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Effect of green tea extract and microwave pre-cooking on the formation of acrylamide in fried chicken drumsticks and chicken wings

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ABSTRACT

Since 2002, it has been well-known that carbohydrate-rich foods have a high level of acrylamide (AA). Some researchers have drawn attention on the formation of AA in coated and fried chicken meat products in recent years. From this viewpoint, the purpose of the present study was to mitigate acrylamide formation in fried chicken drumsticks (CDs) and chicken wings (CWs) using green tea extract (GTE) alone or combined with microwave pre-cooking (MPC) by decrease frying time. In brief, CDs and CWs marinated for one day were divided into eight groups. Four of those were first covered with batter and breading, including 0%, 0.5%, 1.5% and 3% GTE and deep fried in fat for 8.5 min for CDs and 3.5 min for CWs at 175 °C and 8 psi of pressure. In the second step, the remainder of the marinated CDs and CWs were subjected to MPC for 7 min and 5 min, respectively. Then, they were covered with batter and breading including 0%, 0.5%, 1.5% and 3% GTE and deep fried in fat for 5.5 min for CDs and 2.5 min for CWs at 175 °C and 8 psi for pressure. With increasing levels of GTE, the AA concentration decreased gradually in CDs and CWs. In addition, MPC also decreased AA formation in CWs due to the shorter frying time. Moreover, MPC was more efficient at reducing AA formation in CWs when it was combined with GTE. A lighter and more yellowish color was measured in CDs as a consequence of the shorter frying time. It is crucial to state that the incorporation of GTE into the breading or MPC did not negatively affect the sensory properties of CDs and CWs, while it reduced AA formation. In conclusion, it can be stated that GTE alone or combined with MPC is an effective and practical mitigation strategy for AA formation.

1. Introduction

The Swedish National Food Administration and Stockholm University reported that high concentrations of acrylamide (AA) were detected in cooked and fried carbohydrate-rich foods in 2002 (Capuano et al., 2009; Gökmen, Şenyuva, Acar, & Sarıoğlu, 2005; Swedish National Food Administration, 2002). Following this, a great number of research studies were carried out regarding the AA formation mechanism, its level in various foods, reduction strategies and analytical detection of AA (Amrein, Schönbachler, Escher, & Amado, 2004; Gökmen & Palazoğlu, 2008; Gökmen et al., 2005; Hedegaard, Granby, Frandsen, Thygesen, & Skibsted, 2008; Mottram, Wedzicha, & Dodson, 2002; Ölmez, Tuncay, Özcan, & Demirel, 2008; Stadler et al., 2002; Stadler et al., 2004; Yaylayan, Wnorowski, & Perez Locas, 2003). Acrylamide was found to occur during the frying, grilling or baking of foods via the Maillard reaction of reducing sugars with asparagine at temperatures above 120 °C and under low moisture conditions (Erdoğdu, Palazoğlu, Gökmen, Şenyuva, & Ekiz, 2007; Gökmen et al., 2005; Mottram et al., 2002; Stadler et al., 2002; Vattem & Shetty, 2003; Zyzak et al., 2003). Acrylamide is classified as "probably carcinogenic to humans" under the group 2A by the International Agency for Research on Cancer (Amrein et al., 2004; IARC, 1994). Moreover, AA has been identified as a neurotoxic compound (Amrein et al., 2004; Vattem & Shetty, 2003).

Previous studies concerning AA have mostly concentrated on carbohydrate-rich foods such as French fries, bread, potato crisps and biscuits as well as coffee. Potato products have the highest AA content among these foodstuffs (Gökmen et al., 2005) and the AA content of carbohydraterich foods varies between 150 and 4000 μg/kg (Tareke, Rydberg, Karlsson, Eriksson, & Tornqvist, 2002). The presence of AA in meat products, especially coated and fried foods, has been reported by previous authors. Chuang, Chiu, and Chen (2006) noted that the AA level in the outer flour portion of fried chicken legs varied between 22.70 and 65.30 ng/g. Barutçu, Şahin, and Şumnu (2008) investigated the effects of different flour types and microwave frying to reduce AA formation in coated and fried chicken strips. There have been a limited number of studies regarding the AA concentration in fried meat

Abbreviations: AA, acrylamide; CDs, chicken drumsticks; CWs, chicken wings; GTE, green tea extract; MPC, microwave pre-cooking; TAC, total antioxidant capacity.

