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Original Research

Acrylamide Mitigating Effect of Grapefruit Seed and Guava Seed Extracts, and their Combination, in Deep-fried or Air-fried Camel Rice-kofta (Ethnic Egyptian Food)

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Abstract

The goal of this research was to mitigate the quantity of acrylamide produced in camel rice-kofta by including natural antioxidants derived from grapefruit (GFSE) and guava seed extract (GVSE), as well as to assess the mitigation impact of air-frying against deep-frying. Rice-kofta was prepared and divided into four different groups: control, 0.1% GFSE, 0.1% GVSE, and 0.1% mixed grapefruit and guava seed extracts (ME), the weight of each group was about 500 g. Then each one of the four groups divided into two subgroups. The first subgroup was processed using two different cooking methods: deep frying with sunflower oil and air fryer separately. Over the course of 9 days of chilling storage, the other raw subgroup (treated and control) was tested for antioxidant stability (MDA). The results revealed that air-frying reduced acrylamide generation in rice-kofta by 38.2% when compared to deep-oil frying. Addition of GFSE, GVSE, and their combination were able to suppress acrylamide formation in rice-kofta by 21.37%, 36.56%, and 40.70%, during deep-oil frying and 18.96%, 1.49%, and 41.19% in air frying cooking, respectively. The efficiency of GFSE and GVSE in attenuating acrylamide was influenced by the cooking method, with GFSE being more significant in deep-frying and the GVSE mitigation effect being more powerful in air-frying. Considerably, GVSE increased the oxidative stability of rice-kofta at chilling temperature, followed by the mixture extract (ME), as compared to the control. These features could explain why GVSE reduces acrylamide more effectively during air-frying than deep-frying, whereas GFSE has the opposite effect. In conclusion, fruit waste extracts investigated in the current study were able to reduce acrylamide production and improve oxidative stability in camel rice-kofta.

KEYWORDS
Acrylamide, Grapefruit seed extract, Guava seed extract and Air-fryer.

INTRODUCTION

The primary phases of food processing are those that convert raw ingredients into food or food into other products. Washing, cutting, drying, frying, fermenting, cooking, and other procedures are all performed separately or in tandem (Friedman, 2015). In comparison to other cooking processes, frying entails a faster heat transmission. The lowest temperature for frying is 140°C, but most fried foods are prepared at temperatures between 175°C and 195°C (Aladedunye and Przybylski, 2009). The Maillard reaction and high-temperature caramelization of carbohydrates improve sensory properties of processed foods such as scent, colour, crust, and texture. Dehydration of the crust, oil absorption, and unfavourable chemical interactions between various food elements resulting in protein denaturation and low nutritional quality are some of the drawbacks of frying (Ibrahim *et al.*, 2019). Additionally, several chemical components formed at high cooking temperatures, such as Acrylamide, which is thought to be the most serious unintended hazard.

Acrylamide is categorized as Group 2A "possibly carcinogenic to humans" by the International Agency for Research on Cancer since 1994 (Bušová *et al.*, 2020). Acrylamide is a carcinogen and neurotoxin that was initially discovered in thermally processed starch-rich foods including potato chips, biscuits, and bread. Only a little number of screening research has been done on its content in fried meat and/or fish (Ahmed *et al.*, 2018). However, studies have linked a high exposure to processed meats cooked at high temperatures to an increased risk of cancer in humans due to high quantities of carcinogenic chemicals like acrylamide. It is generated as a result of the Millard reaction, which occurs whenever asparagine interacts with reducing sugars, and is enhanced by processing conditions such as high temperature, low water activity, and matrix (Surdyk *et al.*, 2004). Despite the fact that acrylamide can be created at temperatures of 120°C or higher, there is evidence that the chemical can also be formed at temperatures lower than 100°C, primarily in drying operations at 65–130°C (Eriksson, 2005).

Currently, health and food safety organizations, researchers, and food technologists are interested in presenting health food products that are free of dangers that arise during preparation and processing, which will play a vital role in the prevention and treatment of a variety of illnesses (Hassan *et al.*, 2012). So, Numerous research on the impact of the key frying variables such as oil temperature, frying duration, and food additives on acrylamide generation and level have been undertaken during the previous decade.

