Research Article

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Dietary acrylamide intake by potato crisps consumers: A case of Nairobi County

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Abstract: The levels of acrylamide intake because of potato crisps consumption remains unknown in Kenyan context. This study assessed the exposure to acrylamide because of consumption of potato crisps in Nairobi, Kenya. A cross-sectional survey was carried out among 315 crisps consumers in Nairobi, and consumption patterns were collected using a pre-tested structured 7-day recall questionnaire. A total of 43 branded and 15 unbranded potato crisps samples were purchased in triplicates of 100 g and acrylamide was quantified using a gas chromatograph with a flame ionization detector. Consumption data were combined with the data on acrylamide contents from which dietary acrylamide intake was calculated using a probabilistic approach based on @Risk TopRank 6 risk analysis software for excel. The mean estimated acrylamide intake was 1.57 µg/kg body weight (BW) per day while the 95th (P95) percentile was 5.1 µg/kg BW per day, with margins of exposures (MOE) being 197 and 61, respectively. The intake of acrylamide was significantly ($P < 0.05$) higher in unbranded crisps with a mean value of 2.26 and 95th percentile of 6.54 µg/kg BW per day, MOE being 137 and 47, respectively. There were extremely lower MOE indicating higher exposure to acrylamide by the consumers mainly because of the higher acrylamide contents in potato crisps, and hence the need for mitigation measures.

Keywords: exposure, acrylamide, carcinogen, potato crisps, margins of exposure, consumption

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1 Introduction

There has been a general trend of increased consumption of fried potato products with potato crisps being one of the most important industrial product consumed by a large proportion of urban dwellers, including Nairobi (Abong' et al. 2010). The increased consumption is mainly linked to the young generation who find the products convenient with unique appealing sensory properties (Chiou et al. 2012). However, fried potato products have been shown to contain by-products such as acrylamide depending on the level of contamination and consumption (Ogolla et al. 2015). The presence of acrylamide in food products has raised food safety concerns worldwide (Halford et al. 2012).

It is widely agreed that acrylamide is a monomer mainly formed through Maillard reaction involving free asparagine and carbohydrates, the reducing sugars glucose and fructose. Asparagine, the backbone of the acrylamide molecule, is necessary in the reaction, whereas reducing sugars are essential co-reactants especially in the formation of the *N*-glycoside intermediates (Allmadge et al. 2003; Muttucumaru et al. 2017). However, the extent of acrylamide formation is influenced by temperature; formation usually increases above 120°C depending on the food matrix (Yang et al. 2016). Together with French fries, potato crisps have been shown to have relatively high acrylamide contents in a number of recorded research reports (EFSA 2011; Sirot et al. 2012). The high acrylamide contents in these products have been attributed to the high amounts of free asparagine in potatoes compared to other foods that undergo similar processing conditions. The levels are influenced by a number of factors including genetic variation, post-harvest handling, and storage conditions as well processing parameters

(Krishnakumar and Visvanathan 2014; Wiberley-Bradford et al. 2014; Mu et al. 2016; Yang et al. 2016). Cereal products such as bread, breakfast cereals, biscuits cakes, and coffee have also been implicated as major sources of acrylamide. Variation in acrylamide contents can be quite high in different foods. For instance, in Europe where monitoring was undertaken for 3 years, the mean contents of acrylamide were found to range from as low as 37 µg/kg for soft drinks and as high as 1,504 µg/kg for substitute coffee, whereas the highest 95th percentile and maximum levels were recorded in substitute coffee at 3,976 and potato crisps at 4,804 µg/kg (EFSA 2011).

Because of the adverse effects indicated in animal studies, acrylamide has been classified as a probable human carcinogen and a neurotoxicant; more recently being placed in the list of carcinogens and those that affect reproductive health (EPA-USA 2019). Carcinogenic, reproductive, and genotoxic effects of acrylamide have been shown to be mediated partly by epoxide glycidamide that is its main toxic metabolite in animals studies (Doerge et al. 2005; Annola et al. 2008). Animal studies have indicated increased incidences of tumor in different glands such as pituitary, adrenal, and mammary glands after exposure to acrylamide (Friedman et al. 1995). Human studies have indicated mixed results; some indicating positive associations of cancer with acrylamide exposure (Bongers et al. 2012) whereas it lacks in others (Pelucchi et al. 2011; Lipworth et al. 2012).

