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# Evaluation of Effects of Different Processing Methods on The Formation of Acrylamide in Potato Chips

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## ABSTRACT

Acrylamide, a potential carcinogen, forms during high-temperature cooking processes such as frying, baking, and roasting, especially in starchy foods like potatoes. This study aims to evaluate the influence of different frying methods: palm oil, vegetable oil, and air frying on acrylamide formation in home-cooked potato chips. Freshly harvested potatoes were processed under varying conditions of temperature, time, and slice thickness to investigate acrylamide levels using Reverse-Phase High-Performance Liquid Chromatography (RP-HPLC) methods. Results showed significant variation in acrylamide content depending on the processing method. Palm oil frying produced acrylamide levels ranging from 405 to 534 µg/kg, with higher temperatures resulting in increased acrylamide formation. Vegetable oil frying yielded lower acrylamide levels (355–502 µg/kg), while air frying produced the highest levels (604–749 µg/kg). The study found that air frying significantly increased acrylamide content compared to conventional frying methods, likely due to the higher temperature and air-based heat transfer. The ANOVA results indicated that the processing parameters, particularly temperature, significantly influenced acrylamide formation, with $R^2$ values of 98.16%, 97.52%, and 99.23% for palm oil, vegetable oil, and air frying, respectively. This research contributes valuable insights into acrylamide mitigation strategies in potato chips production, with potential implications for improving food safety and quality.

**Keywords:** Acrylamide, Potato chips, Frying, Palm oil, Vegetable oil

## INTRODUCTION

Sweet potato (*Ipomoea batatas* L.), a dicotyledonous plant from the family Convolvulaceae, is one of the most popular domestically grown crops [5], Compared to other root crops, it stands out for its versatility and nutritional profile. Sweet potato produces a higher yield of chips, thrives as an important crop in tropical regions, and serves as a major energy source for millions. Notably, it is the highest producer of carbohydrates among essential crops and plays a critical role in the diets of over one billion people in tropical countries, where it is often considered a traditional or subsistence food (Ray, 2017). As dietary preferences evolve, consumers increasingly seek nutrient-rich foods that cater to aesthetic and therapeutic needs. This shift, particularly among young people and adults, has fueled the demand for innovative food formulations. Sweet potatoes, rich in carbohydrates, proteins, vitamins, and minerals, are a valuable resource in this context. Their adaptability allows for processing into chips and partial substitution of wheat chips in baked goods, expanding their utilization. Such applications have enhanced global awareness of sweet potatoes' potential, particularly in processed food innovations [6].

Native to tropical America, sweet potato thrives in sandy or loamy soils across many warm regions worldwide. It is a starchy, sweet-tasting tuberous root vegetable with smooth skin and various colors, including yellow, purple, orange, and beige (Elaneen *et al*., 2008). With a low to medium glycemic index, it is an excellent source of vitamin A (14,187 IU/100 g), vitamin C (2.4 mg/100 g), calcium (30 mg/100 g), iron (0.61 mg/100 g), and magnesium (25 mg/100 g), making it highly nutritious (USDA National Nutrition Database, 2009–2015). Sweet potato is also affordable, widely available, and delicious. Nigeria

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leads African production, yielding 3.46 million metric tons annually, making it the second-largest producer globally [5],[10]. Frying is a time-honored and widely popular food preparation method. It involves rapid dehydration by heating food to temperatures between 150–200 °C to remove moisture from fruits and vegetables [7]. Beyond dehydration, frying is used to develop the appealing texture, flavor, and taste that consumers prefer. By creating a crispy outer layer while preserving a tender interior, frying has become a cherished culinary technique applied to a wide variety of dishes [15].

