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Acrylamide Intake in Nairobi Kenya: A case of French Fries Consumers

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Abstract

Among the safety concerns in fried potato products are the levels of acrylamide. High intake of acrylamide has been linked to carcinogenicity in animals and it remains a suspect human carcinogen. The current study was intended to assess exposure to acrylamide through consumption of French fries in Nairobi, Kenya. Data on levels of acrylamide was obtained by analysing samples purchased from fast food outlets in Nairobi while consumption survey was carried out in the same region targeting individual consumers. Consumption data was combined with levels and dietary acrylamide exposure was calculated using probabilistic approach. Results indicated that 57.8% of respondents were males while 42.2% were females. Majority (64.1%) of the consumers were in the age bracket of 20- 29 years. About 17.8% of the respondents consumed French fries once daily, while 78.7% consumed fries at least once a week. Average acrylamide levels in French fries significantly ($p<0.05$) differed with point of purchase being highest in middle end hotel fries (412 µg/kg) followed by fries from street processors (354.18 µg/kg) and high-end hotels (136.15 µg/kg). The mean and 95th (P95) percentile acrylamide intakes for consuming street processed fries were respectively 0.693 and 2.469 µg/kg bw/day, while for the middle end hotels were 0.81 and 3.369 µg/kg bw/day, respectively. The mean and 95th (P95) percentile acrylamide intakes for consumption of high-end hotel fries were 0.256 and 1.035 µg/kg bw/day, respectively. When the worst-case scenario was considered, the mean margins of exposure for the street fries (260) and middle hotel fries (223) were below 310 with 95th percentiles being extremely low at 73 and 53, respectively. Consumers of these fries are at high risk of exposure. High exposures in the current study should warrant concern and need for appropriate measures to be taken by appropriate agencies.

Keywords: *Acrylamide; carcinogen; exposure French fries; intake*

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Introduction

French fries are popular deep fat fried products consumed worldwide with their preferences being pegged on diverse reasons. In Kenya for instance, fries from potatoes are popular lunch time dishes in major urban areas due to both delicacy and low cost as well as convenience. Consumption of the fries seem to have increased over the years as evidenced by proliferations of many eating joints and cafeterias in major Kenyan towns that serve the fries accompanied with soft drinks, salads and chicken.

Acrylamide is an important raw material in manufacture of polymeric coagulant aids popularly used in drinking water treatment (FDA, 2004). Its application is also found in organic chemicals and dyes making as well as

textile industry (EPA, 2014). In foods, however, it is formed mainly in high carbohydrate foods fried under higher temperatures above 120 ^{o}C through maillard reaction of simple sugars with amino acid asparagine (Tareke *et al*., 2002). The maillard reaction is important for the development of the desirable and characteristic colour and taste of fried potato and baked products and hence indispensable in such products (Stadler *et al*., 2004; Viklund *et al*., 2007). High levels of acrylamide have been indicated in potato crisps, French fries and substitute coffee (EFSA, 2011). Baked foods such as bread crust, cookies and cakes have also been shown to contain acrylamide.

Acrylamide is a proven carcinogen and genotoxic chemical to animals (Baum *et al*., 2005; Doerge *et al*., 2005; Annola *et al*., 2008). It, however, remains suspect carcinogen to humans due to variations in study results over the world (Ghanayem *et al*., 2005; Khalil and Aziem, 2005; JECFA, 2011; Bongers *et al*., 2012). Acrylamide has been implicated as a risk factor to cancer (NCI, 2014) and has been positively associated to renal cell cancer risks (Hogervost *et al*., 2008). Recent epidemiological studies have also indicated existence of an association of acrylamide intake with the risk of lymphatic malignancies (Bongers *et al*., 2012).

French fries produced in Kenya are unique compared to those from other countries given that potato tubers used in processing are diverse and parameters of processing differ widely with set ups. French fries are made and sold by street processors, middle level hotels mainly cafeterias and joints and high-end hotels. The first two processors may not adhere to any strict temperature and other quality controls since some set ups have no controls at all (Abong and Kabira, 2015). There is, however, no data on acrylamide levels or intake due to consumption of these fries which are currently very popular. As such, safety of these products in relation to acrylamide has not been established in comparison to other parts of the world. The current study sought to evaluate exposure to acrylamide due to consumption of French fries from different sources in Nairobi, Kenya.

