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Quality assessment of potato chips in the local market of Bangladesh

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Abstract

The popularity of potato chips as a snack choice has surged in Bangladesh yet concerns about their safety and nutritional quality persist. This study aimed to evaluate the quality of potato chips available in the local market of Bangladesh. A total of twenty randomly selected brands were subjected to comprehensive analysis, including nutrient composition, microbial contamination, mineral and heavy metal content, and acrylamide levels. Results indicated significant variations among brands, with deviations from established standards in several parameters. While most samples exceeded permissible limits for fat (25%) and salt content (80%), microbial contamination was observed in certain samples, with 40% having a total viable count (TVC) and yeast and mold counts exceeding acceptable limits in several instances. Surprisingly, heavy metals (Pb, As, Cr, or Cd) were notably absent. However, acrylamide levels surpassed safety thresholds in 10% of samples, posing potential health risks to consumers. These findings underscore the importance of stringent quality control measures in potato chips manufacturing and emphasize the need for continued monitoring and regulation to ensure consumer safety and satisfaction.

1. Introduction

The fast-paced urban lifestyle has significantly altered consumer dietary habits (Gasparre and Rosell, 2021) and led to a surge in global demand for snack foods (Benkhoud *et al*., 2022). According to the Global Snack Foods Industry Report (2020), the snack market was valued at $493.4 billion in 2016 and is projected to reach $732.6 billion by 2026 (Reportlinker, 2020). Potato chips are particularly popular due to their appealing sensory characteristics, including shape, flavor, packaging, crunchy texture, and nutritional value (Pęksa *et al*., 2016). The global per capita consumption of potato chips is estimated to be 2.1 kg in 2022 (Statistica, 2022). As an agriculture-based country, Bangladesh ranks 7th in potato production worldwide (Food and Agriculture Organization Statistics Division [FAOSTAT], 2020). The annual demand for potatoes in Bangladesh is 6.5-7 million tons, while production amounts to 9.65 million tons, leaving a surplus of 2 million tons (Bangladesh Bureau of Statistics [BBS], 2019). Potato-based snacks such as potato crackers, potato chips, and French fries are widely consumed in Bangladesh due to the local preference for potato-based foods (Hasan *et al*., 2022). However, concerns about quality and food safety persist, particularly regarding potato chips.

Potato chips are dehydrated snacks with a moisture content of 0.02 g/kg or less, obtained through deep-oil frying. The frying process, conducted at temperatures between 160°C and 180°C, must ensure a high drying rate to achieve the desired structure and texture (Pedreschi and Moyano, 2005). Potato chips typically have a high oil content, ranging from 35% to 45% (wet basis), contributing to their distinctive texture-flavor combination (Garayo and Moreira, 2002; Mellema, 2003). However, traditional potato chip production processes often result in quality losses due to the lack of rigorous sorting and single-stage processing (Arefi *et al*., 2022).

Despite their popularity, excessive consumption of potato chips has been linked to various health issues such as obesity, diabetes, hypertension, and cardiovascular disease, attributed to their high fat and salt content and low fiber, mineral, and protein composition (Saldivar, 2016). Moreover, process contaminants like acrylamide,

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a carcinogen formed during high-temperature frying (>120°C) via the Maillard reaction, pose additional health risks (Bhuiyan *et al*., 2017; Ledbetter *et al*., 2021; Quesada-Valverde *et al*., 2022; Nahid *et al*., 2024a, Nahid *et al*., 2024b). Acrylamide formation is influenced by factors such as temperature, duration of frying, and sugar content in potatoes (Biedermann-Brem *et al*., 2003; Fiselier and Grob, 2005; Maan *et al*., 2020; Nahid *et al*., 2023).

In addition to processing contaminants, microbiological contaminants can compromise potato chip quality and safety if proper hygiene standards are not maintained throughout production, processing, transportation, or storage (Ahmed *et al*., 2020). Therefore, consuming contaminated potato chips containing bacteria, fungi, viruses, or protozoa can pose serious health risks. This study aimed to evaluate the safety and quality of the most commonly consumed potato chips in Bangladesh, providing insights into their manufacturing processes to address concerns regarding food safety and quality for consumers.

2. Materials and methods

2.1 Collection of samples

Branded potato chip samples were randomly selected from street vendors and local shops. Twenty samples were obtained from various locations in Dhaka, Bangladesh, and labeled as S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, and S20 before undergoing analysis.