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Air-frying is a new creative process for preparing fried foods that reduces the oil volume of fried dishes by 90% by spraying hot air over uncooked meals to promote contact between food and oil droplets (Andrés *et al*., 2013). It has increasingly gained favour as an alternative healthy frying method that imparts the same features as traditionally fried items due to its smaller capacity, quicker cooking time, and lower calorie content (Fabre *et al*., 2018).

Other commonly used prevention approaches for lowering acrylamide production in model and actual food systems include the use of various antioxidants derived from plant byproducts (Liu *et al*., 2015). The agriculture and agricultural industries in Egypt generate a lot of waste and/or by-products from different plants and fruits. Treatment of agro-industrial leftovers (seeds and peels) has inspired a virtual boom of interest since they are high in bioactive components, including antioxidants, and can be used as low-quality animal feed to reduce adverse effects on the environment.

Previous research has directly investigated the great potential of seeds and peel as natural antioxidant sources, and it has been suggested that fruit seeds have much higher total antioxidant and phenolic content than edible sections (Soong and Barlow, 2004; Okonogi *et al*., 2007). Grapefruit seeds (Citrus paradisi.) are one of these natural by-products with high antibacterial and antioxidative effects that suppress lipid peroxidation, inhibit off-flavours, enhances the stability of fat-soluble vitamins and colourant components, resulting in improved food freshness and shelf life when tested in different foods versus potassium sorbate or sodium benzoate (Park and Kim, 2006; Kang *et al*., 2017).

Psidium guajava is a tropical and semitropical fruit that is primarily consumed raw. Although guava fruit seeds, a by-product of these fruits, contain anti nutritional flavonoids such as tannin, saponins, and phytic acid, they are also high in antioxidants such as terpenoids, anthroquinones, polyphenol, myricetin, and coumarins (El Anany, 2015; Ilakkiya *et al*., 2020). Antibacterial, antiparasitic, insecticidal, fungicidal, antiviral, and anticancer activities are all present in many of them.

No study on lowering acrylamide levels in camel rice kofta, a well-known, good, and popular Egyptian cuisine, has been published to our knowledge. The purpose of this study is to reduce the amount of acrylamide produced in camel rice kofta by adding natural antioxidants derived from grapefruit and guava seed extract, as well as to compare the mitigation impact of air-frying versus deep-frying.

MATERIALS AND METHODS

Preparation of grapefruit and guava seed extracts (GFSE / GVSE)

Fruits of the guava (Psidium guajava) and grapefruit (Citrus paradisi) were bought in an Egyptian local market in Al-Qaluobia, Egypt. The seeds were extracted from the flesh after the two fruits were sliced into pieces. To remove clinging materials, these were thoroughly but gently rinsed with excess distilled water. For two weeks, the seeds were thoroughly dried at room temperature.

Grapefruit and guave seed extract (Saalu et al., 2009)

The air-dried seeds of guava or grapefruit (100g) were ground to a fraction material and then extracted with 500 ml 100% ethanol using a Soxhlet apparatus extractor at 70°C for 6 hours. The extracts were then filtered using Whatman No.4 filter paper and dried for 4 hours at 45°C using a rotary evaporator. The residue was processed to get 20 mL of dark yellowish solid crude extract, which was kept at -21°C for the experiment. Each sort of seed had to be retrieved individually.

Rice-kofta preparation

Fresh boneless camel meat, rice flour, black pepper, onion, garlic and fresh herbs (to prepare rice-kofta) and sunflower oil were obtained from the Benha, Al-Qaluobia, Egypt local market. Rice kofta was separated into four groups: Group (A) contained rice-kofta only without extract (control), Group (B) received 0.1% grapefruit seed extract (GFSE), Group (C) received 0.1% guava seed extract (GVSE), and Group (D) received 0.1% mixed grapefruit and guava seed extracts (ME) (1:1). The weight of each group was about 500 g. At one gram, GFSE, GSE, and ME were used to replace rice flour (groups A, B and C, respectively). As shown in (Table A), each group was carefully mixed by hand with the other ingredients. Each group was divided into two subgroups after being made into a similar finger shape (15 g). The first subgroup was processed using two different cooking techniques: deep frying with sunflower oil and air fryer separately. When the samples

Table A. Formula of meat-rice kofta samples with different seed extract.

