Uganda Journal of Agricultural Sciences, 2013, 14 (2): 95 - 107 ISSN 1026-0919
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The effect of artisanal preservation methods on nutritional security of "Mukene" *Rastrineobola argentea* caught from Lakes Victoria and Kyoga in Uganda

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Abstract

The artisanal fish preservation methods in Uganda are characterized by extreme operating conditions. Consequently, vital nutritional components diminish in value and quantity which renders fish consumer nutritionally insecure. To establish the magnitude of nutritional loss, duplicate samples of Mukene *Rastrineobola argentea* were collected from Kiginci landing site on L. Victoria and Moone landing site on L. Kyoga. Each set of duplicate samples was divided into five portions and kept on ice. For each preservation method a portion was processed into respective products at Food Bioscience and Agri-Business Laboratories aside from the control (fresh) sample. Both preserved and control samples were analysed for nutrient loss at Department of Chemistry, Makerere University using AOAC methods. The composition of fatty acids was determined by methanolysis gas chromatography and Mass spectrophotometry of the resultant methyl esters. The results indicate that nutrients of all preserved samples did not vary significantly from the control except for some fatty acids. The Eicosapentaenoic acid (EPA) in fresh samples declined from 6.72% to 1.08% in deep-fried samples constituting 83.93% nutrient loss. The sum ratio ω3:ω6 as well as EPA: DHA (Docosahexaenoic) ratio in fried samples also varied significantly ($p<0.5$) lower than 0.668 and 0.20 for the average of either preservation methods and experts recommended ratio respectively. Further research has been recommended to ascertain the causative factor, since Mukene frying is being promoted in the Great lakes region as alternative method to sun-drying. In conclusion, regular consumers of fried Mukene do not benefit much from the nutritional and health attributes of Omega 3 and 6.

Key words: Mukene, nutritional security, Omega 3 and 6

Introduction

Silver fish *Rastrineobola argentea* (also locally known in Uganda as "Mukene") is a silvery tiny fish with an average length of 5 cm and average weight of 15 g. With the declining stocks of high-value and large-sized species; Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus)* stocks, Mukene fishery has become the main stay for the domestic as well as regional markets.

It plays a crucial role in the economic development of Uganda and the region at large. "Mukene" is the third commercially important fish species after the two large-sized fishes and it accounts for 60% of the total fisheries biomass in L. Victoria which has increased from 59,000 MT in 1998 to 120, 000MT (DFR, 2010). In 2012,

Mukene fishery contributed 42% and 67% of total fish catches from Lake Victoria and Lake Kyoga respectively (DFR, 2012). Over 80% of the sun-dried Mukene products is processed into animal feeds and less than 20% is channeled through the distribution chain for human consumption (Legros and Masette, 2010).

Apart from employment, source of income, fish forms the back-borne of food and nutritional security of people's diets. The per capita fish consumption in Uganda is currently estimated at 5.7 Kg which is lower than the world average of 20.1Kg (Speedy, 2003) and over twenty times lower than 154Kg for the Maldives with the highest per capita consumption in the world. This sharply compares with per capital fish consumption of countries where people have good fish eating cultures and habits such as the Maldives which has the highest per capita consumption pegged at 154 Kg in the world.

Mukene is known to have comparable large amount of micronutrients (Kabahenda *et al.*, 2011; Neumann *et al.*, 2014) and therefore its frequent consumption could alleviate hidden hunger among vulnerable groups (Kawarazuka and Béné, 2011).

In the recent past, some work has been done to process "Mukene" into high value products that meet market demands and secure nutritional value of fresh water fishes (Masette, 2005; Legros and Masette, 2010; Masette, 2011). The improved methods include smoking, deep-frying, milling, fermentation and salting. However, the effect of these processing methods on macro and micro nutrients in processed "Mukene" has not been established and probably its nutritional attributes have been highly compromised. Some of these methods have consequential implications on the nutritional security of "Mukene" consumers. The available literature does not explicitly document the consequential effects of processing methods on nutrients. Available information only refers to unspecified nutrient loss in addition to physical loss attributed to trimming (Cutting, 1962).

According to Morris *et al.* (2006) nutritional content may be influenced by several factors which include the genetic make-up of the fish, the water body in which it inhabits, its physiological body condition, maturity at harvest, packaging, storage conditions and method of preparation for processing.

