85 *Egypt. J. Vet. Sci.* **Vol. 56,** No. 5, pp. 903-914 (2025)

Egyptian Journal of Veterinary Sciences

https://ejvs.journals.ekb.eg/

Turmeric and Onion Extracts as Effective Marinating Agents: Reducing PhIP Formation and Improving Quality in Cooked Chicken Breast across Various Cooking Techniques

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Abstract

THE study aimed to assess the impact of turmeric powder and onion extract on the carcinogenic heterocyclic amine (PhIP) formation and quality of chicken breast prepared via several cooking methods (pan frying, roasting, and grilling) to various degrees of doneness. The results revealed a significant difference in the pH values of different cooking methods, ranging from 5.89 to 6.22. Marinating with turmeric powder and onion extracts significantly reduced the cooking loss of treated samples, ranging from 22.63 to 30.26% and 22.88 to 43.21% for turmeric and onion-treated samples, respectively. The addition of turmeric powder and onion extract had a significant impact on the total antioxidant capacity (TAC) compared to untreated control samples. Color parameters showed that there was only a substantial effect for L* values of medium-done grilled and roasted chicken samples, which were lower than the control and turmeric-treated samples. In addition, turmeric-treated samples showed better acceptance in sensory evaluation compared with onion-treated samples. Furthermore, marination with turmeric and onion extract lead to a significant reduction in PhIP formation. The untreated samples, especially those cooked by pan frying, had a significantly higher content of PhIP when compared with other cooking methods. PhIP could be detected only in well-done grilled and fried samples with lower concentrations of 0.2 and 1.7 ng/g in marinated chicken breast muscle samples with turmeric powder. However, PhIP was not detected in onion-marinated samples. Therefore, turmeric powder and onion extract could be applied to minimize heterocyclic amine formation and enhance the quality of cooked chicken breast.

Keywords: chicken breast, PhIP, turmeric powder, onion extract, cooking methods.

Introduction

Over the past few decades, toxicants produced during cooking foods that high in its protein content, such as fish and animal meat have received much attention, where some dangerous substances known as heterocyclic aromatic amines (HCAs) are produced [1]. Foods abundant in protein are essential for the body's growth and development. However, some carcinogens during cooking could be formed and associated with these types of foods. Numerous studies suggested a link between eating certain foods and an elevated chance of developing human cancer [2]. The Millard reaction occurs when meat is heated between 150 and 250°C, simultaneously with the formation of HCAs, which are carcinogenic and/or mutagenic. Creatine or creatinine, carbohydrates, and amino acids—typical ingredients in muscle diets—serve as the precursors for producing HCAs [3]. Cooked meat contains a variety of HCAs that have been identified [3].

The HCA, 2-amino-1-methyl-6-phenylimidazo [4,5-b] pyridine (PhIP), is among the most often

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(Received 12/03/2024, accepted 25/04/2024)
DOI: 10.21608/EJVS.2024.276423.1907

produced HCAs during heating muscle meat by ordinary cooking methods and especially at high temperature [4]. HCA generation in meat is primarily influenced by a number of parameters, including cooking temperature, time, and technique [4]. The concentration of HCAs present in meat is closely correlated with the amount of cooking loss [5]. Additionally, it is pointed out that the most popular cooking techniques by households, such as frying, roasting, smoking, broiling, and baking, could cause the formation of HCAs [6]. Each cooking technique can generate different type of HCA in processed meat [6]. The HCA can be decreased by lowering cooking temperature, duration, or modifying the cooking technique. The amount of HCA predicted to be consumed daily might vary based on the dietary choices and cooking techniques [6]. The International Agency for Research on Cancer [7] and the National Toxicology Program [8] have classified PhIP as a group 2B carcinogen list. Exposure to these substances is suggested to be minimal because they are probable carcinogens. As a by-product of the Millard reaction, PhIP is created when free amino acids and creatine or creatinine condense during meat cooking [9], creating flavor and changing the color and taste of meats. Recently, because of the detrimental consequences of HCAs on human health, numerous trials have been conducted to decrease their formation [10]. Natural antioxidants are an essential tool for reducing HCAs owing to their radical scavenging power also, polyphenols present in natural plants could have the capacity to prevent the formation of intermediates of the Millard reaction which produce HCAs compounds [11].

Due to their non-carcinogenic effect, natural antioxidants are better than synthetic ones. Among the most valuable plants, turmeric *(Curcuma longa),* has phytochemicals and free radical scavenging power. The active ingredient in turmeric, curcumin, is responsible for the antioxidant activities of the plant. Furthermore, with the help of hydroxyl and superoxide radical scavenging activity, it could be a significant factor in preventing lipid peroxidation [13]. According to some research, turmeric extract has a stronger antimicrobial and antioxidant impact on fish when compared to herbal extracts like seaweed, spirulina, beets, and ginger and garlic [12]. Additionally, ready-to-eat foods may benefit from the application of turmeric extracts as natural preservatives [13]. In fortified beverages and milk as colloidal food models, the usage of turmeric extract has also been investigated as nanopolisomes and nanoemulsions loaded, which act as antioxidants and antimicrobials [14]. Nowadays, various studies have concentrated on creating and analyzing edible films that include curcumin as a bioactive substance because of its antibacterial and antioxidant qualities [15].

