Food Science and Technology

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Editors

Chemical Food Safety and Health

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FOOD SCIENCE AND TECHNOLOGY

CHEMICAL FOOD SAFETY AND HEALTH

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INTRODUCTION

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In ancient times human beings hunted animals and collected plants to feed themselves. They were nomads and they moved following herds of animals and foraging for plants with fruits and seeds. After they learned to domesticate animals and plants, man ceased to wander and agriculture began. Often, primitive civilizations settled near water sources, which provided communication pathways across rivers and water for them, their animals and their crops.

The world has changed a lot since that age. In our modern world, animals and plant crops are produced all around the world and meat, dairy products, fish, vegetables, fruits, seeds, honey, etc. and their derivatives travel sometimes thousands of kilometres to their final consumers. All this has changed the manner of food production and commercialization. Now we need an organization to establish world rules to protect public health and facilitate food commerce. In 1962, at World Health Organization (WHO) meeting on food rules, an international group named "*Codex Alimentarius*", was established with the objective of protecting human health and facilitating world trade in food.

Public health is a constant concern for world health authorities because foodborne illnesses are increasingly prevalent. These diseases are caused by microorganisms or harmful chemicals present in the food people eat and drink. Most of the time, these illnesses are caused when certain bacteria, viruses, or parasites contaminate food or water. They also occur when food is contaminated by harmful chemicals or toxins, either during or after processing. Many different foodborne illnesses have been described. Probably most dramatic are those produced by microorganisms, because most of the time they produce an acute disease. On the other hand, chemicals can produce both acute and chronic diseases depending on the level of contaminants present in the food. When the level of contaminants is high, the result may be an acute disease with dramatic consequences, but when the level of contaminants is low; they

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may accumulate in a live organism and produce a long term disease. Usually, chemical contaminants are found in the environment, both naturally and produced by human activity.

The best way to prevent foodborne illness is to prevent contaminants from getting into food. Prevention is therefore the principal focus of all safety quality systems. To this end, the food industry and food rules have changed, to assure people that food products are safe. In the past, the food producer was encouraged to produce safe food by assuring that the final product was safe. So, producers had to sample a large quantity of food and destroy it all if they found any contamination. This system was inefficient for various reasons, including: 1) It was not possible to detect in which part of the process contamination occurred, 2) If sampling failed, contaminated food could reach consumers, 3) When contaminated food resulted in foodborne illness, that produced public alarm and insecurity, 4) Some contaminations that happen at the beginning of production cannot be eliminated during processing. For these reasons, food safety has become an important issue for many world governments and consumers in general. Different countries have taken different actions to assure safe food for consumers. Some have created new rules or changed others, regulating the production of both human and animal food. Canada (1997), Ireland (1999), United Kingdom (2000), European Union (2002), New Zealand (2007), and United States of America (2010), among others, have promulgated food laws promoting global consistency in the production of safe food.

Contamination can happen at any place during processing. It is absolutely necessary to evaluate all the hazards that can occur all along the food production chain, identifying inputs, and analysing and controlling all critical points to keep hazards at acceptable levels. This, by reducing points where contamination can occur it is possible to prevent and avoid it, diminishing the probability of spread foodborne illness.

In a modern system of food safety, all actors in the food chain (producers, transporters and retailers) are responsible for their own segments of the chain and must assure the product they are receiving is in good condition. This is based on a system of trust, with clear rules about responsibilities and penalties.

The bases of this system are:

1) *Focus on whole food production chain*: all points of food production chain are evaluated and monitored. This approach permits focusing resources on those points where it is possible to reduce hazards to acceptable levels. This permits a better utilization of resources.
2) *Focus on preventing contamination*: the main idea is to prevent contamination thereby producing food that is safe for consumers.
3) *Focus on responsibilities*: in this system duties and responsibilities are shared among food producers (all the people involved in food chain), consumers, government authorities, and food safety researchers. Responsibility for safe foods is with the producers. Consumers must be informed and must handle food properly following producer's instructions. Authorities determine legal responsibilities and food safety researchers investigate different kinds of contaminants, safety levels, and the ways to avoid contamination.