Ingredients	Samples (g/1000 g)			
	Control (A)	(B)	(C)	(D)
Mined meat	600	600	600	600
Rice flour	200	199	199	199
Water	100	100	100	100
Black pepper	5	5	5	5
Onion	30	30	30	30
Garlic	20	20	20	20
Salt	10	10	10	10
Cumin	10	10	10	10
Green coriander	5	5	5	5
Green dill	10	10	10	10
Green parsley	10	10	10	10
GFSE	--	1	-	-
GVSE	-	-	1	-
Mixed Extract	-	-	-	1

were cool enough to handle, about 100 g of the samples, were packaged, labelled and delivered to the lab for acrylamide analysis. The other subgroup was raw portions of the samples (treated and control) were held at 4±1°C and chemically analysed every three days (0, 3rd, 6th, and 9th) for antioxidant stability (MDA) value.

Frying processes

The frying procedure is as follows: each group of the camel rice kofta was divided into two portions, with the first being deep fried in a non-stick frying pan. Before inserting the samples, 100 mL sunflower oil heated to 180°C for pan-frying cooking with oil and the samples turned upside down while cooking to avoid colour differences. To prevent altering the amount of deteriorated oil absorbed by the samples on acrylamide assessment, the oil was replaced at each preparation. The second group was fried in an air fryer; a Black Decker® electric air fryer was utilized and set to 180°C for 20 minutes while cooking the camel rice kofta samples, as directed by the manufacturer. The experiment was conducted into triplicate.

Assessment of Acrylamide by HPLC

Sample preparation

Following a modified approach of Wang, H., and F. Feng, the sample preparation technique involves defatting with dichloromethane and ethanol, extraction of acrylamide with acetone, and cleaning with solid phase extraction cartridges (Wang *et al*., 2013). In a butterfly shaker, a finely ground and homogenized food sample (10.0 g) was defatted twice: once with 50 mL dichloromethane and 5 mL ethanol, and then with 50 mL dichloromethane alone for 2 hours at room temperature. At 15°C, the mixture was centrifuged for 20 minutes at 3500 rpm. The supernatant was thrown away, and the precipitate was dried in a vacuum oven at 40°C.

Acrylamide Extraction

For Acrylamide extraction, 20 mL acetone was added to the defatted material. A butterfly shaker was used to vigorously agitate the samples for 30 minutes. The samples were centrifuged for 25 minutes at 15°C at 3000 rpm after being placed in an ultrasonic water bath at 40°C for around 20 minutes. The solvents were filtered using filter paper (Whatman No.1). Using evaporator, the filtrate was evaporated to dryness. To dissolve the residue, 2 mL HPLC grade water: acetonitrile (40:60) was added to the mobile phase and thoroughly agitated. The aqueous solution was filtered using Solid Phase Extraction tubes before being injected onto the column via a 20 l injection loop (Muthaiah *et al*. 2018).

Chromatographic analysis

To assess the acrylamide content, researchers employed HPLC (Agilent HP 1200 Series Apparatus, USA) with a UV-Visible variable wavelength detector (2486) set at 225 nm.

A Spherisorb ODS-2 column (250 x 4.6 mm 5 m) with a 30°C thermostat was used for all separations. An ultrasonic water bath was utilized to extract acrylamide from the sample matrix, eliminate air bubbles from the mobile phase, and separate acrylamide using the mobile phase throughout the experiments. A vacuum pump was used to filter HPLC grade water and acetonitrile, and the resolution of acetonitrile and formic acid was tested. The solvent flow rate was 0.8 mL/min, with a detection wavelength of 210 nm (Wang *et al*., 2013; Muthaiah *et al*., 2018).

Assessment of antioxidant stability (MDA)

Malondialdehyde (MDA) levels in the samples were measured using HPLC (Agilent HP 1200 Series Apparatus, Santa Clara, CA, USA). MDA was evaluated using the procedures reported before (Ahmed-Farid *et al*., 2017; Abd-Elrazek and Ahmed-Farid, 2018). Using an ice-cold homogenizer, a 10% sample homogenate (w/v) and ice-cold 0.1 M Tris-HCl pH 7.4 were created (Glas-Col, USA). The homogenate was centrifuged for 15 minutes at 2000 g at 4°C to remove debris. In addition, 1 mM of stock standard MDA solution was prepared by dissolving 25 µL of 1,1,3,3 tetra-ethoxy-propane (TEP) in 100 mL of water. After that, the 20 nmol/mL working standard was made by dissolving 1 mL of TEP stock solution in 50 mL of 1% sulfuric acid for 2 hours at room temperature, which was then diluted with 1% sulfuric acid to yield a final standard concentration of 1.25 nmol/mL for total MDA analysis.