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products in the literature. Therefore, it is considered necessary to perform further studies.

The consumption habits of people have been heading toward ready-to-eat products due to changing lifestyles in recent years. Correspondingly, the consumption of fried bone-in chicken products such as chicken drumsticks and chicken wings in fast food restaurants has been increasing rapidly throughout the world. In a survey study carried out in Turkey, Yaldırak and Kolsarıcı (2012) reported that most of the participants had increasingly started to consume coated chicken meat products, especially chicken drumsticks and chicken wings, in recent years. The production of chicken drumsticks and chicken wings in a fast food restaurant involves two steps. The first step is covering the raw chicken drumsticks and wings with batter and breading. The second step is deep frying in fat of these battered and breaded products. As is known, breading is a cereal-based covering material which includes different types of flour and starch. The covering material can include reducing sugars and asparagine, which are the major reactants for AA (Yaylayan et al., 2003). Deep frying in fat can be another triggering factor for the formation of AA in fried bone-in chicken products. From this viewpoint, a marketing study was carried out to determine AA levels in the coating of fried bone-in chicken drumsticks and chicken wings purchased from local fast food restaurants. Ten replicates were conducted in this study at different times and duplicate samples were analyzed. The average AA level in chicken drumsticks and chicken wings was found to be 216.88 and 18.94 (ng AA/g coating), respectively. The AA level of carbohydrate-rich foods varied between 150 and 4000 ppb (Tareke et al., 2002). When comparing AA levels in fried bone-in chicken products with carbohydrate-rich foods, it has been noted that the AA levels in fried bone-in chicken products are lower. However, the presence of AA in these products should be emphasized in terms of food safety since AA has carcinogenic and neurotoxic effects.

To date, some methods have been attempted to minimize AA levels in foods and successful results have been obtained (Amrein et al., 2004; Capuano et al., 2009; Erdoğdu et al., 2007; Hedegaard et al., 2008; Zhang & Zhang, 2008). In addition, kinetic model studies to assess AA formation based on the initial concentration of AA precursors have been carried out (Knol et al., 2005; Parker et al., 2012). Reduction of frying time and temperature, decreasing the initial amount of AA precursors, microwave treatment, lowering the pH and the usage of asparaginase, antioxidant compound or divalent cations were some of the mitigation strategies reported by previous studies (Erdoğdu et al., 2007; Sahin, Sumnu, & Oztop, 2007). Erdoğdu et al. (2007) reported that microwave pre-cooking is an effective way to reduce AA formation in French fries by decreasing frying time and temperature. They determined reductions of 36%, 41% and 60% in the AA level in pre-cooked potato strips microwaved for 20, 20 and 30 s and fried at temperatures of 150, 170 and 190 °C, respectively. In addition, the utilization of antioxidants, a practical and easy method, to decrease AA formation has been examined by previous researchers. Vattem and Shetty (2003) reported that cranberry reduces AA formation in fried potato slices but oregano has no effect. Hedegaard et al. (2008) recently determined that the addition of aqueous rosemary extract, rosemary oil or dried rosemary leaves to wheat dough reduces the content of AA in wheat buns by 62%, 67% and 57%, respectively. Green tea extract, which has been used in food studies for many years, is a well-known and strong antioxidant compound due to its catechin content (Zhang & Zhang, 2008). Capuano, Oliviero, Açar, Gökmen, and Fogliano (2010) showed that catechins were effective in reducing AA concentrations in a fat-rich model system, but they did not show an inhibitory effect on the AA content in a bread crisp model. In brief, research studies that aimed to reduce the AA content have been mostly conducted on potato-based products or bakery foods. There are limited studies in the literature regarding AA reduction methods for fried bone-in chicken products.

Therefore, the objective of the current study was to determine the effects of green tea extract alone or combined with microwave pre-cooking to reduce AA formation in fried bone-in chicken drumsticks and chicken wings.