Acrylamide formation is a significant concern associated with various frying methods due to its carcinogenic potential and implications for human health. Since its discovery in 2002, acrylamide has gained considerable attention in food science, technology, and environmental research. Initial studies on acrylamide formation in carbohydrate-rich foods were conducted by Swedish researchers that same year [13]. Acrylamide is primarily formed during the cooking of carbohydrate-rich foods, with its levels influenced by factors such as carbohydrate content, frying time, temperature, and other variables [14]. This compound is produced when food is cooked at high temperatures exceeding 120 °C, which has raised concerns about its toxicological impact. Fried potato products, in particular, have been found to contain significant levels of acrylamide. Moreover, the consumption of high-carbohydrate foods like bread, roasted cereals, and potato chips directly exposes consumers to this compound [11]. This study aims to investigate the concentration of acrylamide in home-cooked potato chips prepared using different high-temperature cooking methods, including palm oil frying, vegetable oil frying, and air frying. By exploring these preparation techniques, the study seeks to contribute to the understanding of acrylamide formation and its mitigation in potato-based products.

# MATERIALS AND METHODS

## Materials and Chemical Reagent

Sweet potato, Palm oil, Vegetable oil, 2-naphthalenethiol, and the following enzymes: pepsin (≥250 U $mg^{-1}$ solid), from porcine gastric mucosa, pancreatin (4 X USP), from porcine pancreas, amylase, from human saliva (500 U) and porcine bile salts, Potassium chloride, sodium bicarbonate and sodium chloride, Acetonitrile (HPLC grade) and acetic acid.

## Sample Preparation

Freshly harvested sweet potatoes were thoroughly washed, and slices with thicknesses of 1.5 mm and 2.0 mm and a diameter of approximately 35 mm were prepared using a slicing machine. The slices were immediately rinsed in deionized water for 1 minute to remove surface starch before frying.
Forty grams of sweet potato slices were fried using three methods:

1. **Palm oil frying**: Pan-frying at 150–180 °C for 5–10 minutes.
2. **Vegetable oil frying**: Pan-frying under the same conditions as palm oil.
3. **Air frying**: Performed at 200–220 °C for 5–10 minutes.

A 400 g portion of the products was fried for each frying method. Oil temperature was continuously monitored during frying using a thermocouple immersed in the fryer. The temperature and duration of the heating medium for all domestic appliances were recorded using an automatic temperature control system. Once frying was complete, the samples were cooled to 20 °C at room temperature for approximately 30 minutes. The cooled products were ground using a blender and stored at 4 °C until further analysis.

## Method

The acrylamide content in the samples was analyzed using Reverse-Phase High-Performance Liquid Chromatography (RP-HPLC). The analysis was performed on a Shimadzu LC-20AD HPLC system equipped with a UV-Vis diode array detector (DAD) set at 200 nm, a vacuum degasser, binary pumps, a thermostated autosampler, and a temperature-controlled column oven. The chromatographic separation was achieved using a Synergi 4 µm Hydro-RP 80 Å 250 × 4.6 mm LC column with a C18 guard column (Phenomenex, Torrance, CA).

The operational conditions were as follows:

- **Mobile phase**: Isocratic mixture of 5mM heptasulfonic acid.
- **Flow rate**: 1.0 mL/min.
- **Injection volume**: 100 µL.

- **Column temperature**: 25 °C.
- **Autosampler temperature**: 4 °C.
- **Retention time**: Acrylamide eluted between 8–9 minutes.
- **Run time**: 30 minutes per injection cycle.

Peak identification was performed based on retention time and the comparison of UV spectral ratios with those of a commercial acrylamide standard. Sample preparation followed the method described by [16] involving the extraction, de-fatting, freezing, and solid-phase extraction (SPE) steps:

1. **Extraction**: Four grams of each food sample were homogenized with 20 mL of 80% methanol in water and shaken in a thermostatted water bath at 60 °C for 60 minutes.
2. **Filtration**: The extract was filtered through filter paper to remove solids.
3. **De-fatting**: Twenty milliliters of hexane was added to the filtrate, shaken for 10 minutes, and the upper hexane layer removed. This step was repeated to ensure thorough de-fatting.
4. **Freezing**: Five milliliters of the aqueous phase was transferred to centrifuge tubes and frozen at -18 °C for 24 hours.
5. **Centrifugation**: The frozen samples were centrifuged at 5,000 rpm (3,000 × g) for 10 minutes to separate the clear supernatant.
6. **Clean-up**: The supernatant was cleaned using Oasis HLB SPE cartridges (6 mL, 200 mg).
7. **Final preparation**: The cleaned sample was filtered through a 0.45 μm nylon syringe filter before RP-HPLC analysis. The acrylamide concentrations were quantified and expressed in μg/kg.