Nevertheless, processing as a procedure affects nutritional components of fish although the magnitude may vary with type of process, fish species and nutritional component. A preliminary study commissioned by FAO observed that Omega 3 (eicosapentaenoic acid (EPA) decreased appreciably with deep-frying using vegetable oil (Masette, 2011). Although frying has been used since antiquity to cook a wide spectrum of products (Saguy and Dana, 2003), it is a recent development in Uganda. Due to their crispy texture, deep-fried Mukene products have gained a market niche among the elite in urban centres and sold in supermarkets like Uchumi, Shoprite, Capital shoppers and Game.

The principal behind this preservation method is the denaturation of proteins including enzymes and water removal by elevated temperatures attained during the frying process. It has been known for long that deep-frying of fish allows the interaction between fish fat and other culinary components of fat like olive or sunflower oil which culminates in specific

changes of eicosapentaenoic acid (EPA C20:5, ω3), docosahexaenoic acid (DHA C22:6,) profile and composition (Sanchez-Muniz *et al.*, 1992). These two fatty acids are known to prevent cardiovascular diseases in humans (Mennicken *et al.*, 2005; Noseda, 2005; Stark, 2008). The present paper seeks to ascertain the previous observations pertaining to deep-frying and establish whether other artisanal preservation methods namely smoking, sun-drying and salting had similar effects on nutritional security of "Mukene".

Materials and methods

Sample collection

Ten (10) basins (300 kg) of freshly caught "Mukene" were purchased from Kiyindi landing site on Lake Victoria, Najja Sub-county-Buikwe District and Moone landing site on Lake Kyoga, Nabiswera Sub-county-Nakasongola District respectively. The samples were transported in insulated fish boxes on ice to Food Bio-Sciences and Agribusiness Research Centre-Kawanda (FBA-Kawanda) laboratories for processing into smoked, salted sun-dried and fried products.

Coding of fresh samples as well as preserved samples was done prior to storage at -10°C and until required for chemical analysis at Makerere University, Department Chemistry.

Sample preparation

The "mukene" samples were subjected to traditional but improved preservation methods namely; sun-drying, salting, smoking and frying after thawing and subsequently prepared for chemical analysis.

Sample preservation

Sun-drying

10 kg of thawed Mukene were washed before drying on small nylon-meshed rack elevated 2 metres above the ground and dried for 3 days, typically drying "mukene" fish for 10 hours per day at temperature of around 28°C. During the drying process, the fish was turned four (4) times in a day to facilitate the drying process. Dried "Mukene" was then sealed in polythene tubing (30 microns thick) and kept at room temperature.

Salting

"Mukene" were washed and then salted with 0.5 kg of salt for each of 6 kg of fresh "Mukene" (ratio 1:12) and finally spread out in the sun to dry at ambient temperatures. It was turned-over every so often to facilitate the drying process which was completed after 2 days. The resultant salted and dried samples were sealed in polythene tubing (30 micron thickness) and kept at room temperature.

Deep-frying

The gas cooker (Model IGNIS made in Brazil) was set at mark 290 °C and vegetable oil Golden fry vegetable oil (fractionated palm oil, fully refined and fortified with vitamin A) made by Bidco (U) Ltd in Uganda, was placed in a locally shallow pan made from mild steel and heated to 180°C. 0.5kg of "Mukene" previously washed and drip-dried for 1hr were deep-fried in hot vegetable oil for 8-10 minutes. The excess oil was drained off for 1hour and samples cooled sufficiently before coding and packaging aluminium foil for storage at -10 °C.

Smoking

"Mukene" was washed then drip dried under sunshine for 1 hour prior to smoking using a Chorkor kiln monitored at 40-80°C. Mango wood (*Mangofera indica*) was used to generate smoke for smoking. The smoking process took 2 days i.e. 16 hours before cooling at room temperature. After smoking, samples were cooled on stainless steel tray for 12 hour, then coded and packaged in aluminium foil before storage in laboratory freezer. Model Electrolux made in Sweden at -10 °C pending subsequent analysis.

Sample preparation for chemical analysis

Using a blender, each sample was ground separately into powder, labelled and stored under frozen conditions till it was subsequently analysed.

Chemical analysis of samples

Samples were analysed in the following ways as described below:

Proximate analysis

All samples were subjected to macro-nutrient analysis using standard AOAC methods. Kjeldahl method (AOAC, 1991) was used to quantify protein; Van Soest *et al.* (1991) method was used to determine crude fibre while Harris (1970) method was used determine gross energy and AOAC 1990 method was used to determine the amount fat or lipid by soxhlet system of extraction.