In order for this system to work properly it must rely on scientific knowledge. The scientific community can establish through research which substances and which levels are harmful to human health.

As mentioned above, some chemical substances can produce either acute or chronic disease. Dioxins and furans are manmade environmental pollutants with deleterious effects in human health. Polychlorinated dibenzo-*p*-dioxin (PCDD) is the name of a family of 75 compounds formed per two benzene rings, linked by 2 oxygen, that can have 1 to 8 chlorine atoms linked to this structure. The most potent and toxic member of them is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). Polychlorinated dibenzofurans (PCDFs) involve 135 molecules with similar origin and effects as dioxins. Both of them occur in a spontaneous and undesirable manner in many industrial processes. The main ways are: as byproducts of industrial processes involving chlorine molecules, and combustion processes of substances that have carbon and chlorine in their molecules, such as in incinerators or accidental fires. Dioxins and furans are: 1) toxic in small doses, 2) persistent (do not degrade easily) and they can remain in the environment for years, 3) bioaccumulative and biomagnificable, they are stored in fatty tissues and increase their concentration along the food chain. Due to their persistence, they can go far, being carried by atmospheric currents, rivers, or by migrant animals such as birds and whales.

The main way (90%) humans are exposed to dioxins and furans, is by contaminated food. Often, contamination occurs in food production chain because of grasses and animal feed that has been contaminated by dioxins and furans produced in industrialized places and then travel a long distances, and their products (beef, dairy products, etc) are finally consumed by humans. Fish and sea food can be contaminated as well, when water is contaminated by sewage. Thus, protecting the food supply is critical. "Good controls and practices during primary production, processing, distribution and sale are all essential to the production of safe food." (WHO)

Dioxins are highly toxic and can cause reproductive and developmental problems, interfere with hormones, damage the immune system, and also cause cancer. Dioxins are ubiquitous, anyone can be exposed to them, and due to their toxicity, efforts must be undertaken to reduce current exposure.

On the other hand, furan is well known to be found in a variety of foods that undergoes heat treatment. Coffee, sauces, soups and ready-to-eat baby food have been reported to have high furan levels. Concern about furan started twenty years ago when some studies based on laboratory animals indicated that they could possibly be carcinogenic to humans. Since then, the USA and the EU have been monitoring different kinds of food. Almost ten years ago they built a broad data base of many different foods and are updating it constantly. The main analytical method for furan detection in foods is headspace gas chromatography/mass spectrometry, its detection limit is less than 1 μg/kg in most of food matrices, however new methods are being developed to diminished the minimal level of detection. Both the mechanism of furan formation in foods and the effects of domestic cooking are not well understood yet, and it has been postulated that different precursors could be participating in their formation. More research is necessary to know clearly the toxicity of furan.

Acrylamide is the monomer of polyacrylamide which is used in some industries. Polyacrylamide is not toxic, but its monomer is. It is known that acrylamide produce cancer in some animals and affect the nervous system in both animals and humans. Although acrylamide has been present in foods for a long time, concerns about it arose in 2002 when the Swedish National Food Authority reported the presence of high levels of acrylamide in food processed at high temperatures. Then FAO/WHO did a consultation to better understand the risk to human health posed by acrylamide in food. Since then FAO (Food and Agriculture Organization of the United Nations)/WHO established an international network on acrylamide in food that allows all interested parties to share relevant data as well as information on ongoing investigations.