Although the daily dietary acrylamide intakes may vary with age and rate of consumption, the estimation by World Health Organization in the world is in the range of 0.3–2.0 µg/kg body weight (BW) for the total population. The intake may reach 5.1 µg/kg BW when the 99 percentile is taken into account (JECFA 2010). In a Polish study, exposure of infants (6–12 months) was found to be higher than the general population being estimated at the minimum to range from 0.41 to 0.62 µg/kg BW per day, on the average level it ranged from 2.10 to 4.32 µg/kg BW per day, whereas for the worst case scenario the exposure ranged from 7.47 to 12.35 µg/kg BW per day (Mojska et al. 2012). In Europe the mean acrylamide exposure has been estimated to range between 0.31 and 1.1 µg/kg BW per day for adults over 18 years, and between 0.43 and 1.4 µg/kg BW per day for adolescents (11–17 years). Major contributors to exposure for adults were fried potatoes, coffee, and soft bread, whereas for adolescents and children they were French fries, soft bread, potato crisps, and biscuits (JECFA 2010).

Although there is an increasing trend toward consumption of crisps in Kenya (Abong' et al. 2010), it is not clear as to what extent the consumers are exposed to acrylamide. There are differences in potato varieties as well as processing parameters for crisps. Even though studies have been carried out in developed countries, there is limited information on acrylamide intake assessment in Kenya and hence the need for this study. Because acrylamide has been proven to be a probable human carcinogenic, possible risk may not to be wished off. The purpose of the current study was to assess the level of intake of acrylamide because of consumption of potato crisps in Nairobi, Kenya.

2 Assessment of exposure to acrylamide and risk characterization

2.1 Materials and methods

2.1.1 Potato crisps consumption data acquisition

Because of limited information on potato crisps consumption in Kenya, consumption data were collected from retail outlets in Nairobi, Kenya, based on potato crisps consumers. Nairobi is the capital city of Kenya and it was purposively selected because of the large number of supermarkets, the greatest presence of crisps processing companies, and retail outlets. This study involved a cross-sectional survey applying quantitative data collection methods. Sampling was carried out as described by previous study (Abong' et al. 2010). A total of 315 consumers including 189 females and 126 males were interviewed from randomly selected retail outlets. Data were collected using a structured 7-day recall questionnaire that had previously been pre-tested with 10 consumers. Data were collected on gender of consumer, frequency and amount of consumption, the preferred brand, estimated individual consumer weight and height, and preferred flavor. The daily consumption was calculated by dividing the weekly intake (kilogram per person) by a factor of 7, and by the estimated BW of an individual or an average weight of 60 kg where the weight was not available (JECFA 2010).

2.1.2 Determination of acrylamide contamination of potato crisps

2.1.2.1 Sampling of potato crisps for analysis

Potato crisps for acrylamide analysis were sampled from different retail outlets and street processors in Nairobi, Kenya. A total of 43 brands sold in different retail outlets were purchased in triplicates of 100 g each, whereas 15 unbranded samples were bought from five different street processors. The main flavors of crisps in the market included onion, tomatoes, chilly, garlic, lemon, and cheese. Utmost care was taken to ensure that no similar brands were purchased from the same retail outlet.

2.1.2.2 Determination of acrylamide in potato crisps

Acrylamide content of potato crisps was determined using gas chromatography (Shimadzu GC 14B, Japan) and Flame Ionization Detector (Shimadzu G-14B, Japan) as described by our earlier study (Ogolla et al. 2015).

2.1.2.3 Assessment of acrylamide intake using a probabilistic approach

Using @Risk TopRank 6 risk analysis software for excel (Palisade, UK), data for acrylamide contents and consumption were fitted to obtain the best distributions. All the formulae for distributions and outputs are presented in Table 1. Independent consumption data were combined with acrylamide contents results and intake calculated. The average exposure and 95 percentile (P95) were obtained and compared with $BMDL_{10}$ to obtain margin of exposure (MOE) for risk characterization. Because of insufficient epidemiological data on carcinogenic effect, a dose–response relationship has been set depending on animal data with JECFA proposing lower limit on the benchmark dose for a 10% response ($BMDL_{10}$) for acrylamide to be 0.31 mg/kg BW per day in case of induction of mammary tumors in rats and 0.18 mg/kg BW per day for Harderian gland tumors in mice (JECFA 2010). To cater for variability and uncertainty, Monte Carlo simulation of exposure was performed using @Risk risk analysis software that combined randomly the consumption and acrylamide contamination distributions. One million iterations were performed to describe the variability.