Materials and methods

Dietary acrylamide intake assessment

French fries consumption patterns in Nairobi

Data on consumption patterns was collected from consumers in Nairobi's fast-food outlets between August 2013 and April 2014, and it involved a cross-sectional survey applying quantitative data collection methods. Sampling was carried out as described by Abong *et al.* (2010). Sample size was determined according to formula: $N=Z^2pq/d^2$, p being proportion consuming fries in Nairobi set at 0.5%, q (1-p) is the proportion not consuming fries while d is the desired degree of accuracy set at 0.05. Thus sample (N) = $(1.96)^2$ (0.5) (0.5)/ $(0.05)^2$=384 consumers. A total of 386 consumers were interviewed from randomly selected fast-food outlets. Data was collected using a structured seven-day recall questionnaire which had previously been pre-tested with 10 consumers. Data collected included age and gender of consumer, occupation, frequency of consumption, estimated weight and height, preferred place of purchase, complains against the product and trends in consumption. The daily French fries consumption was calculated by dividing the weekly intake (kg/person) by a factor of 7, and by the estimated body weight of an individual or an average weight of 60 kg where the weight was not available in accordance to JECFA (2011).

Level of acrylamide in French fries in Nairobi

Data on level of acrylamide in French fries from 100 different fast-food outlets in Nairobi's Central Business District (CBD) was adopted from a study by Ogolla *et al.* (2015) combination with consumption data from the assessment study of the risk of exposure to acrylamide.

Probabilistic assessment of acrylamide exposure due to French fries consumption

French fries consumption and levels of acrylamide were fitted to obtain the best distributions in @Risk TopRank 6 risk analysis software for excel (Palisade, UK). Formulae for distributions and outputs are indicated in Table 1. Independent consumption data were combined with acrylamide contamination results and exposure calculated. The average exposure and 95 percentiles (P95) were obtained and compared

with $BMDL_{10}$ to obtain MOE for risk characterization. Monte Carlo simulation of exposure using one million iterations was performed to describe variability.

Table 1: Formulae for quantitative risk assessment model of acrylamide in French fries in Nairobi

A	B	C
Unit	**Distribution**	**Formula**
Acrylamide, street fries (µg/kg)	Input (Contamination)	RiskNormal (354.18, 222.62)
Acrylamide, middle hotel fries (µg/kg)	Input (Contamination)	RiskInvGauss (441.33, 214.63, RiskShift (-29.33)
Acrylamide, high end hotel fries (µg/kg)	Input (Contamination)	RiskExpon (136.15, Risk Shift (-5.45)
Acrylamide, Overall fries (µg/kg)	Input (Contamination)	RiskInvGauss (394.55, 182.55, RiskShift (-25.38)
Consumption (kg/kg bw/day)	Input (Extent)	RiskExpon (0.0019, Risk Shift (-2.86E-5)
Acrylamide intake in street fries (µg/kg bw/day)	Output	RiskOutput () + B5*B1
Acrylamide intake in middle hotel fries (µg/kg bw/day)	Output	RiskOutput () + B5*B2
Acrylamide intake in high end hotel fries (µg/kg bw/day)	Output	RiskOutput () + B5*B3
Acrylamide intake in overall fries (µg/kg bw/day)	Output	RiskOutput () + B5*B4
Margin of Exposure (MOE)	Output	BMDL10/Intake

Results

French fries consumption in Nairobi Kenya

Out of the 386 respondents in the current study, 57.8 % were males while 42.2 % were female. The education level of the respondents ranged from no formal education (1.6 %) to tertiary level of education who were the majority (48%) as shown in Figure 1.

