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Review Article

BROWNING, ITS CHEMISTRY AND IMPLICATIONS IN DAIRY PRODUCTS: A REVIEW

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Browning- one of the major chemical reaction taking place during processing and storage of food, leads to several changes in the products in terms of colour, flavour, loss of nutritive value, formation of toxic compounds, loss of solubility, along with some desirable aroma and flavour compounds etc. These changes have been induced due to several factors like type of amino acid, type of sugar, temperature, pH, etc. Several studies have been carried out on different dairy products depicting the desirable and undesirable effect of browning on milk powder, infant formulae, pizza cheese, sweet whey powder, confectionaries and bakery products. As browning in some cases causes the formation of some toxic and mutagenic compounds in some cases, it is important to control or minimize it. This can be done by controlling temperature, water activity and pH, high pressure processing, modified atmospheric packaging and also by use of some chemical inhibitors.

Keywords: Browning, Caramelization, Maillard reaction

INTRODUCTION

Browning reactions that take place during processing and storage of foods are widespread phenomena and are important in terms of the alteration of appearance, flavor, and nutritive value. Browning is considered to be desirable if it enhances the appearance and flavor of a food product in terms of tradition and consumer acceptance like in the cases of coffee, tea, snack foods, beer, and in toasting of bread. However, in many other instances, such as fruits, vegetables, frozen and dehydrated foods, browning is undesirable as it results in off-flavors and colors. Another significant adverse effect of browning is the lowering of the nutritive value of the food substance. This problem is of considerable importance to the food industry as it reduces consumer acceptability, and therefore causes significant economic impact, both to primary food producers and the food processing industry (Gogus *et al.,* 2010).

Many plant foods are subject to degradative reactions during handling, processing, or storage, collectively described as browning reactions, that result in the formation of brown, black, gray, or red colored pigments (Nichols, 1985; Feinberg *et al.*, 1987).

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Such reactions are generally grouped into two categories:

- Enzymatic browning *e.g.* browning of cut apples or potatoes
- Nonenzymatic browning *e.g.* Maillard reaction, caramelization and ascorbic acid oxidation (Sapers *et al.,* 2001)

Enzymatic Browning

Appearance, flavour, texture and nutritional value are four attributes considered by consumers when making food choices. Appearance which is significantly impacted by colour is one of the first attributes used by consumers in evaluating food quality. Enzymatic browning is one of the most important colour reactions that affect fruits, vegetables and seafoods. It is catalysed by the enzyme polyphenol oxidase (1, 2 benzenediol; oxygen oxidoreductase, EC1.10.3.1) which is also referred to as phenoloxidase, phenolase, monophenol oxidase, diphenol oxidase and tyrosinase. Polyphenol oxidases are also responsible for development of the characteristic golden brown colour in dried fruits such as raisins, dates and figs.

Polyphenol Oxidases

Polyphenol oxidases were first discovered in mushrooms and are widely distributed in nature. Polyphenol oxidases occur in the chloroplasts of almost all higher plants. PPOs are ubiquitous, copper-containing metalloproteins that are found almost universally in animals, plants, fungi, and bacteria. For PPOs isolated from a great number of fruits and vegetables, there exist different substrate specificities and degrees of inhibition while its level in plants is dependent on the species, cultivar, maturity, and age. In general, PPO activity is very low in young plants, and is often undetectable (Gogus *et al.,* 2010).

Polyphenol oxidase is thought to play an important role in the resistance of plants to microbial and viral infections and to adverse climatic conditions. Phenolics, such as chlorogenic acid, caffeic acid and scopolin, etc., which are substrates of this enzyme have been shown to exhibit fungicidal properties. These melanins form barriers and have antimicrobial properties which prevent the spread of infection or bruising in plant tissues. Plants, which exhibit comparably high resistance to climatic stress, have been shown to posses relatively higher polyphenol oxidase levels than susceptible varieties.

