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Research Article

Evaluation of biochemical, fatty acid and amino acid composition and nutritional indices of salted tilapia from selected markets in Ghana

Christian Larbi Ayisi*, Andrews Apraku and Grace Debra

University for Development Studies, Faculty of Natural Resources and Environment, Department of Fisheries and Aquatic Resources Management, Tamale, Ghana

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***CORRESPONDENCE**
calaqua@126.com

ABSTRACT

The present study was aimed to establish the nutritional quality of salted tilapia from selected open markets across Ghana. Samples were selected from six markets namely Kpando, Akatey, Dambai, Ejisu, Makola and Kumasi Central across four regions (Eastern, Greater Accra, Volta and Ashanti). Fatty acid composition, Amino acids and biochemical composition were analyzed in triplicates including Salt content, water salt phase, and nutritional indices thrombogenic index, atherogenic index and polyene index were measured Protein and moisture content were higher in fish from Dambai (respectively) whiles a high fat content (<8%) was obtained in salted fish from Akatey. Ash content was observed to be influenced by size fish which related to those obtained from Makola market. On measuring the freshness of fish, the pH was below 7 across markets with those from Kumasi Central market recording the highest (6.83±0.23). The same was obtained in salt and percentage water content (%WPS) (21.57±2.46 and 15.38±1.83 respectively). Abundance of oleic and palmitoleic acid were obtained across all markets with the highest in those obtained from Kpando market including n3/n6 fatty acids, although EPA recorded was lower. High polyene and peroxidase index were obtained in fish from Makola market whereas those from Ejisu market recorded the highest thrombogenic and atherogenic indexes. Amino acid contents were not influenced irrespective of markets except those from Akatey. The results of this study indicate salted tilapia from the selected markets are of high quality and are highly recommended as a good source of protein.

INTRODUCTION

Among the countries in Sub-Saharan Africa, Ghana is reported to be the leading producer of tilapia. Ghana is also the leading consumer of tilapia among the Sub-Saharan African Countries (Lumpur, 2015). According to Asiedu *et al*. (2015) Ghanaians have a strong taste of preference for Nile tilapia. Fish is estimated to represent approximately 60% of average animal protein intake in Ghanaian diet with an average per-capita fish consumption estimated to be 21.7 kg in 2009 (Kassam, 2014). Salted tilapia, popularly known as "Koobi" is a delicacy in Ghana and highly consumed in many households.

Recent trends in global food production, processing, distribution and storage are creating an increasing demand for food safety research in order to ensure a safer global food supply (Hoque *et al*., 2016; Umar *et al.*, 2017; Manas *et al.*, 2017; Singh *et al.*, 2017). The image of fish quality among consumers is more often related to nutritional value and sensory properties of the flesh than other characteristics (Grigorakis, 2007).

Despite the importance of salted tilapia to the nutritional needs of Ghanaians, studies to ascertain its nutritional status has not been studied. To our best of knowledge, the nutritional composition of tilapia and other fish products has not been studied in Ghana. The purpose of this present study is to assess the nutritional content of salted tilapia (Koobi) in Ghana.

MATERIALS AND METHODS

Study location and samples collection

In order to have a wide coverage, samples were taken from four Regions in Ghana namely Eastern, Ashanti, Volta and Greater Accra Regions**.** The Regions considered

for this study as well as the open markets are shown in table 1. Samples were collected from May to August, 2017.

Table 1: Sampling markets, size and mean weight of salted tilapia

Region	Name of Markets	Sample Size	Mean Weight (g)
Ashanti Region	Kumasi Central Market	30	78.28
	Ejisu Market	30	75.10
Eastern Region	Akatey	30	82.69
Volta Region	Kpando	30	70.49
	Dambai	30	89.73
Greater Accra	Makola	30	66.29

Chemical analysis

Assays of protein content

Samples were analyzed in triplicates for protein using the methods defined by AOAC (1996). Crude protein was determined using the Kjeldahl method with Kjeltec Auto 2300 Analyzer after digestion with concentrated H_2SO_4 (% DW).

Analyses of lipid content and fatty acid composition

Samples were grinded into powder for determination of lipid and fatty acid contents. Analysis of fatty acids in samples was performed as previously described in (Ayisi *et al.,* 2017). Chloroform-methanol in the ratio of 2:1 (V/V) was used to extract total lipids according to the (Folch *et al.,* 1957) method. 0.4 M KOH-methanol was used to prepare fatty acid methyl esters by transesterification. Individual fatty acids were detected by gas chromatograph (GC-7890A) with methyl heneicosanoate (C21:0) as an internal standard. Peak times of each sample were compared to that of the manufacturer to identify individual fatty acids. The percentages of the individual fatty acids were determined using peak areas. All measurements were performed in triplicates and the fatty acid contents expressed as % total FA.