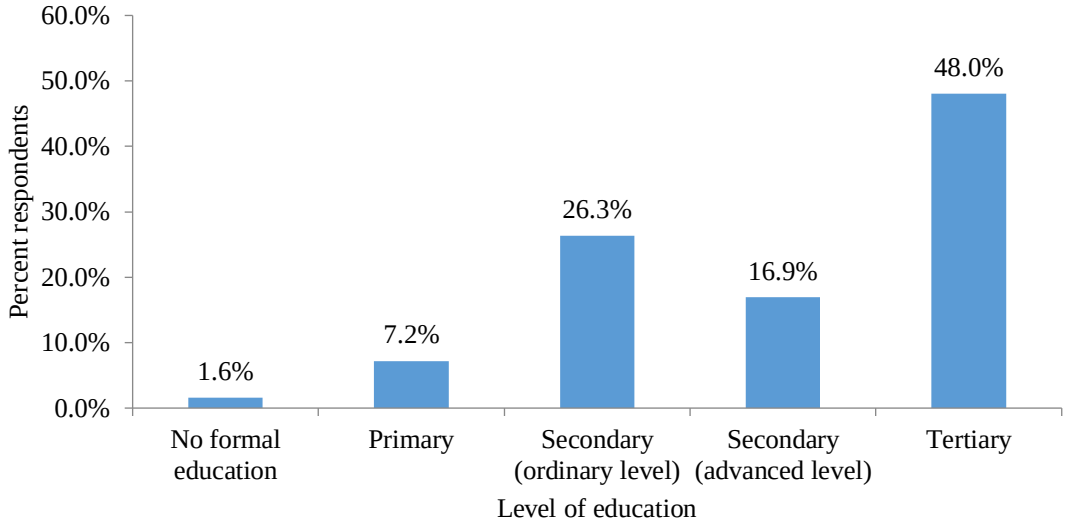

Figure 1: Education levels of French fries consumers in Nairobi

Majority (64.1%) of the respondents were in the age bracket of 20-29 years (Figure 2). It was notable that 71.6 % of the consumers were single as indicated in Figure 3, while only 26.3% were married and living with spouses.

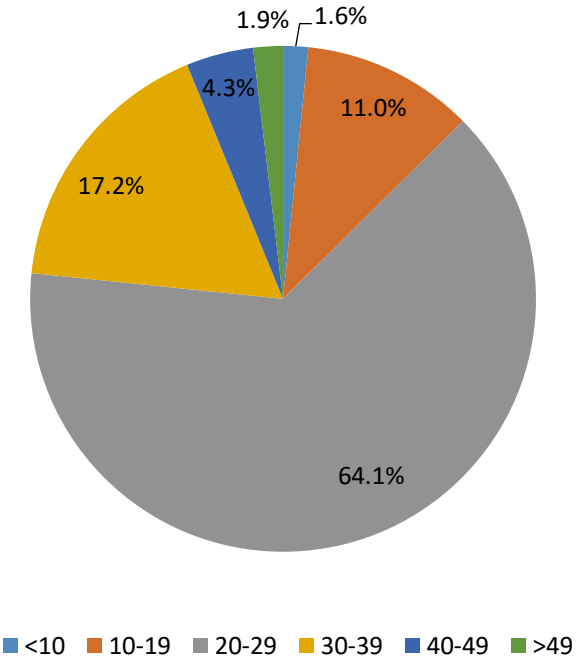

Figure 2: Age (years) distribution of French fries consumers

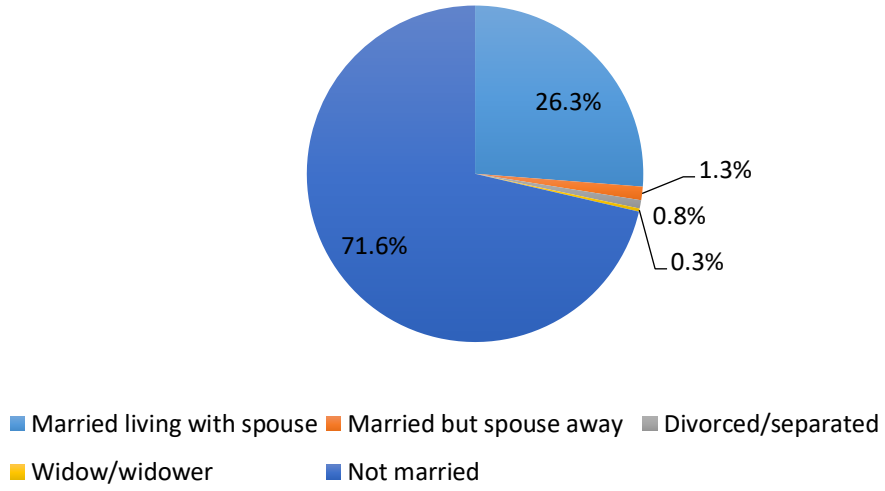

Figure 3: Marital status of French fries consumers

Approximately 17.8% of the respondents consumed French fries once daily, while 20.8% consumed fries twice per week, as shown in Figure 4. The cumulative percentage of respondents who consumed fries at least once a week was 78.7%, while 3.6% rarely consumed them.