Mineral analysis

The "Mukene" samples were digested in concentrated nitric acid and analyzed using an atomic absorption spectrophotometer (Perkin Elmer, 2380).

Fatty acid analysis

Fatty acid analysis was done using the procedure described below:

Direct transesterification of fatty acids in the samples

Fatty acids in the preserved samples were converted to fatty acid methyl esters (FAME) by using direct trans-esterification method (Grahl-Nielsen and Barnung, 1985). Approximately 30–50 mg sample was transferred to thick-walled glass tubes. One ml of anhydrous methanol, containing 2 M hydrogen chloride was added. Nitrogen gas was exchanged with the atmosphere in the tubes and the tubes were securely closed with Teflon-lined screw caps and left in an oven at 90°C for 2 hours.

Extraction of the fatty acid methyl esters (FAME)

After cooling to room temperature, half the methanol was evaporated by nitrogen gas and 0.5ml distilled water was added to reduce the solubility of the formed FA methyl esters (FAME). The FAME was extracted from the methanol/water-phase with 2 x 1.0 ml hexane. The concentration of the FAME in the combined extracts was adjusted by addition of hexane to obtain levels suitable for chromatogram. The resulting fatty acid methyl esters (FAME) were extracted from the mixture by solvent extraction using a water-hexane solvent system (Grahl-Nielsen and Barnung, 1985).

Hexane (1 ml) and water (0.5 ml) were added to the resulting fatty acid methyl esters mixture and after shaking for 3 minutes, the mixture was centrifuged at 1500rpm for 3 minutes. The FAME was obtained from the upper hexane phase of the partition by siphoning.

A second extraction was performed after addition of hexane (1 cm^3) to the residual mixture and repeating the same procedure as described. The extracts were then pooled and stored under refrigeration until GC/MS analysis.

FAME Analysis

One µl of the mixed hexane extracts was injected splitless (the split was opened after 4min), and were separated by chromatography on a 25 m X 0.25 mm fused silica column with polyethylene-glycol (PEG) as stationary phase, with a thickness of 0.2 µm (CP-WAX 52 CB Chrompack) and helium at 20 psi as mobile phase.

The column was mounted in a GCMS (Agilent 6890 N with autosampler 7683B series, fitted with an electronic pressure control and mass selective detection (ionizating energy, 70 eV; source temperature, 250 °C). The injector temperature was 260°C. The temperature of the column was kept at 90 °C for 4 min after injection and thereafter increased to 165 °C at a rate of 30 °C/min, followed by an increase of 3 °C/min to 225°C. The temperature was then maintained at 225 °C for 10.5 min.

The quantitatively most important Fatty Acids (FAs) were identified in the samples, by means of the standard mixture and by mass spectrometry. The peaks were integrated using Chemstation software Thermo LabSystems and the relative amount of each FA in a sample was expressed as a percentage of the sum of all FAs in the sample.

Results

Proximate analysis

The macro-nutrient variation of "Mukene" which was caught from two different lakes; Victoria and Kyoga, did not vary widely (Fig. 1) except that the moisture content did not exceed 65% in fresh samples. The protein content in smoked samples was slightly higher in L. Victoria than L. Kyoga.

The average energy content of "Mukene" caught from the two lakes was 5.01 Kcal/g (Fig. 2). Apart from the fried samples from both lakes, all other samples were slightly below average.

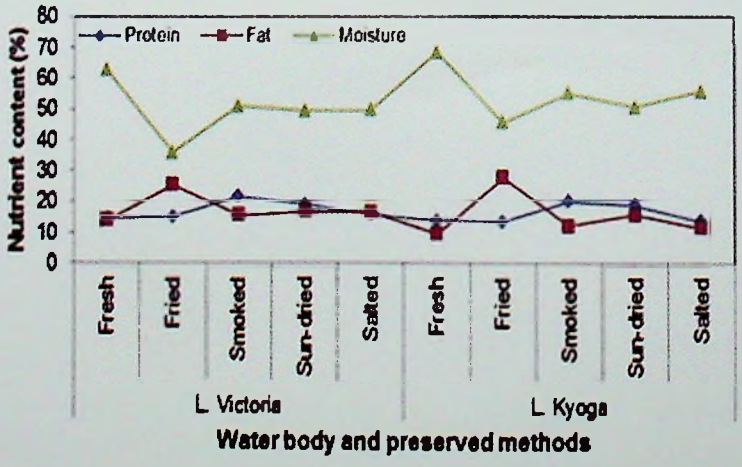

Figure 1. Macro-nutrients variations in fresh and preserved "Mukene" caught from Lakes Victoria and Kyoga.