Enzymatic browning of raw commodities may result from physiological injury; senescence; pre- or postharvest bruising; disruption of the fruit or vegetable flesh by peeling, coring, slicing, or juicing; tissue disruption from freeze–thaw cycling; and tissue disruption by bacterial growth (Sapers *et al.,* 2001). The occurrence of enzymatic browning can limit the shelf-life of fresh-cut fruits and salad vegetables, fresh mushrooms, prepeeled potatoes, and other fresh products of commercial importance (Huxsoll *et al.,* 1989). This problem has held back the development and commercialization of fresh-cut fruits such as sliced apples. Enzymatic browning also may be a problem with some dehydrated and frozen fruits and vegetables. In addition to causing discoloration, in fruit and vegetable products it can also result in loss of ascorbic acid (vitamin C) through reaction with quinines (Sapers *et al.,* 2001). The control of browning in fruits and vegetables hinges upon an understanding of the mechanism(s) responsible for browning in fruits, vegetables and seafoods, the properties of polyphenol oxidase enzyme(s), their substrates and inhibitors, and the chemical, biological and physical factors which affect each of these parameters. Once understood these mechanisms may be applied in either preventing the browning reaction, or slowing its rate, thus extending the shelf life of the product (www.fao.org).

Non-Enzymatic Browning

There are three main mechanisms by which nonenzymic browning occurs in foods: Caramelization, Ascorbic acid oxidation and Maillard reaction. Nonenzymatic browning (NEB) reactions occur during the thermal processing and storage of foods. These reactions cause some desirable and undesirable chemical and structural changes in foods. The mostly known changes are formation of brown color, production of flavors or off-flavors, nutritional loss followed by the reduction of ascorbic acid, amino acids, and invert sugars, and formation of some toxic and mutagenic compounds such as imidazols, HMF, acrylamide, advanced glycation endproducts (pentosidine and argpyrimidine), and melanoidines (Gogus *et al.,* 2010). Participation of free amino groups in browning reactions may result in losses of essential amino acids and reduced protein digestibility (O'Brien and Morrissey, 1989).It represents an important cause of quality loss in foods, and has also been reported as a cause of damage of pharmaceutical products (Kumar and Banker, 1994).

CARAMELIZATION

It involves the heat-induced decomposition of sugars, polysaccharides, polyhydroxycarboxylic acids, reductones, _-dicarbonyl compounds, and quinones undergo browning in the absence of amino compounds. Such reactions occur even in the absence of catalysts, n the food industry, but they require high temperatures, not often encountered. For example, glucose decomposes only above 150°C. Caramelization is accelerated by carboxylic acids and their salts, phosphates, and metallic ions, but even when so catalyzed, the energy requirements exceed those of sugar–amine reactions (Nursten, 2011). Caramelization products vary in chemical and physical properties and in their constituents depending on the temperature, the pH, and the duration of heating (Gogus *et al.,* 2010).

ASCORBIC ACID OXIDATION

Browning of foods is caused by ascorbic acid, which is easily oxidized and decomposed under food processing and storage conditions. The formation of dehydroascorbic acid and diketogluconic acids from ascorbic acid occur during the reaction and are capable of interacting with the free amino acids non-enzymatically, producing a red-to-brown discoloration. Oxidation of ascorbic acid in citrus fruits may cause loss of vitamin C with subsequent darkening of the fruit. Sugars in fruit juices can caramelize when exposed to excessively high temperatures during concentration. Browning due to anaerobic degradation of ascorbic acid is very important in processed fruit juices enriched with vitamin C (Schulz *et al.*, 2007). The browning with ascorbic acid increases with pH, and above pH 7, autoxidation and browning occur even at 25°C (Nursten, 2011).

