REVIEW ARTICLE

NORTH AMERICAN ACADEMIC RESEARCH (NAAR) JOURNAL
2021 SEPTEMBER, VOLUME 4, ISSUE 9, PAGES 44-52
https://doi.org/10.5281/zenodo.5516169

Maillard Reaction: Food Processing Aspects

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OPEN ACCESS

Accepted September 11,2021
Published September 19,2021

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DOI :https://doi.org/10.5281/zenodo.5516169

Pages: 44-52

How to cite this article (APA):
Hosen, A., Al-Mamun, A., Robin, M, A., Habiba, U., & Sultana, R. (2021). Maillard Reaction: Food Processing Aspects. *North American Academic Research, 4(9)*, 44-52. doi: https://doi.org/10.5281/zenodo.5516169

Conflicts of Interest
There are no conflicts to declare.

ABSTRACT

Maillard reaction is a very famous reaction in food science. This paper overviews some information on Maillard reaction which is relevant for easy learning and understanding the Maillard reaction chemistry. Depending on the previous (2000-2015) and latest (2021) information, this contribution is made. This paper shows some effect on food characteristics occurred by Maillard reaction. In this paper how food properties (flavor, color, texture, odor, etc.) are influenced and changed by Maillard reaction is discussed. This paper is also discussed some positive and negative effects of Maillard reaction on foods and on humans. This paper also shows how Maillard reaction products can affect the human health. Production of antioxidants, formation of flavor, browning, and anti-browning activity of Maillard reaction products are also reviewed here

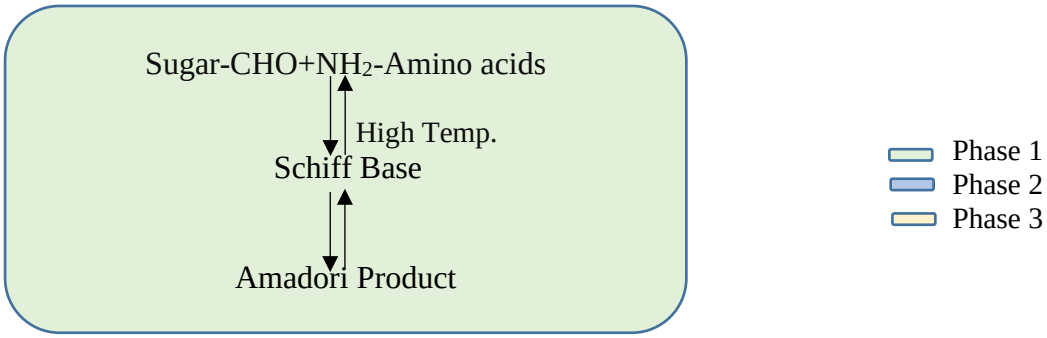
Keywords: FOOD SCIENCE, PROTEIN, MAILLARD REACTION, FUNCTION OF PROTEIN, NUTRITIONAL VALUE

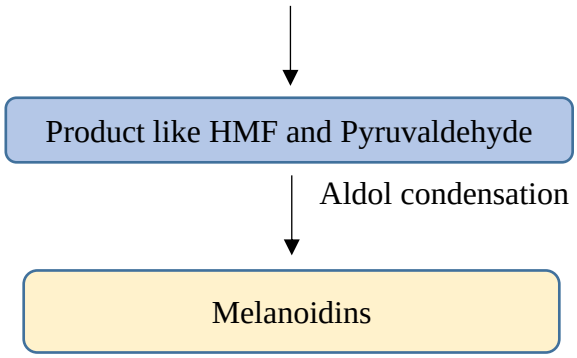
Introduction

When reducing sugars and amino acids react with each other and that reaction changes the characteristics of food properties is known as Maillard reaction [1]. It can be called as nonenzymatic browning reaction also. In this paper Maillard reaction and its effect on food properties is reviewed. This paper emphasizes on the effect of antioxidant on food properties [2] and flavor formation produced by Maillard reaction in foods. It has antibiotic effect too [3]. Development of carcinogens is occurred during this reaction. The concentration of essential amino acid is reduced by the development of carcinogens in the reaction.

Materials and methods

Chemistry of Maillard reaction





Following the model of Hodges, Maillard reaction can be divided into three steps [1]. Firstly, a reaction between sugar and protein or with amino acid is occurred. Mainly the carbonyl part of participated sugar and amino group of participated protein take part in the reaction. For this reaction water and an unstable glycosylamine is produced. Secondly, this unstable glycosylamine makes Amadori rearrangement. This Amadori rearrangement produce a series of chemical compound named amino-ketose compound. Thirdly the amino-ketose compounds undergoes for further rearrangement and then aroma, flavor and color are created.

Characteristics of Maillard reaction

1. Participation of Reducing sugar and principally free amino acids; reaction occurs between two of these chemical compounds [4].
2. Not a single reaction but a whole complex of reaction [4].
3. Depends on p^H and temperature [5].
4. Reaction reach peaks at intermediate water activity 0.5-0.7 [6].
5. Maillard reaction occurs more quickly in alkaline than in acid condition [4].