3 Results and discussion

3.1 Potato crisps consumption survey

Most of the people who consumed potato crisps in Nairobi among the study cohort were mainly women (60%) compared to men (40%). This indicates the fact that women prefer sweet fast foods compared to men who prefer foods that are filling, the preference being genetically determined (Keskitalo et al. 2007). The educational levels of the respondents varied with 37.9% being in tertiary institutions, 37.8% being graduates of secondary ordinary level, whereas 18.9% had secondary advanced level of education. Figure 1 indicates the education levels of the respondents who purchased and consumed potato crisps in Nairobi.

About 51.9% of those interviewed were students, whereas 32.9% were employed and receiving a monthly salary. Only 5.1% were not employed, whereas those who were self-employed and casual laborers were 2.5%. Nairobi city has many colleges and schools and this explains why most respondents were students. Crisps can be consumed as a snack of choice between meals or some people consume crisps as a meal on its own, the choice depending on a number of factors including education and knowledge.

The age of the respondents ranged from 5 to 51 years with a majority (38%) being in the age bracket of 20–24 years, followed by 25–29 years (22.7%). About 89% of those interviewed were youths between the ages of 17 and 35 years (Figure 2). This is an indication that the highest number of consumers of potato crisps are young people in agreement with the previous findings in Kenya

Table 1: Formulae used in quantitative risk assessment model for acrylamide in potato crisps

	A Unit	B Distribution	C Formula
1	Acrylamide, non-branded crisps (µg/kg)	Input (contents)	RiskExtvalueMin (8539.94, 1247.34)
2	Acrylamide, overall sample content (µg/kg)	Input (contents)	RiskTriang (0.0, 16287)
3	Acrylamide, branded crisps (µg/kg)	Input (contents)	RiskExpon (4261.5, 48.98)
4	Consumption (kg/kg BW per day)	Input (extent)	RiskPearson5 (1.899, 0.0)
5	Acrylamide intake (µg/kg BW per day), non-branded crisps	Output	RiskOutput () + B4*B1
6	Acrylamide intake (µg/kg BW per day), overall	Output	RiskOutput () + B4*B2
7	Acrylamide intake (µg/kg BW per day), branded crisps	Output	RiskOutput () + B4*B3
8	MOE	Output	BMDL10/Intake

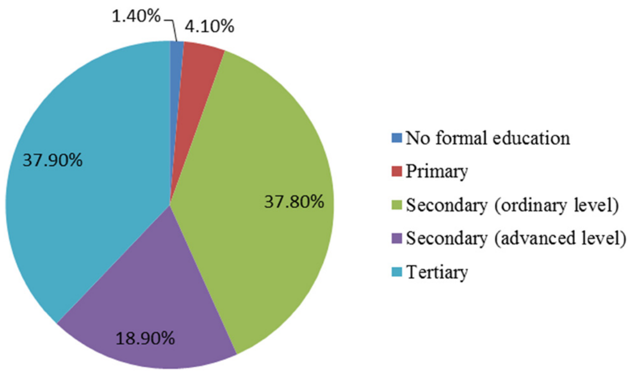

Figure 1: Education levels of potato crisps consumers in Nairobi, Kenya.

(Abong' et al. 2010). This may result in a higher intake of acrylamide among the younger generation.

The most frequently purchased unit package was 100 g (40.5%), followed by 50 g (25.2%), 30 g (12.7%), and 200 g (11.4%). The least purchased package unit was 70 g (3.8%). Approximately 92.1% of the respondents interviewed purchased their potato crisps from supermarkets with only 7.9% purchasing the crisps from kiosks. Reasons given for preference of place of purchase included high quality (72%), proximity (12%), affordability (9.3%), and desire for more quantity (6.7%).

Figure 3 indicates the frequency of consumption of potato crisps expressed as percentages. Most (25%) respondents consumed potato crisps twice a week followed by once per week (23.7%) and once daily (22.4%), whereas the twice a month was the least (5.3%) frequency. Therefore, it shows that a substantial number of the consumers eat crisps daily and up to 75% eat the products in a week. To these consumers, crisps is an important snack whose quality and safety require to be assured.