2.2 Nutrient composition analysis

Each sample of potato chips was meticulously weighed (10 g), finely powdered, and subsequently added to a 50 mL test tube. Nutritional parameters including moisture, carbohydrate, protein, and fat levels were assessed. The moisture content was determined employing a hot air oven where as protein and fat content were analyzed using the Kjeldahl and Soxhlet apparatus (Nahid *et al*., 2024b). The carbohydrate content was measured by the difference value.

Carbohydrate (%) = 100 – (Moisture % + Ash % + Protein % + Fat %).

The energy was calculated using Atwater's conversion factors: 9 kcal/g for fat and 4 kcal/g for carbohydrate and protein (Sánchez-Peña *et al*., 2017). The following equation was used to calculate energy.

Energy (kcal) = (9 × fat) + (4 × carbohydrate) + (4 × protein)

2.3 Mineral and heavy metal analysis

The ash residue extracted from each potato chip was dissolved in a solution containing perchloric acid and nitric acid (in a ratio of 1:4 v/v). Subsequent to cooling, the ash solution was filtered through Whatman filter paper 42. Each solution derived from the potato chips was adjusted to a final volume of 25 mL using deionized water. Following the protocol outlined by Juhaimi *et al*. (2016), an aliquot of the solution was utilized to quantify the presence of minerals and heavy metals within the potato chips. The atomic absorption spectrophotometer (Varian Spectra AAS 220, USA) was employed to determine the concentrations of minerals and heavy metals in the potato chips.

2.4 Microbiological analysis

2.4.1 Pathogens

In this study, four bacteriological strains—total Coliforms, *Escherichia coli* ATCC 25922, *Salmonella* Typhi AE 14612. and *Shigella dysenteriae* AE 14396 —along with one fungal strain *Aspergillus candidus* (Fries) were used for positive control. The microbial isolates were obtained from the Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR).

2.4.2 Bacterial pathogen detection procedures

Microbiological analysis was performed following the protocols outlined in the Bacteriological analytical manual (Maturin and Peeler, 2001). Each sample (25 g) was aseptically weighed and homogenized with 225 mL of buffer peptone water to prepare an aliquot. For the total viable count (TVC), a 1 mL aliquot of the potato chip solution was serially diluted in 9 mL of buffered peptone water, yielding a 10-fold dilution. Subsequently, 1 mL of the diluted sample was plated onto plate count agar using the serial dilution technique and incubated at 37°C for 24 h. After incubation, bacterial colonies were counted, and the results were expressed as the logarithm of colony-forming units per gram (CFU/g). The enumeration of total Coliforms and *E. coli* was conducted by Most Probable Number (MPN) techniques using the 3 tube MPN test with Lauryl Sulfate Tryptose Broth, *E. coli* Broth (EC Broth), and Brilliant Green Lactose Bile Broth described by the Bacteriological Analytical Manual (Feng *et al.,* 2002). The most probable number (MPN) of total coliforms per gram of potato chips was determined using the multiple-tube fermentation technique. Samples were subjected to 10-fold serial dilutions, and aliquots were inoculated into a series of lactose broth tubes containing inverted Durham tubes to detect gas production. After incubation at 35±2°C for 24–48 h, gas formation in the tubes was

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recorded as a positive result for coliform presence. The pattern of positive tubes across the dilution series was then used to estimate the MPN using standard MPN tables. To confirm the presence of coliform bacteria, aliquots from positive tubes were streaked on MacConkey agar plates and incubated under the same conditions, followed by colony morphology and Gram staining for identification (Konrueng *et al.*, 2015).

For the detection of *Salmonella* spp., samples were enriched for 18 h at 37°C using Tetrathionate (TT) Broth and Rappaport-Vassiliadis Soya (RVs) Broth. Following the International Organization for Standardization (ISO). (2017). guidelines (ISO 6579-1:2017), 0.1 mL aliquots from the 10 mL RVs enrichment were transferred into 0.9 mL of Muller-Kaufmann Tetrathionate Novobiocin (MKTTn) Broth. The cultures were incubated at 37°C and 42°C for 24–48 h, respectively. Post-incubation, aliquots from each enrichment medium were inoculated onto Xylose Lysine Deoxycholate (XLD) Agar and Violet Red Bile Medium (VBM) Agar plates, followed by incubation at 37°C for 30 h to identify characteristic colonies (red colony, black center for XLD and colorless colony for VBM). For *Shigella* spp. detection, samples were plated onto *Salmonella*-Shigella (SS) Agar and Hektoen Enteric Agar, followed by incubation at 37°C for 24 h.