### Experimental design

A fractional factorial design (2X3) was proposed, to evaluate the influence of frying process parameters in the total amount of acrylamide formed and its bio accessibility. The factors selected were independent variable Palm oil (P), Vegetable Oil (V) and Air Frying (A) while the dependent variables are temperature (T), frying time (t), and thickness of potato slices (w). Results obtained from the fractional factorial design were subjected to an analysis of variance study using MINITAB® version 16.

## RESULTS AND DISCUSSION

### Results

The results of the study are presented in Tables 1, 2, and 3 respectively.

Acrylamide formation on palm oil potato chips production

The result obtained from palm oil potato chips production on acrylamide formation is shown in Table 1.

**Table 1: Results for average response on Palm oil potato chips**

| Runs | T (ºC) | t (Sec) | w (mm) | Acrylamide (μg/Kg) |
|---|---|---|---|---|
| 1 | 150 | 5 | 1.5 | 405 |
| 2 | 150 | 10 | 2 | 421 |
| 3 | 150 | 10 | 1.5 | 418 |
| 4 | 150 | 5 | 2 | 448 |
| 5 | 180 | 10 | 1.5 | 522 |
| 6 | 180 | 5 | 2 | 503 |
| 7 | 180 | 5 | 1.5 | 517 |
| 8 | 180 | 10 | 2 | 534 |

Acrylamide formation on Vegetable oil potato chips production

The result obtained from palm oil potato chips production on acrylamide formation is shown in Table 2.

**Table 2: Results for average response on Vegetable oil potato chips**

| Runs | T (ºC) | t (Sec) | w (mm) | Acrylamide (µg/Kg) |
|---|---|---|---|---|
| 1 | 150 | 5 | 1.5 | 381 |
| 2 | 150 | 10 | 2 | 405 |
| 3 | 150 | 10 | 1.5 | 355 |
| 4 | 150 | 5 | 2 | 371 |
| 5 | 180 | 10 | 1.5 | 483 |
| 6 | 180 | 5 | 2 | 468 |
| 7 | 180 | 5 | 1.5 | 502 |
| 8 | 180 | 10 | 2 | 461 |

Acrylamide formation on Air Frying potato chips production

The result obtained from air frying potato chips production on acrylamide formation is shown in Table 3.

**Table 3: Results for average response on Air frying potato chips**

| Runs | T (ºC) | t (Sec) | w (mm) | Acrylamide (µg/Kg) |
|---|---|---|---|---|
| 1 | 200 | 5 | 1.5 | 654 |
| 2 | 200 | 10 | 2 | 638 |
| 3 | 200 | 10 | 1.5 | 604 |
| 4 | 200 | 5 | 2 | 653 |
| 5 | 220 | 10 | 1.5 | 735 |
| 6 | 220 | 5 | 2 | 705 |
| 7 | 220 | 5 | 1.5 | 708 |
| 8 | 220 | 10 | 2 | 749 |

# DISCUSSION

## Palm oil effect on acrylamide formation in potato chips

The acrylamide content ranges between 405 and 534 (µg/Kg) when using palm oil for the production of potatoes chips (table 1). Sample 8 has the highest acrylamide content with Temperature of 180$^0$C at 10min and thickness of 2mm while sample 1 has the lowest acrylamide content with temperature of 150$^0$C at 5min and 1.5mm thickness. This study conforms with the findings of [1], who reported that there is a significant increase in the acrylamide level with increase in temperature. The thickness does not really have a great effect on the level of acrylamide. The palm oil has a significant effect on the formation acrylamide because as the temperature increases the frying rate increases so also the acrylamide level increases. In some previous studies, it was indicated that the temperature is required to be higher than 120 °C for the development of acrylamide. But the palm oil effect is still within the range established by European Commission of 750µg/Kg (EC 2017).

