Effect of conventional and pressure frying on lipids and fatty acid composition of fried chicken and oil

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Abstract Lipid class and fatty acid profile of pressure fried (PF) and conventionally fried (CF) chicken and medium of frying were evaluated. Depending on the frying cycle, neutral lipid (NL) content of PF chicken varied from 75–86% as compared to that of CF (84–90%). Similarly, glycolipid (GL) content varied from 11–21% in PF and from 9–12% in case of CF. Phospholipid (PL) was the least among lipid classes in both the products. The fresh frying medium (oil before frying cycle started), NL, GL and PL were 89, 10 and 0.33%, respectively. After the frying cycles were over, NL content of oil used for CF decreased to 82% and GL content increased from 10 to 17%. There was no significant difference ($p \geq 0.05$) between the contents of lipid classes of oil used for PF or CF. Fried chicken and frying medium had higher concentration of linoleic acid and oleic acid irrespective of the frying cycle or frying method. PF chicken had moisture content in the range of 56–58% and total fat was 14% whereas in case of CF chicken it ranged from 49–52% and 18% respectively. TBA and FFA values of CF chicken and oil on repeated frying were higher ($p \leq 0.05$) than PF. In comparison to conventional frying, pressure frying resulted in relatively tender and juicier product presumably due to better retention of moisture ($p \leq 0.05$) and low oil uptake.

Keywords Fried chicken · Pressure frying · Conventional frying · Fatty acid composition · Thio barbituric acid · Lipid class

Introduction

The past few decades have seen increased consumption of poultry meat and this increased popularity is mainly due to their nutritional characteristics - especially relatively high levels of polyunsaturated fatty acids (PUFA) in chicken lipids - which is considered as a positive and healthy aspect by consumers (Bonoli et al 2006). The lack of PUFA in human diet might lead to physiological disorders like insufficient growth, skin alterations, lessening of muscular tone, metabolic alterations, and greater susceptibility to infections. Hence, supplementation of these fatty acids through diet becomes all the more relevant. Further, frying is a common and popular process, often utilized in the food industry due to significant sales of vast quantity of fried products. Frying modifies food properties by inducing water loss, by stimulating thermo-oxidation reactions, changing the color of the product to brown and by modifying the lipid profile (Ramirez et al 2004). Deep-fat frying is one of the oldest and most popular thermal processing techniques used for the preparation of various food products including meat, fish and poultry. Frying has gained its popularity because it generates flavourful products having crispy exteriors and moist and juicy interiors, but on the contrary product absorbs more fat. Pressure frying is used by quality restaurants, convenience stores, delis, supermarkets, schools, hospitals, and other institutional and commercial food service operations to cook delicious fried foods. It is similar to conventional open frying in which foods are heated to cooking temperature in a well filled with cooking oil, except that in a pressure fryer the food is cooked under controlled pressure in a sealed vessel. Pressure frying is known to yield tender and juicier products than atmospheric frying (Rao and Delaney 1995; Mallikarjunan et al 1997). By

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appropriately selecting temperature and pressure in deep fat frying, consumer desired characteristics can be obtained in the end product (Rao and Delaney 1995).

Lipid oxidation is much faster in cooked meat than in fresh meat because cooking accelerates oxidation processes as a result of the high temperatures reached during processing (Kingston et al 1998). The frying medium, usually fats/oils from different sources, have varying fatty acid compositions. The frying medium mainly acts as a heat transfer medium during frying. However, it also becomes an important ingredient of the fried food as the oil penetrates in to the fried food replacing moisture (Moreiras-Varela et al 1988). This is the reason why the fried food characteristics are modified apart from modifications in aroma and lipid profile (Sanchez-Muniz et al 1992). Some authors have reported that the retention of frying medium is directly related to frying time wherein they have reported an increase in the oil content, decrease in moisture contents of the product with an increase in frying time (Esturk et al 2000). This clearly emphasizes the fact that any process that employs high temperature for a shorter time would yield a better product quality.

Against this background, the main objective of the present work was to comparatively evaluate the changes in lipid characteristics and fatty acid profiles of products and frying medium as influenced by two different frying methods viz., pressure frying and conventional deep fat frying.