Even though hazardous substances can be found in foods we also find substances that protect human health. This is the case of polyphenols. Certain kinds of molecules found in plants, vegetables, fruits and seeds, produce several positives effects on human health such as: antioxidants, anti-inflammatories, anti-tumor, anti-carcinogenicity properties, anti-microbial activities and immune system protection, among others. There are more than 8,000 different kinds of molecules of polyphenols reported and they are currently widely studied, due to their beneficial effects on human health. Also in this category are selenium, magnesium and zinc. These important minerals form part of the different important enzymatic complexes, contributing to the oxidation-reduction balance.

Understanding risks, causes of contamination, and the production of hazardous chemicals is essential due to during food production, maintaining safe levels and avoiding contamination is vital to assure food safety for consumers around the world. Additionally, it is important to understand that there exist molecules in food that provide certain health benefits other than nutritional ones. It is necessary to know them, where they occur and what kind of health benefits they produce. With this knowledge, food producers can improve their processes to produce nutritional safe foods which will enhance the consumer's health and quality of life.

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Chapter 1

ACRYLAMIDE MITIGATION IN HEAT PROCESSED FOODS: PATENTED TECHNIQUES

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ABSTRACT

Eating a balanced diet is one of the crucial aspects to reaching a healthier life. In order to accomplish this purpose, the overall quality of foods should be monitored in every step of the production chain. In this sense, processing of foods at high temperature is an antique way to preserve and make them readily available for consuming. Interestingly, another major advantage of food heating is that it adds taste and color, improving the consumer acceptation of the product while reducing microbial growth and inhibiting enzyme activity, that are critical factors for increasing shelf life. Both color and flavor compounds are generated during the thermal food processing mainly by Maillard reaction, along with some toxic compounds such as acrylamide. Maillard reaction is believed to be the main route for acrylamide formation between reducing sugars (glucose and fructose) and the amino acid asparagine. Consequently, a variety of technologies to reduce acrylamide concentration in foods processed at high temperatures have been developed by inhibiting this reaction through changes in process parameters and reductions in acrylamide precursor levels in raw materials. Although most of these techniques have successfully diminished acrylamide content in several foods, it is also critical to control acrylamide formation during food processing without impairing the sensorial attributes of the product. In this book chapter we will list and discuss several of the most recent patents developed for acrylamide mitigation in thermally processed foods. These technologies consider not only their effect on the safety of the product but also in its final sensorial quality. Finally, we propose in this chapter a new mitigation approach which can be transversally applied to different food matrices in order to reduce significantly acrylamide formation without considerable damage their sensorial attributes.

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1. INTRODUCTION

In April 2002, the food safety world was alarmed when Swedish researchers announced the presence of acrylamide in some fried and baked foods, most notably potato chips and baked cereal products (*e.g.* ~ 2000µg/kg and ~ 1500 µg/kg of acrylamide in biscuits and in potato chips, respectively).

Acrylamide is a hazardous contaminant that has been classified by the International Agency for Research of Cancer (IARC) as "*probably carcinogenic for humans*"[1] and recognized by the European Union Scientific Committee on Food (EUSCF) as a genotoxic carcinogen in laboratory animals [2].

The presence of acrylamide in foods has provoked a worldwide concern, thus, in a number of countries several research projects concerning different aspects of acrylamide such as its exposure, mitigation and formation have been conducted. In this respect and considering acrylamide dietary exposure as a critical health issue the European Commission Scientific Committee on Food (SFC) emphasized that acrylamide exposure should be as low as reasonably achievable [2]. Likewise, according to The Joint Institute for Food Safety and Applied Nutrition (JIFSAN) recommendation, dated April 2006, the mitigation of acrylamide level in foods has been desirable and "*new ways for acrylamide reduction should be developed*" [3].

Regarding to its formation acrylamide has shown to be originated principally through the high temperatures reached in Maillard reaction during heat processing of various carbohydrate-rich foods [4]. However, Maillard reaction plays a relevant role during the heat processing of carbohydrate-rich foodstuffs. This highly temperature dependent reaction is instrumental in the development of desirable color, flavor and aroma compounds [5].