**Table 4: ANOVA for Response surface mean model for Palm oil method of processing**

| Source | DF | SSE | MSE | RMSE | F | P | $R^2$ |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Factors | 3 | 1160307 | 386769 | 621.908 | 497.81 | 0.000 | 0.9816 |
| Error | 28 | 21754 | 777 | | | | |
| Total | 31 | 1182062 | | | | | |

The sum of square error (SSE), mean square error (MSE) and the root mean square error (RMSE) for the ANOVA of the Acrylamide when palm oil is use is presented in Table 4. The results shows that, the processing parameters significantly influence (p-value < 0.05) the acrylamide formation when palm oil is used as processing method. The ANOVA shows a high coefficient of determination ($R^2$) of 98.16%. This shows that, the processing parameters accounted for 0.9816 of the acrylamide formation on the potato chips using palm oil as the processing method.


**Figure1: Chart of acrylamide during palm oil method of potato chips**

## Vegetable oil effect on acrylamide formation in potato chips

The acrylamide content ranges between 355 and 502 (µg/Kg) when using vegetable oil for the production of potatoes chips (table 2). Sample 7 has the highest acrylamide content with Temperature of $180^0$C at 5min and thickness of 1.5mm while sample 3 has the lowest acrylamide content with temperature of $150^0$C at 10min and 1.5mm thickness. The result was lower than the one reported by [12]. The vegetable oil has a significant effect on the formation acrylamide because as the temperature increases the frying rate increases so also the acrylamide level increases. This study is with the findings of [8] who reported that there is a significant increase in the acrylamide level with increase in temperature. The thickness does not really have a great effect on the level of acrylamide but the thinner the potato the more the acrylamide level. In some previous studies, it was indicated that the temperature is required to be higher than 120 °C for the development of acrylamide. But the vegetable oil effect is still within the range established by European Commission of 750µg/Kg (EC 2017).

**Table 5: ANOVA for Response surface mean model for Vegetable oil method of processing**

| Source | DF | SSE | MSE | RMSE | F | P | $R^2$ |
|---|---|---|---|---|---|---|---|
| Factors | 3 | 959447 | 319816 | 565.523 | 367.66 | 0.000 | 0.9752 |
| Error | 28 | 24356 | 870 | | | | |
| Total | 31 | 983803 | | | | | |

The sum of square error (SSE), mean square error (MSE) and the root mean square error (RMSE) for the ANOVA of the Acrylamide when vegetable oil is use as a processing method is presented in Table 5. The results shows that, the processing parameters significantly influence (p-value < 0.05) the acrylamide formation when vegetable oil is used as processing method. The ANOVA shows a high coefficient of determination ($R^2$) of 97.52%. This shows that, the processing parameters accounted for 0.9752 of the acrylamide formation on the potato chips using vegetable oil as the processing method.