Materials and methods

Fried chicken processing & formulation Freshly dressed broiler chickens (without skin; 24 nos.) were procured from the local market, brought to the laboratory and washed with potable water. All subcutaneous/trimmable fat, external fascia and all adhering connective tissues were removed from the muscles. The meat was then cut into chunks of 4–8 cm sizes. The binders and all the spices and condiments as mentioned in formulation were procured from local market to prepare the coating mix. The meat chunks were then coated with the coating mix and left for marination at ambient temperature for 2 h.

The coating mix used for marination was prepared by thoroughly mixing corn flour (25.55%), salt (17.89%), *lal mirch* (red chilli) powder (17.03%), *kashmiri mirch* (red chilli) powder (12.77%), garlic powder (10.22%), ginger powder (5.11%), maltodextrin (3.41%), cumin powder (2.55%), black pepper powder (1.70%), cinnamon (1.11%), clove (0.85%), citric acid (0.85%), and turmeric powder (0.42%). For marination, 10% (w/w chicken) of this coating mix was made into a paste by dispersing in 4% water (w/w of chicken). The paste was applied onto the

meat chunks and coated chunks were kept for marination (Rashmi et al 2010)

Frying protocols—pressure frying v/s conventional frying In case of both the frying methods, refined sunflower oil was used as the frying medium. Twelve batches of battered meat chunks were fried in the frying medium, with each batch containing 1 ± 0.1 kg battered chicken. In the case of pressure frying, Broaster Pressure fryer (The Broaster Co. Model 1600, Beloit, Wisconsin, USA) was used. In each batch of pressure frying, 1 Kg battered meat chunks were fried at a temperature of 160 °C and 0.84 Kg/cm^2 pressure for 4 minutes. At the end of the frying, lid was opened and fried meat was removed by draining excess fat. The PF meat was cooled and was taken for further quality study. In contrast, conventional frying involved heating the oil to a temperature of 170 °C, after which battered meat chunks were dropped in to the frying medium and fried for 7.5 minutes. During this frying, meat was stirred well and reversed for uniform cooking and at the end of frying the meat was removed from oil by draining excess fat into the frying medium itself. Twelve batches of frying were carried out using the same frying medium. At the end of 1st, 6th and 12th frying cycles, samples of PF and CF chickens were analyzed for their lipid profile and fatty acid composition. The lipid profile and fatty acid composition served as the control. Similarly, samples of frying medium (oil) were also drawn at the end of 1st, 6th and 12th frying cycles and their lipid profile/fatty acid composition compared to that of fresh oil which served as control. Both the chicken and oil samples were analyzed for lipid oxidation parameters, lipid class composition and fatty acid composition.

Lipid profile and fatty acid composition

Extraction of lipids Lipids from all the chicken samples were extracted by the method of Bligh and Dyer (1959). Briefly, the samples (~100 g) were minced and homogenized using a homogenizer (Polytron PT3100, Kinematica AG, Switzerland) in a solvent mixture of chloroform: methanol (2:1), kept overnight and filtered. The lipid extract was dried over anhydrous sodium sulphate to remove traces of moisture to get total lipid extract and evaporated to dryness using rotary flash evaporator (Superfit, Bangalore, India).

Lipid oxidation parameters About 100 g of fried meat from each batch was minced and blended before using it for further analysis. Free fatty acid (FFA) was determined as per AOAC (2007) procedure. For determination of FFA, an aliquot of 10 g blended sample was mixed with anhydrous

Na_2SO_4 (100 g) and fat was extracted in 100 ml solvent mixture (chloroform: methanol=2:1) and filtered. The chloroform-methanol extract was then washed three times with four to five volumes of distilled water in a separating funnel to remove non fatty acid components contributed by the formulation ingredients. The FFA as percentage of oleic acid was estimated in the washed chloroform-methanol extract by the method of AOAC (2007). Thiobarbituric acid (TBA) values of each sample were determined by the method of (Tarladgis et al 1960).