The average iron and zinc content in samples from both lakes; Victoria and Kyoga was 799.24 mg and 38.5 mg respectively. However, the variation in iron content was more pronounced across treatments in for samples from L. Victoria than L. Kyoga (Table 1) which may be attributed to interactions between treatments and ingredients in the water body.

Mineral analysis

Calcium and phosphorous content in "Mukene" varied with in samples from the two lakes. The average calcium and phosphorous content in samples from Victoria was 2.2 % and 1.2% respectively. For samples from L. Kyoga the average content was 3 % and 1.9 % respectively which was fairly higher than those from L. Victoria. Compared to iron and zinc

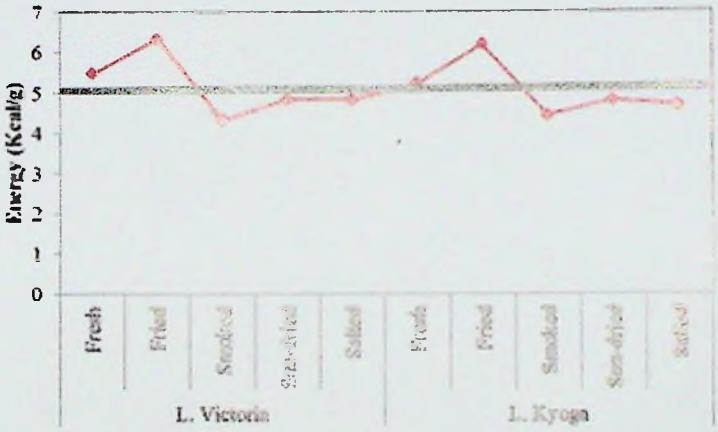

Figure 2. Energy variation in fresh and preserved "Mukene" caught from Lakes Victoria and Kyoga.

Table 1. Micro-nutrients variations in fresh and preserved Victoria and Kyoga "Mukene" in triplicates (n=3)

Lake	Preservation method	Calcium (%)	Phosphorus (%)	Zinc (mg)	Iron (mg)
Victoria	Fresh	2.57±0.23	1.42±0.61	412.5±17.9	30.6±2.3
	Deep-fried	1.87±0.51	0.99±0.07	415.0±26.1	37.8±4.5
	Smoked	1.43±0.04	0.76±0.04	497.5±19.0	43.9±5.2
	Sun-dried	2.45±0.65	1.29±0.17	425.0±22.3	63.0±7.9
	Salted	2.56±0.85	1.36±0.23	562.5±20.4	47.5±4.4
Kyoga	Fresh	2.52±0.06	1.33±0.02	512.5±17.3	28.3±1.7
	Deep-fried	2.16±0.12	1.14±0.09	487.5±34.6	41.4±2.3
	Smoked	2.94±0.86	2.62±0.09	481.3±15.4	71.7±9.6
	Sun-dried	3.46±0.88	2.36±0.18	462.5±21.0	43.0±3.3
	Salted	3.74±1.20	1.98±0.14	482.0±14.1	71.7±6.2

variation, the calcium and phosphorous variation were not pronounced in samples obtained from either lake.

Fatty acid profile and composition

The profile and composition of fatty acids (FAs) were category based on level of saturation; saturated (SFAs, monounsaturated (MUFAs) and polyunsaturated (PUFAs). The FAs in each category varied with preservation method (Table 2). Among the saturated fatty acids (SFAs), hexadecanoic (C16:0) commonly referred to as palmitic acid was more abundant regardless of preservation method. It constituted over 50% of all the FAs identified.

Among the monounsaturated fatty acids (MUFA), hexadecenoic (C16:1n7) or palmitoleic acid occurred in small amounts depending on the preservation method. The most common polyunsaturated fatty acids (PUFAs) were three; Octadecadienoic (C18:2n6) or linoleic, α-Linolenic acid (18:3n3) and Arachidonic acid (20:4n6).