2.4.3 Fungal count procedure

Yeast and mold counts were assessed using the spread plate technique on Dichloran 18% Glycerol (DG18) Agar and Dichloran Rose Bengal Chloramphenicol (DRBC) agar (Tournas *et al.*, 2001). The plates were incubated at 37°C for five days, after which the colony-forming units (CFUs) were enumerated and expressed as log CFU/g. All microbial analyses were performed in triplicate to ensure accuracy and reproducibility.

2.5 Acrylamide extraction by charcoal treatment

Acrylamide extraction from potato chips utilized a novel method. Approximately 10 g of each potato chip sample were crushed in a vessel and dissolved in 100 mL of methanol (MeOH) for duration of 3 h. Subsequently, all methanolic extracts were filtered through filter paper and then transferred to 50 g of activated charcoal. This process was repeated thrice to ensure thorough extraction. The application of activated charcoal played a crucial role in decolorizing the methanolic extracts. Following the activated charcoal treatment, the decolored methanolic extract was dried using a rotary evaporator, weighed, and then stored in a refrigerator at 4°C for further analysis.

2.6 Acrylamide quantification by high-pressure liquid chromatography

Approximately 10 mg of each dried sample from the refrigerator was dissolved in HPLC-grade methanol (MeOH) to attain a concentration of 10 mg/mL. The methanolic solution was then filtered through a 0.22 µm syringe filter (Pall Corporation, USA). Standard acrylamide solutions were also prepared in HPLC-grade MeOH at a concentration of 10 mg/mL. Using a 20 µL injection syringe and a C18 RP column (4.6×250 mm, 5 µm), both sample extracts and the standard acrylamide were separately injected into the HPLC system to establish the calibration curve. Additionally, the standard acrylamide underwent analysis through the same setup with a UV detector to ensure consistency with the samples. Acrylamide separation was achieved under isocratic conditions, employing a methanol and water solution in a 15:85 (v/v) ratio as the mobile phase, with a flow rate of 0.8 mL/min. The detecting wavelength was set at 210 nm (Longhua *et al.*, 2012). To determine the acrylamide levels in the samples, a calibration curve was constructed using a standard acrylamide solution at a concentration of 10 mg/mL. Chromatographic data were collected and processed using Chromeleon 6 software. Sample injections were performed in triplicate to ensure the accuracy of the acrylamide quantification results.

2.7 Statistical analysis

The data analysis was conducted using SPSS software, and the results were expressed as both a percentage and the mean ± standard deviation (SD). These findings were derived from triplicate data sets and meticulously examined for accuracy.

3. Results and discussion

3.1 Nutrient composition

Commercial chips from potatoes were analyzed for their nutrient composition (Table 1). The average moisture, ash, protein, fat, and carbohydrate content ranged from 1.18% to 3.98%, 2.12% to 5.14%, 2.77% to 7.36%, 12.74% to 42.86%, and 44.29% to 75.05%, respectively. Notably, sample S10 exhibited the highest moisture content (3.98±0.01), while sample S5 had the lowest (1.18±0.01). Sample S18 contained the lowest carbohydrate content (44.29±0.01%) but had the highest fat content (42.86±0.03%). Protein content was highest in sample S16 (7.36±0.14%) but lowest in sample S17 (2.77±0.03%). According to the Bangladesh Standards and Testing Institution (BSTI) standards for potato chips (BDS 1927: 2017), the maximum allowable values for moisture, fat, ash, and salt were ≤ 3%, ≤ 37%, ≤ 4%, and ≤ 2%, respectively. The carbohydrate content in all chip samples reflected the abundance of these metabolites in

Table 1. The nutrient composition (% on dry weight basis) of different samples of potato chips.