Separation and quantification of lipid classes Total lipids extracted from different samples (frying medium and fried chicken at 0, 1st, 6th and 12th frying cycles) were employed for separating and quantifying different lipid classes viz., neutral lipids (NL), glycolipids (GL) and phospholipids (PL). The raw meat and fresh oil formed the control or the samples at 0 frying cycle. Lipid class separation was accomplished by column chromatography by employing the methods as reported earlier (Bhaskar et al 2004). Briefly, 1–2 gram of TL was placed on to silica gel column (silica gel at 1:30 w/w of lipid) and successively eluted with chloroform (1:100 w/v of lipid), acetone-methanol (9:1 w/v: 1:150 w/v of lipids) and methanol (1:100 w/v of lipid) to get NL, GL and PL fractions respectively. The solvents in each fraction were then evaporated to dryness using rotary flash evaporator (Superfit, Bangalore, India) and each class was expressed as percentage of total lipids (TL).

Fatty acid composition of lipid extracts The lipids were transmethyalated using 2 M methanolic sodium hydroxide followed by 2 M methanolic hydrochloric acid to obtain fatty acid methyl esters (FAMES). FAMES were analyzed by gas chromatography (Shimadzu GC 2014, Japan) for identifying the individual fatty acids. Briefly, FAMES dissolved in hexane were analyzed using OmegawaxTM 320 fused silica capillary column (30 m×0.32 mm×0.25 μm). The conditions used for GC analysis was injection temperature of 250 °C, detector (FID) temperature of 260 °C and column temperature of 200 °C for 60 mins. The peaks were identified by comparing with authentic standards. Peak areas above 1% of total were only considered for calculation of % composition of fatty acids.

Sensory evaluation Chicken samples (1st, 6th, 12th PF and CF) were subjected to sensory evaluation for juiciness and overall acceptability. The sensory evaluation was carried out by 10 in-house trained panelists using 9 point Hedonic scale (Andres et al 2006). The panel included 5 male and 5 female panelists aged between 25 and 45 years. Samples for evaluation were served separately in a well lit room on coded white enamel plates. Water was provided to rinse

their mouths after consumption of each sample. The mean score for each attribute is reported. The samples were served to panelists at 55 ± 5 °C for evaluation.

Statistical analysis The mean of all parameters were examined for significance ($p\leq0.05$) by analysis of variance (ANOVA) and mean separation and the significant effect was tested by Duncan's Multiple Range Test using software STATISTICA (Statsoft 1999).

Results and discussion

Effect of frying methods on quality characteristics of fried chicken The chicken used for frying studies had moisture and fat content of $75.0\pm4.85\%$ and $16.3\pm0.64\%$ respectively (Table 1). PF chicken had moisture content ranging from 56–58% and CF chicken had 49–52% (Table 1), depending on the frying cycle. Sensory evaluation studies indicated that frying cycles had effect on juiciness and overall acceptability of the product. Sensory score of 1st PF product for juiciness and overall acceptability was around 8.3 ± 0.51 and 8.4 ± 0.52 respectively which slowly decreased to 7.5 ± 0.37 and 7.9 ± 0.34 at the end of 12th frying on a 9-point hedonic scale. The corresponding values for conventional frying were lower, viz., 7.0 ± 0.28 & 7.8 ± 0.61 in 1st frying, 6.5 ± 0.55 & 6.8 ± 0.61 in 12th frying respectively. Pressure frying is known to yield more tender and juicier products—a distinct difference can be felt in comparison to conventional-fried foods, which are often greasy on the outside and dry on the inside (Mallikarjunan et al 1997; Rao and Delaney 1995). By appropriately selecting temperature and pressure in deep-fat frying, consumer desired characteristics can be obtained in the end product (Rao and Delaney 1995).

Effect of frying methods on characteristics of frying medium and lipids of products The total lipid (TL) content (dry weight basis) of raw meat was $16.3\pm0.64\%$ (Table 1). The analysis of different batches of PF and CF of chicken revealed that the TL content (g per 100 g dry weight basis; dwb) varied from 32–34% and 35–41% respectively. The increase in pressure reduced oil uptake by the fried products (Innawong et al 2005). The TL content drastically increased from 16–40% since TL of fried chicken was more than that of raw meat. Among different frying cycles analyzed, lowest TL content of conventional frying (36%) was found in 1st frying and highest in 12th frying (41%). It has also been found that as frying time increased, oil content in the product also increased by replacing moisture. (Esturk et al 2000). In case of pressure frying, there was no marked difference in the TL content of 1st, 6th and 12th frying.