One of the most popular vegetable species worldwide is onion (*Allium cepa* L.), an essential source of flavonoids for the human diet [16]. Some previous studies highlighted the importance of phenolic compounds in marinades which works as inhibitors of polycyclic aromatic hydrocarbons formation by scavenging the free radicals [17]. Onion skin and extracts may be used as a source of bioactive phenolic and polyphenolic chemicals with antibacterial and antibiofilm qualities. Building insulation materials that contain pumped onion skin have been effectively studied [18]. The antifungal effect of nano-chitosan and onion extract coatings on quality of chicken fillet meat during refrigeration [18]. The outcomes showed that chicken fillet meat samples' qualitative attributes could be preserved by using crude onion extract and nano chitosan [19].

Recently, researchers have been particularly interested in plant extracts and spices' ability to prevent HAAs and provide antioxidants activities. According to Keskekoglu and Uren [20], grape seed extract, for instance, may reduce the overall HAA levels in oven-roasted chicken meatballs (37%) and charcoal-barbecued beef meatballs (65%). Extracts from blueberries, raspberries, and strawberries may lessen the production of cancer-causing heterocyclic amines in fried chicken, beef, and camel meats [1]. In contrast to these plant extracts, spices have the ability to improve food flavor and taste while simultaneously inhibiting the production of HAAs. Ginger, a traditional Chinese spice, effectively inhibited the development of HAAs in braised chicken [21]. Turmeric has been supposed to be a more potential spice in reducing HAAs in meat products [22]. Furthermore, The effects of applying oil marinades containing garlic, onion, and lemon juice on the production of heterocyclic aromatic amines (HAAs) in fried beef patties were studied by Gibis et al. [23]. The findings demonstrated a greater decrease in MeIQx in patties when increasing the amount of onion ($p < 0.05$) and garlic ($p < 0.01$) in marinades. Therefore, this study aimed to ascertain the impact of turmeric and onion extracts on the formation of PhIP as a precursor of HCAs using different cooking methods. In addition, some quality properties (pH value, color parameters, cooking loss, and total antioxidant capacity) of chicken breasts cooked by different method and degree of doneness were studied.

Material and Methods

Samples preparation and marination of chicken breast muscle

Onion juice extraction: Fresh onions were chopped into small pieces, placed into a blender, and then squeezed to obtain onion juice. Turmeric powder was provided by the “Imtinan” company in Egypt.

Fresh chicken breasts (skinless and boneless) were bought from a local poultry store (Kafr El-Sheikh, Egypt). The chicken breast samples were rinsed with distilled water and cut into uniform sizes. Chicken breast samples were divided into three main groups (3 samples per group; 100 g for each): The first group (C, untreated control); the second group (T1, treated by adding turmeric powder (1%), the third group (T2, mixed with onion extract 5 ml for each 100 g chicken breast). Within the three main groups, the samples were divided into six subgroups according to the different cooking methods (grilling, roasting, and pan frying) and degree of doneness (medium and well-done).

Cooking methods

In order to conduct pan-frying, samples of chicken breast were cooked to 190 ^{o}C on a Teflon-coated pan. The oil's depth was greater than half the height of the meal. For roasting, samples were placed in the oven at 180- 200 ^{o}C. For grilling, chicken breast samples were placed on iron rods and grilled over charcoal (with a distance of around 8 cm between samples and charcoal) for 10 min.

All cooked samples were processed according to the degree of doneness (doubling the time for well done). The thin chromium-aluminium thermocouples were used to measure the food's temperature. The cooking methods description is illustrated in Table 1.

Physicochemical properties determination

The pH was determined using a pH meter (Jenway 3510, Bibby Scientific Ltd., UK) according to the methods of [24]. Cooking loss was calculated according the procedure of [25], and the following equation was used:

Cooking loss %= [(breast muscle weight before cooking - breast muscle weight after cooking)/ breast muscle weight before cooking] × 100

A Minolta CR-410 colorimeter (Minolta, Japan) was used to record the CIELab coordinates (L*, a*, and b*). Every sample was measured five times from ten distinct sites. L* (L*=0 (black), L*=100 (white), a* (-a*= greenness, +a*= redness), and b* (-b*= blueness, + b*= yellowness) were the parameters that were identified.

Antioxidant capacity (DPPH scavenging activity) was measured using the procedure of [26]. Sample (5 g) and 15 mL of distilled water were blended and filtered through Whatman No. 1. To 3.8 mL of the methanolic DPPH solution, 0.2 mL of the treated samples were added. After shaking the mixture, it was allowed to stand for 15 min at room temperature in the dark. Using a spectrophotometer (6505 UV/Vis, Jenway, UK) at 515 nm.