Statistical analyses

The data was analyzed using SPSS utilizing a one-way variance analysis (ANOVA) (version 20; IBM, Chicago, IL, USA). As averages and maximums, the acquired data and related standard errors of the mean are displayed. Individual acrylamide levels served as the experimental unit for assessing changes within and between groups based on cooking processes and kind of pretreatments. The statistical model includes one fixed effect variable. Tukey's tests were used to analyze the differences between groups and cooking procedures in multiple comparisons (Duncan, 1955). Significant differences were defined as $P<0.05$, and trends were indicated when P is between 0.05-0.10.

RESULTS

There was no significant difference in the mean values of acrylamide calculated in rice kofta treated with different treatments compared to control and cooked using deep-frying method, as shown in Table 1 and Fig. 1. However, the acrylamide concentration of rice beef kofta treated with GFSE and the other group treated with ME were numerically lower than the other two groups.

Results in Table 2 and Fig. 2 revealed that there was no significant difference ($P>0.05$) in the mean values of acrylamide as-

Table 1. Ameliorative effect of various supplements on Acrylamide production in rice kofta processed during deep-frying cooking compared to control.

Groups	Maximum	Mean	Reduction %	P-value
Control	3.2	$2.67^{A} \pm 0.525$		0.2
Guava seed extract (0.1%)	2.1	$2.1^{A} \pm 0.006$	21.4%	
Grapefruit seed extract (0.1%)	1.9	$1.69^{AB} \pm 0.243$	36.7%	
Mixed extract (1:1)	1.7	$1.58^{AB} \pm 0.126$	40.8%	

Significant differences within columns are indicated by different superscript capital letters.

sessed in rice beef kofta processed by air-frying cooking method and blended with different treatments when compared to the control. Despite this, the acrylamide concentration of camel rice-kofta treated with GVSE and the other group treated with the ME was lower than the other two groups (P > 0.05).

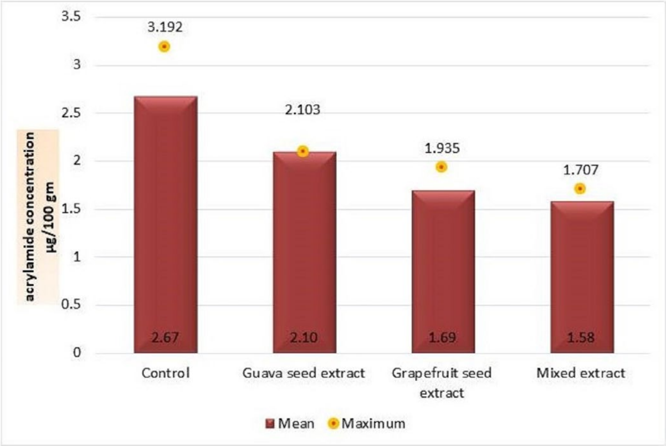

Fig. 1. The maximum and mean values of Acrylamide in camel rice-kofta during deep-frying process.

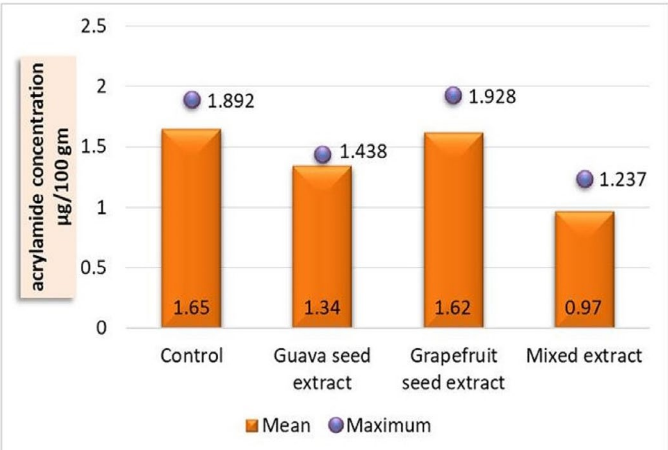

Fig. 2. The maximum and mean values of Acrylamide formed in camel rice kofta during Air-frying process.