Table 1 Quality characteristics of pressure fried and conventional fried chicken and oil

Parameter	Raw Meat	Pressure Frying			Conventional Frying		
		FC-1	FC-6	FC-12	FC-1	FC-6	FC-12
Raw Meat and Fried Chicken Samples							
Moisture, %	75.0±4.85 ^a	56.7±2.4 ^b	57.8±2.4 ^b	58.1±2.61 ^b	49.8±2.37 ^c	50.5±3.01 ^c	52.3±3.66 ^d
Total fat, %	16.3±0.64 ^a	32.4±1.54 ^b	33.5±1.61 ^b	33.9±1.74 ^b	35.9±1.42 ^c	37.9±3.05 ^d	41.2±3.46 ^e
TBA, mg malonaldehyde/Kg	0.17±0.01 ^a	0.34±0.02 ^b	0.39±0.02 ^b	0.57±0.02 ^c	0.50±0.02 ^c	0.51±0.03 ^c	0.56±0.03 ^c
FFA, % oleic acid	0.54±0.02 ^a	0.55±0.02 ^a	0.58±0.02 ^a	0.67±0.04 ^a	2.30±0.12 ^b	3.40±0.19 ^c	4.90±0.25 ^d
Sensory scores of fried chicken							
Juiciness	–	8.3±0.51 ^a	7.9±0.42 ^a	7.5±0.37 ^a	7.0±0.28 ^b	6.9±0.54 ^b	6.5±0.55 ^b
Overall acceptability	–	8.4±0.52 ^a	8.1±0.44 ^a	7.9±0.34 ^b	7.8±0.61 ^b	7.5±0.67 ^b	6.8±0.61 ^c
Fresh Oil and Fried Oil Samples							
TBA, mg malonaldehyde/Kg	0.02±0.001 ^a	0.17±0.009 ^b	0.21±0.012 ^b	0.31±0.018 ^c	0.34±0.014 ^c	0.38±0.018 ^c	0.42±0.022 ^d
FFA, % oleic acid	0.03±0.003 ^a	0.05±0.003 ^a	0.06±0.003 ^b	0.11±0.008 ^c	0.14±0.009 ^c	0.27±0.012 ^d	0.45±0.023 ^e

FC - Frying Cycle. ($n=4$). Means with different letters in a row differ significantly ($p\leq 0.05$)

Oxidative rancidity measured by TBA values (mg malonaldehyde/kg sample) of raw meat was 0.17 ± 0.01 and increased ($p\geq 0.05$) to 0.34 ± 0.02 in 1st PF chicken. Newburg and Concon (1980) and Pikul et al (1984) reported that increase in TBA values in poultry meat is due to the cooking process. On further frying, it increased to 0.39 ± 0.02 in 6th frying and 0.57 ± 0.02 in 12th frying. In contrast, 1st frying of CF chicken had 0.50 ± 0.02 , 0.51 ± 0.03 in 6th frying and 0.56 ± 0.03 in 12th frying. TBA values of CF chicken were higher ($p\leq 0.05$) than PF chicken. PF chicken had lower FFA values (as % oleic acid), 0.55 ± 0.02 in 1st frying, 0.58 ± 0.02 in 6th frying and 0.67 ± 0.04 in 12th frying (Table 1). In case of CF chicken 2.30 ± 0.12 in 1st frying, 3.40 ± 0.19 in 6th frying and gradually increased ($p\leq 0.05$) to 4.90 ± 0.25 in 12th frying. High FFA values (as oleic acid) of 13–15% in matured hams (Martin et al 2000) and 14–17% in buffalo meat burger (Modi et al 2003) were also reported. Increased levels of FFA, however, have no toxicological effect

(Camire et al 1990). Fritsch (1981) also reported that the products of hydrolysis of oils/fats have no adverse effect on the nutritional quality of foods.