DPPH (%) = [1 – (abs solution/abs control) × 100]

Determination of the heterocyclic amine (PhIP)

Extraction of PhIP

The extraction of PhIP was carried out according to [27]. Cooked chicken samples (5 g) were homogenized in 20 mL of acetonitrile + 15 mL of hexane using a homogenizer (Model PA92, STM company, Japan) and then shaken vigorously for 2 min using vortex mixer (Model G-560) Bohemia Company (U.S.A.) Each chicken sample was extracted twice, and the supernatants were mixed. The supernatant was put into a centrifuge tube measuring 50 mL. Strata-X-C SPE cartridge was preconditioned with 3 mL of methyl alcohol and 4 mL of deionized water for cleanup. The acetonitrile extract in 10 mL was placed inside the preconditioned cartridge. After that, the cartridge was rinsed with 3 mL of 0.1 M HCl and 3 mL of methyl alcohol. 3 mL of a 0.2 M ammonia-methanol solution eluted PhIP from the cartridge. Before being injected into the HPLC system, the eluent was passed through a 0.22 m membrane for filtration. Working standard solutions of PhIP were prepared and dissolved in methyl alcohol, filtered through a 0.45 µm syringe filter prior injection in the HPLC.

HPLC conditions

HPLC (Shimadzu Corporation, Japan) was used to determine heterocyclic amine (PhIP). For PhIP separation, the reversed-phase column (150 mm x 4.6 mm I.D., 5 m particle size). Acetonitrile was the mobile phase B, and 0.05 M ammonium formate was the mobile phase A. 0 to 5 min., 95% A to 40% A; 5 to 5.1 min., 40% A to 0% A; 5.1 to 6 min., 0% A; and 6 to 7 min., 0% A to 95% A was the schedule for the binary gradient elution. The mobile phase was changed back to the initial ratio for 5 min. to equilibrate the column before the next injection. The column was maintained at 23 °C. The sample volume was 2 µL, and the flow rate was 0.5 mL/min. PhIP was observed at 316 nm and detected after 4.60 min. The identification of PhIP in chicken samples was established by comparing the retention time of the sample with standard PhIP solutions. Linear regression was carried out, and the coefficient of the regression line (r2) for the PhIP standard curve was 0.99960. The concentration was expressed as nanograms per gram of chicken sample.

Sensory evaluation

To assess the sensory characteristics of treated and untreated chicken breast samples, 15 trained volunteers evaluated the samples. A 5-point hedonic scale was used to rate the samples' color, flavor, tenderness, juiciness, and overall acceptability (1 is highly disliked and 5 is extremely liked).

Statistical analysis

All experiments were carried out in triplicate, and the results are shown as means ± SD. For the data analysis, a two-way ANOVA was employed. Using the CoStat statistical tool, Duncan's multiple range tests ($p < 0.05$) were run to examine the significance degree between the treatments.

Results and Discussion

Physicochemical properties

pH

The best methods for improving the overall physical and chemical characteristics of chicken meat and minimizing the production of HCAs have been demonstrated to involve marinating the meat prior to cooking. The impact of adding turmeric powder and onion extract to breast muscle samples cooked by different methods on the pH values is shown in Table (2). The results revealed a significant difference ($p < 0.05$) between the pH values of various cooking methods, with apparent significant differences due to the marination of the samples with turmeric and onion extract compared with the control samples. The pH values of the investigated samples ranged from 5.89 to 6.22.

The marination of chicken breast muscles with onion extract was observed to have significant decreases in the pH values compared to the turmeric powder. These values are comparable to those obtained by [17]. Park et al. [14] found that the pH of marinated pork was likewise shown to be somewhat acidic. The pork belly was marinated in various concentrations of green tea and yerba mate. The pH values of the examined samples, which ranged from 5.75 to 6.04, were somewhat similar to those found in our study. It has been reported that both onion extract and turmeric have antioxidant and antibacterial characteristics, which can reduce microbial growth in processed products [28].

Cooking loss

Cooking loss is primarily related to the cooking method, particularly the cooking temperature, time, or degree of doneness. Results of cooking loss are illustrated in Table 2. Both grilling and pan-frying methods significantly increased the cooking loss of chicken breast muscles compared with roasted samples ($p < 0.05$). Adding turmeric powder and onion extract resulted in a reduction in cooking loss of the investigated samples. The cooking losses of chicken breast muscles ranged from 22.63 % to 34.85 % and from 22.88 % to 43.21 % for turmeric and onion-treated breast samples, respectively. A report of [29] showed that cooking loss increased as the temperature rises. [30] ascribed cooking loss to the evaporation of water and fat drippings. Chicken skin contains the majority of the fat, and a little portion attaches to the muscle tissue as intermuscular fat. The higher cooking losses obtained with the pan frying methods in the present study agreed with [31], who reported that roasting chicken breast fillets recorded a 21.4% cooking loss. [32] mentioned that higher pan-frying temperature increases water loss, and the decline in protein content results in a higher cooking loss. Additionally, [33] reported that turmeric powder has potent antioxidant activity, thus maintaining membrane integrity, boosting muscular tissue's ability to store water, and reducing cooking loss.