Acrylamide reduction percentages were determined to assess the precise ameliorative effect of air-frying versus deep-frying. As rice kofta is air fried with GVSE, the acrylamide content is reduced by 36.3 % when compared to the same group produced by deep-frying (P < 0.05). Though air-fried rice kofta with extracts from guava seed and grapefruit seed lowered acrylamide percentages more than deep-fried rice kofta, there was no statistically significant change (P > 0.05). Notably, the amounts of acrylamide in rice kofta produced with GFSE and cooked using both frying methods were comparable (P > 0.05) (Table 3, Fig. 3).

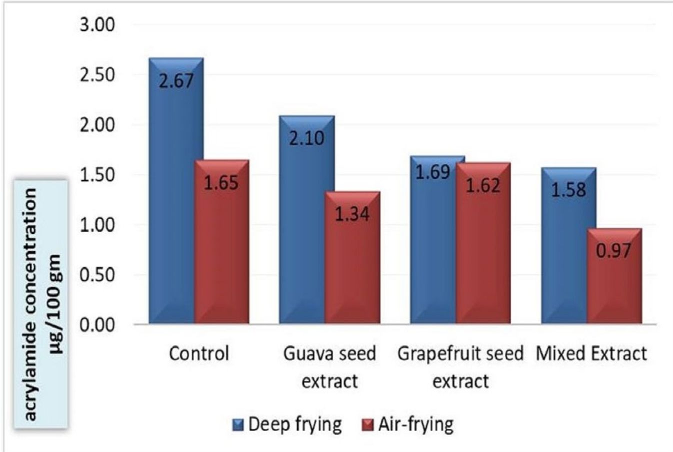

Fig. 3. The impact of cooking method on the mean acrylamide levels in rice-beef kofta cooked with two different cooking methods including deep-frying and air-frying.

For 9 days, the antioxidant stability of camel rice-kofta pre-treated with GFSE or GVSE, as well as their mixture, was investigated to see whether antioxidants from integrated extracts are implicated in acrylamide mitigation activities. MDA concentrations in camel rice-kofta pre-treated with GVSE were significantly lower than in the control and other treatments from the first to the ninth day of chilling. On the third day, GFSE antioxidant activity was comparable to GVSE, despite the fact that its starting level was higher on the first day. From the first to the ninth day of chilling, camel rice-kofta pre-treated with the mixture extracts (ME) had continuously increased MDA concentrations (Table 4, Fig. 4).

Table. 2. Ameliorative effect of various supplements on Acrylamide production in rice kofta processed during air-frying cooking compared to control.

Groups	Minimum	Maximum	Mean	Reduction %	P-value
Control	1.41	1.89	$1.65^{A} \pm 0.244$		0.30
Guava seed extract (0.1%)	1.23	1.44	$1.34^{AB} \pm 0.102$	18.80%	
Grapefruit seed extract (0.1%)	1.32	1.93	$1.62^{A} \pm 0.304$	2%	
Mixed	0.70	1.24	$0.97^{AB} \pm 0.268$	41.20%	

Significant differences within columns are indicated by different superscript capital letters.

Table 3. Ameliorative influence of different treatments on Acrylamide production in rice kofta prepared by deep-frying versus air-frying.

Groups	Deep frying (Maximum)	Air-frying (Maximum)	Reduction (%)	Standard Error	P-value
Control	2.67	1.65	38.2	0.38	0.22
Guava seed extract (0.1%)	2.10	1.34	36.3	0.24	0.02
Grapefruit seed extract (0.1%)	1.69	1.62	4	0.27	0.88
Mixed extract	1.58	0.97	38.70	0.20	0.17

Table. 4 Compare the antioxidant properties of different integrated extracts, including GFSE or GVSE, and their mixtures on the oxidative stability of camel rice-kofta.