In order to that, a major challenge of both scientists and inventors has been to reduce acrylamide levels in foods as much as possible while maintaining their sensorial attributes intact [6].

During the last decade, patented reduction methods of acrylamide have principally focused on changing processing parameters such as pressure and temperatures (e.g. vacuum frying or atmospheric frying at low temperatures [7-12]. Some post-frying techniques of acrylamide removal in foods have been implemented; however its use is impractical since it destroys the product structure.

Moreover, other strategies for acrylamide mitigation have considered diminishing the levels of acrylamide precursors (reducing sugars and the amino acid asparagines) by using enzymes and other amino acids [13-22].

Likewise, modifying unit operations such as blanching of raw materials and Sodium Chloride (NaCl) solution soaking after blanching has also been implemented as a viable alternative [23] as well as novel methods which include genetic engineering, where modified plant DNA has led to reduced acrylamide contents [24].

While all of the mentioned technologies have shown a successful decrease in the acrylamide content of food products, consumer acceptation of these low-acrylamide foods remains a pending issue.

The present book chapter will focus on recent patented techniques for acrylamide mitigation in starchy foods in order to propose a new mitigation approach which can be applied to significantly reduce the acrylamide formation without damage the sensorial attributes of food products.

2. Acrylamide, A Chemical Approach

Acrylamide, also known as acrylic amide, acrylic acid amide, ethylenecarboxamide, propenamide, and propenoic acid amide, is a low molecular weight vinyl compound (71.08 g/mol). It possesses two functional groups, an amide group and the electron-deficient vinylic double bond that makes it readily available for a wide range of reactions, including nucleophilic and Diel-Alder additions and radical reactions. These reactions are of significant importance in biological systems. Reactions of the amide residue include hydrolysis, dehydration, alcoholysis and condensation with aldehydes, while the vinylic double bond reacts with ammonia, aliphatic amines, phosphines, chlorine, bromine, bisulphite and dithiocarbamates, as well as proteins [23]. The structure of acrylamide molecule is shown in Figure 1.

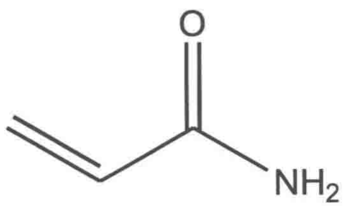

Figure 1. Chemical structure of acrylamide molecule.

Acrylamide is a small hydrophilic molecule [25]. It is an odorless solid and its color ranges from colorless to white. Also, it is soluble in a number of polar solvents, *e.g.* acetone, acetonitrile, water and susceptible to polymerization during heating, which prevents the determination of boiling point at ambient pressure. At 3.34 kPa (25 mm Hg), it boils at 125 °C. It is regarded as a thermally unstable compound. The most important chemical and physical parameters of acrylamide are listed in Table 1.

Table 1. Physicochemical parameters of acrylamide

Parameter	Specification
Chemical formula	C_3H_5NO
Molecular weight	71.08 g/mol
Melting point	84-85 °C
Solubility	216 g/100 g water at 30°C
Boiling point	125 °C at 3.34 kPa
Vapor pressure	0.007 mm Hg at 20 °C
Vapor density (Air=1)	2.4 at 175 °C
Specific gravity	1.122 kg/dm^3 at 30 °C

Despite its toxicity, polymers of acrylamide (polyacrylamide) are extensively used in modern chemical technology for a variety of purposes. These include their use as flocculants for sewage and wastewater treatment, as coagulants for clarifying drinking water, as sealants for construction of dams, tunnels and water reservoirs, as soil stabilizers in roadways construction, as binders in paper and pulp industry and as additives/adhesives/fixatives for manufacturing various industrial and cosmetic products. In analytical biochemistry, polyacrylamides are widely used for chromatography and electrophoresis (*e.g.* for separation and purification of proteins) [26, 27].