Sample	Moisture	Carbohydrate	Fat	Protein	Ash	Energy value (kcal/100 g)
S1	2.16±0.02	62.15±0.01	26.17±0.03	4.38±0.01	5.14±0.02	501.66±0.20
S2	2.66±0.01	68.52±0.06	21.26±0.04	4.40±0.02	3.16±0.01	483.0±0.17
S3	1.53±0.01	53.52±0.04	36.66±0.03	5.38±0.01	2.91±0.01	565.55±0.08
S4	1.63±0.02	53.24±0.03	34.97±0.03	6.69±0.01	3.47±0.01	554.40±0.12
S5	1.18±0.01	54.21±0.04	34.05±0.03	7.04±0.03	3.53±0.01	551.43±0.11
S6	1.44±0.01	55.99±0.04	32.96±0.03	5.72±0.01	3.89±0.05	543.51±0.36
S7	3.32±0.02	58.06±0.05	29.17±0.04	5.38±0.02	4.08±0.01	516.27±0.12
S8	1.66±0.01	49.11±0.04	42.35±0.04	3.74±0.03	3.14±0.02	592.55±0.30
S9	3.85±0.01	64.16±0.04	24.54±0.04	5.33±0.02	2.12±0.01	498.80±0.23
S10	3.98±0.01	63.49±0.04	23.06±0.03	6.92±0.01	2.55±0.03	489.18±0.05
S11	2.77±0.01	75.05±0.03	12.74±0.04	6.53±0.01	2.92±0.02	440.92±0.23
S12	3.95±0.01	66.91±0.03	22.04±0.04	4.45±0.01	2.65±0.01	483.83±0.21
S13	3.15±0.01	53.58±0.01	34.08±0.02	6.05±0.01	3.15±0.01	545.21±0.07
S14	2.16±0.01	51.90±0.02	37.95±0.04	5.83±0.01	2.17±0.02	572.44±0.27
S15	2.95±0.01	51.61±0.02	38.24±0.03	4.59±0.01	2.62±0.02	568.93±0.14
S16	3.79±0.10	47.82±0.12	38.20±0.05	7.36±0.14	2.83±0.02	564.53±0.53
S17	3.97±0.01	62.11±0.01	27.95±0.06	2.77±0.03	3.20±0.05	511.07±0.52
S18	2.54±0.04	44.29±0.01	42.86±0.03	6.55±0.04	3.77±0.01	589.04±0.27
S19	1.50±0.16	68.37±0.25	21.87±0.10	5.18±0.02	3.08±0.02	491.03±0.61
S20	2.17±0.04	62.59±0.06	26.47±0.03	4.31±0.05	4.45±0.04	505.85±0.12

Values are expressed as means±SD of triplicate determination.

the original raw material, potatoes (Andre *et al*., 2007). However, the high-fat content (>37%) observed in 25% of the samples may be primarily attributed to oil uptake during the frying process, influenced by factors such as frying time, temperature, and oil quality (Joshee *et al*., 2019). Incorporating oil and fat-rich ingredients during chip formulation could further increase fat content in the final product (Mazurek *et al*., 2016).

Further analysis revealed energy values ranging from 440.92 to 592.55 kcal/100 g for the chip samples, indicating their characteristic feature as hyper-energetic products. This increased energy value is mainly due to high calories from fat and carbohydrates compared to proteins. The high carbohydrate and fat levels in chips may stimulate a strong attraction for hyper-energetic snacks, leading to excess consumption for pleasure rather than hunger (Ouhtit *et al*., 2014). Moreover, the high moisture content (>3%) in 35% of the samples could potentially compromise product quality (Purwani *et al*., 2006). Although the ash content fell within the acceptable range for most samples, 80% exhibited high salt content (>2%), ranging from 1.26% to 2.96%. This high salt content could contribute to various health-related issues, including hypertension and cardiovascular diseases (Tanase *et al*., 2011). When comparing branded versus non-branded potato chips, further investigation into factors such as ingredient quality, frying methods, and seasoning practices could provide insights into the observed differences in nutrient composition and overall product characteristics.

3.2 Microbial contamination

Despite being a dry food item, potato chips are not immune to microbial contamination, which can occur due to improper processing steps. This poses potential health risks, especially for children, who may suffer serious consequences from consuming contaminated chips. According to the Bangladesh Standards and Testing Institution standards (BSTI, 2017), the maximum permissible limits in potato chips for the total viable bacterial count and total coliform count were 5.0×10^4 CFU/g and 10 MPN/g, respectively. Additionally, *E. coli*, *Salmonella* spp. and *Shigella* spp. should be absent. In this study, the total viable count (TVC) in 60% of potato chip samples was within the acceptable limit (Table 2). However, *E. coli*, *Salmonella* spp. and *Shigella* spp. were absent in all samples. Nevertheless, samples S7, S9, S10, S12, S13, S16, and S17 showed the presence of yeast and mold counts at unsatisfactory levels. Moreover, yeast and mold counts exceeded the acceptable limit ($>10^3$) according to East African Standard (EAS, 2010) in 35% of potato chip samples. The contamination could be attributed to various factors, including residual water activity (<0.85), moisture, temperature, environmental conditions, production processing faults, improper storage, and packaging. It is imperative for manufacturers to adhere to strict hygiene and quality control measures to mitigate the risk of microbial contamination and ensure the safety of potato chip products.