Days	Groups					
	Control	Grapefruit seed extract 0.1%	Guava seed extract 0.1%	Mixture	SEM	P-value
Day 0	3.85^{eC}	4.37^{bD}	2.88^{dB}	7.70^{aC}	0.06	0
Day3	9.32^{aB}	5.19^{bC}	5.61^{bA}	9.35^{aB}	0.19	0
Day 6	8.57^{aB}	9.09^{aB}	5.22^{bA}	8.96^{aB}	0.25	0
Day 9	11.34^{bA}	13.73^{aA}	5.27^{cA}	12.91^{aA}	0.41	0

MDA Concentration nmol/g. Significant differences within rows are indicated by different superscript small letters, while significant differences within columns are indicated by different superscript capital letters.

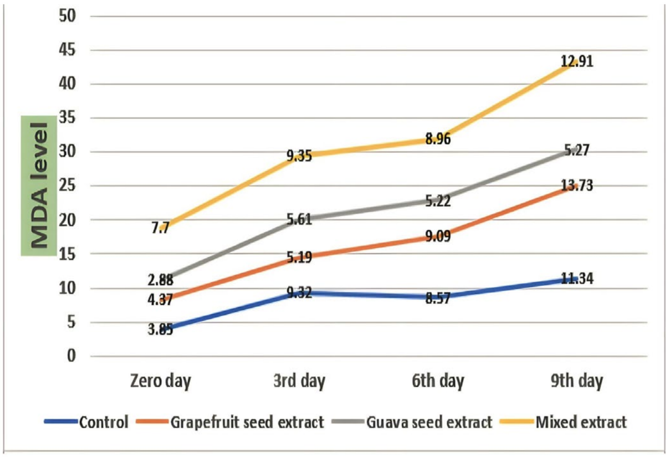

Fig. 4. Different values of MDA estimated during 9 days in different treated groups and the control one.

DISCUSSION

The current study compared two processing methods, deep-oil frying and air-frying, to mitigate acrylamide production in traditional camel product in Egypt, camel rice-kofta. The ameliorative effect of extracts of guava seed (GVSE), Grapefruit seed (GFSE), and their combination on acrylamide formation in rice kofta was also studied. In our previous acrylamide screening investigation, we reported that the highest acrylamide contents in camel products were found in Rice-kofta (3.103 µg/100 g) (Elsheshtawy *et al*., 2022). In addition, deep-fried ready-to-eat camel items showed considerably higher mean acrylamide levels (1.70) than grilled samples (0.54 µg/100g) ($P<0.05$) in this investigation (Elsheshtawy *et al*., 2022).

Deep-oil frying is one of the most traditional and widely used processing methods in the manufacture of a wide range of fried dishes (Asokapandian *et al*., 2020). However, the prevalence of obesity in industrialized and developing countries, which is attributable to oil consumption from cheap fried meals, as well as the production of acrylamide, a probable carcinogen in fried and baked foods exposed to high temperatures, has heightened consumer concerns (Bhurosy and Jeewon, 2014; Baskar and Aiswarya, 2018). In the current experiment, the maximum value generated by the control sample under deep-frying was comparable with that reported during earlier screening study (Elsheshtawy *et al*., 2022). The high temperature used, combined with dehydration, oil intake, and chemical processes such as protein denaturation and carbohydrate caramelization, explains the strong association between deep-oil-frying and the high acrylamide compound (Gertz, 2014; Sengar and Sharma, 2014). Among the techniques for reducing the negative effects of dietary acrylamide are the addition of food elements such as antioxidants (Friedman and Levin, 2008). Phytochemicals are a wide category of substances that belong to secondary metabolites of plants and include polyphenols, flavonoids, steroidal saponins, organosulphur compounds, and vitamins (Forni *et al*., 2019). Few studies have used current extracts to investigate their acrylamide mitigation efficiency as well as the impacts on oxidative stability during storage scenarios, and these considerations were the same reason for pre-treatments of rice-kofta with these extracts in present investigation. Previous research has shown that each antioxidant's unique structure allows it to perform a distinctive role in either boosting or inhibiting acrylamide formation (Kahkeshani *et al*., 2015). Mixing rice-kofta with seed extracts, particularly GFSE, and their combination with GVSE under the deep-oil frying conditions reduced acrylamide levels compared to control, but not statistically significant ($P>0.05$). Grapefruit seed extract (GFSE) has strong antibacterial, antifungal, antiviral, liver-protective, antioxidant, neuroprotective, and cardioprotective activity due to its high content of flavonoids such as limonin, naringin, narirutin, or naringenin, and hesperidin, as well as ascorbic acid, tocopherol, citric acid, limonoids, sterols, minerals, and numerous other bioactive (Cvetnic and Vladimir-Knezevic, 2004; Ahmed *et al*., 2018). There could be two mechanisms at effect in the decrease of acrylamide in pre-treated rice-kofta with grapefruit extract. The first flavonoids such as naringenin hesperedin have the ability to strongly scavenge asparagine-derived amide group intermediates in the Maillard reaction, diverting them from the routes leading to acrylamide production (Cheng *et al*., 2009; Zhu *et al*., 2009). The second pathway might linked to ascorbic and citric acid, which result in acidic pH, which reduces acrylamide production by inhibiting the reaction between a asparagine and a carbonyl compound, preventing the formation of the corresponding Schiff base, a key intermediate in the Maillard reaction and in the formation of acrylamide (Mestdagh *et al*., 2008; Yuan *et al*., 2011). Asparagine precipitation by complexation with proanthocyanidins (condensed tannins) from grape seeds was one of the mechanisms described for lowering acrylamide accumulation (Zhu *et al*., 2009).