3. Acrylamide in Foods: Understanding of its Formation

Since the initial finding that acrylamide may be formed from naturally-occurring substances in certain foods processed at high temperature, food safety scientists have been undertaking studies to determine how acrylamide is formed *in situ* during the cooking of carbohydrate-rich foods.

In the early stages of research regarding to acrylamide formation mechanisms in heated foods, two mainly pathways were proposed: (i) Via reaction between reducing sugars and amino acids in the Maillard reaction and (ii) Via direct reaction between acrolein (a fatty acid oxidation product), with ammonia followed by oxidation to acrylamide [28].

In this respect, a number of mechanistic studies have shown that the first pathway is the most likely vehicle for acrylamide formation. For instance, Mottram, Wedzicha [4] found that considerable quantities of acrylamide were formed when asparagine, the most likely amino acid precursor of acrylamide, and glucose, a common reducing sugar, reacted at 185°C in phosphate buffer. Similarly, Stadler [29], [30] found that in equimolar glucose and asparagine model systems acrylamide pyrolysed at 180°. Additionally, Becalski, Lau [31] showed that ^{15}N-labeled glucose and asparagine in ratios similar to those found in potatoes produced ^{15}N labeled acrylamide.

Furthermore, both Stadler [29] and Mottram, Wedzicha [4] postulated that Maillard reaction was the main pathway of acrylamide formation, suggesting the sugar asparagine adduct N-glycosylasparagine as a possible direct precursor of acrylamide under pyrolytic conditions. In the same way, Zyzak [15] elucidated the mechanism of acrylamide formation confirming the presence of Maillard´s key intermediates such as a decarboxylated Schiff base and 3-aminopropionamide by using isotope substitution experiments.

Interestingly, real time monitoring of reducing sugars, asparagine and water contents in heated potato, wheat and rye systems have shown that precursor diminishing is accompanied by an increase in acrylamide formation, which reaches its maximum value near the end of the heating cycle [32].

Moreover, the non-enzymatic browning that is a consequence of Maillard reaction, has shown to be a good predictor of acrylamide content in starchy foods processed at high temperatures [33].

On the other hand, the acrolein route to acrylamide formation has been discarded since studies have confirmed that the addition of antioxidants did not affect acrylamide formation [34].

Most available data indicate that acrylamide´s major formation pathway in food is likely to be the Maillard reaction, in which the reducing sugars react with asparagine when the food is heated and, through a cascade of reactions, shows that the side chain of asparagine is converted to acrylamide.

4. Acrylamide Reduction Methods

4.1. Changes in Process Parameters

Acrylamide formation in foods may be influenced differently by several factors during their processing, such as: temperature, heating time, browning level, water activity and pH. The effect of temperature, heating time, surface over volume ratio (SVR) and browning level on acrylamide formation in fried potatoes was studied by Taubert et al. It was found that in potato shapes with low SVR, acrylamide consistently increased while temperature and processing time increased as well [26]. On the other hand, in shapes with intermediate to high SVR, the maximum acrylamide formation took place at 160-180 °C, while higher temperatures or prolonged processing times made acrylamide level to decrease. Furthermore, studies on the effect of water activity on acrylamide formation in model systems concluded that by controlling moisture, it may be possible to uncouple concurrent reactions related to Maillard reaction [35].

The effect of metal ions over acrylamide formation has also been studied by several authors who concluded that the use of NaCl and $CaCl_2$ for instance could minimize the acrylamide formation during frying. These authors suggest that ionic and electronic associations between cations and asparagine suppress early-stage Maillard reactions [36, 37]. The preventive effect of Ca^{2+} ions may be due to the observed inhibition of the formation of the intermediate Schiff base that leads to acrylamide formation [38]. Model studies showed that acrylamide elimination, possibly via polymerization, increased in the presence of table salt [39]. Friedman and Levin [23] found that changes of the ionic strength induced by positively charged Na^+ ions affect the rate of addition reactions of amino groups of amino acids to the double bonds of conjugated vinyl compounds such as acrylamide. It is therefore also possible that changes in the ionic micro-environments near the potato strips contribute to the observed mitigating effects of positively charged metal ions.

