

# Food safety of potato processed in the aspect of acrylamide risk

## Abstract

Potato is an important contributor in terms of food security and poverty alleviation as a substitute for staple food. They are an important supplier of carbohydrates in the form of starch and are a good source of fiber and nutrients like niacin, vitamin C and B, proteins, minerals such as potassium, magnesium and iron. They have bioactive phytochemicals such as phenolic acids, flavonoids, folates, kukoamines, anthocyanins and carotenoids with a healthy antioxidant property. Processing potatoes especially frying processes and baking at high temperature generates adverse changes which lead to the formation of a hazardous chemical compound, acrylamide in potato products. This article provides detailed information on existing methods of reducing acrylamide content in foodstuffs and enables consumers to evaluate and select acrylamide reducing agents.

**Keywords:** acrylamides, food safety, potato

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**Abbreviations:** AA, acrylamide; SH, sulfhydryl; EPA, environmental protection agency; GST, glutathione S-transferase; GA, glycidamide; MOE, exposure margin; FSA, food standards agency; HA, heterocyclic amines

## Introduction

Potato prices are not sustained by policies, and have a tendency to alter in response to production. They are seasonal crop, small changes in demand and supply lead to rather great price variations. The consumption global trend is considered by growing demand of Asia and South America especially from Middle East, Brazil and East Asia (Figure 1). However for processing the demand is mainly from the United States and Belgium. The increased demand for processed potato products like fries and chips will drive the demand for potatoes and will also affect potato prices in the future.<sup>1</sup> Potatoes are often a high priced vegetable in developing countries and a cheap staple food in many developed countries.<sup>2</sup> In the previous half century (1961-2010) the average production tonnage of Potatoes were 290601 Kilo T; Period 2011-14 has a considerable jump of 28.9% growth over previous half century (Figure 2).

Fresh potato consumption, once the mainstay of world potato utilization, is decreasing in many countries, especially in developed regions. The demand for fast food, snacks and convenience food industries have spiked due to rising urban inhabitants, growing incomes, the diversification of foods and lifestyles.<sup>3,4</sup>

## Potatoes cooked at high temperatures

The acrylamide (AA) is presented in a large number of foods and its level differ widely within each food group analyzed, despite it has so far not been detected in raw foods. For example, raw potato has negligible levels of acrylamide (<0.030mg/kg of potato) but, if you make potato chips, the level of acrylamide can skyrocket to 1.2mg/kg.<sup>5</sup> Bakery products use of starch resistant additives from cereal starches, increase the dietary fiber without drastically affecting their taste and appearance, thus whole grain cereal foods are fiber-containing foods,

with advantages over purified fiber supplements, amongst this display the acrylamide potato chips is consumed as snacks.<sup>6-11</sup>

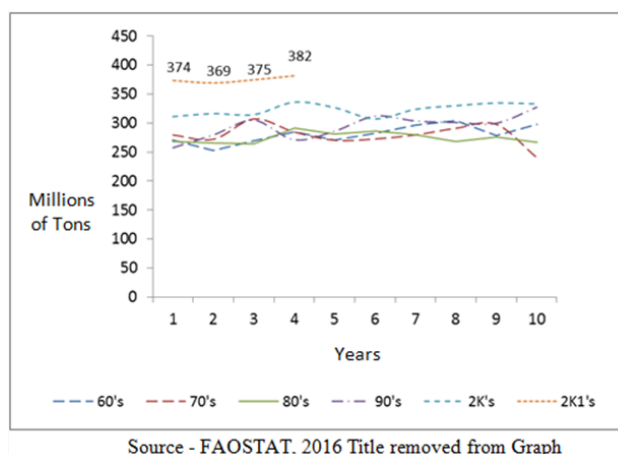


Figure 1 Potato production worldwide (1961-2014).

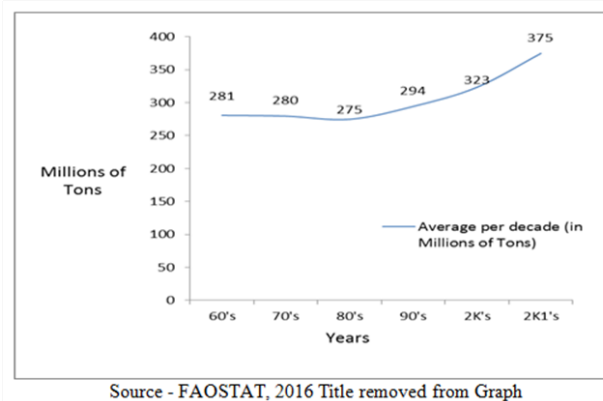


Figure 2 Potato production-Growth per decade (1961-2014).