MAILLARD REACTION

In 1912, the French chemist Louis-Camille Maillard first observed that yellow-brown pigments formed in the reaction among sugars and amino acids, peptides, and proteins in a heated solution. Food chemists have recognized the practical relevance of this reaction to many chemical and physical changes during processing and storage of food. The first review (in English) on the Maillard chemistry in food systems was published in 1951. Since then, numerous reviews on this subject have appeared. The biological importance of this reaction has been recognized only in the last 20 years. It is now well established that the reaction is linked to glycosylated hemoglobin (HbAlc) in diabetes, hardened lens crystallins in cataract disease, and a number of other aging proteins. The Maillard reaction occurs between carbonyl compounds, especially reducing sugars, and compounds with free amino groups, such as amines, amino acids, and proteins. This reaction may have either beneficial or detrimental effects (Ajandouz *et al.,* 2001). The Maillard reaction is a complex reaction and is influenced by many factors, such as temperature, pH, time, water activity, types and concentrations of amino acids, and sugars. Changing any of these factors will alter the reaction rate, reaction pathways, and reaction end-products (Martins *et al.,* 2001).

Mechanism of Maillard Reaction

I. Initial stage (colorless, no absorption in the near-UV)

   A. Sugar-amine condensation

   B. Amadori rearrangement

II. Intermediate stage (colorless, or yellow with strong absorption in the near-UV)

   C. Sugar dehydration

   D. Sugar fragmentation

   E. Amino acid degradation

III. Final stage (highly colored)

   F. Aldol condensation

   G. Aldehyde-amine polymerization; formation of heterocyclic nitrogen compounds (melanoidines)

Changes Occurring During Maillard Reaction

Formation of Color

The colored products of the Maillard reaction are of two types: the high-molecular-weight macromolecule materials commonly referred to as melanoidins and the low-molecular-weight colored compounds containing two or three heterocyclic rings (Ames *et al.*, 1998). Color development increases with increasing temperature, time of heating, increasing pH, and intermediate moisture content (aw 0.3 to 0.7). Of all the amino acids, lysine makes the largest contribution to color formation, and cysteine has the least effect on color formation.

Formation of flavor and aroma compounds

Type of sugars and amino acids involved reaction temperature, time, pH, and water content (Jousse *et al.*, 2002). In general, the first factor mentioned determines the type of flavor compounds formed, and the second factor influences the kinetics. The most common route for formation of flavors via the Maillard reaction includes the interaction of á-dicarbonyl compounds (intermediate products in the MR, stage 2) with amino acids through the Strecker degradation reactions. Alkyl pyrazines and Strecker aldehydes belong to commonly found flavor compounds from the MR.

Formation of Antioxidants

In the Maillard reaction, high antioxidant capacity was generally associated to the formation of brown melanoidins (Yen and Hsieh, 1995). The formation of melanoidins with antioxidant capacity can predominate only in a particular phase of processing (Manzocco *et al.,* 2001). In the case of coffee, the antioxidant capacity decreased as roasting intensity increases. Although the chemical browning of polyphenol substances may play some role, the loss in antioxidant capacity during the advanced phases of the roasting process can be mainly attributable to the pyrolisis of coffee components, including melanoidins and phenols (Manzocco *et al.,* 2001). Since food colour can be simply evaluated by means of quick and non-destructive methodologies, the existence of an eventual correlation between colour and antioxidant properties could be useful to optimize processing conditions not only on the basis of the sensorial characteristics but also from the antioxidant properties point of view (Manzocco *et al.,* 2001).

Loss of Solubility

Melanoidin formation is invariably accompanied by an increase in molecular size, which almost always results in a decrease in solubility. However, the stability of milk upon lowering of pH and in the presence of calcium is improved by preheating, which is attributed to the modification of lysine residues and the consequent increase in negative charge on casein (Nursten, 2011).

Reduction of Nutritive Value

In various milk products (milk powder, UHT milks, sterilized milks), the Maillard reaction leads to the loss of nutritional value (Erbersdobler and Somoza, 2007). Swedish scientists announced that certain foods that are processed or cooked at high temperatures contain relatively high amounts of a known carcinogen, acrylamide (Mottram *et al.,* 2002). Several months after the Swedish announcement, a number of research groups simultaneously discovered that acrylamide is formed during the Maillard reaction, and the major reactants leading to the formation of acrylamide are sugars and the amino acid asparagines (Stadler *et al.,* 2002).

