Strategies to Reduce the Formation of Acrylamide in Potato Chips: A Market and Consumer's Prospective

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ABSTRACT

Acrylamide, a toxic compound and possible carcinogen is formed in high heated starchy foods like potatoes through the process of the Maillard reaction in which reducing sugars and the amino acid asparagine play a major role. Various strategies which are described in this paper have been employed to reduce the formation of acrylamide in potato chips. Among these tuber genetics, harvesting time, storage conditions frying temperatures and time, soaking and use of various additives seem to be effective tools for the industry as well as for consumer food preparation. The results of various studies will help the industry to adopt practical effective and innovative ways to reduce the levels of acrylamide even further and calm the markets from demanding to provide warning labels and the manufactures to pay penalties and higher costs.

Key words: Acrylamide, Potato Chips.

INTRODUCTION

The formation of acrylamide, a neurotoxic compound and possible carcinogen, in heated foodstuffs has been an issue of ongoing investigations in markets and consumers and a matter of research in many scientific groups worldwide (Elmore *et al*., 2005). Acrylamide is formed in heated mainly starchy foods through the process of the Maillard reaction in which sugars react with the amino acid asparagine the role of which is well established. However the relative importance of different sugars and / or carbonyls as reactive species the type of model system as well as the conditions employed may play a crucial role in its formation. (Koutsidis *et al*., 2008; Koutsidis *et al*., 2009). It is suggested that both molecular mobility and sugar reactivity would determine the relative effect of sugars on acrylamide formation, whereas temperature may also play an important role in determining these relative reactivates. (Wedzikcka *et al*., 2005)

Asparagine, through its participation in the Maillard reaction, has been identified as the major precursor of acrylamide, and heat-treated products containing relatively high amounts of asparagine have been shown to yield correspondingly high acrylamide concentrations. The importance of the Schiff base of asparagines which corresponds to the dehydrated N-glycosyl compound has been recognized. Decarboxylation of the Schiff base is a key step and the reaction product ends in acrylamide either directly or via 3-aminopropionamide (Zyzak *et al*., 2003).

The industry, given the interest of the markets, has conducted significant research to discover and apply methods to reduce acrylamide in numerous products. At the same time practical ways for consumers have been proposed for the minimization of acrylamide during home preparation of foods. However a cost-effective solution by any reduction technique in the industry poses an expense which is likely to be transferred to the consumers. There have been many studies on parameters starting from the potato varieties and cultivation conditions to technological measures such as which oil is most appropriate for frying and which frying conditions such as frying times and temperature, pre-drying or hydration, pH values addition of additives like salt, enzymes, amino-acids and herbs use of various equipment and product to oil ratio , assure the quality and safety of fried products and minimize acrylamide in potato chips. This paper concerns with the use of various strategies to reduce the formation of acrylamide in potato chips taken into account the market's view, the industry and the consumers.

Work and progress made to date

Public and market awareness of the problem of the presence of acrylamide in heated foods like French fries, (chips) and crisps, is on the rise and the industry is trying hard to find ways to reduce it.

This is because studies in animals have shown that acrylamide induces cancer and also affects reproductive performance.

In February 2005, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) carried out a safety evaluation of acrylamide in food concluding that the issue poses a human health concern. This conclusion was consistent with an opinion published by the Scientific Committee on Food (SCF) in 2002. Since uncertainties remained, JECFA concluded that the safety of acrylamide should be re-evaluated in the light of further research and that efforts should be made to reduce acrylamide levels in food. In April 2005 the European Food Safety Authority (EFSA) Panel on contaminants in the food chain (CONTAM) stated its agreement with the principal conclusions and recommendations of the JECFA evaluation.

Exposure data which are required to evaluate the link between acrylamide and cancer are very limited. In 2002, the European Commission began collecting occurrence data on the levels of acrylamide in foods. EFSA has taken over this task in 2006, in co-operation with Member States.

A wide range of actors including national food safety authorities in the EU Member States, academia and food manufacturers have sought to better understand acrylamide and to reduce levels in foods. Many countries continue to contribute to the growing body of research and data. Workshops on this issue have been organized by EFSA in 2003 and the European Commission jointly with the European food and drink industry association (CIAA) in 2006.

Efforts have been made by food manufacturers to modify recipes and processes to reduce acrylamide occurrence in foods such as French fries, snacks and crisps. The CIAA has published an "Acrylamide Toolbox" based on existing knowledge in the food industry which is regularly updated. The European Commission has funded a number of research projects including the HEATOX project to look at heat-generated food toxicants, in particular at acrylamide, focusing on identifying, characterizing and minimizing risks.

EFSA organized a scientific workshop in Spring 2008 with all interested parties including JECFA and members of the HEATOX project in order to discuss EFSA's further contribution in providing scientific advice regarding acrylamide and its relation to health.

EFSA will continue to monitor ongoing developments in scientific research. There are uncertainties as regards the link between acrylamide and cancer risk in humans while the results with animal studies are unequivocal. In human studies some results suggest a link between acrylamide exposure and cancer whilst others do not support such a conclusion.

In the area of analytics great progress has also been made for the estimation of acrylamide in food matrices (Roach *et al.*, 2003) with methods such as liquid chromatography mass spectrometry

(LC-MS/MS) achieving high precision and accuracy (Stadler. 2005).