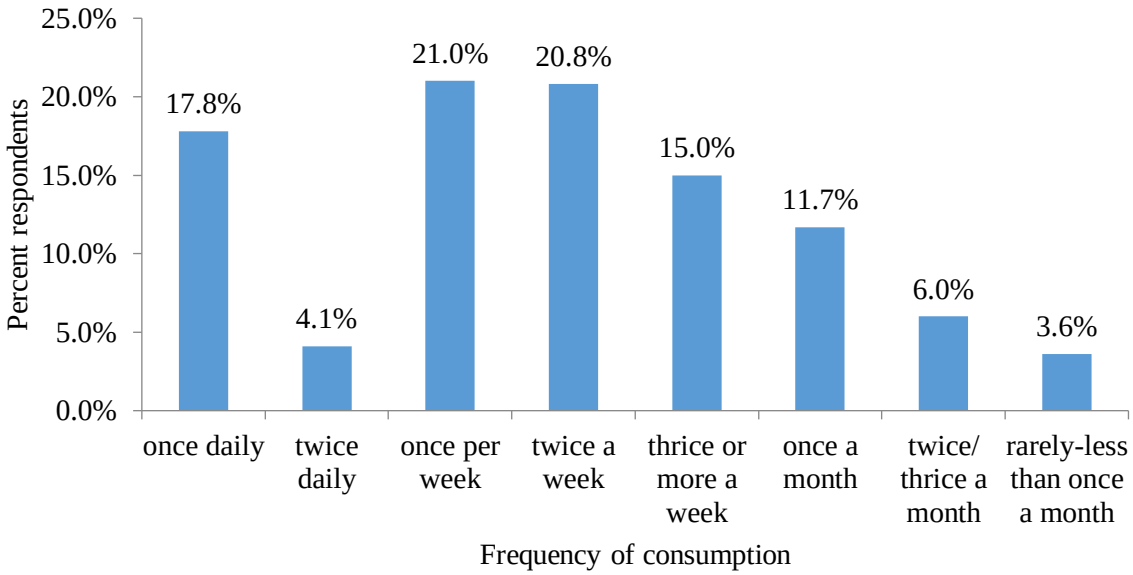

Figure 4: Frequency of consumption among French fries consumers

Majority (82.5 %) of the respondents purchased a plate of fries (~311.7 g). The least purchased unit package was 'less than 20 g (0.5%) that were street samples. Other unit weight categories were half plate (155 g), 70 g, 50 g and 30 g frequently bought by 5.7 %, 4.4 %, 2.2 % and 4.6 % respondents, respectively. Majority (95.4 %) of the respondents consumed the entire amount of fries they bought on their own while 4.6 % of the respondents

shared portions with their friends, children or siblings.

Cafeteria/ fast food outlets were the most common (68 %) fries-eating places among the respondents, while 13.4 % bought the fries from the roadside/streets as shown in Figure 5.