PUFAs damage and health lipid indices

The polyene index (PI) was used as a measure of PUFA damage (Lubis and Buckle, 1990) whilst the thrombogenic index (TI) and atherogenic Index (IA) were used to assess the nutritional quality of the samples (Ulbricht and Southgate, 1991). These were calculated as follows: PI= ((C20:5 + C22:6)/C16:0)
Atherogenic Index (IA) = (C12:0 þ 4 (C14:0 þ C16:0))/(SumMUFAs + Sum PUFAs)
Thrombogenic Index (TI) = [(C14:0 + C16:0 + C18:0)/(0.5* Sum MUFAs + 0.5 Sum n6 PUFAs + 3* Sum n-3 PUFAs + (n-3/n-6))]
Peroxidation index = 0.025 x (% monoenoics) + 1 x (% dienoics) + 2 x (% trienoics) + 4 x (% tetraenoics) + 6 x (% pentaenoics) + 8 x (% hexaenoics) (Hulbert *et al.,* 2007).

Analyses of amino acid composition

Quantitative determination of amino acids was carried out at the College of Food Science and Technology, Shanghai Ocean University (Shanghai, China) following the principle of the Moore and Stein method (Moore and Stein, 1963). Protein samples were hydrolyzed into their constituent amino acids using a constant-boiling 6 N hydrochloric acid in an oven at 110 C for 24 h (Horwitz and Latimer, 2007). The amino acids were then analyzed in a Hitachi L-8800 Amino Acid Analyzer. The amino acid results are expressed in milligram amino acid per 100 g edible portion on fresh weight basis of the samples. The Leu/Ile ratios were calculated while the predicted protein efficiency ratio (P-PER) was determined using one of the equations developed by Alsmeyer et al. (1974), i.e. P-PER = 0.468 + 0.454 (Leu) 0.105 (Tyr).

Ash and moisture content analysis

The ash content was determined in burning oven-dried sample by muffle furnace at 550°C. Moisture content was determined by oven drying of 5 g of fish muscle at 105 C until a constant weight was obtained (AOAC, 1996).

Analysis of pH and salt content

The pH measurements were done with a digital pH-meter (Jenco pH meter, 6230 N, USA) by placing the electrode into the homogenized samples of 5 g fish flesh plus 10 mL distilled water. The level of salt was determined using a salt meter (SA287, Guangdong, China) after addition of 10 volumes of distilled water to each sample (Kanno *et al.,* 2012).

Water phase salt estimation

Moisture content was used to calculate %WPS (water phase salt) in the samples. WPS is the amount of salt in the product relative to the product's moisture and is obtained using the following calculation (Losikoff, 2008). %WPS = %salt/ [%salt + %moisture] x 100

Statistical analysis

All results are presented as mean ± standard error of the mean (SEM). Data were analyzed by one-way Analysis of Variances (ANOVA) to test the differences in samples from each sampling sites. Where significant differences were found ($P < 0.05$), Tukey's test was used to compare all parts of a column and to rank the groups. Statistical analyses were made using GraphPad Prism 5.

RESULTS AND DISCUSSION

Proximate composition of salted tilapia from study area

Protein content

The protein content of salted tilapia from the six markets is shown in Table 2. Proteins are among the most important macronutrients comprising human diet and play a wide range of physiological functions exerted by their components (building blocks) amino acids (Shaheen et al. 2016). The protein content of samples from the six markets were significantly different ($p<0.05$). It ranged from 36.20 to 45.15. The highest amount of protein content was recorded in samples from Dambai, whilst the lowest was recorded in samples from Makola.

Lipid content

The lipid content of salted tilapia from the six markets is shown in Table 2. The lipid content of samples was similar, irrespective of the sampling site. Total lipids ranged from 4.51 (Kpando) to 8.35 (Akatey). It is worth noting that salted tilapia from Akatey could be classified as high fat content fish (>8%) whilst others are classified as medium fat content fish (4-8%) based on the classification of Ackman, 1990.

Moisture content

The moisture content of salted tilapia from the six markets is shown in Table 2. Moisture content of salted tilapia from the six markets ranged from 36.20 to 45.15. Samples from Dambai were significantly higher ($p<0.05$) than samples from Makola but non-significantly higher ($p>0.05$) than samples from Kumasi Central market, Ejisu, Akatey and Kpando.

Ash content

The ash content of salted tilapia from the six markets is shown in Table 2. Ash content was significantly different among different sampling markets ($p<0.05$). Ash content ranged from 29.03(Dambai) to 47.95 (Makola). Kpando, Kumasi Central and Ejisu had ash content of 0.47, 39.71 and 37.84 respectively whilst Akatey had 32.76. Generally, ash is influenced by the size of the fish, with smaller sized fish having higher ash content. This could be attributed to the higher bone to flesh ratio in smaller sized fish as opposed to lower bone to flesh ratio in larger sized fish (Daramola et al. 2007). Our result supports this assertion as samples from Makola with smaller weight (66.29 g) recorded ash contents which was significantly higher than samples from Akatey and Dambai with bigger weights (82.69g and 89.3 g respectively).

Salt, pH and %WPS content of salted tilapia from study area.

Table 3 shows the Salt, pH and %WPS content of salted tilapia from the six markets. The mean pH ranged from 5.94 to 6.83. Samples collected from Kumasi Central were significantly ($p<0.05$) higher than those collected from Akatey, Kpando, Dambai and Makola. The freshness or spoilage of fish is determined using pH as an indicator (Binici and Kaya, 2017). Generally, fresh fish has a pH close to neutral. The pH content however increases as the quality (freshness) decreases (Latifa *et al.*, 2014). The pH recorded in samples across all study areas were slightly lower than 7 (neutral) which could suggest the samples were still in their fresh state and had not degraded.