Figure 4 shows the preference in consumption based on flavor of the potato crisps, onion and chilly or plain salted being preferred. The current findings closely agree with a previous study in Nairobi (Abong' et al. 2010) indicating that consumer preference has remained generally the same for about 3 years. Reasons given for the choice of specific flavors consumed included irresistibility, taste, delicious nature, quality of the product, and the crunchy nature of the potato crisps. The brands that were preferred by the respondents were Amigos (27.8%), Tropical Heat (21.5%), Deepys (8.9%), Chigs (2.5%), Eskay (1.3%), Urban Bites (1.3%), Hoops (1.3%), Yankee Doodles (1.3%), Wow (1.3%), Krackles (1.3%), Kripsii (8.9%), Happys Golden (1.3%), Pringles (1.3%), and Potato crisps (6.3%).

About 81% of the respondents interviewed had no complaints about the crisps they consumed. The majority complaining stated the following reasons: the quantity packaged being quite less compared to the price charged; some crisps in the packages being broken down into tiny pieces; and high fat and salt content. Despite these complaints, 59.5% noted that their consumption rate was increasing because of the sweet taste, increased income, and the availability of the potato crisps. Some respondents (27.9%) indicated that their consumption was decreasing because of increased cost of living, high fat and salt content because of related health complications, and the high pricing of the potato crisps.

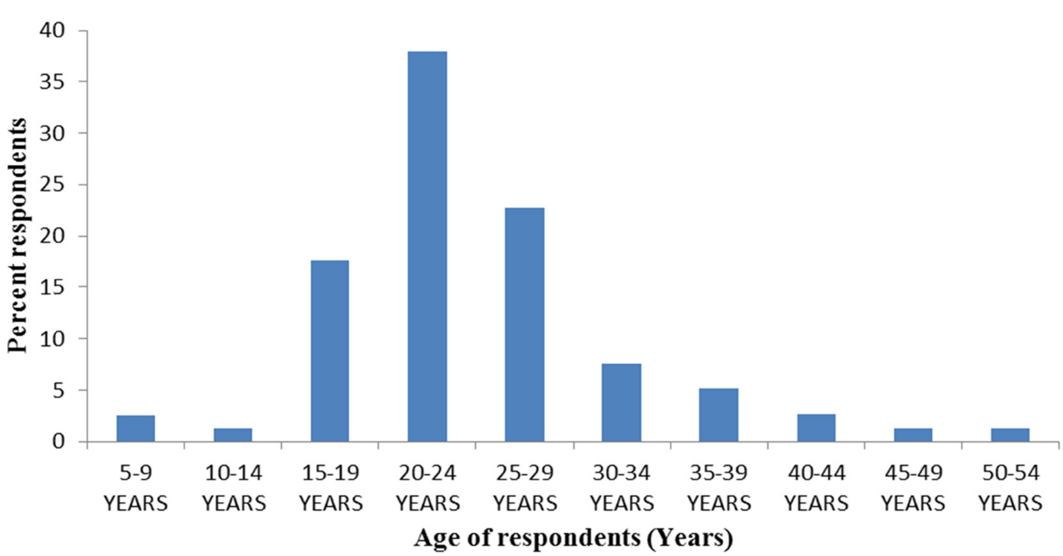

Figure 2: Age of respondents of crisps consumers in Nairobi.

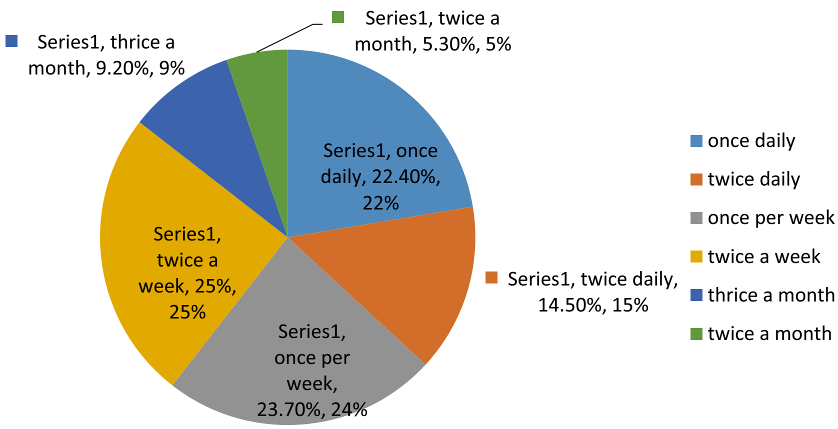

Figure 3: Frequency of potato crisps consumption by respondents.