Acrylamide is not a food additive, but is formed during the heating process in varied diets predominantly having carbohydrate. These carbohydrates rich foods when fried in oil over 120°C assist in the formation of acrylamides. The European Union's acrylamide monitoring database, the United States Food and Drug Administration's acrylamide survey data and the WHO's summary information and Global Health Trends database have diverse nutritional acquaintance databases comprising different food groups to evaluate the acrylamide existence in potatoes. Assessment of acrylamide incidence in nourishment merchandises is of great apprehension in many countries.<sup>12,13</sup> The estimates of nutritional acrylamide intake available projected that the concentration of acrylamide was higher in fried potato products (French fries and potato chips), tailed by cereals, crisp breads, biscuits and other bakery products.<sup>14</sup>

Through prepared in a variety of ways by mashing, boiling, steaming, roasting, frying, and baking; the healthiest way of cooking is by boiling and baking. However, the tastier aspects of potatoes come when roasted and fried in hot oil (140°C to 180°C) resulting in high absorption of fat and added salt. During then minerals get reduced, ascorbic acid improves in content. Acrylamide (a carcinogen) occurs when frying and roasting potatoes above 120°C temperature. High potato consumption was associated with higher risk of pancreatic cancer.<sup>12,15</sup>

The interest in acrylamide increased in 2002 after the Swedish scientists reported on the formation of this substance when frying and baking certain foods. Studies on the toxicity of acrylamide and its metabolite, glycidylide, indicate the neurotoxic, genotoxic and carcinogenic activity of these substances. Acrylamide in food is a reduction reaction of amino acid asparagine glucose and fructose. The formation of acrylamide is part of the Millard reaction, leading to brown and changes the flavor of cooked foods. When frying or baking above 120°C, acrylamide forms at elevated cooking temperatures when moisture levels lower. Several foods with high acrylamide concentrations are observed in potato products (French fries and potato chips); cereal foods (cookies, crackers, breakfast cereals and toasted bread); and in drinks (coffee, prune juice and canned ripe black olives).<sup>16,17</sup> The estimations of WHO (2003) for the risk evaluation, recently evaluated by international bodies agreed on acrylamide probably being carcinogenic to human, concludes that the theoretical models to calculate the actual human risk are not sufficiently reliable to quantify the risk. Estimating of exposure over longer periods of time, including chronic or lifetime exposures could be assessed given within the present state of knowledge for acrylamide.

### High concentration of acrylamide

Cancer risk is high in starch-containing foods cooked at high temperatures which have high concentration of acrylamide. French fries and potato chips consumption has associated cancer risk, as they are from fried/baked potatoes.<sup>18,19</sup> Subjecting foods to high temperatures during processes such as: frying could give rise to the formation of acrylamide, a chemical that is carcinogenic to humans and animals are neurotoxic to humans, with a double risk for pancreatic cancer, is predominantly linked to food.<sup>20,21</sup> (Table 1).

**Table 1** Mean content of acrylamide in selected foodstuffs

Product	Acrylamide content (ppb)	
	Granda C et al. <sup>5</sup>	Other authors
Potato chips	170-3700	<50-3500
Potato chips (sweet)	767-2762	780-3200
French fries (baked)	356-1325	170-2287
French fries	49-1900	67-2100
Breads and Bakery products	ND-364	70-430
Cereals	47-266	30-1400
Coffee	175-351	170-350

Source: Granda C et al.<sup>5</sup> Reduction of acrylamide formation in potato chips by low-temperature vacuum frying, journal of food science.