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Table 2. Microbial analysis (CFU/g) of different samples of potato chips.

Samples	Parameters					
	TVC	Total coliforms	*E. coli*	*Salmonella*	*Shigella*	Yeast and mold count
S1	5.15×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S2	6.15×10^3	<0.3*	<0.3*	Absent	Absent	$<10^3$
S3	3.29×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S4	4.51×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S5	4.55×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S6	4.64×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S7	5.20×10^4	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S8	3.05×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S9	4.65×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S10	4.35×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S11	2.18×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S12	3.19×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S13	6.15×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S14	4.16×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S15	5.01×10^3	<0.3*	<0.3*	Absent	Absent	$<10^3$
S16	2.72×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S17	5.45×10^5	<0.3*	<0.3*	Absent	Absent	$>10^3$ **
S18	2.90×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S19	6.63×10^4	<0.3*	<0.3*	Absent	Absent	$<10^3$
S20	7.27×10^3	<0.3*	<0.3*	Absent	Absent	$<10^3$

* As per the MPN chart, MPN <0.3 indicates absence of test organism in 1 g.
** $>10^3$ indicates the presence of test organisms at an unsatisfactory level in 1 g of sample.

3.3 Heavy metal contamination and mineral composition

Several studies have highlighted the association between inadequate micronutrients (minerals) and severe malnutrition, increased disease conditions, and mental impairment. At the same time, higher content of some minerals like salt may be detrimental to health. Salt (%) can contribute towards hypertension, blood pressure, cardiovascular diseases and obesity (Kongstad and Giacalone, 2020). Thus, it has been a public health goal to lower the dietary sodium intake. In the recent study, almost all the samples contained salt (%) ranging from 1.26 to 2.96 (Figure 1), where 80% samples exceeded the minimum salt % (≤ 2) according to BSTI (BDS 1927: 2017). Most people are consuming 9 to 12 g salt per day, which should be less than 5 g (equivalent to 2 g sodium), which should be less than 30% of the population by 2025 (World Health Organization (WHO), 2020). Being the last ingredient to be added, the manufacturer can pay attention to the addition of salt. Besides, calcium (Ca) is essential for bone formation, maintenance, growth, blood clot formation, absorption of vitamin B12, and muscle contraction (Soetan *et al.*, 2010). The results of the Ca content analysis in the potato chip samples are presented in Figure 2. Calcium was detected in 45% of the samples, with concentrations ranging from 1.14 to 15.21 mg/100 g.

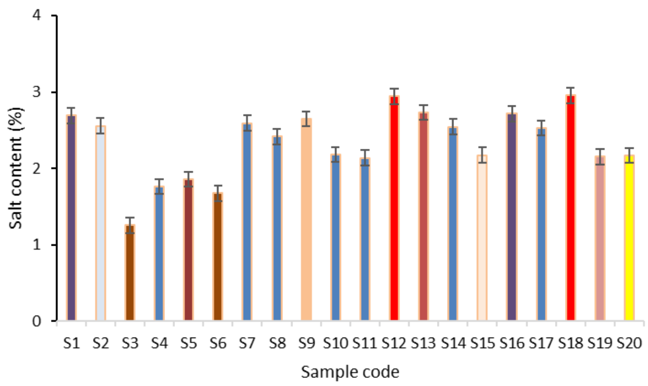

Figure 1. Salt content (%) of the different samples of potato chips.

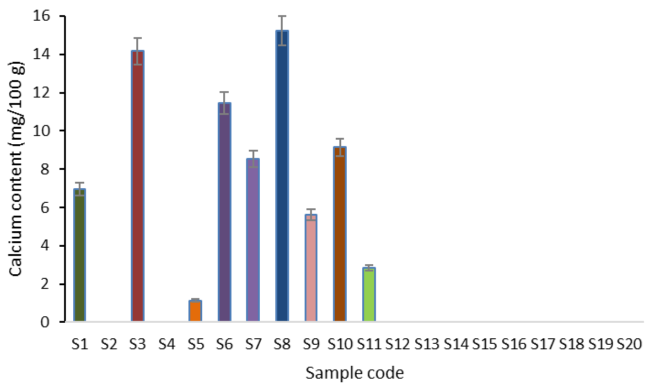

Figure 2. Calcium content (mg/100 g) of the different samples of potato chips.