Formation of Toxic Compounds

Acrylamide is classified as a probable human carcinogen by the International Agency for Research on Cancer (IARC, 1994). Studies to date clearly show that the amino acid asparagine is mainly responsible for acrylamide formation in cooked foods after condensation with reducing sugars or a carbonyl source. Moreover, the sugar–asparagine adduct, N-glycosylasparagine, generates high amounts of acrylamide, suggesting the early Maillard reaction as a major source of acrylamide (Stadler *et al.,* 2002).

Loss of Biological Value

Lysine is an essential amino acid and so its loss through the Maillard reaction seriously detracts from the nutritional value of milk, which is a good source of lysine. When lactose reacts with protein in dairy products, lactulosyllysine residues are formed. On hydrolysis, these give yields of 40% recovered lysine and 32% furosine (Nursten, 2011).

Furosine: An Early Maillard Reaction Index

The early stage of the Maillard reaction can be monitored through the amount of furosine (N-2-furoylmethyl-L-lysine) in milk. Furosine arises from acid hydrolysis (6 *N* HCl at 110°C for 24 h) of lactulosyl-lysine. Furosine can be considered a good indicator of the earliest stage of the Maillard reaction because it gives an assessment of unavailable lysine produced during heat treatment of milk.In Italy, the furosine level in pasteurized milk is regulated by law and should not exceed 8.6 mg/100 g protein (Jahreis *et al.,* 1999-).

Furfural Compounds: Indices of the Intermediate

Hydroxymethylfurfural (HMF) is the product of the dehydration of hexoses (free or linked to protein) due to the presence of concentrated acids. HMF is formed not only from Amadori compounds, but also from sugars (lactose isomerization). It is considered a good index of the severity of milk heat treatment and is suitable as a marker of the most severe heat treatments (UHT and sterilized milk) (Manzi and Pizzoferrato, 2006). Traditionally, HMF is determined by a colorimetric method. The HMF level in commercial UHT milk (stored below 50°C) is also related to temperature and time of storage, and increases with higher temperature.

Factors Affecting the Maillard Reaction

These factors may be distinguished as those relating to the reactant composition, e.g., type of amino acid, sugar type,sugar:amino acid ratio, and external factors such as moisture level, temperature, and pH (Gogus *et al.,* 2010).

Amino Acid Type

Amino acid type which is used or present in the medium is very important in the Maillard reaction Some amino acids have two reactive groups therefore these types of amino acids rapidly react with the sugars to produce brown pigment.. Kwak and Lim (2004) found that the color intensity of the MRPs from the lysine was the highest followed by basic and nonpolar amino acids such as arginine, phenylalanine, leucine, isoleucine, and valine. The next group was the acidic amino acids such as aspartic acid and glutamic acid.

Type of Sugar

Reducing sugars are essential ingredients in these reactions, providing the carbonyl groups for interaction with the free amino groups of amino acids, peptides, and proteins. The increasing order of brown pigment formation is: d-xylose > l-arabinose > hexoses > disaccharides. D-Fructose has also been reported to brown at a much faster rate than glucose during the initial stages of the browning reaction, but it then falls behind. Sucrose, as a nonreducing sugar, will only participate when the glycosidic bond is hydrolyzed and the reducing monosaccharide constituents released. Hydrolysis of the glycosidic bond in sucrose is facilitated by a low pH, resulting in an increase in the Maillard reaction rate in protein–sucrose systems (Gogus *et al.,* 2010).

Sugar-Amine Ratio

An excess of reducing sugar over amino compound promotes the rate of Maillard browning, Warmbier *et al.* (1976) found that, the browning rate increased to a maximum at glucose: lysine ratio of 1:3 (present in casein). Since, the initial step of formation of the Schiff base is dependent on the concentration of both, sugar and amino acid, its formation increases with decreasing sugar: amino acid ratio. The effect of increasing the amino acid concentration shows a greater increase in browning than that of increasing the sugar content on a molar basis and the increase for both is greater than the relative concentration increase (Gogus *et al.*, 2010).