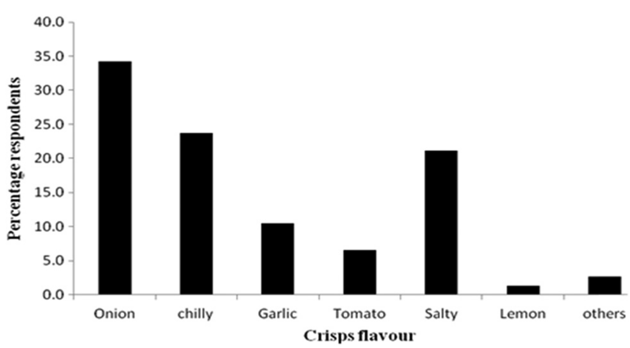

Figure 4: Percentage consumption based on the flavor of potato crisps.

3.2 Acrylamide intake and risk characterization

3.2.1 Acrylamide content, consumption, and intake

Table 2 presents the summary results of distribution fit for acrylamide contents and consumption as well as simulations for acrylamide intake in potato crisps, both consumption and contents being defined with continuous distributions. Acrylamide content in potato crisps was defined with an extreme value minimum distribution with a mean of 7819.96 µg/kg for non-branded crisps from street processors, whereas an exponential distribution characterized acrylamide contents of branded crisps mainly from supermarkets with a mean of 4212.53 µg/kg. Overall acrylamide content was defined with a triangular distribution with a mean of 5,429 µg/kg. On the contrary, consumption data followed Pearson's distribution with a mean value of 3.0×10^{-4} kg/kg BW per day. Significantly higher content values were found in unbranded crisps samples compared to branded samples from retail outlets.

Acrylamide contents in the current study appear to be higher compared to the values reported by other researchers in Italy (27–1,400 µg/kg) by Tateo et al. (2010), Sweden (30–2,300 µg/kg) by Tareke et al. (2002), Iran (244–1,688 µg/kg) by Taher et al. (2010), France (954 µg/kg) by Sirot et al. (2012), and Chile (40–1,770 µg/kg) by Pedreschi et al. (2010). Variation in acrylamide in potato crisps is influenced by a number of factors ranging from agronomic practices, storage conditions to processing parameters (Meulenaer et al. 2008). Potato variety plays a major role in determining the levels of reducing sugars and has been shown to have a direct relationship with acrylamide (Williams 2005; Abong et al. 2009; Claeys et al. 2010). Post-harvest handling and storage conditions have profound effect on the contents of reducing sugars. Storage at temperatures below 8°C generally leads to accumulation of reducing sugars which requires tubers to be reconditioned before frying to achieve low acrylamide contamination and desired color. However, this is cultivar dependent as indicated by other studies (Abong et al. 2009; Abong et al. 2015; Muttucumaru et al. 2017).

Pre-frying activities such as soaking in water, blanching, and coating have been shown to reduce acrylamide formation in crisps because of leaching with subsequent reduction of the Maillard reaction necessary for acrylamide formation (Liu and Scanlon 2007; Wiberley-Bradford et al. 2014). On the contrary, frying at elevated temperature for long duration is a major facilitator to acrylamide contamination (Cummins et al. 2008; Yang et al. 2016). The size of the product may also influence acrylamide contents that tend to be higher in thin slices or sticks (Taylor et al. 2009). Acrylamide contamination seems generally high in Nairobi potato crisps, a scenario that may be attributed to many factors. The use of any available potato tuber by processors especially from the

Table 2: Results of distribution fitting and simulations of acrylamide intake in potato crisps

Unit	Output (mean)	Min–max
Acrylamide, non-branded crisps (μg/kg)	7,819	−8,814 to 11,834
Acrylamide, overall content (μg/kg)	5,429	0.001–16,273
Acrylamide, branded crisps (μg/kg)	4,212	−48 to 72,667
Consumption (kg/kg BW per day)	3.0×10^{-4}	0.00–0.348
Acrylamide intake (μg/kg BW per day), non-branded crisps	2.25	−8.22 to 2059.49
Acrylamide intake (μg/kg BW per day), overall consumption	1.57	0.00–1744.13
Acrylamide intake (μg/kg BW per day), branded crisps	1.22	−0.67 to 4198.21

streets and use of immature tubers may be significant contributors (Matthaus et al. 2004; Abong et al. 2010). Uncontrolled frying temperature, which is a common scenario in Kenya, is no doubt another contributor to higher acrylamide contamination. Branded crisps sold in the retail outlets come from small-medium to large enterprises some of which have raw material and processing control while the majority lacks the control measures.