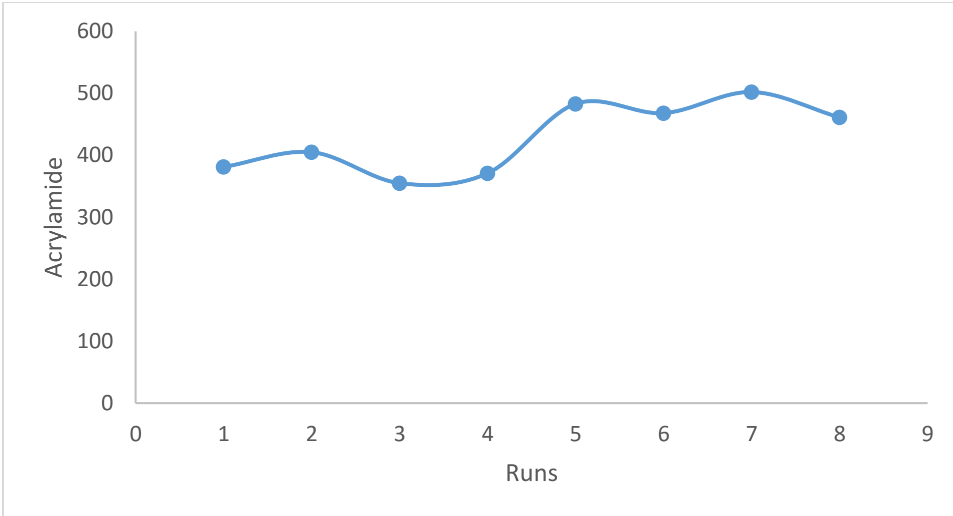


**Figure 2: Chart of acrylamide during vegetable oil method of potato chips**

## Air frying effect on acrylamide formation in potato chips

The acrylamide content ranges between 604 and 749 (μg/Kg) when using air frying for the production of potatoes chips (table 3). Sample 7 has the highest acrylamide content with Temperature of 220$^0$C at 5min and thickness of 1.5mm while sample 2 has the lowest acrylamide content with temperature of 200$^0$C at 10min and 1.5mm thickness. The result was lower than the one reported by [9]. 790(μg/Kg) was reported by [9]. Using microwave for potato chips production. The result is conformed with the one reported by reported by [12]. The air frying has a significant effect on the formation acrylamide because as the temperature increases the frying rate increases so also the acrylamide level increases. This study is with the findings of [8] who reported that there is a significant increase in the acrylamide level with increase in temperature. The thickness does not really have a great effect on the level of acrylamide but the thinner the potato the more the acrylamide level. Air frying effect is at the closer to the established limit by European Commission of 750μg/Kg (EC 2017).

**Table 6: ANOVA for Response surface mean model for air frying method of processing**

| Source | DF | SSE | MSE | RMSE | F | P | $R^2$ |
|---|---|---|---|---|---|---|---|
| Factors | 3 | 2440639 | 813546 | 901.968 | 1199.79 | 0.000 | 0.9923 |
| Error | 28 | 18986 | 678 | | | | |
| Total | 31 | 2459625 | | | | | |

The sum of square error (SSE), mean square error (MSE) and the root mean square error (RMSE) for the ANOVA of the Acrylamide when air fryer is used is presented in Table 6. The results shows that the processing parameters significantly influence (p-value $< 0.05$) the acrylamide formation when air fryer is used as processing method. The ANOVA shows a high coefficient of determination ($R^2$) of 99.23%. This shows that, the processing parameters accounted for 0.9923 of the acrylamide formation on the potato chips using air fryer as the processing method.

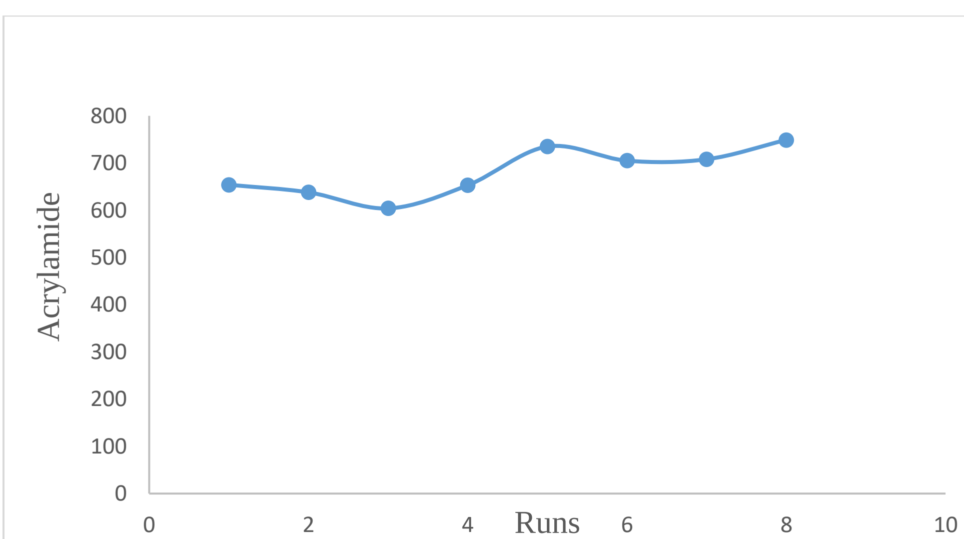


**Figure 3: Chart of acrylamide during air frying method of potato chips**

The preparation methods using vegetable oil exhibited lower acrylamide content compared to those utilizing air frying. The highest acrylamide levels in potato chips (749 µg/kg) were observed with air frying. These findings indicate that air frying, similar to conventional heat processing methods, contributes to acrylamide formation in potato products. Moreover, air frying may even promote acrylamide formation more effectively than conventional methods, such as frying in palm oil or vegetable oil.