Formation of acrylamide in potato products and methods for its minimization and control

Influence of Potato cultivar and storage conditions

According to previous studies potato cultivar is an important factor for the formation of acrylamide (Eriksson, 2005). Although acrylamide is not present in raw potato (before cooking or processing) (Jackson and Al-Taher, 2005), both asparagine and reducing sugar content varied significantly among different cultivars emphasizing the importance of the starting raw material on the acrylamide forming potential in later processing stages.

The formation of acrylamide is mainly depending on free asparagine and reducing sugars, limiting factor being the sugar (Biedermann-Brem *et al*., 2003; Amrein *et al*., 2004; Becalski *et al*., 2004; De Wilde *et al*., 2005) as asparagine is usually more abundant in potatoes than reducing sugars (Amrein *et al*., 2007). On the other hand when the molar ratio of reducing sugars to asparagine content is greater than two, meaning that there is an abundance of reducing sugars then the asparagine content might be the limiting factor for acrylamide formation (Matsuura-Endo *et al*., 2006). However in a different study no correlation was found between precursors (asparagine and sugars) content and acrylamide formation (Skog *et al*., 2008).

Except from the genetic factors, reducing sugar content in potato tubers tend to decrease over the course of the growing period reaching a minimum level at the end of the growing season (Silva and Simon, 2005). This is a good indication to the right time of harvesting at the point of chemical maturity to reduce the potential of high acrylamide formation during processing.

Storage of potato tubers in low temperatures (< 8 C) causes an increase in reducing sugar content a phenomenon known as " low temperature sweetening" (Isherwood,1973). This increase results in an enhancement of the brawn- pigment during processing of chips and French fries and hence in higher acrylamide production (Matsura-Endo *et al*.,, 2006). According to the same authors potato tubers for chip processing should be stored at 8-12 C in order to avoid this increase in sugar content.

Effects of cooking temperatures and time

Many studies on acrylamide formation in potato chips have shown that the major factors contributing to the acrylamide production are frying temperatures and time (Kita and Lisinska, 2005, Jackson and Al-Taher, 2005). When the frying temperatures were very high (180-190 C) , the acrylamide levels increased exponentially at the end of frying. This was most likely due to the fact that acrylamide formation occurs mainly at the surface of potatoes when the temperature is likely to rise to >120 C, when acrylamide formation is believed to form(Tareke *et al*., 2002). A similar effect with temperature has the baking time probably due to acrylamide formation in the dry crust of the potato chips (Jackson and Al - Taher, 2005).

Effects of different frying oils

Previous reports on this subject have suggested that the frying oil could influence the formation of acrylamide in French fries but their conclusions were contradictory. In one study when six different oil types were examined (Gertz and Klostermann, 2002) it was postulated that palm oil exhibited much higher acrylamide formation, compared to the other deep-frying oils. In another study it was found that olive oil resulted in higher formation of acrylamide compared to corn oil (Becalski *et al.,* 2003). On the other hand, Matthäus *et al*. (2004) and Williams (2005) could not find any significant effect of the oil type which is in agreement with our findings. Obviously, there is not a general consensus regarding the influence of the heating medium on acrylamide formation (Mestdagh *et al*., 2005). In our laboratory we tested the effects of three frying oils in acrylamide production in potato chips during frying. Although the mean values for olive oil and soybean oil were higher than in case of corn oil no statistically significant differences ($p<0.05$) were found among the three oils due to great variability of the acrylamide being estimated (Varzakas *et al*., 2014, unpublished data).

Use of Additives

The addition of amino acids has been proposed as a mitigation strategy to reduce the levels of acrylamide in crisps, flat breads, and bread crust, while glycine has received particular attention as an additive that could potentially reduce acrylamide formation by either competing for available Maillard reaction intermediates or reacting with acrylamide itself through Michael addition type reactions. Other amino acids including cysteine (Biederman *et al*., 2002) glycine, alanine, lysine, glutamate and glutamic acid (Rydberg *et al*., 2003) have been found to reduce acrylamide formation in heated potatoes. However no practical application seems to be feasible for the industry due to unpleasant odor and flavor imparted in potatoes.

The herb Rosemary (Rosemarinus officinalis) when added to olive oil as frying oil resulted in 25% reduction in acrylamide formation (Becalski *et al*., 2003)

Acid treatments especially with ascorbic acid or citric acid (Ryderg *et al*., 2003) resulted in major reductions of acrylamide in cooked potatoes. This is probably due to the fact that acrylamide information is minimized at low pH values (<pH5).

Soaking and Rinsing

Simple soaking and rinsing of potatoes before frying for at least 15 min was found to be very effective in reducing acrylamide up to 63% (Jackson and Al-Taher, 2005). This is a attributed to leaching out sugars and asparagine from the surface of potatoes.

A further reduction in acrylamide up to 75% can be achieved by acidifying the soaking solution with vinegar (1:3 with water) and or citric acid (2%) as reported by Jung *et al*., 2003. The action of acids will lower the pH of the solution.

CONCLUSIONS

Among the various strategies for the reduction of acrylamide in potato chips, the most important and effective ones are generally recognized to be the following:

1. Selection of potato cultivars with low content in reducing sugars and asparagine.
2. Harvesting time at the end of the growing season when the concentration of sugars are at a minimum level.
3. Storage of potato tubers at temperatures not lower than 8-12 C.
4. Avoidance of high (>180-190 C) frying and baking (>250 C) temperatures.
5. Avoidance of long frying and baking times. Use the browning of chips as an indicator of “doness” of the frying process.
6. Use of soaking of the peeled potatoes, preferably in an acidic environment, at least 15 min before processing to remove the acrylamide precursors.
7. Consider using some additives during frying like the herb *Rosmarinus officinalis*.

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