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Influence of superheated steam and deep frying cooking on the proximate, fatty acids, and amino acids composition of chicken sausage

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Abstract

This study was performed to examine the effect of deep frying and Superheated steam (SHS) oven on the proximate composition, fatty acid composition, and amino acid composition of chicken sausage. The results showed that the moisture content statistically decreased after cooking. The protein content and total ash increased after cooking. The fat content showed insignificant reduction during SHS cooking, whereas the frying process showed significant increase in total fat content. The fatty acid composition was affected more by the frying process, which showed an increase in the proportions of SFA, PUFA, and the ratio of n-6/n-3 while the SHS cooking insignificantly affected the fatty acid composition. The amount of total amino acid showed significant increase after cooking. The present study provides possible application of SHS oven as a healthy technique for cooking food compared with the deep frying process.

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Introduction

Chicken sausages, which are considered as very popular and highly consumed in many countries, are found to have a good source of polyunsaturated fatty acid (PUFA) compared to pork and beef sausages (Khaksar *et al*., 2010). Normally, chicken sausage has to be cooked before being consumed as a chief palatable, digestible and safe product. Deep-frying is a popular and common method that is widely used in food preparation. It is a complicated process, because many factors are at work. Some of them rely on the process, while others on the type of fat and food used. During frying, water evaporates and the oil penetrates into the food and becomes an important ingredient of the fried food (Ramírez and Cava, 2005). In addition, undesirable changes might happen during frying such as thermal oxidation, losses in nutrients and essential fatty acids in which the unsaturated fatty acids are more subjected to oxidation than other fatty acids (Haak *et al.*, 2007). Further, heat treatments result in decrease amino acid content through desulfuration, isomerization or deamination; reaction with methionine, lysine, and tryptophan that is considered as the highest amino acid susceptible to deterioration during processing (Lisiewska *et al*., 2008).

Recently, the partnership between diet and health has been extensively studied and increasing number of consumers has been encouraged to enhance their eating habits (Juárez *et al*., 2009). Most current dietary guidelines recommend that the daily consumption of amino acids should be about 93.5 mg/kg (Joint, 1985), and the total fat for individuals should be no more than 30% of the total calorie consumption. Saturated fat (SFA) should not be in excess of 10% of the total calorie intake (Nishida *et al*., 2004; Leosdottir *et al*., 2005). It is necessary to establish recommendations for cooking the most common food using methods that will help consumers adhere to the nutritional recommendations. Thus, Superheated steam (SHS) may offer an alternative cooking method. SHS is generated from the addition of sensible heat to water, thus leading to increase in temperature over boiling point or saturation temperature at the given pressure (Abdulhammed *et al*., 2013). In contrast to saturated steam, a drop in temperature will not happen in condensation of the steam as long as the temperature is still higher than the saturation temperature at the processing pressure (Cenkowski *et al*., 2007). Various products have been processed with SHS such as sweet potato (Hatamipour *et al.*, 2007), chicken meat (Nathakaranakule *et al*., 2007), potato chips (Kingcam *et al*., 2008), Asian noodles (Pronyka, 2008), oat goat (Cenkowski *et al.*, 2011), and pork slices (Sa-adchom *et al*. 2011). SHS offers advantages such as, an oxygen-free environment,

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which lowers the percentage of oxidation and nutrient loss, improves thermal degradation due to the increase in heat transfer, improves energy efficiency and accelerates drying rate (Cenkowski *et al*., 2007; Somjai *et al*., 2009).

To the best of our knowledge, there was no literature report on the effect of SHS on fat, fatty acid composition, amino acid composition, and lipid oxidation in chicken sausage. This study was therefore, conducted to determine the impact of deep frying and SHS oven cooking on the total fat, fatty acid composition, and amino acids composition of chicken sausage.

Materials and Methods

Sample preparation and cooking

Ready-to-cook commercial chicken cocktail sausage was supplied from a local hypermarket. The chicken cocktail sausage was packaged in polyethylene bags of 800g per pack and was transported directly to the laboratory. The chicken cocktail sausage was held under frozen conditions (-18 to -20°C) in a freezer until the cooking process. Each individually chicken cocktail sausage weighs approximately 11g, was cooked using the SHARP SHS oven (AX-1500) with temperatures : 150°C for 4.30 min. and deep frying – the sausage samples were placed in a wire mesh basket and immersed in palm oil in a deep fryer for 4.0 min at 150°C. After frying, the basket was shaken and the samples placed on absorbent paper towels. Heating treatments were considered complete when all the samples had reached an internal temperature of 70°C (Domínguez *et al*., 2014).

Proximate chemical composition

Moisture, protein, Fat and ash contents were determined in accordance with standard method of AOAC (2000).