Despite the fact that it needed much longer processing times, air frying is being marketed as a viable alternative to deep-oil frying for generating products with significantly lower fat and acrylamide content but similar moisture and colour qualities (Sansano *et al*., 2015; Teruel *et al*. 2015; Lee *et al*., 2020). Under present air-frying situations, the maximum acrylamide values of control and rice kofta integrated with GVSE, as well as a combination of extracts from guava seed and GFSE, were generally lower than those exposed to deep-frying conditions. These findings indicate that air-frying is linked with lower acrylamide levels than deep-frying conditions. The slower temperature progression during air-frying resulted in slower moisture loss and colour development reactions (Teruel *et al*., 2015). Deep-oil-fried chicken meat had previously been found to contain higher acrylamide (6.19 µg /kg) than air-fried chicken meat (3.49 µg/kg) (Lee *et al*., 2020). Air-frying lowered acrylamide concentration in fried potatoes by around 90% when compared to conventional deep-oil frying (Sansano *et al*., 2015).

When air-frying was performed, similar to deep-frying, there was no significant difference in acrylamide levels between the control and the extract-treated groups when air-frying was used. Furthermore, though not statistically significant, the reduction was linked to GVSE and its combination with GFSE. In addition to polyphenols, which have strong antioxidant properties, guava contains a lot of vitamin C (VC). Water-soluble vitamins, including VC, were found to be capable of decreasing acrylamide synthesis by 50% and 42% in the chemical and food model systems, respectively, but no substantial suppression was discovered when it was administered to potato samples prior to frying (Zeng *et al*., 2009). These findings suggest that discrepancies in the acrylamide mitigation characteristics of either GFSE or GVSE in the current study could be related to variation in cooking circumstances. Many reports indicated that high temperatures, such as roasting, destroyed the antinutritional flavonoid components of GVSE, which include tannins, saponins, and enzyme (amylase and protease) inhibitors. Total phenolic contents and antioxidant activity increased concomitantly, but within a specific thermal duration, which could be due to the release of more bound bioactive phenolics from cellular constituent breakdown and degradation of polymerized polyphenols, specifically hydrolysable tannins, and the hydrolysis of other glycosylated flavonoids (Gallegos-Infante *et al*., 2010; El Anany, 2015). Diverse chemical structural features of phenolic or antioxidant compounds may undoubtedly lead to different acrylamide generation effects. By reacting with particular intermediate precursors, they might either protect the acrylamide from degradation or prevent acrylamide formation in the Maillard reaction (Zhu *et al*., 2009; Hamzalıoğlu *et al*., 2013). It is possible that air-frying released such a bioactive molecule with acrylamide-mitigation properties, whereas deep-frying did not. This could explain why their combination has a fixed modest acrylamide mitigation efficacy when used on rice-kofta in both frying processes.