Numerous studies have demonstrated that various factors influence acrylamide formation, including temperature, heating time, sugar compound types, and water content [4]. In addition to heating temperature and time, the mode of heat transfer is a critical process factor affecting acrylamide levels. [17] emphasized the importance of considering the heat processing method as a contributing factor to acrylamide formation.

Air frying differs from conventional heating methods in its mechanism of heat transfer. Traditional methods like boiling, roasting, or frying primarily rely on convection, conduction, or radiation for heat transfer. In contrast, air frying achieves a rapid temperature increase within foods due to its ability to generate heat energy internally, which may account for its higher propensity to form acrylamide.

# CONCLUSION

In conclusion, This study has demonstrated the significant impact of processing methods specifically frying with palm oil, vegetable oil, and air frying on the formation of acrylamide in potato chips. Acrylamide formation was found to increase with higher temperatures and longer frying times across all three methods, with palm oil, vegetable oil, and air frying producing different levels of acrylamide. Notably, air frying resulted in the highest acrylamide levels, though all methods remained within the safety limits established by the European Commission (750 µg/Kg).

Results showed significant variation in acrylamide content depending on the processing method. Palm oil frying produced acrylamide levels ranging from 405 to 534 µg/kg, with higher temperatures resulting in increased acrylamide formation. Vegetable oil frying yielded lower acrylamide levels (355–502 µg/kg), while air frying produced the highest levels (604–749 µg/kg). The study found that air frying significantly increased acrylamide content compared to conventional frying methods, likely due to the higher temperature and air-based heat transfer. The ANOVA results indicated that the processing parameters, particularly temperature, significantly influenced acrylamide formation, with $R^2$ values of 98.16%, 97.52%, and 99.23% for palm oil, vegetable oil, and air frying, respectively. The study confirms that processing parameters such as temperature, time, and potato slice thickness play crucial roles in acrylamide formation. For instance, thinner slices and higher temperatures led to elevated acrylamide levels, particularly in air frying. The findings are in alignment with previous research, which highlighted temperature as a key factor in the Maillard reaction responsible for acrylamide production.

The results provide valuable insights for food manufacturers and regulatory agencies aiming to reduce acrylamide levels in potato chips. Future research could explore further optimization strategies, such as exploring alternative frying techniques, using acrylamide mitigation agents, or modifying potato composition through breeding or processing pre-treatments.

# RECOMMENDATIONS

**1.** Explore other cooking techniques beyond frying, such as microwaving, steaming, or vacuum frying, and evaluate their effects on acrylamide formation. This would expand the scope beyond conventional frying methods (palm oil, vegetable oil, and air frying). By testing these methods, you could identify healthier and lower acrylamide-producing alternatives for chip production.

**2.** Investigate the impact of different sweet potato varieties (e.g., orange, purple, white, and yellow) on acrylamide levels. Since different sweet potato varieties have varying compositions of sugars, moisture content, and amino acids like asparagine, they may lead to different acrylamide formation rates during processing. This would offer a more comprehensive view of how variety selection affects product safety and quality.

**3.** Investigate whether alternative processing innovations (e.g., partial dehydration before frying) could help in acrylamide reduction while maintaining desirable product attributes like crispiness and flavor. You could conduct sensory evaluations to assess how these changes impact consumer acceptance.

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### Author Contributions:

Salaudeen H. O.: Conceptualization, funding and Writing original draft.

Omale P. A.: Conceptualization, review and editing

Shuaib S. A.: Review and editing

Abba J.: Funding, review and editing. All author read and approved the final manuscript

### Competing Interest:

The authors declare that thy have no competing interest.