Oxidative rancidity measured by TBA values of fresh oil was 0.02 ± 0.001 and increased to 0.17 ± 0.009 in 1st PF oil. On repeated frying, it increased ($p\leq 0.05$) to 0.21 ± 0.012 in 6th frying and 0.31 ± 0.018 in 12th frying. In contrast, 1st frying of CF oil had 0.34 ± 0.014 and further increased ($p\leq 0.05$) to 0.38 ± 0.018 in 6th frying, 0.42 ± 0.022 in 12th frying. PF oil had lower FFA values (as % oleic acid). FFA of fresh oil was found to be 0.03 ± 0.003 which was similar to earlier reports by Orthoefer and Cooper (1996) which said fresh frying oil should have FFAs less than 0.05%. 1st PF oil had 0.05 ± 0.003 , 6th PF oil had 0.06 ± 0.003 and gradually increased to 0.11 ± 0.008 in 12th PF oil. In contrast CF oil had higher ($p\leq 0.05$) values than PF oil, 0.14 ± 0.009 in 1st frying, 0.27 ± 0.012 in 6th frying and 0.45 ± 0.023 in 12th frying. Che Man et al (1999) observed an increase in the percentage of FFAs for 5 days of potato chips frying and pointed out a promoting influence of water

Fig. 1 Lipid class of pressure fried (PF) and conventional fried (CF) chicken. ($n=4$) **Fig. 2** Lipid class of pressure fried (PF) and conventional fried (CF) oil. ($n=4$)

Table 2 Fatty acid composition (%) of total lipids (TL) of raw meat and frying cycles (1st, 6th & 12th) of pressure fried and conventional fried chicken

Fatty Acid	Raw meat	Pressure Frying			Conventional Frying		
		FC-1	FC-6	FC-12	FC-1	FC-6	FC-12
C16:0	25.1±1.87	15.7±1.02	13.3±0.94	12.9±0.91	12.9±0.92	13.0±0.88	11.5±0.68
C16:1	7.1±0.52	2.9±0.12	2.4±0.14	2.0±0.10	2.0±0.11	2.2±0.13	2.5±0.15
C18:0	6.4±0.51	5.0±0.37	4.2±0.35	4.8±0.38	4.8±0.37	4.5±0.38	5.0±0.46
C18:1n-9	37.7±0.28	32.5±0.26	32.9±0.28	33.0±0.27	33.0±0.29	32.5±0.26	33.3±0.24
C18:2	19.4±1.18	41.7±3.87	47.3±34.02	47.4±4.06	47.4±4.01	47.8±3.89	45.0±2.87
ΣSFA	31.5±2.77	20.6±1.84	17.5±1.24	17.7±1.31	17.7±1.18	17.5±1.17	16.5±1.21
ΣUSFA	64.2±5.84	77.0±6.86	82.5±7.68	82.3±7.75	82.3±7.51	82.5±7.58	80.7±7.04
Unidentified	4.3±0.37	2.3±0.18	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	2.8±0.20

FC - Frying Cycle, SFA - Saturated Fatty Acids, USFA - Unsaturated Fatty Acids

from the fried product to the frying medium on the process of lipid hydrolysis.

The lipid class of chicken is shown in Fig. 1. NL content was found to be the highest i.e. 61%, GL being 27% and PL being the least 12% in raw meat. On frying, the NL content of PF and CF chicken increased whereas GL and PL content decreased. In case of PF chicken, NL content increased (74.8–84.5%) on repeated frying. On contrary, GL content reduced from 21.1% on 1st frying to 11.3% on 12th frying. There was no change in the PL content.

The lipid class of oil is shown in Fig. 2. NL content of fresh oil was found to be the highest 90%, GL being 10% and PL being the least 0.33%. The content of NL (% TL) of 1st PF and CF oil was found to be 84% and 86% respectively. PL content of 1st PF and CF oil was found to be 0.29 to 4.22% respectively. In different cycles of pressure frying, there was no change in PL content, whereas in conventional frying, it was 4.22% in 1st frying and reduced to 0.79% in 12th frying.