### Acrylamide

Acrylamide is a naturally occurring substance in food resulting from heat treatment, e.g. baking, grilling or frying.<sup>5,8,9,22</sup> Acrylamide ( $C_3H_5NO$  [ $CH_2=CH-CO-NH_2$ ], according to IUPAC:2-propenamide) is a low molecular weight organic compound consisting of carbon atoms (50.69%), hydrous (7.09%), nitrogen (19.71%) and oxygen (22.51%) with a molecular weight of 71.08g. Under normal conditions, it is white crystalline, with a melting point of 84.5°C and a density of 1.122g/cm<sup>3</sup> at 30°C. Due to its low volatility, its boiling point is 192.6°C at 1 bar (101.3kPa). Due to the presence of characteristic functional groups, the compound is polar and very well soluble in water as well as in other polar solvents such as methanol or ethanol. In contrast, it is insoluble in benzene and heptanes.<sup>23-27</sup> This colorless and odorless crystalline substance is very soluble in water, easily reacts in air and polymerizes, i.e. single molecules of acrylamide (monomers) can bind together to form a larger molecule (polymer) with new properties.<sup>8,9,28,29</sup>

Acrylamide is a highly reactive organic compound having in its structure a conjugated double bond and an amide fragment. The high chemical activity of this compound results mainly from the presence in its molecular bonds of electrophilic multiple. Double bonds play the role of nucleophilic attack of amino ( $-NH_2$ ) or sulfhydryl ( $-SH$ ) amino acids, peptides and proteins. By virtue of the presence of the amide group, this compound can form hydrogen bonds.<sup>30</sup> It reacts with a number of chemical compounds in which both vinyl and amide groups are involved. These include, but are not limited to, nu-kylophil addition reactions and Diels-Alder reactions. The acrylamide as well as other vinyl-containing compounds may also undergo the Michael addition reaction. This compound exhibits both weakly acidic and weakly alkaline properties. Due to the presence of the amide group, it also has amide-specific reactions, including hydrolysis, dehydration, alcoholysis, and condensation reaction with aldehydes.<sup>3,4</sup>

Acrylamide is produced by reacting asparagine with reducing sugars, which, like asparagine, are present in potatoes); acrylamide is formed at temperatures higher than 120°C. The amount of acrylamide formed depends on: heat treatment temperature and time.

Asparagine content reduces sugar in potatoes. But when potato is oil fried acrylamide is formed, which is a potential hazardous health compound that occurs during the preparation and/or processing, although previous studies have shown no carcinogenic effects in humans, acrylamide is still a neurotoxin. Acrylamide toxicity studies have shown occurrence of DNA damage; however, on higher doses, neurological and reproductive effects have been observed. Acrylamide is found in many different food products, including those produced industrially, prepared in the catering industry and in households. It is found in such basic foods as bread, potatoes, as well as in some other products such as potato crisps and chips, biscuits and coffee.<sup>9,24,30-32</sup> Acrylamide in 1994 was classified by the International Agency for Research on Cancer<sup>33</sup> as a possible carcinogenic compound for humans.<sup>34,35</sup> According to the World Health Organization (WHO), total daily acrylamide consumption in various European Union countries ranges from 0.3 to 2.0 µg/kg body weight. The maximum limits for acrylamide content in food products have not yet been determined. In accordance with European Union legislation, the acrylamide concentration in drinking water is 0.1 µg/dm<sup>3</sup>, while the Environmental Protection Agency (EPA) regulations in the USA say the maximum acrylamide level is 0.5 µg/dm<sup>3</sup> (Official Journal of the European Union No 330 of 5 December 1998; European Council Directive 98/83/EC.<sup>25</sup> It is now known that acrylamide is exposed to people eating foods that have been exposed to heat treatment in low humidity.<sup>25</sup> In addition, the presence of acrylamide was found in the smoke produced during the combustion of tobacco products.<sup>27,36,37</sup>

### Biotransformation and extraction of acrylamide

Acrylamide is absorbed by the human body through the gastrointestinal tract, respiratory tract and skin, subsequently succumbing to biotransformation<sup>24,38</sup> analyzed the concentration of acrylamide in the tissues and urine of women and men. The lowest concentration of this compound in the urine was 1 mg/ml. In breast milk the concentration was 5 mg/ml, and in the perfusion with the placenta-2 mg/ml, suggests direct exposure of the baby to acrylamide already in the fetus would lead to higher vulnerability to acrylamide toxicity. The risk of cancer<sup>38</sup> estimated was 1 case per 100, with an acrylamide dose of 1 µg/kg body weight per day.<sup>26,27</sup>