Salt

There was a significant difference ($p<0.05$) in salt content of samples. Salt content ranged from 21.57 to 50.50. Samples collected from Kpando had higher mean salt contents compared to those sampled from Dambai, Ejisu and Kumasi Central market. The implication is that samples collected from Kpando are likely to possess higher amounts of inorganic matter/compounds as compared to the other samples.

Percent WPS

Percentage water salt values recorded ranged from 15.38 to 48.29. Samples from Kpando was significantly higher ($p<0.05$) than samples from Ejisu, Kumasi Central and Dambai but was similar to samples from Makola and Akatey. %WPS is a measure used to compare the amount of salt in fish to the moisture content of the same fish. This is a good indicator of preservation and food safety. Apart from samples from Kumasi Central which recorded %WPS of 15.38 which was below the recommendation of the FDA (USA), all other samples were higher than the recommended 20% which is not a good indication of the quality of the sated tilapia Kumasi Central.

Fatty acid composition

The fatty acid compositions of salted tilapia from the sampling markets are presented in Table 4. In all, twenty-four (24) individual fatty acids were identified in the samples. Saturated fatty acids (SFA) and mono unsaturated fatty acids (MUFA) recorded in this study were significantly different and ranged between 37.72 to 45.47 and 27.43 to 42.83 respectively. Samples from Makola recorded the least SFA and MUFA whilst samples from Ejisu and Dambai recorded the highest SFA and MUFA respectively.

Generally, Oleic acid (C18: 1n9) was the most abundant polyunsaturated fatty acid (12.16% to 27.53%) followed by palmitoleic acid (C16:1n7) (10.23% to 20.81%). Samples from Kpando recorded significantly higher levels of oleic acid. This was followed by samples from Dambai. The oleic acids from the two Markets were higher than those from Ejisu, Makola, Akatey and Kumasi Central Market. Huynh and Kitts (2009) reported that fish with higher levels of oleic acids had corresponding lower lipid contents. Our results agree to these reports as samples from Kpando (4.51) and Dambai (5.47) had the least lipid contents.

The ratios of n-3/n-6 and n-6/n-3 ranged from 0.56 to 2.02 and 0.49 to 1.68 respectively. Samples from Kpando recorded the highest and least mean values of both n-3/n-6 (2.06) and n-6/n-3 (0.49) respectively. The least n-3/n-6 ratio was however recorded in samples from Kumasi Central Market (0.59), whilst samples from Ejisu (1.68) recorded the highest n-6/n-3 ratio. Salted fish from Kumasi Central Market recorded an n-6/n-3 ratio of 1.66 whilst that of Ejisu was 1.68. Akatey, Kpando, Dambai and Makola recorded average n-6/n-3 ratio of 1.55, 0.49, 1.68 and 0.99 respectively.

The n-3/n-6 ratio index has been suggested for assessing the nutritional value of fish, and an increase in human dietary n-3/n-6 fatty acids helps in reducing cancer and cardiovascular risks (Piggott and Tucker, 1990). In this study, the n-3/n-6 ratio was generally not high. Despite the relatively lower amount of n-3/n-6 ratio, the amounts of n-6/n-3 ratio were lower in samples from all markets. Diets with n-6/n-3 ratios lower than 4.0 have been marked as desirable for consumption since it aids in the prevention of cardiovascular risk (Department of Health & Social

Security, 1984). Based on this, we can infer that salted tilapia from all the six markets are suitable for consumption.

Samples from Ejisu recorded the least n-3 PUFA (6.26) whilst the highest was recorded in samples from Makola (15.78). On the other hand, n-6 PUFA ranged between 5.50 (Kpando) to 19.40 (Makola). EPA ranged between 0.42 (Ejisu) to 0.90 (Central market) whilst DHA ranged between 1.37 (Ejisu) to 3.51 (Makola).

n-3 PUFA, specifically DHA and EPA have been reported to be essential to consumers. These fatty acids have beneficial effects on human health such as ability to prevent certain cancers such as colorectal cancer (Theodoratou *et al.,* 2007) and prostate cancer (Demark-Wahnefried *et al.,* 2001). In addition they are reported to suppress some autoimmune diseases such as lupus erythematous, psoriasis, multiple sclerosis and Crohn's disease (Simopoulos, 2002). Also, these fatty acids are essential since they reduce the risk of cardiovascular diseases (Calò *et al.,* 2005). According to the US Department of Agriculture, an average daily intake of EPA+DHA is 250 mg.

Whilst Frankel (1998) reported fish generally have EPA values ranging between 5-10% based on the lipid content, Pigott and Tucker (1987) reported an EPA content of fish in the range of 3.3 and 10.6%. The EPA content recorded in this study was very low with all samples recording an EPA content <1. Interestingly, there was no correlation between salt content, pH as well as % wps with EPA.

Foods with a ratio of PUFA/SFA less than 0.45 are considered undesirable to humans (Department of Health and Social Security Diet & cardiovascular disease, 1984) due to the ability of such foods to induce an increase in blood cholesterol levels. The PUFA/SFA recorded for this study was generally above 0.45, except samples from Ejisu and Kpando which recorded a value of 0.41 each.