Fatty acid composition

Fatty acid methyl ester FAME was prepared according to the method of Mondello *et al.* (2006). The methyl esters were separated by gas chromatography (Shimadzu Scientific Inc., USA) with flame ionization detector (GC-FID). A BPX 70 (SGE, Australia) column consisting of a 30 m x 0.32 mm fused silica capillary coated with 70% cyanopropyl polysilphenylene-siloxane of 0.25 µm film thickness was used, with Helium as the carrier gas at constant linear velocity (28 cm/s). The injector temperature was 250°C and the detector temperature 280°C. The oven was programmed as follows: 80°C for 2 min, 5°C/min to 200°C for 10 min and 10°C/min to 230°C for a further 10 min. Fatty acid were grouped as follows : saturated (SFA) ,mono (MUNA) and poly (PUFA) fatty acids.

Amino acids composition

Amino acids composition was determined in according to the method described by Jensen *et al.* (2014).

Statistical analysis

All the analyses were carried out in triplicate for each sample and the data analysis was carried out using ANOVA followed by post hoc analysis using Duncan multiple comparison analysis. All data were analyzed using SPSS (Statistical Package for Social Science) software version 17.0 (IBM Corporation, Armonk, New York 10504-1722, United States).

Results and Discussion

Proximate composition

The changes in moisture, protein, fat and ash contents of chicken sausage after cooking processes are shown in Table 1. The moisture content of the chicken sausage varied from 64.45% to 61.31%, showing a decrease after cooking. The higher reduction in moisture content was found in the deep frying sample. This was due to the high level of dehydration during frying compared with oven cooking (Weber *et al*., 2008). The protein content of the raw sample was about (13.46 mg/100 g) and it significantly increased to (14.28 mg/100 g), and (14.04 mg/100 g) for SHS and deep frying samples, respectively. This observation suggests that the protein nitrogen was not lost during heating. Total fat content shows that the raw sample (39.77%) exhibited insignificant ($p< 0.05$) reduction during SHS cooking (39.72%). Meanwhile, its value increased significantly during deep frying processing (44.81%), which is due to fat absorption from the frying oil (Koubaa *et al*., 2012). The ash content of chicken sausage (2.34%) shows an increase in both SHS and deep frying cooking and the highest value was found during the deep frying process (2.72%). It has been reported that the increase in fat, protein and ash contents might be explained by the reduction in moisture content after heating treatment (Hosseini *et al*., 2014).

Fatty acid composition

Fatty acid compositions of chicken sausage before and after cooking are investigated in Table 2. The PUFA was dominated by linoleic acid (C 18: 2n-6) as

Table 1. Proximate composition (g/100 g, mean ± SD) of raw, SHS-cooked and deep fried-cooked chicken sausage

Samples	Moisture	Protein	Fat	Ash
Raw	57.45 ± 0.11^{c}	6.46 ± 0.16^{a}	27.76 ± 0.44^{a}	2.34 ± 0.03^{a}
SHS	56.23 ± 0.19^{b}	7.28 ± 0.11^{b}	27.72 ± 0.26^{a}	2.47 ± 0.02^{b}
Deep Frying	52.97 ± 0.13 ^{a}	7.04 ± 0.05^{b}	31.47 ± 0.59^{b}	2.72 ± 0.03^{c}

Within a column values with different letters are significantly different ($p<0.05$).

Table 2. Fatty acid contents (%, mean ± SD) of raw, SHS-cooked and deep fried-cooked chicken sausage

Fatty acid %	Raw	SHS	Deep frying
C12:0	5.57 ± 1.83^{a}	4.44 ± 1.48^{a}	5.73 ± 2.6^{a}
C14:0	1.26 ± 0.01^{b}	1.19 ± 0.09^{a}	1.24 ±0.06^{ab}
C16:0	25.05 ± 1.01^{a}	24.27 ± 0.53^{a}	28.05 ±0.15^{b}
C18:0	5.61 ± 0.47^{a}	5.49 ±0.33^{a}	5.42 ± 0.13^{a}
C16:1	5.00 ± 0.20^{b}	4.64 ± 0.28^{b}	4.03 ± 0.26^{b}
C18:1	38.87 ± 0.42^{a}	37.44 ± 1.09^{b}	38.94 ±0.1^{b}
C20:2	0.31 ± 0.29^{a}	0.16 ± 0.19^{a}	0.17 ± 0.26^{a}
C18:2 n-6	17.0 ± 0.18^{a}	16.48 ± 1.02^{a}	19.73 ± 0.43^{b}
C18:3 n-6	1.29 ± 0.65^{a}	1.09 ± 1.03^{a}	1.85 ± 1.18^{a}
C20:3 n-3	2.56 ± 0.19^{a}	2.61 ± 0.15^{a}	2.35 ± 0.29^{b}
C20:5 (n3) EPA	0.14 ± 0.05^{b}	0.12 ± 0.07^{b}	0.09 ± 0.09^{b}
C22:6 (n3) DHA	0.20 ± 0.05^{c}	0.09 ± 0.05^{b}	0.08 ± 0.05^{a}
∑SFA	37.64 ± 0.64^{ab}	35.48 ± 1.13^{a}	40.74 ± 2.73^{b}
∑MUFA	44.76 ± 0.87^{b}	42.16 ± 1.13^{a}	42.86 ± 0.85^{ab}
∑PUFA	21.91 ± 0.41^{a}	21.43 ± 0.94^{a}	25.27 ± 0.23^{b}
PUFA/SAFA	0.58 ± 0.02^{a}	0.62 ± 0.05^{a}	0.602 ± 0.03^{a}
∑ n-6	18.95 ± 0.34^{a}	18.58 ± 0.89^{a}	22.77 ± 0.59^{b}
∑ n-3	2.96 ± 0.21^{a}	2.87 ± 0.17^{a}	2.86 ± 0.3^{a}
n-6/n-3 ratio	6.41 ± 0.45^{a}	6.47 ± 0.45^{a}	9.17 ± 1.18^{b}