On studies in men aged 18-52 showed that the half-life of acrylamide in the human body ranges from 2 to 7 hours, which indicates the free excretion of this substance. In addition, it was shown that only a small amount of acrylamide is excreted in the urine, and 90% of its amount is metabolized.<sup>38</sup> One of the pathways for the metabolism of acrylamide in the liver, involving cytochrome P450 2E1, is transformed into an epoxy derivative-glycidide.<sup>39</sup>

Glicamide is the major metabolite of acrylamide in the body, with the cytochrome P450 monooxygenase (mainly CYP2E1 isoenzyme) converts acrylamide into a reactive epoxy form-glycidide.<sup>40</sup> Cytochrome P450 (CYP) belongs to the hemoprotein superfamily, which in turn plays a key role in the bioactivation and detoxification of harmful substances. CYP1A and CYP2E are thought to be primarily involved in the metabolism of carcinogens whereas CYP3A, CYP2D and CYP2C are responsible for drug metabolism.<sup>40</sup>

Glicamide is most often bound to glutathione. Glutathione conjugates are produced by reaction, and the coupling is catalyzed by glutathione S-transferase (GST) glutathione family enzymes. These conjugates are in succession N-acetylated N-acetyltransferase enzyme steps CoA (N-acetyltransferases CoA-NATCoA). The final

reaction products are N-acetylcysteine derivatives, in the mercaptans: N-acetyl-S-(3-amino-2-hydroxy-3-oxopropyl) cysteine and also N-acetyl-(2-carbamoyl-2-hydroxyethyl) cysteine.<sup>42-45</sup>

### Cancer risk

Food rich in saturated fats are associated with increased risk for cancer. A balanced diet of adequate vegetables, fruits, and fiber-rich grains, provide protection against cancer. However, fried foods due to the creation of carcinogenic or mutagenic heterocyclic amines (HA) through the cooking process are related with higher risks of cancer. Further, deep-oil fried vegetables and salted or sundried Ribbonfish, are at higher rate of risk in gastric carcinoma<sup>46-49</sup> and reported that there was a positive association between acrylamide-hemoglobin levels and estrogen receptor positive breast cancer. Epidemiological studies indicated, that dietary acrylamide intake is not associated with other cancer risks, prostate cancer,<sup>50</sup> or bladder cancer, gastrointestinal cancer, brain cancer, thyroid cancer<sup>51</sup> and lung cancer.<sup>52</sup> Acrylamide dietary exposure in amounts normally consumed by Swedish adults in some products has no measurable impact on the risk of three major types of cancer.<sup>53</sup> Fourteen different food items with high (300-1200 micrograms kg<sup>-1</sup>) or moderate (range 30-299 micrograms kg<sup>-1</sup>) of acrylamide content in adult consumers were examined. When acrylamide intake was studied in adult diets, there was no association with bladder or kidney cancer. Unexpectedly, there was a reversal trend for colorectal cancer, with the highest risk being 40% lower than the lowest quartile. There was evidence that dietary acrylamide exposure in amounts normally consumed by Swedish adults, in some products, has no measurable effect on the risk of three major types of cancer. It should be noted, however, that the risk of acrylamide content in all food products in adult consumers cannot be directly investigated. Hitherto, the neurotoxic effects of acrylamide<sup>54</sup> on the human body have been proven. The genotoxic activity of acrylamide is manifested primarily by its metabolic transformation into the glycidide epoxide derivative. The carcinogenic effect of acrylamide has been demonstrated in animal studies only. Epidemiological studies do not provide any evidence that acrylamide is ingested with the diet and initiates cancer in humans. Acrylamide exposure is measured by measuring the concentration of adducts of this substance in the body, that is, the specific compounds formed by the combination of acrylamide with hemoglobin or DNA.<sup>27</sup>

### Human exposure to acrylamide and the development of cancer

So far, only a small number of studies have shown a negligible association between the exposure of the general population to acrylamide and the increase in malignancy. The relationship between acrylamide exposure (studies in Denmark), manifested by elevated concentrations of acrylamide adduct and glycoside with hemoglobin and increased incidence of breast cancer.<sup>49</sup> However, the authors conclude that significant increases in morbidity only occurred in the subgroup of smokers.<sup>48</sup>