All categories of fatty acids (FA) varied according to type of category and

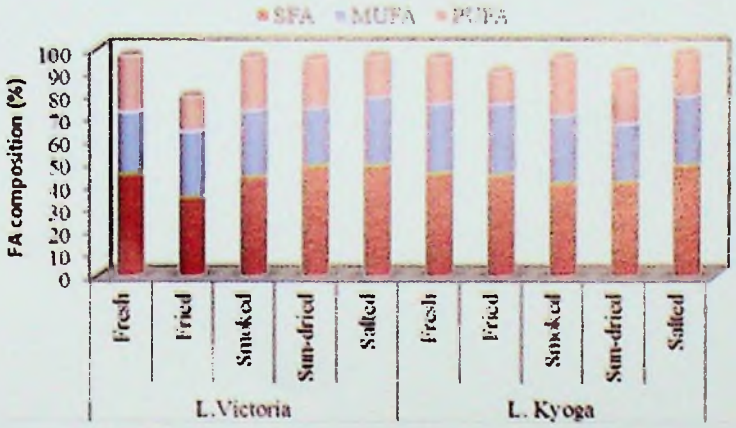

Figure 3. FA compositional variations in "Mukene" caught from lakes Victoria and Kyoga.

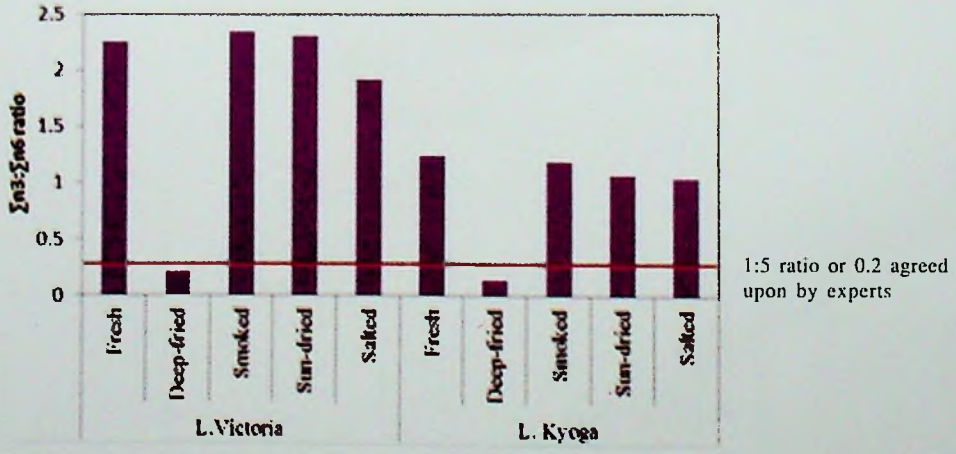

Figure 4. The sum ratio of ω3:ω6 in preserved "Mukene" caught from lakes Victoria and Kyoga.

Table 2. Fatty acid profile, composition (%) and variations in "Mukene" in Lakes Victoria and Kyoga

Fatty acids	Victoria					Kyoga				
Systematic and common names	FH	DF	SM	ST	SD	FH	DF	SM	ST	SD
12:0 Dodecanoic (lauric)	8.29	-	-	0.00	-	5.24	-	-	-	0.38
14:0 Tetradecanoic (myristic)	3.99	1.56	3.68	4.47	5.83	4.09	1.57	3.75	4.47	3.70
Iso 15:0Pentadecenoic	0.94	-	1.03	1.24	1.35	1.04	-	0.88	1.08	1.10
15:0 Pentadecyclic	1.68	0.24	0.93	1.02	1.15	1.54	0.16	1.08	1.30	1.11
16:0 Hexadecanoic (palmitic)	29.01	32.95	25.05	28.26	27.87	28.25	36.29	22.88	26.40	22.40
Iso 17:0 Heptadecenoic	1.08	-	1.13	1.26	1.38	1.05	-	1.25	1.38	1.34
17:0 Heptadecanoic (margaric)	-	-	0.59	0.33	0.56	-	-	-	3.17	0.22
18:0 Octadecanoic (stearic)	-	-	11.30	12.04	10.36	9.35	6.37	10.28	11.81	10.54
20:0 Eicosanoic (arachidic)	-	-	-	-	-	0.55	-	0.51	-	0.50
14:1n5 Tetradecenoic(myristoleic)	-	-	-	-	-	0.21	-	0.27	0.33	0.46
16:1n7 Hexadecenoic (palmitoleic)	8.72	0.90	9.74	11.69	13.29	8.56	1.12	8.84	9.69	8.83
17:1n9 Heptadecenoic	1.08	0.16	0.83	0.99	0.69	1.10	-	0.93	1.12	1.05
18:1n9 Octadecenoic (oleic)	12.85	7.56	10.63	12.85	7.85	12.54	-	13.38	14.88	-
18:1n12Octadecenoic (petroselinic)	-	-	3.91	-	-	-	-	-	-	-
18:1n7 Octadecenoic (vaccenic)	4.52	-	4.00	4.41	3.45	4.53	3.98	4.95	5.28	14.77
20:1n9 Eicosenoic (gondoic)	-	0.31	-	-	-	-	0.29	-	-	0.33
24:1n9 Tetracosenoic (nervonic)	-	-	-	-	-	-	-	1.50	-	-
18:2n6 Octadecadienoic (linoleic)	3.44	11.70	3.19	3.18	2.07	3.57	11.78	5.25	4.99	5.77
18:3n3 á-Linolenic acid	2.81	0.41	2.81	2.45	3.14	2.76	0.50	3.31	2.76	3.47
20:3n6 Dohom-y-linolenic	-	-	-	-	-	0.72	-	1.09	-	0.43
20:4n6 Arachidonic acid	3.43	0.53	3.04	2.41	2.55	3.26	0.52	3.83	2.84	3.06