All consumers in the current study were exposed to acrylamide, the amount increasing with consumption. The mean acrylamide intake for overall crisps content was found to be 1.57 μg/kg BW per day, whereas the 95th (P95) percentile was 5.1 μg/kg BW per day (Table 3).

The acrylamide intake was higher in non-branded crisps with a mean value of 2.26 μg/kg BW per day and 95th percentile of 6.54 μg/kg BW per day. The intake is dependent on acrylamide content and consumption amounts (Arribas-lorenzo and Morales 2011). High acrylamide contents of potato crisps are a major contributor to the current high exposure to acrylamide by crisps consumers in Nairobi, Kenya. Together with roasted coffee, biscuits, and French fries, potato crisps have been identified at the international level to be a major contributor to acrylamide exposure (JECFA 2010; EFSA 2011; Sirot et al. 2012). The mean exposure in the current study was high when compared to 0.40 and 0.43 μg/kg, respectively, reported by Mestdagh et al. (2007) and Sirot et al. (2012) which considered total diet studies in Belgian and French populations. However, the current exposure levels are quite high when compared to other research findings when only potato crisps is taken into account compared to the findings of Sirot et al. (2012) who found an exposure of 0.01 in France, Bongers et al. (2012) who found an exposure of 0.047 in the Netherlands, and other researchers (Arribas-lorenzo and Morales 2011) who found exposure from crisps in Spain to be 0.045.

3.2.2 Risk characterization

As an unavoidable food component that may be carcinogenic and genotoxic for humans, the MOE approach has been proposed and adopted as a useful concept giving an indication of the possible extent of a given risk to acrylamide (EFSA 2005; JECFA 2005). The MOE compares the lower limit on the benchmark dose for a 10% response ($BMDL_{10}$) for a selected tumor from animal studies and the exposure (intake) of a population group. Therefore, it follows that the higher the MOE, the lower the relative risk of a given substance and vice versa. The calculated MOEs for the mean were 115 and 197, respectively, for both $BMDL_{10}$ of 0.18 and 0.31 mg/kg BW per day, whereas for 95th percentile they were 35 and 61, respectively. The MOE for the 95th percentile for non-branded potato crisps was extremely low (28). Because FAO/WHO (JECFA 2010) considers MOEs of 45–310 for acrylamide to raise a public health concern, the mean and 95th percentile values determined in this study can raise concern for crisps in

Table 3: Estimated MOE for the mean and 95th percentile of dietary exposure to acrylamide of crisps consumers in Nairobi, Kenya

	Overall crisps		Branded crisps		Non-branded crisps	
	Mean	P95	Mean	P95	Mean	P95
Dietary exposure (μg/kg BW per day)	1.57	5.10	1.22	4.24	2.26	6.54
MOE ($BMDL_{10}$ = 180 μg/kg BW per day)[a]	115	35	148	42	80	28
MOE ($BMDL_{10}$ = 310 μg/kg BW per day)[a]	197	61	254	73	137	47

[a] $BMDL_{10}$ defined for carcinogenic and toxigenic effects (JECFA 2010).

Kenya. On the same note, if the conclusions of EFSA/WHO (JECFA 2005) which places any MOE lower than 10,000 to be of public health concern, then the level of exposure in this study raises in general concern that requires redress. This indicates that an emphasis on efforts to reduce acrylamide contents in Kenyan potato crisps should continue.

4 Conclusion and recommendations

The high exposure to acrylamide by potato crisps consumers in Kenya is because of high acrylamide contents, street processed consumers being more at risk. Concerted efforts to reduce the high exposure are warranted. The national Bureau of Standards as well as ministry of Health (food safety division) need to take the lead of not only formulating guidelines to reduce acrylamide in crisps but also creating awareness and training actors along the value chain. The current study only focused on potato crisps consumers and did not consider acrylamide contribution from total diet and seasonal variation. It also did not include children who may be more exposed.

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