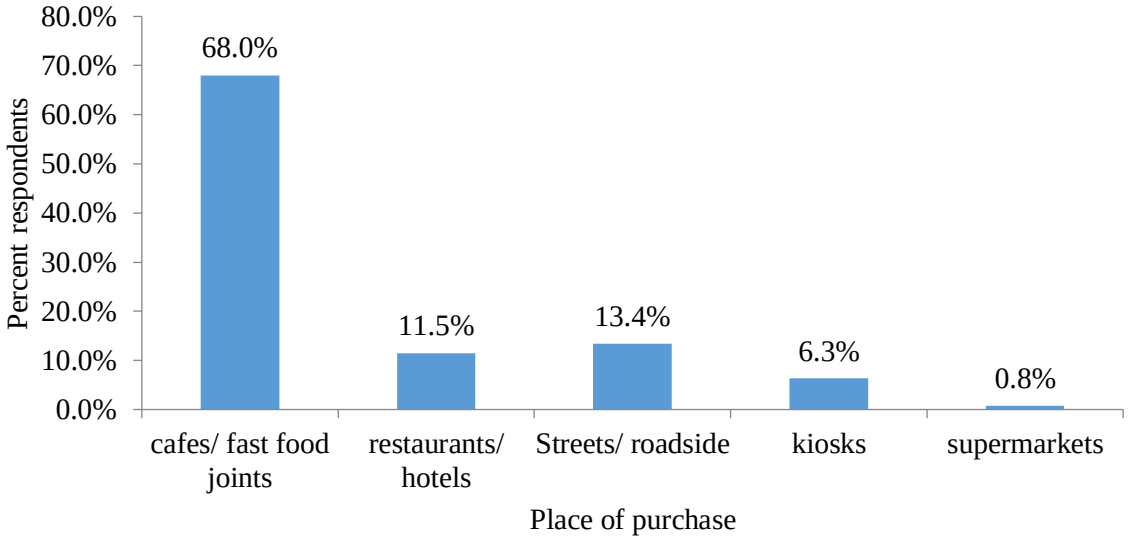

Figure 5: Place of purchase for French fries by consumers in Nairobi

The other places of purchases were restaurants or hotels, kiosks and supermarkets. Respondents had various reasons for purchasing fries in their preferred outlets with quality and affordability being the most popular reasons at 28.3 % and 32 %, respectively. The other reasons included quantity served, proximity, hygiene and good .

customer service as shown in Figure 6. There was also a significant (χ^2= 78.962, p=<0.01) association between employment and frequency of consumption. The single college students being main consumers compared to employed and salaried people