### Potato chips compared with other chips

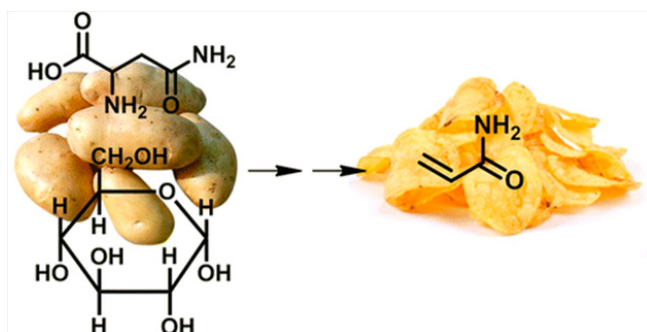
High potato yields and quality are important determinants for the suitability of a given variety for large scale local production. Varieties with higher specific gravity and dry matter tend to have higher yields and better quality of finished chips and French fries. Moreover, colour of French fries and chip finished products depends on sugar content of tubers.<sup>2</sup> In places with diverse food habits, a wide range



of deep-fried and high temperature processed foods like chips, pure, tandoori, potato sticks, and potato 'bhujia', consumers do not attach more importance to brand or unbranded food, but are moved towards colour, taste, crispiness and affordable price.

Chips are one of the most common evening or leisure snack. Potato, jack fruit, sweet plantain and plantain chips are prevalent variants in this chain. Quality<sup>55</sup> of fresh and processed potatoes are evaluated by subjective and objective techniques, but mostly measured through sensory evaluation rather than with any experimental methods.<sup>56</sup> Storage of chips varieties over as long period in shops lead to life style diseases like diabetes, cardiovascular diseases and cancer.<sup>47</sup>

The acrylamide in food samples from the Potato chips of South Indian market had a mean value of  $1456.5 \pm 22 \mu\text{g}/\text{kg}$ ; median value  $1533.9 \mu\text{g}/\text{kg}$  and a range of  $82.0\text{--}4245.5 \mu\text{g}/\text{kg}$ .<sup>57</sup> Inferring with the mean values the potato was approximately 300times more concentrated with acrylamide than any other chips; while in the median the variation was around 700times higher. The order of increase in concentration was plantain, sweet potato, Jack fruit and then Potato. Even the HPLC chromatograms showed that potatoes had an acrylamide peak when compared with other chips.<sup>25,56</sup> (Figure 3).



**Figure 3** Acrylamide in foods.

Acrylamide formation is depended strongly on frying conditions due to reusing of oil; and chemical composition of samples especially reduces sugars with asparagine content.<sup>9</sup>

EFSA was asked to give a scientific opinion on acrylamide in food. Acrylamide is widely used as an industrial chemical. It also happens when some foods are prepared at temperatures above  $120^{\circ}\text{C}$  in foods containing asparagine and reducing sugars. The highest acrylamide content was found in the following products: "Coffee and coffee substitutes", followed by "potato chips and snacks and potato fried products". On average, 95.1% of the exposure to acrylamide nutrients in various studies and age groups was estimated at  $0.3$  to  $1.9 \mu\text{g}/\text{kg}$  body weight (b.w.) per 12days and  $0.6$  to  $3.4 \mu\text{g}/\text{kg}$  body weights per day. Individual favorites towards fried food will have a significant impact on the exposure of people in the diet to acrylamide. After oral ingestion, acrylamide is absorbed from the gastrointestinal tract and distributed to all organs. Acrylamide is largely metabolized, mainly by conjugation with glutathione, but also by the glycidamide (GA) epoxidation.<sup>25,27</sup> GA formation is believed to represent the pathway underlying the genotoxicity of acrylamide carcinogens. Neurotoxicity, adverse effects on male reproduction, developmental toxicity and carcinogenicity has been identified as possible critical endpoints for acrylamide toxicity in experimental animal studies. Data from human studies were not sufficient to assess the dose. CONTAM was selected with BMD L10 of  $0.43 \text{mg}/\text{kg}$  body weight per day for

peripheral neuropathy in rats and  $0.17 \text{mg}/\text{kg}$  body weight per day for tumor effects in mice. The Panel stated that current levels of dietary exposure to acrylamide are not concerned about non-cancerous effects. However, although human studies have not shown acrylamide as a human carcinogen, the margin for being a human carcinogen, the exposure margin (MOE) in dietary studies and age groups indicate a concern about cancer.<sup>7,34</sup>