Color parameters.

Data One key sensory factor that could influence consumer approval is the color of poultry products. Myoglobin interactions with intrinsic and extrinsic variables are responsible for color of cooked meat [34]. The L*, a*, and b* color attributes were used to perform the instrumental color analysis of chicken breast samples (Table 3).

Chicken breast samples marinated with turmeric powder had higher L* values (79.02, 77.72 for grilled and well done cooked samples, respectively) and (78.39 for roasted medium cooked sample) compared to the other groups. In contrast, the turmeric marinated pan-fried medium done (76.16) and well done (76.56) cooked samples had similar L* values compared to onion extract marinated and control samples.

The highest level of a* value was recorded for onion-marinated roasted and pan-fried cooked chicken samples (3.62, 3.30, and 3.56, 3.46 for medium and well-done cooking, respectively). The turmeric marinated grilled medium done cooked sample had the lowest red color intensity (a*) (0.43). On the other hand, no statistically significant differences were found ($p > 0.05$) in b* values (yellow color) between all cooked chicken samples and controls. It has been reported that color changes in cooked chicken breast samples may be attributed to the colored products of Millard reaction [35].

Total antioxidant capacity (TAC)

The ability to measure a pure chemical or food extract's antioxidant potential using TAC has been widely accepted [36]. A food's antioxidant activity may serve as a helpful indicator of oxidative stability [37]. The effect of marination with turmeric powder and onion extract on the total antioxidant capacity (TAC) expressed as DPPH scavenging activity of chicken breast muscles is illustrated in Table 4. The results revealed that turmeric and onion-treated marinated samples were significantly higher ($p < 0.05$) than unmarinated ones. The TAC ranged between 24.35 and 36.24% for turmeric and onion-treated marinated samples and 6.77 and 18.02% for untreated control samples. The results of the various cooking methods didn't reveal any significant differences ($p > 0.05$) for each treated sample with medium and well-done cooking. The higher total antioxidant capacity of turmeric-treated samples may be attributed to the presence of curcumin [38]. Also, the onion have vigorous antioxidant activity due to flavonoids, mainly quercetin [39]. Wang et al. [40] investigated the antioxidant activity of chicken wings treated with marinades enriched with polyphenols. They discovered that each of the compounds had different free-radical scavenging activity. The rate of antioxidant penetration into meat may be restricted, saturation may happen, and the intake of various antioxidants is varied.

Effect of marination with turmeric powder and onion extract on heterocyclic amine (PhIP) reduction

One of the most detrimental changes in cooked food is the formation of HCAs. The most prevalent HCA chemical produced by cooking is PhIP [41], as also indicated in Figure 1 (a, b, c and d). PhIP contents of the breast muscle samples cooked by different methods are illustrated in Figure 2. The results revealed that PhIP levels ranged between 0.4 and 16.8 (ng/g). The unmarinated (control) chicken breast muscle samples showed high concentrations of PhIP. Among the unmarinated samples, those cooked by pan-frying had significantly highest level of PhIP (16.8 ng/g). PhIP could be detected only in well-done grilled and fried samples with lower concentrations of 0.2 and 1.7 (ng/g) in marinated chicken breast muscle samples with turmeric powder. However, PhIP was not detected in onion-marinated samples. This result is similar to [42], who did not detect PhIP in beef samples marinated with onion and cooked by pan frying. According to [43], PhIP made up more than 50% of the total HCAs generated in fried ground beef patties, and their production noticeably increased when cooking temperature raised. [44] found that meat marinated in a turmeric-garlic sauce contains a small amount of PhIP. [17] found that PhIP could be detected in fried chicken meatballs marinated with 1 % turmeric powder at 0.69 ng/g.

This finding suggests that turmeric may be able to successfully inhibit the production of HCAs. This decrease may be related to turmeric's antioxidant properties. According to [45], curcumin can inhibit the production of HCAs. Furthermore, Gibis and Weiss [23]detected PhIP at a level of 10.47 ng/g in grilled chicken patties, and Khan et al. [1] detected PhIP at a level of 1.33-2.55 ng/g in fried chicken treated with different fruit extracts. Nerurkar et al. [44] discovered a low amount of PhIP in a turmeric-garlic marinated meat. This study also showed that PhIP could not be detected in onion-marinated samples. This outcome may be explained by the strong antioxidant activity of onions due the presence of flavonoid, mainly quercetin [39], demonstrated that quercetin suppresses PhIP from developing. [46] found that PhIP could not be determined in meatball samples marinated with 0.25 or 0.50 % onion extract. Furthermore, the main active ingredient in turmeric is curcumin, which greatly inhibited the formation of harman and norharman in braised chicken. By directly eliminating norharman and harman and preventing the development of their essential intermediates, such as THCA and carbonyl compounds, curcumin may be able to reduce their contents in braised chicken items [22].