Influence of Maillard reaction products on food properties

1. Food industry becomes interested for generating individual aromas.
2. Industries use this reaction for heading individual type of aromas and colors.
3. Depending on the chemical structures sensory attributes can be evaluated.
4. Nutritional quality loss of food products.
5. There is a possibility of cross-linkage between the molecules of protein and Maillard reaction products.
6. Tendency of producing antioxidants properties.

1. Millard reaction on Soy bean

Main use of soy bean is cooking oil. Soy bean has some other uses. It can be used as flakes, concentrates, grits etc. It contains omega-3 fatty acid which is beneficial for heart. It gives huge support to the bones and bones diseases and works against cancer [6]. Soy bean is heated in three ways. They are 1. Microwave heating treatment, 2. Extrusion heating treatment, 3. Infrared heating treatment.

Microwave heating treatment can be given in two ways. Heat treatment for 1-2 minute which can be called by name short time and heat treatment for 3-5 minute can be called by long time. If soy bean is heated in microwave

for short time (1-2 min) it is found that a compound named acrylamide is highly produced. On the other hand, if it is heated for long time (3–5 min) production of acrylamide becomes lower than short time. Depending on temperature profile and time, formation of acrylamide is highly fluctuate during extrusion and infrared heating conditions. If temperature and time is increased then formation level of acrylamide gets higher and when temperature and time decreases then formation level of acrylamide gets lower. Those above processes are affected by time and temperature. Production of HMF depends on time and temperature. If the temperature and time is increased, production of HMF gets higher and if time and temperature decrease then production of HMF gets lower. Production of HMF becomes very higher among those three processes is in microwave heating treatment condition[7]. When extrusion and infrared heating treatment condition is applied the level of furosine gets higher from the very beginning. But when microwave heating treatment is applied the maximum value of furosine level is reached after 3 minutes. One thing is noticeable here is that, the level of furosine value becomes similar with the 2 minutes at 4 minutes in microwave treatment. Soy bean has antioxidant properties. Improvement of antioxidant properties of soybean has been shown in microwave heating treatment condition [7]. Soy bean can be soaked in water. After soaking in the water, the water is soaked soy bean if heated at 98°C temperature, it is found that almost forty-four (44%) percent of the raw flavonoids were absent in the finished products [8]. The reason lying behind this may be due to the moisture content.

2. Maillard reaction on Milk Processing

Milk is consumed world-wide. It is enriched with sugar and protein compound. There are mainly two types of processing method used in milk processing. 1. Ultra-High Temperature treatment (UHT) and 2. Conventional Sterilization process. These methods are used for processing. So during the processing of milk a high temperature is applied on the process system and milk gets directly contacted by heat. For this phenomena Maillard reaction products can be formed. Lactose is one of the chemical compound of milk. A reaction between this lactose and ε-amino group of lysine which is a residue of milk proteins is occurred. This results in lysine loss in milk. The lysine loss is proportionate to the degree of heating treatment temperature. For this reason, there is no possibility of having modified lysine in the product. So, lysine can not be remain nutritional compound any more in milk. Maillard reaction products sometimes can be worked as chelating compounds and can affect mineral bioavailability [9]. The term solubility loss, in milk protein concentrate powder is a recent hearing issue. It is claimed that Maillard reaction is responsible for this solubility loss.

A recent study has shown that enzymes may inhibit Maillard reaction development [11]. Faox I and Faox II is such type of two enzymes. There are some factors for example vitamin A, casein, and iron effect on processing milk. For these factors processed milk sterilized by ultrahigh temperature treatment may have different types of HMF [10].

3. Maillard reaction on Meat Processing

In meat processing, Maillard reaction involves for changing color and flavor of meat. It is an organic chemical reaction. In this organic reaction reducing sugars and amino acids react with each other. For this reaction, complex mixture of compound acids are produced. Then amino acids and certain simple sugars rearrange themselves in ring through heat and reflect light in such a way that it can give the meat a brown color. Different types of cooking techniques are performed. High temperature may increase the Heterocyclic amine (HCA) in meat processing. This HCAs can increase the risk of various types cancer in human body. Frying and boiling of food is responsible for increasing HCAs [12,13-15] and these HCAs are responsible for different flavor and taste in food items. Heterocyclic compounds are responsible for flavor forming. It is found that in roasted compound some heterocyclic compounds such as pyrazine, oxazole, and thiazoles are responsible is found. They are responsible for flavor formation. Pyrazine level is increased at the time of high heat treatment and grilling process [16]. Condensed two alpha ketone molecules which is derived from the Strecker degradation [17], form the alkylpyrizne which acts as an intermediate Maillard reaction pathway.

In processed food heterocyclic amines (HCA) are found. There are more than 25 types of heterocyclic amines are found in processed food [18]. Duck meat is processed by deep frying, microwave cooking, pan frying or boiling and charcoal grilling. In duck meet processing, MRPs got higher in pan frying process when it is compared to other four types of cooking process. Between boiling and microwave heating treatment, microwave heating is the most appropriate method of processing of duck meat in regard of MRPs formation. Charcoal grilled duck and chicken breast had high level of HCAs and pan-fried meat has lesser HCAs than them. As a result, it can be concluded that roasting process decreases HCAs remarkably [19]. A study said that commercially cooked meat and restaurant meat contain less amounts of HCAs [20-21].