Effect of water activity

Nonenzymatic browning reactions may occur as a result of heating, dehydrating, or concentrating food constituents. The role of bound and unbound water in browning reactions has been investigated by several authors. Almost all of the results showed that a maximum browning rate occurs at water activities between 0.4 and 0.6 depending on the type of the food substance. At lower water activities the reaction rate decreases as a result of the increasing diffusion resistance due to high viscosity, whereas at higher water activities the reaction rate again slows down, due to the dilution of the reactants. Even at low water activities sucrose may be hydrolyzed to form reducing sugars which have a potential for browning. Labuza *et al.* (1992) have found that the formation of browning products of dehydrated skim milk at 54°C is the maximum at 75% relative humidity, and the rate decreases with decreasing relative humidity. Eichner (1975) had studied the effect of water activity in the different steps of the Maillard mechanism by determining the reaction intermediates in a model system containing glucose-lysine (1:1 mol) and MCC (14 g/g glucose) at 40°C, at water activities between 0.23 and 0.82. He found that the decrease in the free amino group of lysine was minimum at *aw 0.23, and maximum around* water activities 0.62-0.75. Not only the rate of formation of reducing browning intermediates, but also their rate of decomposition appeared to increase at higher water activities and the nature of the reducing intermediates changed due to a change in water activity. Since by the law of mass action, the rate of a reaction is proportional to concentration, a decrease in concentration by the dilution with water will decrease the rate.

Influence of Temperature

Increasing temperature results in a rapidly increasing rate of browning. In foods containing fructose, the increase may be 5-10 times for each 10° rise. If the color intensity is measured, it may also be increased with increasing temperature because of the changing composition and increasing carbon content of the pigment. The structure of the melanoidins synthesized at room temperature differs considerably from those synthesized at higher temperatures in that they have different types of aliphatic carbons and fewer unsaturated carbons (Gogus *et al.,* 2010).

Influence of pH

Maillard reaction is low at low pH and increases progressively as the pH is increased. The effect of pH on amino–carbonyl interaction has been investigated by Wolfrom *et al.*(1974) who showed that in an alanine–glucose system Maillard browning is most intense at pH 7, Both the initial pH of the product and the buffering capacity of the system, influence the rate and direction of the Maillard reaction.

Influence of the Type of Carbohydrate

Under the slightly acidic conditions (pH 5–6) in most foods, the hydrolysis of sucrose could proceed at a slow rate and produce the reactants. If the food contains an acid-like citric acid, the hydrolysis is fairly rapid. In the presence of enzymes, as in the case of lactase in cultured milk or yogurt, the hydrolysis to glucose and galactose is rapid. Reducing disaccharides and reducing oligosaccharides are less reactive than monosaccha-rides (Ananth Narayan, 1997)

Influence of Metal Ions

Copper, iron, and cobalt salts may enhance amino–carbonyl interactions. Bohart and Carson (1955) have reported that even small amounts of manganese (0.4 ppm) inhibits the rate of browning in air. Other metal ions inhibit browning includ-ing tin. Rendleman and Inglett (1990) have extensively investigated the influence of $Cu2+$in the Maillard reaction and have concluded that cupric ions enhance the rate of Maillard browning in several model systems. Melanoidin pigment exhibited a strong affinity for $Ca2+$ and $Cu2+$ ions.

Maillard Browning in Dairy Products

Powder Storage

Milk powders are very sensitive to the Maillard reaction as they contain a relatively high concentration of lactose and proteins with high lysine level. A number of detrimental reactions occur in powder over time, which limits its shelf life. Shelf life of milk powders can vary depending on composition, manufacturing conditions, type of packaging, and storage conditions. Medium to high preheat treatments cause protein denaturation and Maillard reactions in the milk, and these reactions form antioxidants, which slow down fat oxidation. Milk powders are hydroscopic and will adsorb moisture from the air. Moisture absorption speeds up the Maillard reaction and increases powder caking. Milk powders are relatively stable at storage temperatures up to 20°C; however, above 30°C deteriorative reactions proceed rapidly (Oldfield and Singh, 2005).