Sensory evaluation

Sensory evaluation is a method for the assessment of food products' oxidative stability, and consumer acceptance [47]. In general, color influences how well consumers accept meat and its products. The quality of raw meat, additives, packaging, and storage conditions significantly impact the shelf life and quality of meat products [48]. Figure 3 shows the sensory parameters of the different cooked breast muscle samples. In general, turmeric-treated breast samples showed slightly better acceptance from the panelists concerning the color, odor, taste, tenderness, juiciness, and overall acceptability parameters, followed by onion-marinated breast muscle samples compared with control samples with significant differences ($p < 0.05$). Our results agree with those of [49], who found that turmeric did not cause abnormal flavor, color, or smell in chicken meat. According to Febrianta et al. [50], chicken breast muscles marinated in microencapsulated turmeric extract improved the chilled product's taste attractiveness and other sensory qualities. Furthermore, Olorunsanya and Omiyale [51] reported that chicken breast treated with onion extract had a better result than the control. As mentioned before, onion extract and turmeric have antibacterial characteristics, which can reduce microbial growth in meat and chicken products [28] and there was a positive relationship between microbial growth and the formation of biogenic amines and harmful compounds in such products [52]. So, the use of these natural additives, herbal extracts and essential oils will be promising in improving chicken meat quality and safety [53, 54].

Conclusion

This investigation examined the formation of PhIP in chicken breast muscles cooked with different methods depending on the degree of doneness marinated with turmeric powder and onion extract. The findings showed that samples of marinated onions had similar pH levels to that of controls. Also, the cooking loss of breast muscle samples decreased by adding turmeric and onion extract. Adding these additives increased the total antioxidant capacities of the marinated samples. Furthermore, the treated samples revealed significant differences for L* and a* values and no significant differences for b* value than the control sample. Sensory evaluation revealed that turmeric-treated breast samples showed slightly better acceptance from the panelists, followed by onion-marinated samples. Marination with turmeric powder and onion extract reduced the level of PhIP in the examined samples. Overall, it is suggested that using turmeric powder and onion extract during cooking breast muscles can reduce the carcinogenic effect of PhIP and enhance their quality characteristics.

Acknowledgments

The authors acknowledge all members of the Food Control Department, Faculty of Veterinary Medicine, Kafrelsheikh University.

Authors' contributions

R.A. and G.A.K. collected samples, experimental and laboratory investigations. All team members wrote, revised the original draft, and approved the final manuscript.

Funding statement: there is no funding.

Informed Consent Statement: Not applicable

Data Availability Statement: Data are available upon request

Conflicts of Interest: The authors declare that they have no competing interests.

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TABLE 1. Cooking methods description

Cooking technique	Description
Pan- Frying	Dry heat cooking method, in a Teflon-coated pan on the stovetop, which was preheated to 190 °C. Each sample of chicken breast (100 ± 2 g) was fried separately per side with oil (the oil's depth is no more than half the food's height). The samples touched the bottom of the pan.
Roasting	The samples of chicken breast (100 ± 2 g) were placed separately in a shallow pan and uncovered in an oven. Roasted at 180-200 °C for 15 min.
Grilling/BBQ	In the bottom of an oven, charcoal was placed and began to burn for 5 minutes. When there were no more flames, the charcoal was leveled with a rake. 100 g of chicken breast sample was placed on iron rods and grilled for 5 min on each side, for a total cooking duration of 10 min, with a distance of around 8 cm between samples and charcoal. The samples' surface temperatures were around 200 °C.

TABLE 2. pH and cooking loss values for cooked chicken breast samples

Parameters	Cooking method	Degree of doneness	Control	Turmeric Powder	Onion Extract
pH	Grilling	Medium done	6.0 ± 0.02^{Ba}	6.08 ± 0.00^{Ac}	5.90 ± 0.01^{Cb}
		Well done	5.98 ± 0.02^{Ba}	6.07 ± 0.01^{Ac}	6.03 ± 0.00^{ABa}
	Roasting	Medium done	5.93 ± 0.00^{BCa}	5.99 ± 0.01^{Ad}	5.92 ± 0.01^{Bb}
		Well done	5.93 ± 0.01^{Ba}	6.01 ± 0.01^{Ad}	5.91 ± 0.00^{Bb}
	Pan-frying	Medium done	5.90 ± 0.00^{Cb}	6.15 ± 0.02^{Ab}	5.96 ± 0.01^{Bc}
		Well done	5.90 ± 0.01^{Bb}	6.22 ± 0.01^{Aa}	5.89 ± 0.01^{BCb}
Cooking loss	Grilling	Medium done	51.13 ± 0.48^{Aa}	22.63 ± 0.42^{Cd}	32.98 ± 0.47^{Bb}
		Well done	55.46 ± 0.36^{Ab}	28.63 ± 0.86^{Cc}	43.21 ± 1.12^{Ba}
	Roasting	Medium done	21.47 ± 0.49^{Ae}	23.65 ± 1.97^{Ad}	22.88 ± 1.59^{Ac}
		Well done	28.63 ± 0.75^{Ad}	34.85 ± 0.60^{Aa}	35.52 ± 0.84^{Ab}
	Pan-frying	Medium done	43.3 ± 1.92^{Ac}	26.17 ± 0.60^{Bb}	30.75 ± 0.76^{Bb}
		Well done	62.76 ± 2.36^{Aa}	30.26 ± 0.42^{Ca}	40.77 ± 0.23^{Ba}

The data are expressed as mean ± SEM. The different capital letters show a significant difference in the same raw, while the other small letter shows a considerable difference in the same column at $p < 0.05$.