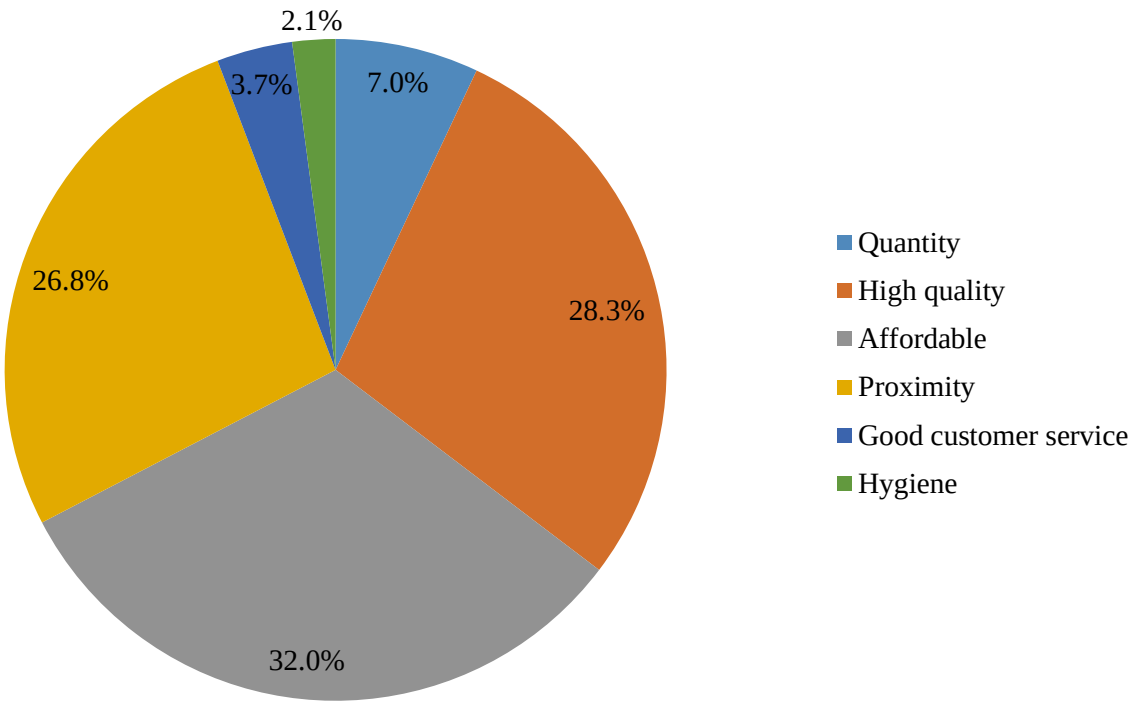

Figure 6: Reasons for preferred outlet for French fries consumers

The most preferred condiment to be taken with fries was tomato sauce (50.6 %) followed by chilli sauce (22.8 %), salad (19.4 %) and ketchup (7.2 %) in the respective order. This might be because both tomato and chilli sauces are the most common sauces in fast food outlets, relatively cheap and in some outlets, offered free. Ketchup is more costly and therefore mostly made available to customers in the high-end outlets. The choice for condiments was based on flavour or taste enhancement, availability and good quality. Some respondents reported preference for chilli sauce thinking it neutralizes high fat content in the fries, while salad was preferred for perceived health / nutritious quality.

The major (54 %) complaint by consumers concerning French fries was on oiliness or sogginess (Figure 7). Other complaints raised on fries included greenness, dark brown colour, too hard or dry, undercooked and cold fries.

Approximately 49 % of the respondents indicated that their consumption trend for French fries was declining, mainly due to the need to embrace healthier lifestyles. Other reasons cited for the declining trend were that fries are increasingly becoming expensive given the current high cost of living. Twenty-two (22) percent of the respondents were indifferent while 29 % indicated that their trend for French fries consumption over the past 2 years was increasing because they were tasty, affordable compared to other meals as well as being a convenient food.

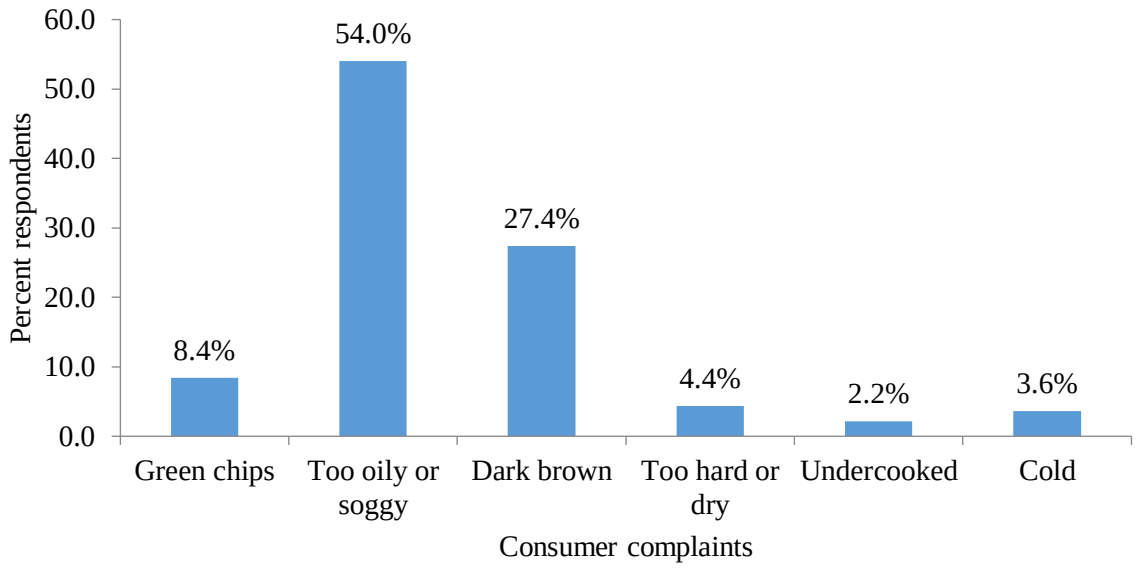

Figure 7: Complaints raised by French fries consumers

Exposure to Acrylamide due to French fries consumption in Nairobi Kenya

Acrylamide levels in French fries significantly ($p<0.05$) deferred with point of purchase. The results of distribution fit for levels acrylamide and consumption as well as simulations for acrylamide intake in French fries were defined with continuous distributions as indicated in Table 2. Levels of acrylamide in street processed fries was defined with normal distribution with mean of 354.18 µg/kg, while fries from middle hotels and cafeterias had the highest mean of 441.33 µg/kg and overall fries with mean levels of 394.55 µg/kg were defined by an InvGauss distribution. On the other hand, high end hotels had the lowest mean of 136.15 µg/kg and were characterized by an exponential distribution. Significantly higher ($p<0.05$) contamination values were found in middle end hotel samples followed by street and high-end hotel samples, respectively.