Nutritional quality indexes of the lipid fraction in muscle

The nutritional quality indexes/ indices analyzed for each sampling site are shown in figure 1 (A-D). Polyene index (PI), Peroxidase index (PeI), Thrombogenic index (TI) and Atherogenic index (AI) were all significantly different among sampling sites. Polyene index ranged between 0.06 and 0.21 with an average of 0.10 whiles peroxidase index ranged between 40.06 and 106.6 with an average of 44.25. Atherogenic index ranged between 2.05 and 3.0 with an average of 2.54 whilst thrombogenic index ranged between 0.51 and 0.97 with an average of 0.72. TI and AI were used to define the nutritional quality of salted tilapia from the various markets whilst PI was used as an indicator for damage of PUFA. Generally lower values of PI represent a decomposed PUFA. The PI recorded in this study was low, implying a decomposed PUFA. This could also signify a possibility of increase in peroxide value and thiobarbituric acid index even though we didn't analyze these two parameters.

Relationship between salt content, pH, %WPS and fatty acid composition of salted tilapia

In order to ascertain the relationship between salt content, pH, %wps and fatty acid composition, Pearson's correlation analysis was used. The results of the analysis are shown in Figure 2.

Salt content had a strong negative and positive correlation with pH (-0.9609, 0.0022) and % wps (0.9829, 0.0004) respectively. Also, pH and % wps had significant negative correlation (-0.9340, 0.0063). Salt content, pH as well as % wps did not have significant correlation with fatty acids detected in samples. It is however worth noting that salt content and % wps correlated (non-significantly) positively with total n-3 fatty acids but negatively (non-significant) with total n-6 fatty acids. Whereas a non-significant negative correlation was observed between 20:5n-3 (EPA) and salt content (-0.1827, 0.7288) and % wps (-0.2298, 0.6612), 22:6n-3 (DHA) and 22:4n-6 (ARA) correlated positively (non-significant) with salt content (0.3908, 0.4435; 0.2217, 0.6586 respectively) and % wps (0.3494, 0.4971; 0.1281, 0.9433).

From the above results, it could be deduced that irrespective of the salt content, the fatty acid composition of the salted fish samples are not altered. In order words, the fatty acid composition of the samples was not influenced by their salt content. The salt content however influenced both pH and % wps. As the salt content increases, the pH of the samples decreased whilst % wps increased.

Relationship between salt content and Nutritional quality indexes of the lipid fraction in muscle.

A correlation analysis was run to evaluate how salt relates to the nutritional indices studied. The correlation results are shown in Table 6. There was no significant correlation between salt content of samples and nutritional indices. It is however, worth noting that, salt correlated positively with PI (0.298, 0.566) and Peroxidase index (0.134, 0.801), whilst a negative correlation was recorded between salt content and AI (-0.591, 0.217) and TI (-0.514, 0.297). There was a significant positive correlation between Peroxidase index and PI (0.850, 0.032) and a significant negative correlation between Peroxidase index and TI (-0.820, 0.046). TI had a significant positive correlation with AI (0.940, 0.005).

From the correlation analysis, it is evident that AI, PI, TI and Peroxidase index are independent of the salt content of the samples. This is because there was no significant correlation between salt content and these nutritional quality index (AI, PI, TI and Peroxidase index). It is worth noting that AI and TI are dependent on each other whilst PI is dependent on PeI and TI.

Amino acids

The amino acids recorded in this study are shown in table 6. The amino acid profile (dispensable and non-dispensable amino acid) of salted tilapia sampled from selected market differed significantly (P<0.05). TAA ranged between 4.44±0.89 to 29.86±1.68, Kpando market salted tilapia with the highest TAA while salted tilapia sampled from Akatey had the lowest TAA. These differences could be attributed to source of tilapia, concentration of salt used for preservation (processing), handling during processing and most importantly the composition of feed or food (diet) accessible to tilapia before capture or harvest.

Glutamic acids are important for proliferation of cells. In addition to this they possess immune boosting properties by carrying ammonia to the immune system

(Deutz *et al.*, 1982). In this study the concentration of glutamic acid ranged between 0.68-4.90 mg/g. This signify that, with the exception of samples from Akatey, consuming salted tilapia from Kpando, Makola, Kumasi Central market, Ejisu and Dambai could boost the immune system. Glutamic acid was the highest amino acid reported in this study and it is in agreement to previous study by Osibona (2011) and Funmilayo (2016).

Table 2 Proximate composition of salted tilapia from study area.

S/No	Name of Markets	Lipid	Moisture	Protein	Ash
1	Kumasi Central	7.16±1.17	49.67±2.21	$39.41±2.87^{ab}$	$3.971±4.35^{ab}$
2	Ejisu Market	7.72±0.54	46.24±0.52	$41.60±0.36^{ab}$	$3.784±1.83^{ab}$
3	Akatey	8.35±0.91	39.72±3.78	$44.05±2.42^{ab}$	$3.276±3.64^{a}$
4	Kpando	4.51±0.50	44.42±2.33	$40.79±0.95^{ab}$	$4.047±1.11^{ab}$
5	Dambai	5.47±1.14	43.89±5.69	$45.15±0.24^{b}$	$2.903±1.06^{a}$
6	Makola	7.73±0.92	42.06±2.78	$36.20±1.57^{a}$	$4.795±2.01^{b}$
p-value	----------	***0.0891***	***0.4168***	***0.0340***	***0.0047***

Table 3 pH, Salt and %WPS content of salted tilapia from study area.