Sweet Whey Powder

High-quality sweet whey powder (SWP) is a free flowing powder with a slight yellowish hue that can degrade into a brown colour during storage. It is well recognized that non-enzymatic browning (NEB) through the Maillard reaction is a major deteriorative mechanism active during the storage of SWP (Dattatreya and Rankin, 2006). The studies on sweet whey powder indicated that samples at temperature of 60æ%C was intended to represent the conditions of handling wherein the SWP is spray dried, bagged and palletized immediately without adequate cooling. A temperature of 80°C represented an accelerated storage condition for Maillard browning. Temperatures higher than 80°C were not employed since this may also lead to caramellization (Dattatreya and Rankin, 2006).

Infant formulae

One of the most important modifications induced by heating and long storage conditions is the Maillard reaction, which involves amino acids and reducing carbohydrates and can produce a loss in nutritive value (Contreras-Calderón *et al.,* 2009). Various chemical indices can be used to evaluate heat-induced damage in proteins by Maillard reaction in infant formulas. Early stages of the Maillard reaction have been studied by furosine determination during infant formula storage (Contreras-Calderón *et al.,* 2009).

Pizza Cheese

The continuously increasing pizza popularity has led to the tremendous growth of cheese products, especially Cheddar and Mozzarella cheeses, which are two major varieties of cheese used as toppings for pizza and some other prepared consumer foods. In order to achieve desirable quality of these consumer foods, the cheese products used are required to have certain functional properties such as melting, browning, oiling-off, shreddability and stretchability.

Browning is a property of cheese that results in patches of darkened colour on the cheese surface during baking before consumption. It is of high commercial interest to the manufacturers of both pizza and cheese because about 50% of pizza restaurants reported quality problems in cheese browning. It is widely believed that the browning of cheese during baking is mainly caused by Maillard reaction. A strong correlation was found between the darkness of cheese colour and galactose content for processed cheese and Mozzarella cheese. Bley *et al.* (1985) used galactose-fermenting strains to control the browning of cheese. Mukherjee and Hutkins (1994) isolated galactose-fermenting, galactose-non releasing species to make low browning Mozzarella cheese.

Though browning is considered as a defect in processed cheese, for cheese used as toppings, browning may be considered as a desirable property (Wang and Sun, 2003)

UHT Milk

Milk heat treatments can produce very complex effects among milk constituents. The amount of lysine loss in the Maillard reaction has been proposed as a marker of the severity of heat treatment. Both furosine and lactulose are good thermal indicators of heat damage. Pellegrino and coworkers also evaluated the effect of preheating (80-90°C) in the UHT process using the furosine/lactulose ratio. The preheating procedure can negatively affect milk quality because during this process the Maillard reaction can carry on, while lactulose is not produced (Manzi and Pizzoferrato, 2006).

Confectionery Products

The development of brown colours is one of the main problems that limit the shelf-life of confectionery products manufactured with white chocolate or their substitutes. Due to its composition, white chocolate is a product with a low water activity, with a high percentage of fat, a relative high concentration of reducing sugars (mainly lactose) and proteins but no antioxidants; so both milk oxidation and NEB reactions can take place (Vercet, 2003).

Bakery Products

The formation of colour in bakery products during baking is widely known as browning. Browning is the result of non-enzymatic chemical reactions which produce coloured compounds during the baking process; such reactions are the Maillard reaction and caramelization. The development of browning in bakery products is a dynamic process mainly influenced by temperature and water activity of the system, and results from the production and accumulation of coloured compounds during baking, i.e. principally HMF and melanoidins (Purlis, 2010).

Measures to Control Browning

As Maillard reaction causes the formation of some toxic and mutagenic compounds in some cases, therefore, it is important to control or minimize it in food processing. It can be controlled or inhibited by:

- controlling temperature, time, water activity, and pH;

- reduction of reducing sugar and/or amino nitrogen content;
- packaging with gas;
- application of high hydrostatic pressure and
- Use of chemical inhibitors such as sulfites, flavonoids, and cations.