Within a row values with different letters are significantly different ($p<0.05$).

the most abundant omega-6 fatty acid and α- linoleic acid (C 18: 3n-3) as the most abundant omega-3 fatty acid. The SFA was dominated by palmitic acid (C 16: 0) and stearic acid (C18: 0). Results showed that the SFA of the raw sample slightly decreased during SHS cooking. However, this reduction was insignificant ($P<0.05$). Similar findings were observed in the study of Hosseini *et al.* (2014). They noted that baking of kutum roach had no impact on total SFA. While, the deep frying sample showed significant ($P>0.05$) increase in SFA due to the increase in (C16:0) during frying, this might be attributed to the exchange in fatty acid during frying between the sample and the frying oil (Ramírez *et al.*, 2005). The SHS and deep frying cooking did not affect the total MUFA of chicken sausage. Though C18:1 shows significant reduction during SHS cooking, it increased after frying. This increase may be related to the fatty acid composition of frying oil (Hosseini *et al.*, 2014). Compared to the raw sample, the PUFA showed insignificant ($p>0.05$) reduction during SHS cooking. However, the deep frying process increased the proportion of the PUFA. This increase in PUFA related to the increase in the (C18:2 n-6) n-6 fatty acid. This could be explained by the oil uptake during frying, which could have affected the composition of the fatty acid of the fried sample. Weber *et al*. (2008) showed that frying in soy oil resulted in a higher increase of n-6 content compared with canola oil and hydrogenated vegetable oil due to the higher content of n-6 in soy oil. The n-3 fatty acid showed insignificant effect during SHS cooking. On the contrary, its value tends to decrease during the frying process. Ramírez *et al.* (2005) demonstrated microwave and baking cooking had no influence on the n-3 and n-6 fatty acid content. Weber *et al.* (2008) reported that frying in hydrogenated vegetable oil resulted in a significant reduction in the n-3 content. The changes in the fatty acid profile food during cooking are a consequence of the water loss and the thermal treatment caused by these processes. The fried samples showed great changes in the fatty acid profile when compared to the raw samples,

Table 3. Amino acid composition (%) of raw, SHS-cooked and deep fried- cooked chicken sausages

Amino Acid %	Raw	Superheated Steam	Deep frying
Hydroxyproline	0.72±0.05^{b}	0.55±0.06^{a}	0.55±0.05^{a}
Aspartic acid	2.77±0.23^{a}	3.31±0.08^{b}	2.95±0.21^{ab}
Serine	3.35±0.16^{a}	3.17±0.11^{a}	3.23±0.07^{a}
Glutamic acid	5.18±0.02^{a}	5.63±0.18^{a}	5.27±0.24^{b}
Glycine	5.88±0.10^{ab}	5.69±0.01^{a}	6.40±0.51^{b}
Histidine	1.97±0.02^{a}	1.88±0.03^{b}	1.86±0.03^{b}
Arginine	4.40±0.14^{b}	4.14±0.10^{a}	4.40±0.08^{b}
Threonine	4.55±0.10^{b}	4.31±0.12^{a}	4.53±0.08^{b}
Alanine	6.91±0.24^{a}	6.67±0.01^{a}	6.73±0.17^{a}
Proline	6.37±0.21^{a}	7.03±0.36^{b}	6.62±0.20^{b}
Cystine	0.04±0.01^{a}	0.03±0.01^{a}	0.03±0.01^{a}
Tyrosine	1.91±0.08^{a}	1.97±0.05^{a}	1.83±0.06^{a}
Valine	5.84±1.02^{a}	8.17±0.10^{b}	8.12±0.09^{b}
Methionine	2.44±0.02^{a}	2.42±0.06^{a}	2.46±0.10^{a}
Lysine	4.12±0.30^{a}	4.03±0.14^{a}	3.86±0.24^{a}
Isoleucine	9.03±0.08^{a}	8.98±0.11^{a}	9.02±0.23^{a}
Leucine	15.67±0.10^{a}	15.63±0.24^{a}	15.42±0.05^{a}
Phenylalanine	9.36±0.24^{b}	9.07±0.06^{ab}	8.88±0.24^{ab}
Total Amino Acid	90.52±0.93^{a}	92.69±0.21^{b}	92.15±0.5^{b}