S/No	Name of Markets	pH	Salt	%WPS
1	Kumasi Central	$6.83±0.23^{a}$	$21.57±2.46^{a}$	$15.38±1.83^{a}$
2	Ejisu Market	$6.55±0.05^{ab}$	$30.53±4.65^{abc}$	$23.83±4.89^{ab}$
3	Akatey	$5.96±0.09^{c}$	$46.63±0.67^{cd}$	$40.30±2.35^{bc}$
4	Kpando	$5.94±0.04^{c}$	$50.50±4.91^{d}$	$48.29±6.75^{c}$
5	Dambai	$6.41±0.09^{c}$	$31.77±3.54^{abc}$	$24.68±5.68^{ab}$
6	Makola	$6.24±0.08^{bc}$	$46.13±1.61^{bd}$	$40.68±1.74^{bc}$
p-value	----------	***0.0013***	***0.0003***	***0.0012***

Table 4 Fatty acid composition in muscle tissue of salted tilapia (Koobi), from study area expressed as percentages of total lipids.

Fatty Acids	Central Market	Ejisu	Akatey	Kpando	Dambai	Makola	Average	p-value
C12:0	$0.34±0.06^{a}$	$0.29±0.01^{ab}$	$0.17±0.02^{bc}$	$0.09±0.00^{c}$	$0.21±0.00^{abc}$	$0.17±0.03^{bc}$	0.21	0.0015
C14:0	$4.6±0.87^{bc}$	$7.20±0.85^{ab}$	$4.30±0.37^{bc}$	$6.76±0.55^{ab}$	$8.80±1.07^{a}$	$2.42±0.37^{c}$	5.68	0.0006
C16:0	$29.62±2.92^{ab}$	$30.55±1.366^{a}$	$29.53±0.33^{ab}$	$29.88±0.72^{ab}$	$24.86±0.66^{b}$	$26.61±0.33^{b}$	28.50	0.0493
C18:0	$6.45±0.31^{b}$	$6.68±0.06^{b}$	$6.96±0.71^{ab}$	$3.99±0.09^{c}$	$8.20±0.37^{ab}$	$9.01±0.75^{a}$	6.88	0.0002
SFA	$41.01±0.71^{b}$	$44.77±0.25^{a}$	$40.96±0.80^{b}$	$40.73±1.30^{b}$	$42.07±1.02^{ab}$	$38.22±0.49^{b}$	34.28	0.0012
C16:1n7	$11.87±1.27^{bc}$	$19.89±1.84^{a}$	$15.45±0.18^{b}$	$11.86±0.39^{bc}$	$12.75±0.72^{bc}$	$10.23±0.17^{c}$	16.41	0.0001
C18:1n7	$4.28±0.14^{a}$	$1.75±0.19^{c}$	$2.85±0.08^{b}$	$2.60±0.23^{bc}$	$2.78±0.16^{b}$	$4.21±0.22^{a}$	3.07	0.0001
C18:1n9	$13.84±1.32^{c}$	$15.31±1.45^{c}$	$13.65±0.56^{c}$	$27.57±0.53^{a}$	$21.02±0.22^{b}$	$13.16±1.09^{c}$	17.42	0.0001
C20:1n9	$0.41±0.03^{a}$	$0.36±0.01^{a}$	$0.39±0.05^{a}$	$0.98±0.04^{b}$	$0.80±0.16^{b}$	$0.83±0.01^{b}$	0.62	0.0002
MUFA	$30.40±0.11^{cd}$	$37.28±0.86^{b}$	$33.35±0.15^{c}$	$43.01±0.61^{a}$	$37.35±0.10^{b}$	$28.43±0.83^{d}$	34.93	0.0001
C16:3n3	0.95±0.05	0.45±0.00	1.13±0.15	0.56±0.00	nd	Nd	0.77	0.0115
C18:3n3	$4.22±0.16^{b}$	$2.27±0.03^{c}$	$4.73±0.28^{b}$	$3.50±0.25^{bc}$	$2.69±0.36^{c}$	$7.75±0.36^{a}$	4.19	0.0001
C18:4n3	$0.37±0.01^{b}$	$0.56±0.01^{b}$	$0.45±0.03^{b}$	$1.53±0.24^{a}$	1.07±0.06	$0.48±0.04^{b}$	0.74	0.0001
C20:3n3	$0.54±0.01^{b}$	$0.28±0.0^{b}1$	$0.53±0.01^{b}$	$0.41±0.05^{b}$	$0.37±0.00^{b}$	$1.22±0.11^{a}$	0.55	0.0001
C20:4n3	$0.47±0.00^{c}$	$0.43±0.00^{c}$	$0.47±0.02^{c}$	$0.70±0.05^{ab}$	$0.79±0.06^{a}$	$0.52±0.02^{bc}$	0.56	0.0014
C20:5n3(EPA)	$0.90±0.02^{a}$	$0.50±0.02^{b}$	$0.52±0.02^{b}$	$0.72±0.04^{ab}$	$0.66±0.08^{ab}$	$0.84±0.11^{a}$	0.69	0.0026
C22:5n3	$1.28±0.04^{a}$	$0.95±0.00^{b}$	$0.97±0.01^{b}$	$1.39±0.14^{ab}$	$1.14±0.02^{a}$	$1.40±0.03^{a}$	1.18	0.0006
C22:6n3(DHA)	2.12±0.00	1.44±0.17	1.42±0.19	2.81±0.26	2.38±0.18	4.51±0.19	2.44	0.0001
n-3 PUFA	$10.85±0.15^{c}$	$6.86±0.12^{e}$	$10.22±0.37^{bc}$	$11.62±0.09^{b}$	$9.10±0.42^{d}$	$16.72±0.25^{a}$	10.89	0.0001
C16:2n6	$0.84±0.02^{ab}$	$0.34±0.01^{d}$	0.97±0.08a	$0.53±0.00^{cd}$	nd	$0.64±0.01^{bc}$	0.66	0.0003
C18:2n6	12.51±1.31	8.69±0.23	10.85±0.42	3.10±0.24	7.19±0.70	11.22±0.37	8.92	0.0001
C18:3n6	0.72±0.03	0.49±0.01	0.62±0.04	0.55±0.02	0.60±0.06	0.42±0.01	0.56	0.0018
C20:2n6	0.74±0.02	Nd	0.43±0.01	Nd	0.35±0.01	0.58±0.02	0.52	0.0004
C20:3n6	0.43±0.08	0.40±0.03	0.39±0.01	0.29±0.00	0.48±0.00	0.58±0.00	0.42	0.0023
C20:4n6 (ARA)	1.71±0.06	1.02±0.01	1.70±0.15	0.97±0.05	1.27±0.09	1.77±0.09	1.40	0.0001
C22:4n6(ARA)	0.44±0.02	0.27±0.04	0.42±0.01	0.31±0.00	0.39±0.00	0.74±0.16	0.42	0.0086
C22:5n6	0.66±0.06	0.35±0.11	0.49±0.08	Nd	0.48±0.00	1.49±0.14	0.69	0.0002
n-6 PUFA	$18.05±0.45^{b}$	$11.56±0.51^{c}$	$15.87±0.38^{b}$	$5.75±0.32^{d}$	$10.72±0.67^{c}$	$16.56±1.32^{a}$	13.08	0.0001
Total PUFA	28.90±2.05	18.42±3.80	26.02±2.17	17.03±1.88	18.82±4.02	33.28±1.09	23.74	0.0021
PUFA/SFA	0.70±0.07	0.41±0.05	0.63±0.09	0.41±0.04	0.45±0.07	0.87±0.10	0.58	0.0001
DHA/EPA	2.35±0.16	2.88±0.47	1.94±0.52	3.90±0.33	3.60±0.72	5.35±0.29	3.34	0.0019
EPA/ARA	0.53±0.06	1.85±0.38	1.23±0.27	2.32±0.19	1.69±0.22	1.13±0.05	1.45	0.0028
EPA+DHA	3.61±0.07	1.94±0.04	1.94±0.08	3.53±0.20	3.04±0.17	5.33±0.42	3.18	0.0004
n-3/n-6	0.60±0.02	0.59±0.08	0.64±0.01	2.02±0.31	0.84±0.16	1.00±0.22	0.94	0.0001
n6/n3	1.66±0.18	1.68±0.22	1.55±0.03	0.49±0.01	1.18±0.42	0.99±0.03	1.25	0.0001