Temperature

Since these reactions have been shown to have a high temperature coefficient, lowering of the temperature during the processing or the storage of food products can help to minimize these reactions (Gogus *et al.,* 2010).

Water Activity

The Maillard reaction being moisture dependent for optimum activity, it can be inhibited by reducing the moisture content through dehydrating procedures.

pH

The pH of the Maillard browning reaction is an important parameter for both the reaction rate and the characteristics of the products. Since the Maillard reaction is generally favored at the more alkaline conditions, lowering of the pH might provide a good method of control (Gogus *et al.,* 2010).

Biochemical Agents

Removal or conversion of one of the reactants of the Maillard reaction controls the browning. For instance, glucose or other fermentable sugars in liquid egg whites, egg yolks, or whole eggs can be removed by yeast or bacterial fermentations. The use of commercial glucose oxidase-catalase preparations is a widely used alternate commercial method for removing glucose. A study has been performed to control the Maillard browning in fried potato chips. Browning of chips could be decreased upto 60% with an increased yield of acceptable chips after the yeast treatment at the optimum yeast concentrations.

Modified Atmosphere Packaging

Modified atmosphere packaging is useful in excluding oxygen by using an inert gas that reduces the possibility of lipid oxidation, which in turn could give rise to reducing substances capable of interacting with amino acids. While this reaction does not appear to influence the initial carbonyl amino reaction, exclusion of oxygen is thought to effect other reactions involved in the browning process. Effects of modified atmosphere packaging (MAP) on browning in glucose syrups stored at 25°C and 45°C were studied. They found that in the absence of oxygen, the browning rate in the glucose syrup samples was low while it increased with the increase in oxygen content (Gogus *et al.,* 2010).

High Pressure

Komthong *et al.*(2003) studied the effect of high hydrostatic pressure (100 MPa) combined with pH (6.0, 7.0, and 8.0) and temperatures (80°C and 90°C) on the Maillard reaction of the sugar (glucose or fructose)-amino acid (leucine, lysine, or glutamate) solution models. They found that both the formation of browning products and HMF content decreased by the high pressure treatment.

Chemical Inhibitors

Due to the wide occurrence of the Maillard reaction products during the production and storage of various different food products, it would be of great interest to limit this reaction in the undesirable cases. A variety of chemical inhibitors have been used – "sulfites" are the most widely used. However, the restrictions to the use of sulfite agents in foods promoted the scientists to develop alternatives to sulfites. Therefore; calcium salts, thiols, aspartic and glutamic acids, phenolic acids, and various flavonoids have been studied as alternatives to sulfites. Sulfites/Sulfur dioxides are commonly used as food additives. They are known as food preservatives but also have an important role as inhibitors of enzymatic and nonenzymatic browning. However, they are subject to regulatory restrictions because of their adverse effects on health (Gogus *et al.*, 2010).

Sulfite residues in foods have been responsible for some severe allergic reactions in susceptible individuals, usually asthmatics. Fatal anaphylactic reactions have been reported (Taylor *et al.*, 1986). The FDA has restricted use of sulfites in certain categories of foods where there is no means of alerting sensitive consumers to their presence (FDA, 1986). FDA established labeling requirements for foods containing sulfites and affirmed the GRAS status of sulfiting agents in 1988 (FDA, 1988a, 1988b). Fear that use of sulfites as browning inhibitors for fruit and vegetable products might be restricted prompted the food industry to seek alternatives.

CONCLUSION

It can be seen that the network of the Browning reactions is well established, but a great deal of detail needs to be filled in with respect to the chemical, quality-related, and applied. Though browning is considered to be undesirable for certain products, it has turned out to be demanding in case of some. The majority of Traditional Indian Dairy Products are yet to be evaluated keeping an eye, the browning parameters and maillard reactions, in order to further optimize the products and determine the best suitable quality for human being as a consumer.

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