### The european union food industry confederation toolkit on acrylamide

After the discovery of acrylamide in food, the food industry and other stakeholders, including regulators, have taken action to investigate how acrylamide arises in food and what methods can be used to reduce its contents in foodstuffs. The Confederation of Food Industry (CIAA) coordinated the activities and collected results to develop an acrylamide instrument.<sup>7</sup> Studies in Europe union and in the world show that the acrylamide content varies widely from less than  $10 \mu\text{g}/\text{kg}$  to over  $8,000 \mu\text{g}/\text{kg}$ , depending on the product. Among the products containing high amounts of acrylamide are the products obtained from potato tubers, such as fried crisps and fries and cereal coffee, especially containing chicory. Substantial quantities of this compound also contain cereal products.<sup>9,20,21,25,45,58</sup>

The study, carried out by the Market for Change, includes 92 potato snacks from Britain's largest snack brands and its own brand of crisps in the supermarket market. It turned out that a sample of sweet potato chips from Tyrrells had the highest level of acrylamide at  $2483.6 \mu\text{g}/\text{kg}$ ; This level is 2.5times higher than the European benchmark and more than 83times higher than the lowest concentration.<sup>59</sup> The presence of acrylamide in food is considered a public health hazard by the European Food Safety Authority,<sup>44</sup> as it increases the risk of developing cancer in the young generation, and the children are most at risk.<sup>36</sup> In addition, recent studies conducted by the UK Food Standards Agency (FSA) have shown that currently consumers in the UK consume higher levels of chemical, acrylamide substances than desirable and identified fried potatoes as the main factor for acrylamide.<sup>7</sup> A total of sixteen samples exceeded the recommended EU reference rate ( $1000 \mu\text{g}/\text{kg}$ ), supermarket branded products (12samples), which are significantly worse than the major snack brands (4samples). Worst brands of supermarkets are Morrisons and ALDI, with three products above the safe standard (Table 2).

### How to reduce the formation of acrylamides

The low temperature maintained for extended periods in potatoes causes an increase in the sugar. Therefore, these potatoes are used in food types which are with reduce sweetness such as French fries and chips which are dark in color, which is non-enzymatic browning reactions with reduction of sugars and amine groups of free amino acids. During frying potato the formation of acrylamide can be reduced by any of the following studies.

- Use potato cultivars adapted for deep frying.<sup>16,17,37</sup>
- Reduce the salting of products while preparing food.<sup>20,60,61</sup>
- Soaking of tubers in calcium chloride 2% and citric acid 1% for 60min can reduce the formation of acrylamide.<sup>11</sup>
- Creation of tuber storage conditions in a controlled atmosphere.<sup>60,61</sup>
- Low dose microwave irradiation does not affect the formation of dyes and acrylamide while frying potato tubers.<sup>60,61</sup>

- vi. Intensive research-French fry and potato chip producers to select potatoes that are low in reducing sugars to minimize browning.<sup>16,17</sup>
- vii. Methods for reducing acrylamide content in ready-to-eat fries.<sup>8</sup>
- acrylamide content of fries. Manufacturers are advised to choose the methods that best suit their product types, their production methods, and product quality specifications.<sup>8</sup> Methods for reducing acrylamide in potato chips and French fry:

The following methods are effectively used to reduce the

**Table 2** Acrylamide content in food products in various brands of grocery stores in UK

Brand	Product	Acrylamide (µg/kg)
Tyrrells	Sweet potato lightly sea salted crisps	2483.6
Morrisons	Cheese & onion flavored popped potato snacks	2067.5
Morrisons	Sea salted crinkle cut potato crisps	1825.8
Aldi (Passions)	Barbeque flavor popped potato chips	1778
Seabrook	Natural sea salt lattice crisp	1708
Co-Operative (Truly Irresistible)	Smoked paprika sweet potato hand cooked crisps	1680.7
Co-Operative (Christmas)	Crunchy potato 3D Christmas Tree-sour cream-chives	1541.6
Seabrook	Sea salt and red wine vine garlattice crisps	1525.9
Aldi (Snack rite)	Belight reduced fat assorted potato crisps	1440.2
Tesco	Variety flavour thick crinkle cut potato	1400.2
Seabrook	Sea salted crisps	1326.5
Waitrose (Essentials)	Salt your own crisps	1252.1
Aldi (Snack rite)	Ready salted potato crisps	1229.2
Morrisons	Ready salted potato sticks	1198.5
Sainsbury's	Ready salted potato sticks	1076
ASDA	Salt your own potato crisps (plain potato crisps-sachet of salt)	1021.2