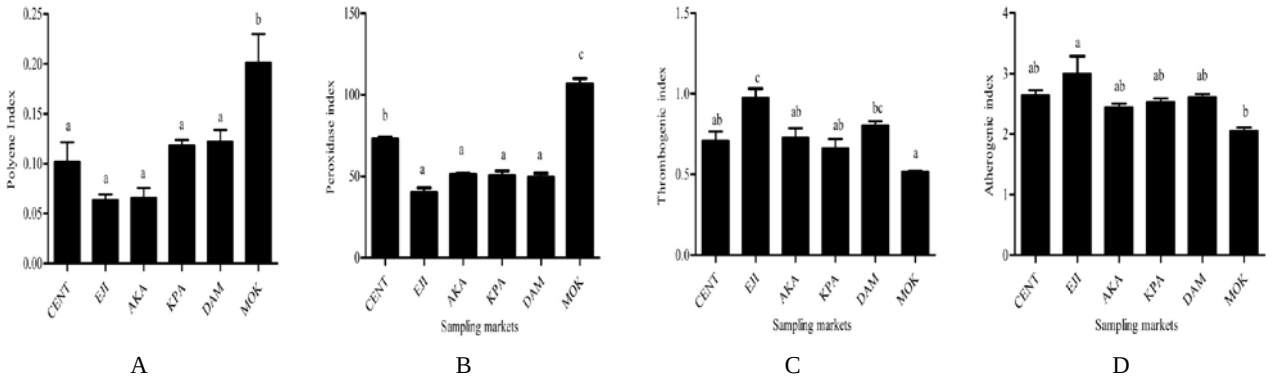

Fig 1: Nutritional quality indexes of the lipid fraction in muscle of salted tilapia from sampling sites.