4. Maillard reaction on Plant Derived Food Processing

Fruits and vegetables have advantageous health effects on human body. Keeping the nutritional value of fruits and vegetables becomes a challenge when transported or storage. So, for maintaining the quality and keeping the immensity of favorable health effects, methods of processing plays an important role. Furoylmethyl derivatives (FM) compounds can be found in fruits and vegetables depending on temperature profile which is used for the treatment of fruits and vegetables. When orange juice is processed furomethyl derivatives have been found [22]. In tomato processing, products [23] and when carrots are dehydrated presence of furoylmethyl derivatives have been identified [24]. It has found that different types of carrots contain different amount of FM. When carrots are dehydrated that contains large amount of FM. On the contrary carrot which is sealed or for mini carrot or for carrot juices it is found that they contain small quantity of FM. It has been seen that handling time or time of processing plays a crucial factor at heating treatment. Formation of FM mostly depends on processing time [24]. Vacuum frying is one of the processing methods for vegetables and fruits. Vacuum frying is used for preserving the fruits and vegetables for long time. If potato, chips of carrot and slices of apple are fried by vacuum, number of total carotenoids levels can be hold on remarkably reported by Dueik and Bouchon (2011) [25]. They also reported that ascorbic acid level can also be hold on remarkably if potato, carrot

chips and apple slices are vacuum fried [25].

Production of prooxidants in vegetables depends on thermal conditions. When low temperature is applied, prooxidants are caused with an increasing rate and when high temperature is applied prooxidants are produced with a decreasing rate. But it is observed that applying high temperatures swells the properties of antioxidant. Maillard reaction products has effect on prooxidant properties. However, Maillard reaction products can swallow the properties of prooxidants [26-27].

Enzymatic browning is common case for vegetables. Polyphenol oxidase is responsible for enzymatic browning. During postharvest handling and in processing conditions polyphenol oxidase is formed. Maillard reaction products can prevent this browning activity [28]. Generally, enzymes like polyphenoloxidases (PPOs) and tyrosinases take part in browning reaction. They can oxidize the Maillard reaction products. Being oxidized, Maillard reaction products form quinonic compounds. These quinonic compounds are used to generate brown colorant and for this the attribute of the food properties is hampered. Antiallergenic property has been shown by Maillard reaction products [29].

5. Some Other Impacts of MRPs on plant-Derived Food

An enzyme named Angiotensin-I converting enzyme (ACE) is known as commanding enzyme. It can control the blood flow. For cardiovascular diseases, ACE inhibitors are highly used. The ACE inhibitors has inhibitory peptide. This inhibitory peptide can inhibit the ACE enzyme. This phenomena keeps blood pressure low [30]. The chemical compound casein hydrolysate has ACE inhibitory activities. On optimum circumstances, this casein hydrolysate that has the ACE inhibitory activity can successfully be increased by Maillard reaction reported by Hong and colleagues (2014) [31].

Ginsenoside Re is a chemical compound. It is extracted from Panax species. It can show antioxidant properties, neuro and nephroprotective activities and many other beneficial health activities. If it is treated with amino acid it can be used for human body treatment. For this the temperature profile should be 100-130 degree Celsius [31]. This can be useful for renal disease treatment [32].

Bactericidal activity is found on plant derived foods. Aminoreductone has shown its bactericidal activity on different types of microbes [33]. On yeast Maillard reaction products has negative impact [34].

Table 1 : Use and effect of Maillard reaction on different food products

Food	Use	Effect
Soy Bean	Cooking Oil	Improvement of antioxidant and in some cases beneficial health issue
Meat	Source of protein	Color changing and nutritional effect

Milk	Drinking purpose	Loss of lysine and nutritional compound
Vegetables and fruits	Consumed materials	swallow the properties of prooxidants
Pasta	Fast Food Item	can change flavor, color, functional properties, and nutritional values

Conclusion

Everything has merits and demerits. Maillard reaction is not exception from this. Maillard reaction products has shown some positive characteristics. Maillard reaction has antiallergenic characteristics and both positive and negative bactericidal characteristics on food products. Maillard reaction products also have antioxidant properties, prooxidant properties etc. Some Maillard reaction products can damage the food quality. For Maillard reaction some foods become toxic. Maillard reaction is also used for generating new types of aroma and color. It is also used for controlling the production of different types of aroma or unwanted things in the reaction. Based on temperature profile, duration of temperature, processing methods, processing steps some food becomes healthy for consumption and some lose its nutritional qualities by occurring Maillard reaction. The MR is a ubiquitous reaction taking place in heat-treated foods and also those foods stored during long time at room temperature. The development of the MR is desired in products where a brown color and a special aroma are expected, such as coffee, bread, and meat. Contrary, many efforts have been done by the food industry in order to limit the extension of the MR in foods like milk or fruit juices, where brown colors denote a low-quality product.

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