Table 2. Continued

Fatty acids	Victoria					Kyoga				
Systematic and common names	FH	DF	SM	ST	SD	FH	DF	SM	ST	SD
20:5n3 Eicosapentaenoic (EPA)	4.63	0.48	4.61	3.33	4.18	4.39	0.43	3.63	2.35	2.71
22:5n6 Docosapentaenoic	0.76	0.13	0.73	0.53	0.95	0.59	-	0.64	0.37	0.48
22:5n3 Docosapentaenoic acid (DPA)	1.16	0.55	0.95	0.80	0.87	1.08	-	0.83	0.48	0.79
22:6n3 Docosahexaenoic (DHA)	8.62	11.17	8.00	5.17	6.84	4.21	10.84	5.53	3.63	4.52
Sum ratio ù3:ù6	2.26	1.02	2.35	1.92	2.46	1.53	0.96	1.18	1.05	1.11
Ratio EPA:DHA	0.54	0.043	0.58	0.64	0.611	1.043	0.040	0.656	0.647	0.60

Key: FH= fresh; DF= fried; SM= smoked; SD= sun-dried; ST= salted

preservation method applied. Evidently, the percentage SFAs was higher than MUFA or PUFA. In the majority of treatments, it constituted almost 50% while PUFA constituted less than 20% of the total FAs.

The sum ratio of Omega 3 to Omega 6 (ω3:ω6) is indicative of the dietetic importance of the fatty acids in human diet. In the present study, it varied according to preservation method and water body. Apart from deep fried samples, all treatments were above the recommended 1:1 ratio. Evidently, the ω3:ω6 ratio was higher in L. Victoria "Mukene" than L. Kyoga counterpart (Fig. 3) regardless of the preservation method. The variation may be attributed to diet within the respective lakes.

Discussion

The nutritional value of "Mukene" from both lakes Victoria and Kyoga was found to be unaffected by the four preservation methods and its lipid quality was comparable to other tropical fishes. This finding compares favourably with results of other studies done on tropical freshwater which indicated that tropical fishes are good sources of poly unsaturated FA (Özogul *et al.*, 2007). The high levels of micro-nutrients in all treatments of Mukene underscore its importance in diets of vulnerable members of Ugandan society. In a recent UDHS study among mothers of productive age and children < 5 year-age group, the Ministry of Health (MoH) found that iron deficiency in these vulnerable groups was 24.9 % and 50 % respectively.

Iron is a principal ingredient in red blood cells required by pregnant mothers and children under five years of age. Ndeezi *et al.*, (2010) found that 54.3 % of the children aged 1-5 years in Uganda had

low serum zinc (< 10.0 ìmol/L). Zinc deficiency is wide spread in low-income countries and is responsible for 4 % of childhood deaths and 1 % of the burden of disease in Africa. Calcium deficiency is associated with bone fractures and osteoporosis (Greer and Krebs, 2006).