Fatty acid compositions of TL of chicken are presented in Table 2. As reported earlier (Gray and Crackel 1992), the most abundant FA in chicken was oleic acid (C18:1)

followed by palmitic (C16:0), linoleic (C18:2) and stearic acids (C18:0), which represented about the 90% of total fatty acids. In raw meat, oleic acid (37.7%) was the dominant fatty acid followed by palmitic acid (25.1%), linoleic acid (19.4%), palmitoleic acid (C16:1) (7.1%) and stearic acid (6.4%). Unsaturated fatty acids (64.2%) were predominant when compared to saturated fatty acids (31.5%). On frying, there was alteration in the fatty acid profile of the meat since frying involves an exchange of fatty acids between the fat in the meat and the culinary fat used (Sanchez-Muniz et al 1992). There was a significant increase ($p \leq 0.05$) in linoleic acid content from 1st PF chicken (41.7%) to 12th PF chicken (47.3%) whereas palmitic acid content reduced from 1st PF chicken (15.7%) to 12th PF (12.94%). The changes in case of other fatty acid were negligible. Conventional frying also followed a similar pattern.

Fatty acid composition of the total lipid extract of different types and various frying cycles of oil as shown in Table 3 indicates the dominance of poly unsaturated fatty acids in all the samples analyzed. In case of fresh oil, linoleic acid (maximum 60.8%) was found in higher

Table 3 Fatty acid composition (%) of total lipids (TL) of fresh oil and frying cycles (1st, 6th & 12th) of pressure fried and conventional fried oil

Fatty Acid	Fresh oil	Pressure Frying			Conventional Frying		
		FC-1	FC-6	FC-12	FC-1	FC-6	FC-12
C16:0	7.2±0.68	6.5±0.55	6.8±0.57	6.9±0.61	6.7±0.54	7.7±0.65	8.8±0.76
C18:0	3.9±0.27	3.6±0.28	3.7±0.29	3.8±0.28	4.0±0.37	4.1±0.39	4.3±0.37
C18:1n-9	27.5±0.25	27.3±0.24	27.5±0.26	26.6±0.21	27.2±0.19	28.1±0.21	29.2±0.21
C18:2	60.8±5.85	62.0±5.91	62.0±5.87	58.5±4.79	61.0±5.64	59.1±4.95	56.3±5.02
ΣSFA	11.1±0.95	10.1±0.87	10.6±0.91	10.7±0.94	10.8±0.89	11.8±1.06	13.1±1.25
ΣUSFA	88.3±8.07	89.3±8.24	89.4±8.16	85.1±7.84	88.2±7.99	87.2±7.92	85.5±7.96
Unidentified	0.6±0.05	0.6±0.05	0.0±0.0	4.3±0.36	1.1±0.09	1.0±0.08	1.4±0.12

FC - Frying Cycle, SFA - Saturated Fatty Acids, USFA - Unsaturated Fatty Acids

concentration followed by oleic acid (maximum 27.5%). However, palmitic acid (7.2%) and stearic acid (3.9%) was found in lower concentration. Palmitoleic acid was absent in oil. High amount of linoleic acid was observed in all the fried oils as well. On continuous frying, there is a slight decrease in linoleic acid from 1st PF oil (62%) to 12th frying (58.4%). Similar case was found in CF oil showing decrease in the amount of linoleic acid from 1st frying (61%) to 6th (59.1%) and to 12th (56.3%). In CF oil, palmitic acid, stearic acid and oleic acid have increased from 6.74–8.83, 4–4.27 and 27.2–29.18% respectively. Unsaturated fatty acids were dominant constituting around 89%. This signifies that during frying there was no significant change in the fatty acid profile.

Conclusion

In conclusion, pressure frying yields a fried product with better quality characteristics mainly due to better moisture retention, reduced oil uptake, higher juiciness and overall acceptability, in comparison to conventional frying. Neutral lipids constituted the major lipid class in total lipids of different samples as well as frying oil. However, both the processes do not significantly alter the lipid characteristics and fatty acid composition. Fatty acid composition of frying medium as well as fried product indicates the dominance of linoleic acid and oleic acid. The dominance of unsaturated fatty acids in the fried product possibly maximizes the health benefits afforded by these fatty acids.

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