TABLE 3. Color parameters (L*, a*, and b*) of for cooked chicken breast samples

Color parameter	Cooking method	Degree of doneness	Control	Turmeric powder	Onion extract
L^*	Grilling	Medium done	74.41 ± 1.66^{ABb}	79.02 ± 0.82^{Aa}	72.11 ± 1.75^{Bb}
		Well done	75.57 ± 0.38^{Ab}	77.72 ± 0.82^{Aa}	76.91 ± 1.21^{Aa}
	Roasting	Medium done	70.97 ± 1.10^{Bc}	78.39 ± 0.68^{Aa}	73.17 ± 0.90^{Bc}
		Well done	80.44 ± 0.65^{Ba}	76.57 ± 0.26^{Aa}	77.36 ± 1.5^{Ca}
	Pan-frying	Medium done	79.90 ± 1.34^{Aa}	76.16 ± 0.51^{Aa}	76.98 ± 0.75^{Aa}
		Well done	80.19 ± 1.32^{ABa}	76.56 ± 0.18^{ABa}	81.37 ± 0.34^{Aa}
a^*	Grilling	Medium done	1.72 ± 0.37^{Ab}	0.43 ± 0.15^{Bb}	2.66 ± 0.26^{Aa}
		Well done	2.11 ± 0.06^{Aa}	0.76 ± 0.09^{Bb}	1.13 ± 0.17^{Bb}
	Roasting	Medium done	0.68 ± 0.32^{Ba}	2.74 ± 0.18^{Aa}	3.62 ± 0.42^{Aa}
		Well done	0.71 ± 0.23^{Cb}	2.07 ± 0.39^{Ba}	3.30 ± 0.16^{Aa}
	Pan-frying	Medium done	0.67 ± 0.12^{Bb}	0.70 ± 0.24^{Bb}	3.56 ± 0.36^{Aa}
		Well done	0.65 ± 0.20^{Bb}	0.80 ± 0.23^{Bb}	3.46 ± 0.38^{Aa}
b^*	Grilling	Medium done	14.25 ± 1.43^{Aa}	17.62 ± 1.70^{Aa}	14.71 ± 0.95^{Aa}
		Well done	18.06 ± 0.04^{Aa}	14.79 ± 0.30^{Aa}	16.32 ± 1.30^{Aa}
	Roasting	Medium done	18.81 ± 0.67^{Aa}	13.14 ± 0.61^{Aa}	16.68 ± 0.43^{Aa}
		Well done	15.42 ± 0.55^{Aa}	14.77 ± 0.71^{Aa}	13.96 ± 0.26^{Aa}
	Pan frying	Medium done	15.90 ± 0.34^{Aa}	15.75 ± 0.84^{Aa}	13.55 ± 0.61^{Aa}
		Well done	13.76 ± 1.62^{Aa}	13.76 ± 0.39^{Aa}	15.28 ± 0.26^{Aa}

The data were expressed as mean ± SEM. The different capital letters show a significant difference in the same raw, while the other small letter shows a considerable difference in the same column at $p < 0.05$.

TABLE 4. Total antioxidant capacity (TAC) for cooked chicken breast samples

Parameters	Cooking method	Degree of doneness	Control	Turmeric Powder	Onion extract
Total antioxidant capacity	Grilling	Medium done	9.67 ± 0.73^{B}	30.67 ± 0.79^{A}	27.15 ± 1.18^{A}
		Well done	6.77 ± 0.77^{B}	27.65 ± 0.69^{A}	24.62 ± 0.51^{A}
	Roasting	Medium done	18.02 ± 1.12^{B}	36.24 ± 1.25^{A}	33.69 ± 1.15^{A}
		Well done	15.04 ± 0.97^{B}	33.37 ± 1.59^{A}	30.02 ± 1.06^{A}
	Pan-frying	Medium done	15.55 ± 0.86^{B}	30.30 ± 0.92^{A}	27.95 ± 0.90^{A}
		Well done	9.76 ± 0.62^{B}	24.35 ± 0.72^{A}	24.82 ± 1.04^{A}

The data were expressed as mean ± SEM. The different capital letters show a significant difference in the same raw, while the other small letter shows a considerable difference in the same column at $p < 0.05$.

