching has adverse effects like cell wall rupture, blackening and other undesired structural changes. MW blanching might be used to minimize the adverse effects of IR blanching. Research is needed to optimize the process with the objective to minimize the retention of enzymes that causes degradation and to maximize the retention of nutrients, micronutrients and volatiles. Although some important enzymes like catecholase, pectinesterase, catalase, lipoxygenase, L-asparaginase, polygalactouronase, capsanthin, ribulose-phosphate 3-epimerase play a vital role in the metabolism and shelf life of capsicum, they are poorly studied for *Capsicum annuum* L. The effects of the processing steps, especially blanching, should be analyzed on these enzymes thoroughly to increase the shelf life without compromising with the nutritional components.

Substantial research has been done on the effect of processing on ascorbic acid; some phenolic compounds (capsaicinoids, di-hydro capsaicinoid, etc.) and a few major volatiles like hexanal, linalool, etc. but the effect of processing steps on the nutrients, micronutrients and volatiles is not yet studied in detail. A detailed analysis on the effects of processing on the enzymes, nutrients, micronutrients, volatiles and other structural changes is imperative to optimize thermal treatment of food products. Based on degradation of harmful enzymes and/or retention of useful enzymes, nutrients, micronutrients and volatiles; the processing factors need to be optimized to get good quality products. In conclusion, the chemical constituents of the food need to be analyzed properly in order to optimize the steps in food processing.

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