Frequent consumption could alleviate hidden hunger among vulnerable groups as it was also reported by Kawarazuka and Béné (2011). Another study by Steiner-Asiedu (1991) indicated that smoking and cooking did not affect the fatty acid composition of the fish but the palm-kernel oil used in frying masked the fatty acid pattern in the fried fish. Recently, Masa *et al.* (2011) found that Nile perch, Nile tilapia, Mukene, lungfish (*Protopterus aethiopicus*), Victoria squeaker (*Synodontis victoriae*), and two catfishes (*Clarias gariepinus* and *Bagrus docmac*) from Lake Victoria, Uganda were a rich source of omega-3.

The nutrient loss of 83.93 % in EPA during deep-frying of "Mukene" confirmed by this study is unacceptable in view of its nutritional attributes associated with reduction of health risks associated with coronary heart diseases. Regular consumption of fish has been known to reduce the risk of cardiovascular related diseases particularly antihypertensive and varicose veins (Huss, 1995).

These essential fatty acids are necessary for body metabolism and the most important are eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and linolenic acid (ALA). They are known to play a favourable role in prevention of coronary heart disease. The ω3/ω6 ratio is the sum of all PUFA omega 3s and omega 6s and constitutes an omega-3 index that defines the n-3 status of an animal (Harris *et al.*, 2004). In human nutrition, the uptake of polyunsaturated fatty acids (PUFA) of the ω3 type is too low compared to the uptake of the ω6 type PUFA, with a ratio of around 25:1 and yet the recommended ratio is 5:1 (Mennicken *et al.*, 2005). The Omega 3 index could be used as a new risk factor for coronary heart disease (Stark, 2008). Apart from EPA loss, it has been reported by several authors (Swastawatia *et al.*, 2012; Koodziejska *et al.* 2004; Zoto *et al.*, 1995) that smoking reduces the level of lysine in fish.

Salting is known to reduce á-amino nitrogen, non-protein nitrogen, salt-soluble nitrogen, total free amino acids, essential amino acids and sulfhydryl groups, during salting and sun drying (Sannaveerappa *et al.*, 2004). The reduction in these parameters was slightly higher in wet-salted fish compared with dry-salted fish.

Essentially, the array of processed fish products in Uganda are critical to national food security as they provide the much required protein to children suffering from kwashiorkor and well-balanced supply of vital minerals.

Conclusion

As much as fried Mukene product meets the culinary demands of most Ugandan consumers, it does not provide the coronary health benefits associated with Omega 3 EPA; as reflected in the sum ratio of ω3:ω6. In this regard, promotion of frying as a preservation method in its current form by extension workers and development partners may be premature. However, with modification of the frying temperature, the method can undoubtedly play a vital role in alleviation of micro-nutrient deficiencies.

Owing to the unacceptably high post-harvest losses in the "Mukene" fishery,

declining per capita fish consumption fish, the attending socio-economic hardships and high levels of hidden hunger in the country, processors using affordable and improved preservation methods with controllable processing conditions will be crucial in ensuring the nutritional value of "Mukene".

Fortunately, sun-drying, salting and smoking preservation methods did not have significant effect on its macro as well as micro nutrient content and generally conserved the nutritional value of Mukene. As expected, the unpreserved fresh (control) samples retained all chemical nutrients but most "Mukene" consumers distaste cooked fresh "Mukene". Essentially, the study elucidated the effect of traditional preservation on the nutritional security of Mukene caught from lakes Victoria and Kyoga.

Recommendations

The nutrient value loss observed in deep fried fish samples demands for intervention since the majority of "Mukene" consumers prefer it crispy. This may require modification of the frying method which may entail reduction of temperature without altering the desired flavour and taste. Probably a vacuum fryer could be tried out to ascertain whether lowering temperature under a vacuum can produce the desired crispy fried product.

Alternatively the vegetable oil being used for frying could be fortified with EPA. The sun-drying and smoking as preservation methods should be promoted because of their nutrient retention compared to the other methods although the smoking operation is known for loss of vital amino acids like lysine. As a mitigation measure to fight iron deficiency (anaemia) in Uganda, efforts should be made to fortify the staple carbohydrate based foods with fish powder or households urged to complement their daily diets with fresh or processed fishery products.

Promotion and consumption of small fish like "Mukene" in population groups with low intakes of milk and milk products should be encouraged to increase calcium and phosphorus intake. This measure will undoubtedly call for increased production of fish, probably through aquaculture systems as opposed to fisheries capture. Further studies should include clinical trials so that nutritional aspects are evaluated against the purported health benefits attributed to consumption of fish.

Acknowledgement

We gratefully acknowledge Food and Agriculture Organization of the United Nations (FAO) for funding the study, fishers residing at Kiyindi and Moone landing sites and laboratory staff for chemical analyses.