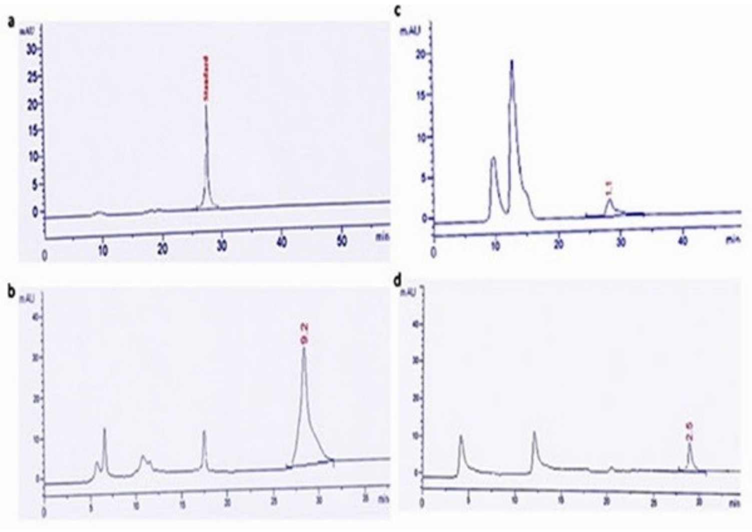


Fig. 1. HPLC chromatograms of standard PhIP (a), PhIP in the samples cooked by pan frying (b), PhIP in the samples cooked by roasting (c), and PhIP in the samples

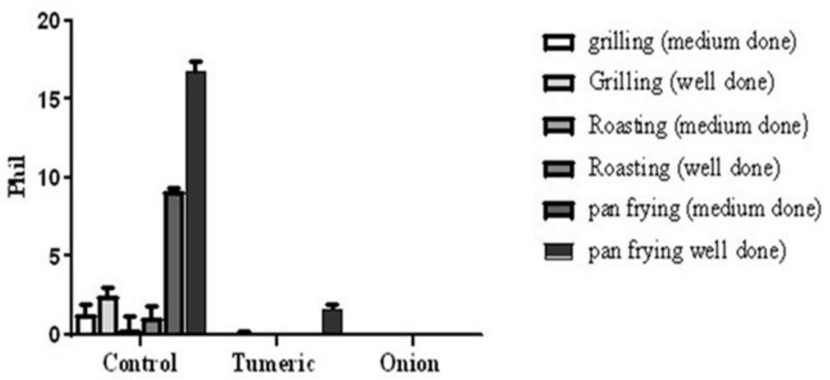
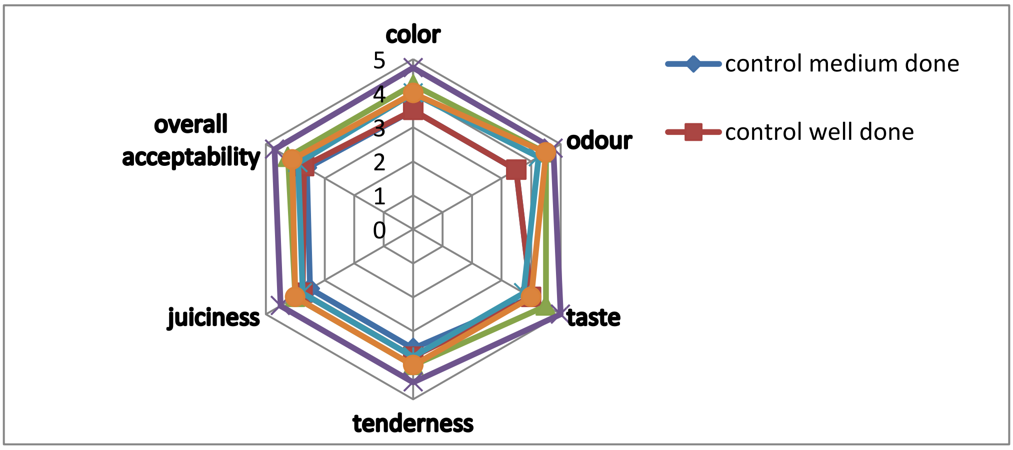
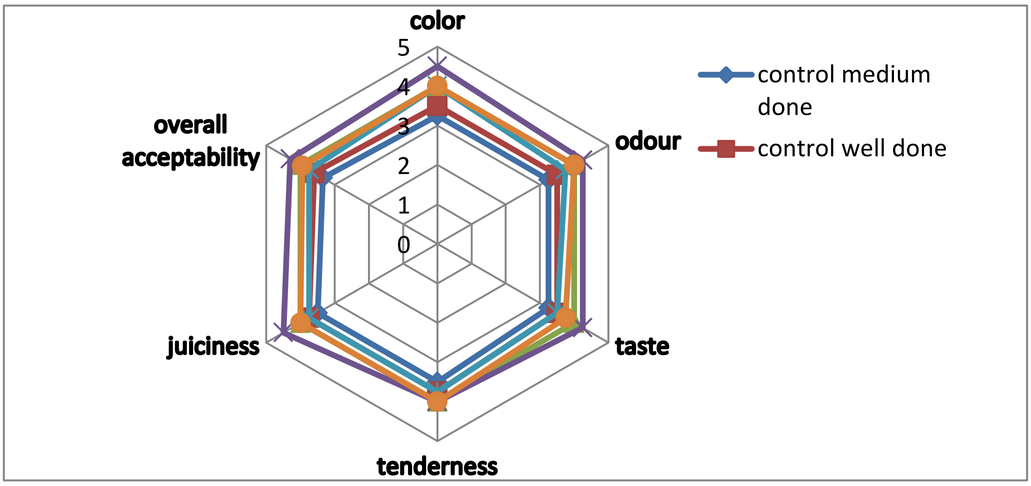