2. Material and methods

2.1. Chemicals and consumables

Petroleum ether, sulfuric acid, boric acid, sodium hydroxide, hydrochloric acid, copper(II) sulfate penta-hydrate, potassium sulfate, acetone, methanol, formic acid, ethanol, potassium hexacyanoferrate trihydrate, zinc sulfate and disodium tetraborate decahydrate were obtained from Merck (Darmstadt, Germany). ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt), potassium peroxodisulfate, Trolox [(±) 6 hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid], HPLC grade acetonitrile, HPLC grade acetone, FMOC chloride, n-hexane, glacial acetic acid, sodium acetate, Ca-EDTA, acrylamide (99%), L-asparagine (≥98%), D-(+)-glucose (≥99.5%), and D-(−) fructose (≥99.5%) were purchased from Sigma-Aldrich (St. Louis, MO, USA). Nylon membrane syringe filters (0.45 μm), Oasis MCX (1 mL, 30 mg) solid-phase extraction (SPE) cartridges, Acquity UPLC HSS T3 columns, Sep-Pak C18 classic cartridge and Sugar-Pak I columns were supplied by Waters (Millford, MA, USA). Rapid resolution Zorbax SB-C18 columns were provided by Agilent (Agilent Technologies, Waldbronn, Germany). Marinade sauce and breading were supplied from a commercial company, Holland Fried Chicken (HFC), Ankara, Turkey. Guardian green tea extract 20S was purchased from Danisco (Copenhagen, Denmark).

2.2. Production of coated and fried chicken drumsticks and chicken wings

The production process described in the Introduction section was simulated in the laboratory to provide the desirable color, texture and sensory properties. 24 h postmortem chicken drumsticks (CDs) and chicken wings (CWs) were supplied from a commercial facility in Turkey. They were marinated with a marinade sauce and stored at 4 °C overnight. The basic ingredients of the marinade sauce were oil, salt, red pepper, black pepper, coriander, ginger, coconut, garlic, citrate, basil, cumin, rosemary and thyme. Marinade yields were 103.07% and 103.97% for CDs and CWs, respectively. On the following day, 2 kg of breading including 0%, 0.5%, 1.5% and 3% green tea extract (GTE) was prepared. Batter was made by dissolving 500 g of breading including GTE in 875 mL of water. Marinated CDs and CWs were divided into eight groups. Four of those groups were first dipped into the batter and then breading to produce following treatments: T1-D) CDs—0% GTE, T2-D) CDs—0.5% GTE, T3-D) CDs—1.5% GTE, T4-D) CDs—3% GTE; T1-W) CWs—0% GTE, T2-W) CWs—0.5% GTE, T3-W) CWs—1.5% GTE, T4-W) CWs—3% GTE. Battered and breaded product yields were 111.57% and 123.97% for CDs and CWs, respectively. After the covering process, CDs and CWs were deep fried in fat for 8.5 min and 3.5 min respectively in a high pressure fryer (HFC, Ankara, Turkey) at 175 °C and 8 psi of pressure. Frying yields were 83.60% and 84.85% for CDs and CWs, respectively. Regarding remaining four groups of marinated CDs and CWs, microwave pre-cooking (MPC) was used to shorten the frying time. Upon the completion of the marinating process, marinated CDs and CWs were placed in a tray as a monolayer and microwaved (a benchtop microwave, HMT84G451, Bosch, Germany) at 360 W 7 min and 5 min, respectively. Microwave yields were 97.28% and 98.21% for CDs and CWs, respectively. Then, CDs and CWs were also covered with the same batter and breading including 0%, 0.5%, 1.5% and 3% GTE. For the next step, CDs and CWs were deep fried in fat for 5.5 min and 2.5 min, respectively, under the same conditions to produce the following treatments: T5-D) CDs—0% GTE + MPC, T6-D) CDs—0.5% GTE + MPC, T7-D) CDs—1.5% GTE + MPC, T8-D) CDs—3% GTE + MPC; T5-W) CWs—0% GTE + MPC, T6-W) CWs—0.5% GTE + MPC, T7-W) CWs—1.5%