On the other hand, frying products have shown one of the highest levels of acrylamide content, which has led several authors to study the effect of frying conditions on acrylamide formation in order to reduce it. Some results have shown that vacuum frying may be a mitigation alternative process for producing fried products with lower amounts of acrylamide [40]. For instance, in French fries, all the acrylamide is accumulated in the crust (no acrylamide presence in the core). Similarly, all the content of acrylamide in bread is located in the crust with no accumulation in the crumb; the amount of acrylamide in the bread crust increased with both baking time and temperature in the interval test [41]. These issues have led us to review recent information regarding to next challenges in processing for reducing acrylamide formation in foods. In that sense, researchers have focused using different approaches. For example, a patented method and an apparatus applied vacuum or/and light radiation to starchy foods. The starchy food could be flushed with a stream of gas such as air, oxygen, nitrogen, carbon dioxide, ozone, or a combination of them. Besides, the starchy food could be heated at a temperature among the ambient temperature to about the boiling point of acrylamide. This method was applied for removing acrylamide in potato chips and the treated samples (vacuum treatment: 85 °C, 0.001 torr, 10 min; light radiation: UV, 30 min), presented much lower acrylamide contents that the control samples [11]. Similarly, Bourg, Desai [42] and Bourg, Desai [43] disclosed a method for reducing the level of acrylamide in starch based food ingredients such as corn, wheat, barley, rye among other whole grains and mixtures thereof that are used to make fabricated food products. In a first invention, a method is presented towards reducing enzymes in corn, describing a process that comprises roasting corn, cooking the roasted corn, steeping the roasted corn, washing the corn to remove the pericarp layer and grinding the roasted corn to make roasted dough with reduced final acrylamide levels. In a second invention, acrylamide was removed from the food ingredients by polymerizing (using steam heat), dissolving (using an aqueous solution) and/or causing the vaporization (using vacuum pressure) of the acrylamide. These authors tested their invention in raw materials (corn kernels) in which it was possible to separate the germen by soaking. Then, they applied a sufficient heat to form polyacrylamide over the germen (since in this portion the most acrylamide is produced). The obtained product presented an acrylamide reduction about 90 % (from an initial value of 900 ppb of acrylamide).

In this way, another invention was developed to offer an efficient and easy way for restaurants and fine dining establishments to provide high quality fried foods that have a reduced acrylamide level. This invention may also be fully or partially applied to domestic preparation of fried food and considered a water blanching system to parboil high glycemic food immersed in water to remove reducing sugars. Potato samples were cut to the desired shape and size, and then they were blanched in water for 3 to 10 minutes depending on the size and shape of potato strips at a temperature of about 76 °C to about 88 °C. The acrylamide reduction level obtained with this method reached 80% to 90% (from an initial acrylamide amount of 2200 ppb) [7].

Another invention for reducing acrylamide concentration in thermally processed foods relied on the manipulation of various unit operations, particularly the peeling, cooking and selection unit operations [9]. For example, the peeling operation could be modified to provide a fully peeled potato slice. This invention comprised providing a continuous feed of peeled and sliced raw potatoes wherein the continuous feed of raw potato slices had at least 80% of potato peel removed. Then, potato chips could be analyzed and defective chips were removed before packaging. It is worth noting that the use of blanching solution with some amino acids (1% L-cysteine) to reduce acrylamide content in final products was also included in the flow sheet of the process. The authors also tested different kinds of heating methods, such as atmospheric and vacuum frying, microwave assisted frying and baking (in atmospheric and vacuum conditions). All the examples showed that vacuum conditions and pre-treatment applied in order to diminish the acrylamide precursors (*e.g.* blanching and soaking in amino acid solutions) resulted to be efficient technologies for mitigating acrylamide content in high acrylamide products (foods with acrylamide content at least about 1000 ppb). Finally, the optimized acrylamide reduction in products was about 90 % (from an initial acrylamide amount of 1900 ppb for potato chips) while keeping intact their sensorial properties (texture, flavor and color).