To assess the precise ameliorative effect of air-frying versus deep-frying, acrylamide reduction percentages were calculated. When rice kofta is air fried with GVSE, the acrylamide level is lowered by 36.3% compared to the same group produced with deep-frying. Though rice kofta air-fried with a combination of extracts from guava seed and grapefruit seed reduced acrylamide percentages more than deep fried, there was no statistically significant difference. The current findings support prior reports that air frying, as demonstrated here with camel rice kofta, can lower acrylamide formation when compared to deep fried. Air-frying displayed comparable sensory attributes to deep-oil frying while still retaining nutritional quality and being safer, which may increase customer attractiveness as a deep-fat frying alternative (Lee *et al*., 2020). Notably, the acrylamide levels in rice kofta prepared with GFSE and processed using both frying methods were comparable. This slight reduction suggests that the GFSE moderating impact would be prominent during deep-fat frying. The previously proposed explanation was that antioxidants that are stable at high temperatures increase the reaction system's antioxidant capacity and reduce acrylamide destruction; however, easily oxidizable (i.e., unstable) antioxidants are oxidised to form more quinones and free radicals, which counteract their antioxidant activity and increase acrylamide destruction by attacking the alkene bond of acrylamide (Ou *et al*., 2010).

The antioxidant stability of camel rice-kofta pre-treated with GFSE or GVSE and their mixture was studied for 9 days to evaluate if antioxidants from integrated extracts are involved in acrylamide mitigation activities. From the first to the ninth day of chilling, MDA concentrations in camel rice-kofta pre-treated with GVSE were considerably lower than in the control and other treatments. Earlier research found that P. guajava leaves extract suppressed lipid oxidation, improved pooris oxidative stability, and reduced acrylamide levels in fried sunflower oil (Nagpal *et al*., 2022). GFSE antioxidant activity was similar to GVSE on the third day, despite the fact that its initial level was higher on the first day. Grapefruit seed extract was able to delay lipid peroxidation and showed antimicrobial properties during cold storage when tested as a natural antioxidant and functional curing agent ingredient in meat products, chicken breast (Kang *et al*., 2017). Surprisingly, camel rice-kofta pre-treated with the extracts mixture (EM) had consistently higher MDA concentrations from the first to the ninth day of chilling; however, this does not imply that there were no antioxidant activities because the initial MDA level was higher than other groups, including the control, but the increase over storage time was 5.21 nmol/g, which was significantly lower than the increase calculated for MDA values in the control (7.49 nmol/g), and GFSE (9.36 nmol/g). These findings suggested that antioxidant components of added extracts have a role in acrylamide reduction, and that cooking methods have an impact on such activities. Guava seed and grape seed extracts have been suggested as powerful antioxidant sources for food system stabilization, particularly unsaturated vegetable oils. By boosting hydrolytic stability, reducing double bond conjugation, and minimizing polyunsaturated fatty acid losses, they were able to prevent thermal deterioration of the tested oil (El-Kady *et al*., 2017).

Many studies have shown that adding different natural antioxidants at varying concentrations and extraction methods reduces the production of acrylamide. Green Tea Extract (GTE) (Mitsumoto *et al*., 2005; Demirok and Kolsarıcı, 2014), Rosemary herb mixed to maize or olive oil, rosemary extract, rosemary oil, and dried rosemary leaves are just a few examples (Hedegaard *et al*., 2008; Urbančič *et al*., 2014). Sage inhibited lipid oxidation in Chinese-style sausage and muscle meals (Fasseas *et al*., 2008; Zhang *et al*., 2013), whereas sweet orange peels and orange waste extract greatly lowered acrylamide levels (Sawalha *et al*., 2009; Seyedi *et al*., 2021), with apple extract being the most potent (Cheng *et al*., 2010). Blueberry, mangosteen, and longan extracts, on the other hand, had no effect, but curcumin, and dragon fruit extracts increased acrylamide production (Cheng *et al*. 2010; Hamzalıoğlu *et al*., 2013).

CONCLUSION

Fruit waste extracts investigated in the current study was able to reduce acrylamide production and improve oxidative stability in camel rice kofta. The efficiency of GFSE and GVSE in attenuating acrylamide was influenced by the cooking method, with GFSE being more significant in deep-frying and the GVSE mitigation effect being more powerful in air-frying. GVSE considerably increased the oxidative stability of rice kofta at chilling temperature, followed by the mixture extract (ME), as compared to the control.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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