Fig. 2. The Concentration of PhIP of chicken samples treated with turmeric powder and onion extract with different cooking methods and degree of doneness.

a



b



c

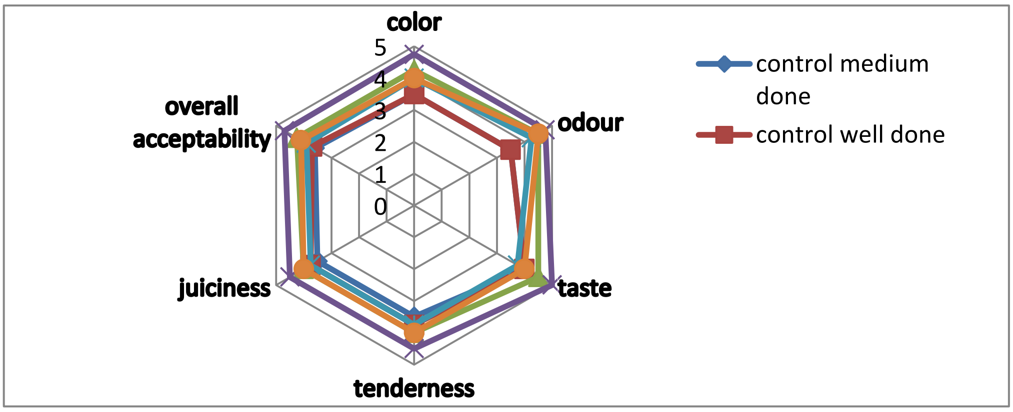


Fig. 3. Sensory evaluation of chicken breast samples treated with turmeric powder and onion extract with different cooking methods and degree of doneness. Grilled samples (a), pan-fried samples (b), and roasted samples (c).

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مستخلصات الكركم والبصل كعوامل تتبيل فعالة لتقليل تكون PhIP وتحسين الجودة في صدور الدجاج المطبوخة عبر تقنيات الطبخ المختلفة

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المستخلص

هدفت الدراسة إلى تقييم تأثير مسحوق الكركم ومستخلص البصل على تكوين الأمينات الحلقية غير المتجانسة المسببة للسرطان وجودة صدور الدجاج المحضرة عبر طرق طهي متعددة (القلي والتحمير والشوي) بدرجات مختلفة من التسوية. أظهرت النتائج وجود اختلاف معنوي في قيم الرقم الهيدروجيني لطرق الطهي المختلفة حيث تراوحت من 5.89 إلى 6.22. أدى التتبيل بمسحوق الكركم ومستخلصات البصل إلى تقليل فقدان الطهي للعينات المعالجة بشكل ملحوظ، حيث تراوح من 22.63 إلى 30.26% و22.88 إلى 43.21% للعينات المعالجة بالكركم والبصل، على التوالي. كان لإضافة مسحوق الكركم ومستخلص البصل تأثير كبير على القدرة الكلية لمضادات الأكسدة مقارنة بالعينات غير المعالجة. أظهرت معلمات اللون أنه لم يكن هناك سوى تأثير كبير لقيم L* لعينات الدجاج المشوي والمحمر متوسطة النضج، والتي كانت أقل من عينات التحكم والعينات المعالجة بالكركم. بالإضافة إلى ذلك، أظهرت العينات المعاملة بالكركم قبولاً أفضل في التقييم الحسي مقارنة بالعينات المعاملة بالبصل. علاوة على ذلك، يؤدي التتبيل بمستخلص الكركم والبصل إلى انخفاض كبير في تكوين PhIP وكانت العينات غير المعالجة، وخاصة تلك المطبوخة عن طريق القلي، تحتوي على محتوى أعلى بكثير من PhIP مقارنة بطرق الطهي الأخرى. يمكن اكتشاف PhIP فقط في العينات المشوية والمقلية المطهية جيدًا بتركيزات أقل تبلغ 0.2 و1.7 نانوجرام/جرام في عينات عضلات صدور الدجاج المتبلة بمسحوق الكركم. ومع ذلك، لم يتم الكشف عن PhIP في عينات البصل المنقوع. لذلك، يمكن استخدام مسحوق الكركم ومستخلص البصل لتقليل تكوين الأمينات الحلقية غير المتجانسة وتحسين جودة صدور الدجاج المطبوخة.

الكلمات المفتاحية: صدور دجاج ، PhIP ، مسحوق الكركم، مستخلص البصل، طرق الطهي.