## REFERENCES

[1] Bertuzzi, T., Mulazzi, A., Rastelli, S., Sala, L., Pietri, A. (**2018**). Mitigation measures for acrylamide reduction in dough-based potato snacks during their expansion by frying. Food Add. Contaminants Part A, 35, 1940–1947.

[2] EC (European Commission). Commission Regulation EU of 20 November 2017 Establishing Mitigation Measures and Benchmark Levels for the Reduction of the Presence of Acrylamide in Food. Available online: https://publications.europa.eu/en/publication-detail/-/publication/1f3b45fb-ce6b-11e7-a5d5-01aa75ed71a1/language-en (accessed on 20 September 2019).

[3] Elameen, A., *Et al,* 2008.Analysis of genetic diversity in a sweet potato (ipomeabatatas L.) germplasm collection from Tanzania as revealed by AFLP.Genet.Resour. Crop Envol., 55:397-408.

[4] Elfaitouri, T. A., Ghazali, H. M., Sumnu, G., Ariffin, A. A., & Tan, C. P. (2018). *Effect of Microwave Frying on Acrylamide Formation in Potato Chips*. *2*(2), 33–37.

[5] FAO. 2016. Crop Production Data. Available at http://www.fao.org/faostat/en/#data/QC (accessed December 29, 2016).

[6] FAO (2015) Food and Agricultural Organiation (FAO) of the United Nations, FAO Statistical database (FAOSTA). Available from: http://faostat3.org/browse/Q/QCE.

[7] Gertz, C. (2014). Fundamentals of the frying process. European Journal of Lipid Science and Technology, 116(6), 669–674.

[8] Genovese, J.; Tappi, S.; Luo,W.; Tylewicz, U.; Marzocchi, S.; Marziali, S.; Romani, S.; Ragni, L.; Rocculi, P. (**2019).** Important factors to consider for acrylamide mitigation in potato crisps using pulsed electric fields. Innovative Food Sci. Emerging Technol., 55, 18–26.

[9] Joanna M., Elzbieta G., Joanna K. (2011). The effect of Domestic Preparation of some potato products on acrylamide content. Plant Foods Human Nutrition. 66: 307-312

[10] Makos, D. 2016. Sweet potato agronomy research in Ethiopia: Summary of past findings and future research directions. Agric. Food Sci. Res., 3:1-11.

[11] Mekawi, E. M., Sharoba, A. M., & Ramadan, M. F. (2019). Reduction of acrylamide formation in potato chips during deep-frying in sunflower oil using pomegranate peel nanoparticles extract. *Journal of Food Measurement and Characterization, 13*(4), 3298–3306

[12] Pedreschi, F.; Mariotti, M.S.; Granby, K. (**2014).** Current issues in dietary acrylamide: Formation, mitigation and risk assessment. J. Sci. Food Agricul., 94, 9–20.

[13] Tareke, E., Rydberg, P., Karlsson, P., Eriksson, S., & Tornqvist, M. (2002). Analysis of acrylamide, a carcinogen formed in heated foodstuffs. *Journal of Agricultural and Food Chemistry, 50*(17), 4998–5006.

[14] Vinci, R. M., Mestdagh, F., & Meulenaer, B. D. (2012). Acrylamide formation in fried potato products – Present and future, a critical review on mitigation strategies. *Food Chemistry, 133*(4), 1138–1154

[15] Wang, X., Chen, L., McClements, D. J., & Jin, Z. (2022). Recent advances in crispness retention of microwaveable frozen pre-fried foods. *Trends in Food Science & Technology*.

[16] Wang Y, Wu X, McClements DJ, Chen L, Miao M, Jin Z. Effect of new frying technology on starchy food quality. Foods. (2021) 10:1852.

[17] Yaseen, S. S., Khalf, A. A., & Ai-Hadidy, Y. I. (2020). A study of Chemical Composition and determination of acrylamide in fried potato chips. *IOP Conference Series: Materials Science and Engineering*, *928*(5).