On the other hand, some authors have developed acrylamide mitigation technologies based on lowering the pH of the food products. Rydberg, Eriksson [44] and Rydberg, Eriksson [45] studied the effect of pH on acrylamide formation concluding that the dependence of acrylamide formation exhibited a maximum around at pH value of 8. Lower pH values enhanced acrylamide elimination and decelerated its formation. Besides, the following organic acids also induced acrylamide diminishing in French fries: benzoic, propionic, and sorbic acids. Citric acid and the amino acid glycine also mitigated acrylamide formation in a potato model system indicating that increased acidity may be used to decrease acrylamide formation in potatoes and possibly other foods [46]. The beneficial effects of low pH could result not only from protonation of the reactive free $R\text{-}NH_2$ group of asparagine to the nonreactive $R\text{-}NH_3{}^+$ form, but also from partial acid-catalyzed hydrolysis of asparagine to aspartic acid and of acrylamide to acrylic acid. However, low pH may adversely affect the taste of foods according to the organic acid concentration [47].

In this sense, many studies were conducted [48, 49] in an attempt to develop a method to effectively reduce the formation of acrylamide finding that, when a nucleophilic alpha-amino group of the asparagine is protonated and converted into a non-nucleophilic amine, the formation of asparagine can be effectively reduced. Therefore, their inventive method has the effect of highly reducing acrylamide by a simple treatment with a pH-lowering agent. So, foods should be treated with a pH-lowering agent whose pH was lower at least about 0.5 to 2.0 units lower than the intrinsic pH of the food. For this purpose, the pH-lowering agent was added to the foods at a concentration of about 0.02%-20.0% by weight. The pH-lowering agent which could be used included organic acids or their salts, a buffer solution containing the organic acid or it salt, inorganic acid or its salt, a buffer solution containing the inorganic acid or its salt, fruit juice, and a mixture of them. These inventors tested the effect of citric acid in two concentrations on acrylamide formation in fried and baked corn chips (0.1 % and 0.2%, respectively). In fried products the acrylamide amount was reduced from 45% to 80% for each concentration, respectively. In the same way, treated baked products also presented an acrylamide reduction of about 59 % and 73% for each concentration, respectively. This inventive method has the effect of highly reducing the formation of acrylamide without affecting the flavor and color of the foods or food ingredients tested. Additionally, Tomoda, Hanaoka [8] developed a similar method to diminish acrylamide content in instant fried noodles by using "*kansui*": a pH -lowering agent, which contains potassium carbonate, sodium carbonate, sodium hydrogen carbonate, potassium salt or sodium salt of phosphoric acids as well as an aqueous solution or a dilution with wheat flour, as specified in the food additive official regulation of Food Sanitation Japanese Law. In this way, acrylamide levels in the different kind of noodles tested were reduced from 100 ppb to 30 ppb. These results indicated that by changing some parameters of food processing such as time, temperature, pressure and pH; it would be possible to diminish the acrylamide content of high-temperature processed foods while maintaining intact their acceptability.

4.2. Reduction of Precursor's Levels in Raw Materials

One strategy to reduce acrylamide content in heat-processed foods would be to reduce the precursor levels in the raw materials. In this sense, various patented pre-treatments have been studied such as incorporating and/or exposing the food piece to: (i) Food grade micro-organisms (yeasts, bacteria and fungi) [19, 37, 50-52]); (ii) Asparaginase enzyme that converts free asparagine into aspartic acid [14-21]; (iii) Another amino acid that does not form acrylamide [13, 17, 20, 31, 45, 49, 53-60]; (iv) Saccharides and/or phenolic compounds