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

Unit	Output (Mean)	Range (90% CI)
Acrylamide , street chips (µg/kg)	354.18	43-714
Acrylamide , middle level hotel chips (µg/kg)	441.33	19-1715
Acrylamide , high end hotel chips (µg/kg)	130.7	2-402
Acrylamide , Overall Contamination (µg/kg)	369.17	14-1404
Consumption (kg/kg bw/day)	0.002	0.00013-0.0058
Acrylamide intake (µg/kg bw/day), street chips	0.693	0-2.47
Acrylamide intake (µg/kg bw/day), middle level hotel chips	0.806	0-3.4
Acrylamide intake (µg/kg bw/day), High end hotel chips	0.256	0-1.03
Acrylamide intake (µg/kg bw/day), overall	0.722	0-3.05

The mean and 95th (P95) percentile acrylamide intakes for consuming street processed fries were respectively 0.693 and 2.469 µg/kg bw/day, while for the middle end hotels were respectively 0.81 and 3.369 µg/kg bw/day (Table 3). On the other hand, mean and 95th (P95) percentile acrylamide intakes for consumption of high-end hotel fries were 0.256 and 1.035 µg/kgbw/day, respectively.

Table 3: Estimated Margins of Exposure (MOE) French fries consumers in Nairobi, Kenya

	Street Fries		Middle Hotel fries		High-end hotel fries		Overall Fries	
	Mean	**P95**	**Mean**	**P95**	**Mean**	**P95**	**Mean**	**P95**
Dietary exposure (µg/kg bw/day)	0.693	2.469	0.81	3.369	0.256	1.035	0.722	3.05
MOE (BMDL10=180 µg/kg bw/day)1	260	73	223	53	703	174	249	59
MOE (BMDL10=310 µg/kg bw/day)1	447	126	385	92	1211	300	429	102

[1]$BMDL_{10}$ defined for carcinogenic and toxigenic effects (JECFA, 2011).

P95 refers to 95th percentile

Characterization the risk of consuming French fries

Margins of exposure (MOE) between 45 and 310 for acrylamide have been considered to be of concern to the health of the consumers according to JECFA (2011). In this case the lower limit on the benchmark dose for a 10% response ($BMDL_{10}$) when carcinogenic or toxigenic effects are considered. Higher MOEs would mean lower risk of a given contaminant while a lower fraction would mean higher risks.

Discussion

Consumption of French fries

Even though one would believe that French fries are consumed more by females, the current results showed this to be contrary. Nairobi city is inhabited by diverse groups of people many of whom work in the city. The Central Business District (CBD) where this research was carried have more men who are taking part in different employment activities and hence this observation. Many of the city workers have reasonably good level of education and hence the significant association between frequency of consumption and the level of education (χ^2= 47.206, p= 0.013).

Majority of the respondents were in the youthful age bracket of 20-29 years. These results are similar to the findings of Abong' *et al*. (2010), who observed that most crisps consumers are young people, and in the same age group. About 17.2% of the respondents were aged 30-39 while 11% were aged 10-19 years, the rest were below 10 and above 40 years old. As people grow older, they tend to be more health-conscious, therefore watch their diet by cutting down on fatty foods such as French fries. Likewise, the diet of children below 10 years is dictated by their parents/guardians who try to ensure that they have healthy meals. Moreover, access to French fries by children in African set-up is quite limited to occasional gifts from parents hence the low consumption frequency.

French fries serve as affordable, convenient ready-to-eat foods for single persons, most of whom have little time to prepare foods at home and hence the reason for most being single. This explains the higher levels of preference among college students than the salaried employees. Consumers preferred tomato sauce as a condiment to be taken with fries. This might be because both tomato and chilli sauces are the most common sauces in fast food outlets, relatively cheap and in some outlets, offered free. Ketchup is more costly and therefore mostly made available to customers in the high-end outlets. The choice for condiments was based on flavour or taste enhancement, availability and good quality. Some respondents reported preference for chilli sauce thinking it neutralizes high fat content in the fries, while salad was preferred for perceived health / nutritious quality.