Table 5: Correlation analysis between salt content and nutritional quality index

	SALT	AI	PI	TI	PeI
SALT	-				
AI	-0.591 (0.217)	-			
PI	0.298 (0.566)	-0.796 (0.058)	-		
TI	-0.514 (0.297)	**0.940 (0.005)**	-0.792 (0.060)	-	
PeI	0.134 (0.801)	-0.807 (0.052)	**0.850 (0.032)**	**-0.820 (0.045)**	-

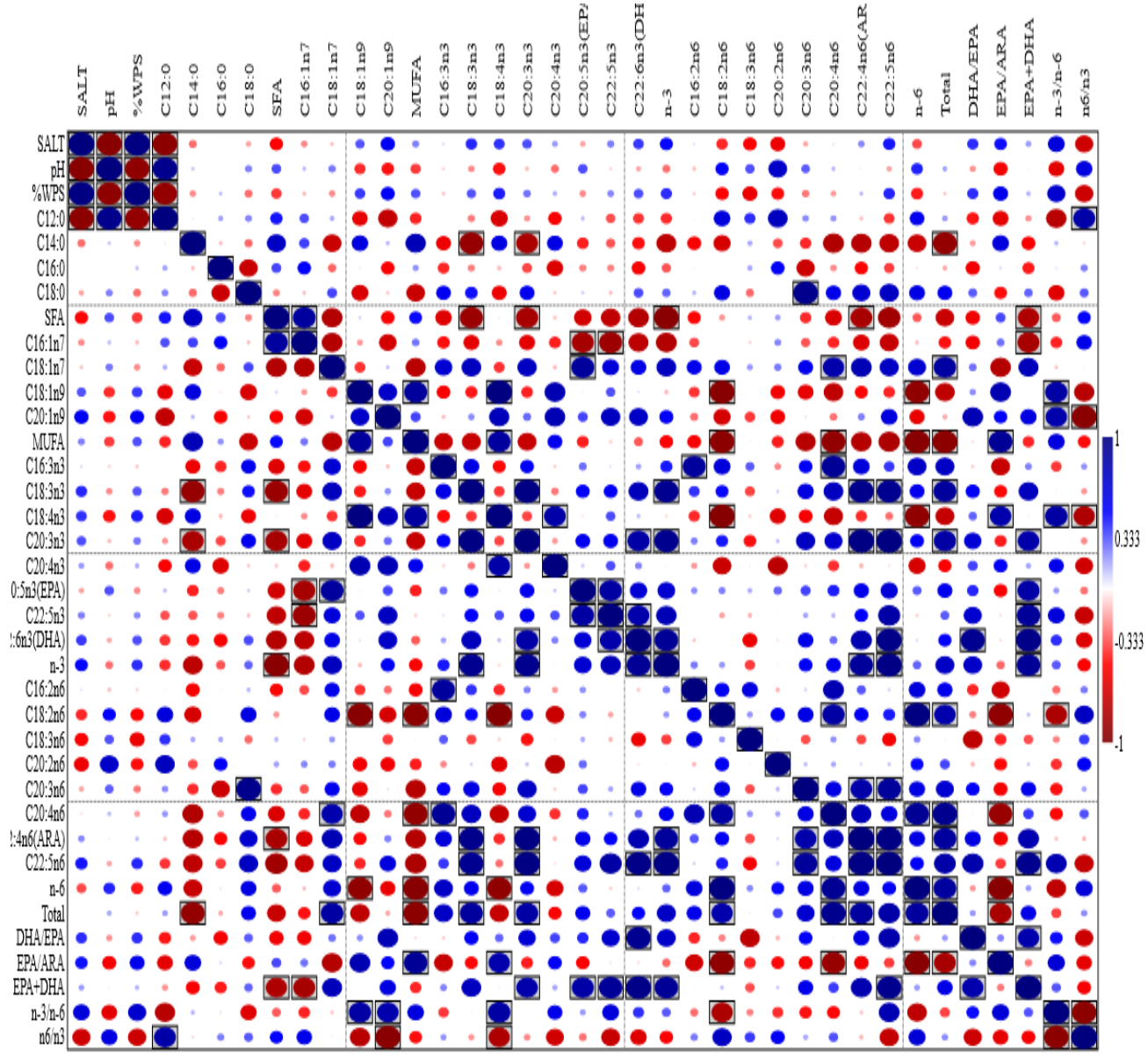

Fig. 2: Relationship between salt content, pH, %wps and fatty acid composition of salted tilapia. Brown colors correlate negatively whilst blue colors correlate positively. Boxed symbols correlate significantly. The bigger the symbols, the stronger the correlation