Values in the same row followed by a different letter are significantly deferent ($P < 0.05$).

possibly due to simultaneous moisture loss and oil absorption occurring during processing. In addition, these changes mainly rely on the composition of the frying oil and were not identical for the different fatty acids because some of the fatty acids increased, while the others decreased (Garcıa-Arias *et al.*, 2003). Recently, nutritionists have concentrated on the ratio of ω-6/ω-3 for PUFA/ SFA in the human diet due to its risk factor in cancer and coronary heart disease. In accordance with WHO recommendations; the ω-6/ω-3 ratio should not be higher than 5:1 in the total human diet (Vujković *et al*., 1999). Further, the ratio of of PUFA/ SFA should be more than 0.45 (HMSO, 1994). With reference to our results, it was found that the ratio of ω-6/ω-3 ranged from 6.41 in raw samples to 9.17 in fried samples. Thus, according to the ω-6/ω-3 ratio, SHS chicken sausage had better health properties compared to fried samples. The PUFA/ SFA ratio ranged from 0.58 to 0.62, which was over the minimum recommended value.

Amino acids composition

The composition of the amino acid in chicken sausage is represented in Table 3. The main amino acids were found to be leucine, phenylalanine, isoleucine, and alanine. Whereas, the less abundant amino ones were cystine and hydroxyproline. In this study, heat treatment resulted in significant ($p< 0.05$) changes in some amino acids. From raw to cooked samples, the significant changes were observed for aspartic acid, glutamic acid, histidine, arginine, threonine, and proline.

It has been reported that the alteration in amino acid composition mainly rely on the processing treatments and the investigated species (Kmiecik *et al*., 2010). During heating, there were significant losses in hydroxyproline, histidine, arginine, glycine, and theornine. The losses in amino acid composition might be attributed to the denaturation of the protein and the Millard reaction that happened during heating treatment Lisiewska *et al.*, 2008; Korus, 2012). Wu and Mao (2008) reported that the histidine was lost during processing and confirmed that this amino acid is due to the heating treatment, and the losses in lysine could be attributed to the Millard reaction that occurred during processing. Lisiewska *et al.* (2008) mentioned that the destruction in amino acids composition could be attributed to the reaction between side chains of some protein-bound amino acids with each other or with other molecules present in the food. On the other hand, it could be seen from Table 3, that there were significant increases in the proportion of aspartic acid, glutamic acid, glycine, and valine after cooking. The increase in amino acid contents is a consequence of water loss during the heating process (Barampama and Simard, 1995). The total amino acid composition for the raw sample was about (90.52%) and exhibited a significant increase to about (92.69%) and (92.15%) for SHS and deep frying samples, respectively (Table 2). Similar findings were observed in the studies of Nurhan, (2007) and Wu and Mao, (2008) in which they found

that there was an increase in the total amino acids after processing and concluded that the heating process does not induce losses in the amino acids.

Conclusion

The influence of SHS oven and deep frying cooking methods on the proximate composition, fatty acid composition, and amino acid composition were investigated. The results showed that there was a gradual decrease in moisture content after cooking. The protein and ash content exhibited a significant increase after cooking. The total fat content showed insignificant reduction during SHS cooking. However, the deep frying cooking process showed an increase in fat content due to the fat absorption, which has an adverse impact on health. The SFA, MUFA, and PFUA were marginally influenced by SHS cooking. However, the SFA and the PUFA were increased during the deep frying process; while it had no impact on the MUFA. The deep frying increased the n-6 of PUFA that had a negative effect especially on the ratio of n-6/n-3. The amino acid composition significantly increased after treatment, but it showed insignificant difference between the SHS and deep frying processes. Finally, from the nutritional point of view it could be concluded that the application of SHS oven for cooking food had more beneficial properties. It had lower fat, SFA, and n-6/n-3 ratio that have a positive impact on health such as lowering serum cholesterol levels compared with deep frying cooking. Also, the SHS cooking could improve the amino acids content in the sample. The present study provides possible application of SHS oven as a healthy technique for cooking food compared with the deep frying process.

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