Source: Diane Benford et al.<sup>37</sup> EFSA scientific opinion on acrylamide in food.

### Agronomy

- Choose varieties with the lowest possible content of reducing sugars, taking into account regional differences and seasonal variations. The choice of suitable potatoes for a given product should be based on the color of the frozen sample or the ability of other instruments to control the acrylamide content.
- Check the sugar content of the potato tubers or test fry (to obtain a golden color). Avoid potatoes that produce a dark color product.
- Storage and transportation of potatoes.

Potatoes should be stored at >6°C. You need to control the storage conditions from the farm to the processing plant; At low outdoor temperatures, potatoes should be protected from cold air. Avoid lots of potatoes that have stood overnight outside (without any protection) in the cold.<sup>16,17,54,62,63</sup>

Test potatoes should be tested for potatoes that have been stored for long periods at low temperatures. If the resulting product is dark in color, consider leaving the potatoes warm for two weeks. Regularly test frying tests.

### Processing

- Blanching. Before frying, blanch pieces of potatoes in water to reduce sugar content. Addition of acidic sodium pyrophosphate in

the final blanching phase may reduce acrylamide content in the final product;

- Pre-frying. Use pre-frying fries. Acrylamide is formed especially during the last stages of frying. The amounts of acrylamide found in pre-fried fries are small.
- Thickness of fries. Cut the potatoes into thicker cuts. Thickly cut French fries contain less acrylamide than thinly cut.<sup>25</sup>
- Final machining. When preparing the fries, follow the instructions given on the packaging. Do not extend the preparation time (heat up to slightly golden color, reduce the preparation time for smaller quantities, do not cook at temperatures above 160°C). Frying at lower temperatures until you get the same color will increase the fat content of the final product.<sup>8</sup>

House methods for reducing acrylamides in potato products:

- Monitoring the content of reducing sugars;
- Blanching pieces of potatoes in hot water for a prolonged period of time to reduce the amount of reducing sugars and obtain the right color;
- Controlling the temperature and final heat treatment time;
- Get a brighter golden color during thermal processing.<sup>8,16,17,37</sup>

## Conclusion

A lucrative potato chips trade is about more than supply and demand. It's about designing ways to lure customers to engage with purchase, consumption and to be encouraged as a repeat customer. Hence to retain existing customers to increase the frequency of their consumptions, this study was initiated. People will be willing to purchase food items when it is not harmful to health. Therefore, the review studies on the harmful effects of acrylamide, and its metabolites indicated 3 potential types toxicity: neurotoxicity, genotoxicity and carcinogenicity. It has been proven that the neurotoxic effects of acrylamide affect the human body, while genotoxic activity of acrylamide manifests itself mainly after its metabolic transformation to glycidide the epoxy derivative. The carcinogenic effects of acrylamide have been done (so far) only on animals, but not on humans and that too acrylamide exposure assessment was measured on the adducts, or specific compounds formed because of the combination of acrylamide with hemoglobin or DNA. Therefore, there is no study that has proven evidence that acrylamide taken with a diet initiates tumor in humans. The proposed technique for reducing the obtainability of free asparagine or reducing sugars, modifying other ingredients, and changing cooking time or temperature is only to ameliorate the chance of risking with cancer. There are various techniques which are performed and said to be useful for different types of potato products, selecting potatoes which are low in reducing sugar, controlling storage conditions, and reducing the time or temperature of cooking are frequently cited methods. Reducing acrylamide in diet and protecting other quality aspects will remain a major challenge, may be scope for future research would tend to focus on the following issues: factors affecting the quality of food, consumption of vegetable protein and vegetable protein products, probiotics, acceptance of functional foods by consumers.

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## Conflicts of interest

None.

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