References

Cutting, C.L. 1962. The influence of drying, salting and smoking on the nutritive value of fish, In: Heen, E. *et al. Fish in nutrition.* pp. 161-179.

Department of Fisheries Resources (DFR). 2010. Internal Reports.

Department of Fisheries Resources (DFR). 2012. Annual report: Background to the Budget

Greer, F.R. and Krebs, N.F. 2006. Optimizing bone health and calcium intakes of infants, children, and adolescents. *Pediatrics* 117(2): 578-585.

Harris, W.S., Sands, S.A., Windsor, S.L., Ali, H.A., Stevens, T.L., Magalski, A.

and Borkon, A.M. 2004. Omega-3 fatty acids in cardiac biopsies from heart transplantation patients correlation with erythrocytes and response to supplementation. *Circulation* 110(12):1645-1649.

Huss, H.H. 1995. Quality and quality changes in fresh fish. FAO Fisheries Technical paper 348.

Kabahenda, M.K., Amega, R., Okalany, E., Husken, S.M.C. and Heck, S. 2011. Protein and micronutrient composition of low-value fish products commonly marketed in the Lake Victoria region. *World Journal of Agricultural Sciences* 7(5).

Kawarazuka, N and Béné C. 2011. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. *Public Health Nutrition* 14(11):1927-1938.

Koodziejska, I., Niecikowska, C., Zdzisaw, E., Sikorski and Koakowska A. 2004. Lipid oxidation and lysine availability in Atlantic mackerel hot smoked in mild conditions. bulletin of the sea fisheries institute. pp. 16.

Legros, D. and Masette M. 2010. Testing of different processing methods for Mukene for human consumption and fish meal in Uganda. Mission Report - IND017UGA Secretariat of ACP Group of States.

Masette, M. 2011. Product development and testing of mukene-based products: Increase supply of Mukene (*Rastrineobola argentea*) for human consumption. FAO Report TCP/UGA/ 3204 (D).

Masette, M. 2005. Improved processing technologies Mukene *Rastrineobola argentea*. FAO report.

Mennicken, L., Ponsuksili, S., Tholen, E., Thi Kim Khang, N., Steier, K., Petersen, J. and Wimmers, K. 2005. Divergent selection for omega3: omega6 polyunsaturated fatty acid ratio in quail eggs. *Archiv Fur Tierzucht* 48 (5):527.

Morris, A., Barnett, A. and Burrow, O.J. 2006. Effect of processing on nutrient content of foods. caj articles no3c pp 161 http://amro.who.int/English/CFNI/cfni-caj37No304-art-3.pdf.

Namboozo, J. 2004. The biology and spread of Brycinus nurse and *Neobola bredoi* in L. Albert. Paper presented at NaFIRRI Review and Planning workshop, Jinja, Uganda.

Ndeezi, G., Tumwine, J.K., Bolann, B.J., Ndugwa, C.M. and Tylleskär, T. 2010. Zinc status in HIV infected Ugandan children aged 1-5 years: a cross sectional baseline survey. *BMC Pediatrics* 10 (1):68.

Neumann, C.G., Bwibo, N.O., Murphy, S.P., Sigman, M., Whaley, S., Allen, L.H., Guthrie, D., Weiss, R.E., Demment, M.W., Oloya, J., Kiwanuka, S.N., Drorbaugh, N., Nel, E.D., Siekmann, J.H., Obudho, J.A., Iombo, M.M., Mbuya, N.V., Ogola, T.D. and Ogola, C.A. 2003. Animal source foods as approach to improve diet and nutrition outcomes. Improving Diets and Nutrition.

Nowak, G. 2005. Fats and oils (including omega 3, omega 6). Therapeutische Umschau. *Revue therapeutique*, 62(9), 625-628.

Sannaveerappa,T., Ammu, K. and Jose J. 2004. Protein-related changes during salting of milkfish (*Chanos chanos*). *Journal of the Science of Food and Agriculture* 84(8):863-869, DOI: 10.1002/jsfa.1682.

Speedy, A.W. 2003. Global production and consumption of animal source foods. *The Journal of Nutrition* 133(11): 4048S-4053S.

Stark, K.D. 2008. The percentage of n-3 highly unsaturated fatty acids in total HUFA as a biomarker for omega-3 fatty acid status in tissues. *Lipids* 43(1):45-53.