Table 6: Amino acid composition (mg/g) of salted tilapia from selected markets

Amino acids	Markets							
	Ejisu	**Dambai**	**Central Market**	**Akatey**	**Makola**	**Kpando**	**Average**	**p-value**
IAAs[a]								
Phenylalanine	1.10±0.16[a]	1.14±0.15[a]	0.93±0.13[a]	0.36±0.04b	0.82±0.06[a]	1.27±0.08[a]	0.93	0.0133
Tyrosine	0.77±0.11[a]	0.78±0.13[a]	0.68±0.02[a]	0.13±0.00[b]	0.60±0.08[ab]	0.91±0.08[a]	0.65	0.0084
AAA[b]	**1.87±0.14[b]**	**1.92±0.16[b]**	**1.61±0.10[c]**	**0.49±0.03[e]**	**1.42±0.10[d]**	**2.18±0.07[a]**	**1.58**	**0.0001**
Histidine	0.62±0.06a[b]	0.63±0.03[ab]	0.53±0.09[ab]	0.13±0.04[c]	0.33±0.00[bc]	0.66±0.04[a]	0.48	0.0025
Isoleucine	0.86±0.16[a]	1.01±0.05[a]	0.77±0.00[ab]	0.34±0.02[b]	0.64±0.00[ab]	1.03±0.10[a]	0.78	0.0072
Leucine	1.98±0.09[a]	1.93±0.16[a]	1.66±0.36[a]	0.52±0.01[b]	1.46±0.12[ab]	2.08±0.13[a]	1.60	0.0079
Lysine	2.12±0.03[a]	2.11±0.05[a]	1.73±0.12[ab]	0.36±0.02[c]	1.46±0.08[b]	2.16±0.13[a]	1.66	0.0001
Methionine	0.34±0.04[ab]	0.26±0.00[bc]	0.42±0.04[a]	0.17±0.00[c]	0.24±0.00[b]	0.33±0.02[abc]	0.29	0.0051
Threonine	1.27±0.19[a]	1.27±0.22[a]	1.12±0.11[a]	0.22±0.06[b]	0.91±0.04[ab]	1.49±0.08[a]	1.05	0.0060
Valine	1.04±0.18[ab]	1.17±0.09[a]	0.92±0.12[b]	0.48±0.10	0.75±0.04	1.15±0.10	0.91	0.0373
ΣIAAs	**10.10±0.51[b]**	**10.30±0.43[b]**	**8.76±0.062[c]**	**2.71±0.09[e]**	**7.21±0.26[d]**	**11.08±0.71[a]**	**8.35**	**0.0001**
Arginine	1.72±0.01[a]	1.51±0.04[b]	1.44±0.03[b]	Nd	0.89±0.04[c]	1.48±0.00[b]	1.40	0.0001
Alanine	1.89±0.30[a]	1.75±0.23[a]	1.70±0.26[a]	0.47±0.11[b]	1.25±0.00[ab]	2.01±0.08[a]	1.51	0.0116
Aspartic acid	3.43±0.53[a]	3.42±0.39[a]	3.00±0.34[a]	0.27±0.03[b]	2.41±0.16a	4.08±0.20[a]	2.76	0.0017
Glutamic acid	4.38±0.27[a]	4.18±0.22[a]	3.66±0.57[a]	0.68±0.10[b]	3.06±0.45[a]	4.90±0.27[a]	3.47	0.0015
Glycine	2.67±0.39[ab]	2.31±0.21[ab]	2.58±0.04[ab]	0.15±0.01[c]	1.72±0.25[b]	3.08±0.06[a]	2.09	0.0007
Proline	1.47±0.12[ab]	1.32±0.16[ab]	1.48±0.07[ab]	Nd	0.97±0.-04[b]	1.73±0.04[a]	1.39	0.0001
Serine	1.26±0.08[a]	1.17±0.19[a]	1.10±0.07[a]	0.17±0.02[b]	0.89±0.12[a]	1.42±0.06[a]	1.00	0.0181
ΣDAAs[d]	**12.37±0.95[b]**	**11.67**±0.25[c]	**10.96**±0.39[c]	**1.57±0.12[e]**	**8.44**±00.29[d]	**14.07**±0.29[a]	**9.84**	**0.0006**
ΣAAs	16.83±**1.06[b]**	15.67±**1.13[b]**	14.98±**1.25[c]**	1.74±**0.33[e]**	11.19±**1.52[d]**	18.70±**2.19[a]**	13.18	0.0004
TAA	27.00±**4.11[b]**	26.02±**4.30[b]**	23.70±**0.25[c]**	4.44±**0.89[e]**	18.41±**1.42[d]**	29.86±**1.68[a]**	21.57	0.0003
Leu/Ileu	2.30±**0.45**[a]	1.90±**0.22**[d]	2.15±**0.26**[b]	1.52±**0.18**[e]	2.28±**0.25**[a]	2.0±**0.27**1[c]	2.05	0.0002
P-PER	0.43±0.04	0.40±0.06	0.28±0.05	-0.23±0.01	0.19±0.02	0.47±0.04	0.25	0.0001

CONCLUSION

It can be concluded that, irrespective of the locations of markets in Ghana, nutritional compositions of salted fish are not affected by their preservation mechanisms or processing. The freshness of salted fish and its quality were shown in all aspects as not compromised and will not affect consumer health or implicate them. However, it can be recommended that, further studies from different regions be conducted in relation to non-salted fish in this regard to compare and establish completely if the nutritional quality from this study is not impacted through this preservation

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