Exposure to acrylamide and risk characterization

The current levels of acrylamide in fries from Nairobi are relatively low compared to those reported in Sweden (22- 821 µg/kg) by Hellenäs *et al.* (2013), however, falls within the ranges (0-2349 µg/kg) reported by Mestdagh *et al.* (2007) in their study in Belgium. In comparison to potato crisps, however, the current levels have narrow range and may be considered quite low. For instance, Tateo *et al.* (2010) found levels ranging from 27 to 1400 µg/kg in Italy, Boroushaki *et al.* (2010) found levels ranging from 244 to 1688 in Iran, while Ogolla (2013) found extremely high levels up to 9499 µg/kg from Kenyan crisps.

Acrylamide in fried products vary considerably depending on the raw material characteristics, methods of handling and storage as well as the processing methods and parameters. Storage conditions which increase reducing sugars such as temperature below 8 ^{o}C as well as harvesting immature tubers is likely to increase acrylamide (Abong' *et al*., 2009; De Meulenaer *et al.,* 2008). On the other hand, characteristics of potatoes depend on the variety under consideration. The variety will influence acrylamide levels depending on reducing sugars and asparagine that are inherent in the raw tubers (Amrein *et al*., 2007; Abong', 2009; Claeys *et al*., 2010).

Acrylamide that results from non-enzymatic browning, maillard reaction between reducing sugars and amino acid asparagine is also known to vary with processing methods and frying conditions. Frying thinner slices at lower temperature will result into lower levels of acrylamide and the vice versa is true (Cummins *et al*., 2008; Biedermann *et al*., 2010; Ogolla, 2013). Blanched or coating of the fries may also reduce the level of acrylamide (Zhiqiang and Scanlon, 2007; Pedreschi *et al.,* 2010, Troung *et al.,* 2012). The variation in levels of acrylamide in the different samples of fries in Nairobi most probably depend on the use of different potato tubers by processors, as well as the varied size and temperature of processing (Abong' *et al.,* 2010). The street processors and middle level hotels that had higher levels of acrylamide normally process under uncontrolled frying temperature and sometimes use any available tubers especially in times of scarcity (Abong' *et al.*, 2010). On the other hand, high end hotels samples had quite low levels of acrylamide that may be attributed to proper temperature and raw material controls.

Even though the acrylamide levels were not very high, variations in the outlets for sourcing contributed to noticeable differences in intakes and margins of exposure the level of contamination being critical factor to be considered (Arribas-Lorenzo and Morales, 2009). Relatively high consumption of fries may be the major contributor to high intakes and low margins of exposure. The current levels of acrylamide exposure seem quite high considering that only French fries were under evaluation. Sirot *et al.* (2012) considered total diet studies and found a mean intake of 0.43 for a French population, while Bongers *et al.* (2012) and Katz *et al.* (2012) found mean acrylamide intakes of 0.40 and 0.44 for Netherlands and United States of America, respectively.

When the worst-case scenario was considered, the margins of exposure for the street fries (260) and middle hotel fries (223) were below 310 with 95th percentiles being extremely low at 73 and 53, respectively. It therefore follows that fries consumers of > 0.002 kg/kg bw/day or a man weighing 65 kg consumes more than 120g of fries especially from the middle hotels and street processors would be at risk. This raises safety concern in Kenyan fries. On the other hand,

EFSA/WHO (2005) placed any MOE lower than 10,000 to be of public health concern. This means that consumption of French fries from any source in Nairobi, Kenya would lead to exposure of acrylamide and hence safety concern that requires concerted efforts.

Conclusion

The levels of exposure can be attributed to high acrylamide and high consumption of French fries by Kenyan population in Nairobi. Acrylamide exposure is higher for consumers of mid-hotel and street processed fries that led to lower Margin of Exposure indicating higher risk to consumers. High exposures in the current study should warrant concern and need for appropriate measures to be taken by appropriate agencies.

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