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Excessive quantities of heavy metals in food have been linked to various disorders, including teratogens, carcinogens, and mutagens (Magomya *et al*., 2013). The irrigation of crops with arsenic (As)-enriched groundwater and its transfer through the water-soil-crop-food system represent primary routes for arsenic contamination in the human food chain (Bhattacharya *et al*., 2009; Bhattacharya *et al*., 2010). Therefore, the concentrations of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and arsenic (As) in the potato chip samples were also analyzed. However, heavy metals were not detected in any of the samples.

3.4 Acrylamide content

HPLC analysis revealed the presence of acrylamide in 65% of the chip's samples, with concentrations exceeding the fixed threshold values in chips of 750 µg/kg (EU, 2017) for 10% of the samples (S5 and S8) (Figure 3). The acrylamide content ranged from 93.51 to 1777.96 µg/kg in the analyzed samples, comparable to the levels found in Ethiopian potato chips, which ranged from 211 µg/kg to 3515 µg/kg (Deribew and Woldegiorgis, 2021). The starchier a food product is, the higher its sugar content, leading to increased acrylamide formation (Ledbetter *et al*., 2021). Notably, a significant variation in acrylamide levels was observed within the potato chip samples. Factors influencing acrylamide levels include processing conditions such as frying time and temperature, as well as chip thickness, with thicker chips requiring more heat input. Additionally, vegetable composition, influenced by origin, annual agricultural variations, and storage conditions, plays a significant role in determining acrylamide content (Quesada-Valverde *et al*., 2022). These factors likely contributed to the elevated acrylamide levels observed in samples S5 and S8. Studies have shown that average acrylamide intake ranging from 0.2 to 4 µg/kg body weight is high (WHO, 2005). Consumption of acrylamide-containing chips may increase the risk of cancer, DNA damage, birth defects, and fetal malformations, as acrylamide is carcinogenic in multiple organs and toxic to nerve cells (Dourson *et al*., 2008; Hogervorst *et al*., 2008; Capuano and Fogliano, 2011).

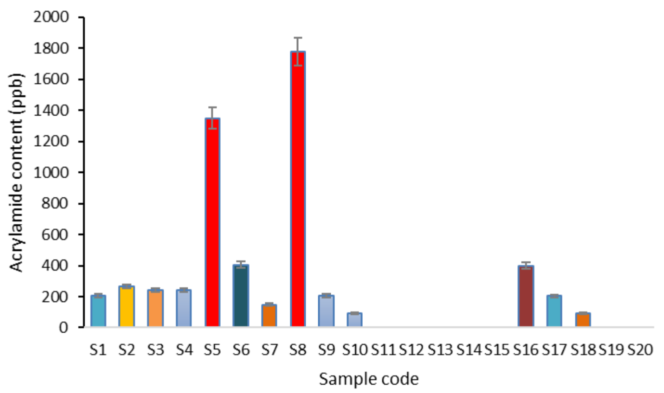

Figure 3. Acrylamide content (ppb) of the different samples of potato chips.

Bangladesh currently lacks established guidelines regarding permissible levels of acrylamide in food. While various countries have implemented recommendations and guidelines to address acrylamide in foods, including the Food and Drug Administration (FDA) guideline on acrylamide in foods (FDA, 2016), the Heatox project report (Hellenas *et al*., 2005) and the acrylamide toolbox (Food Drink Europe [FDE], 2019). The regulatory authorities in Bangladesh should prioritize addressing this issue.

4. Conclusion

This study focused on evaluating the fate of contaminants during food processing, providing valuable insights into potential health risks associated with consuming potato chips. The results highlighted the low nutritional value of potato chips, characterized by high levels of salt, fat, and moisture content, which could serve as sources of process contamination, microbial contamination, and health-related diseases such as hypertension. The detection of acrylamide in 65% of the samples suggests a potential health risk for consumers. However, the analysis of contaminants did not raise safety concerns despite microbial contamination, which may be attributed to the high moisture content observed. The varying results among potato chip samples within each group could be attributed to differences in raw materials and variations in thermal treatments during preparation, processing, manufacturing, and storage processes.

Conflict of interest

The authors declare no conflict of interest.

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