ChemSearch Journal 13(1): 120 – 127, June, 2022
Publication of Chemical Society of Nigeria, Kano Chapter

Received: 18/05/2022 Accepted: 04/06/2022
http://www.ajol.info/index.php/csj

Proximate Composition and Energy Contributions from Fat and Protein in the Body Parts of Stockfish (*Gardus morhua*)

[1*]Adeyeye, E. I. and [2]Olaleye, A. A.
[1]Department of Chemistry, Ekiti State University, P.M.B. 5363, Ado-Ekiti, Ekiti State, Nigeria
[2]Department of Chemistry, Federal University Dutse, P.M.B. 7156, Jigawa State, Nigeria
***Correspondence Email:** adeyeyeilesanmi2012@gmail.com

ABSTRACT
Proximate composition of stockfish (*Gardus morhua*) organs was analytically examined using standard techniques. *Gardus morhua* is one of the lean fishes highly sought for due to its nutrition value. The proximate values (g/100g) showed low levels of crude fat (2.55-3.85), crude fibre and carbohydrate (< 0.01 in each case). However, the values were high in the following: crude protein (79.4 – 84.7), dry matter (90.6 – 93.8) and organic matter (82.2 – 87.3). The gross energy (mainly from crude protein and crude fat) was high at 1465 – 1535 kJ/100g (346 – 362 kcal/100g). The total fatty acid (g/100g edible portion, EP) in the crude fat ranged from 1.79 – 2.70 g/100g EP whereas that of other lipids (such as sterols, sphingolipids and phospholipids) ranged from 0.840 – 1.16g/100g EP. The percentage energy contribution due to protein (PEP%) in the total energy (kJ/100g) was high at 90.4 – 93.8% with equivalent utilizable energy due to protein (UEDP%) (Assuming 60% utilization) at 54.2 – 56.3%.In the daily energy requirement, an infant would have to consume between 204-214g whereas an adult would require 691-723 or 829-867g (depending on their physiological state) to satisfy their needs per day. The water deficit created by consuming the samples ranged from 1096-1187ml and the required water balance for complete metabolism ranged from 157-170ml. There was little or no variation among the samples in most of the parameters investigated.

Keywords: Energy contributions, *Gardus morhua*, Proximate composition, Water deficit

INTRODUCTION

Fish has been considered as one of the cheapest and most available sources of animal protein and other required essential nutrients in human diets (Sadiku and Oladimeji, 1991). It has been reported that fish provides about 22% of the total protein intake in sub-Saharan Africa (FAO, 2003). Pamploner-Roger (2006) reported that available fats in fishes contain unsaturated fatty acids which are heart friendly as they help reduce blood triglycerides. Variation in the type, quality and nature of nutrients in fishes could be due to species, type of food and feeding habits of the fishes. In addition to the general acceptability of fish as a veritable source of vitamins, it also contains polyunsaturated fatty acids and minerals required for healthy growth (Andrew, 2001). Stockfish (*Gardus morhua*) belongs to the family Gadidae, Genus *Gardus* and species *morhua* (Wikipedia, 2009 a and b). It is usually unsalted, dried by sun and wind on wooden racks on the foreshore called flakes or in special drying houses (Wikipedia 2009 b). The word stockfish is borrowed from Dutch *stokvis* (stick fish), probably referring to the wooden racks on which stockfish are traditionally dried or because the dried fish resembles a stick (Ogunleye and Olaiya, 2015). Nigeria is one of the prominent West African countries where stockfish are being traded and consumed in large quantity. The kind of sound stockfish produce in the pot informed the name “Akporoko” among the Annang tribe in Nigeria (Wikipedia, 2009 b). Stockfish is very rich in protein, B vitamins, iron and calcium with a mild flavour and a dense white flesh that flakes easily (Kurlansky,1997).Production of stockfish starts from immediately after the fish are caught. They are hung on wooden rack for three months usually between February and May after which the fish are then matured for another 2-3 months indoors in a dry and airy environment (Kurlansky, 2014).

Nigeria is one of the leading importers of fish in Africa with per capital consumption of 1.2 million metric tons (Ukoha *et al.*, 2014). During processing of stockfish, some of the anatomical parts such as the head together with the gills and eyes are either discarded as wastes or sold to people who could not afford to buy the stockfish due to low income. This study therefore aims at investigating the proximate composition of different body parts of sotckfish with a view to give preliminary information on whether or not any of the body parts could be consumed in lieu of the other.

MATERIALS AND METHODS

Stockfish samples used for this study were purchased from four major markets in Ado-EKiti, Ekiti State, Nigeria. The markets are Shasha, Oja-Oba, Oja-Irona and Oja-Okesha. The samples were kept inside sterile polythene bags.

Sample Preparation

Various body parts: gills, bones head, skin, muscle and eyes were carefully removed from the body with stainless steel knife and oven dried to a constant weight at 60^{o}C for 22h. After drying, the samples were separately homogenized with the aid of ceramic mortal and pestle and kept separately inside plastic containers prior to use for proximate analysis.

Sample Analysis

Moisture content was determined gravimetrically using ventilated oven set at 105^{o}C to dry the samples to constant weight (AOAC, 2006). Crude protein was determined by multiplying the estimated nitrogen content by a factor of 6.25 (Pearson, 1976). Extraction of crude fat (CF) was carried out by Soxhlet extraction apparatus with chloroform/methanol (2:1 v/v) mixture (AOAC, 2006). Crude ash was determined by igniting the samples in a muffle furnace set at 550^{o}C (AOAC, 2006).Crude fibre was determined by the method of AOAC (2006) and carbohydrate was estimated by difference, i.e.

Carbohydrate (g/100g)=100 (Moisture +Crude protein + Crude fat + Fibre + Ash) (1)

Total energy from protein and fat in kJ/100g and kcal/100g was estimated using the Atwater factors (Muller and Tobin, 1980)

Total energy (kJ/100g) = (fat x 37) + (protein x 17) (2)

Total energy (kcal/100g) = (crude fat x 9) + (crude protein x 4) (3)

Utilizable energy due to protein (UEDP%) = % protein energy in total energy x 60% (4)

Energy requirement for infants per day = $\frac{740\ kcal}{\text{Total energy}}\ x\frac{100}{1}$ ------------------------ (5)

Energy requirement for adult per day = $\frac{2500 kcal}{\text{total energy}}\ x\frac{100}{1}$ (6)

Energy requirement for adult per day = $\frac{3000\ kcal}{\text{total energy}}\ x\frac{100}{1}$ (7)

Conversion of CF to total fatty acid (TFA) (Anderson, 1976): Crude fat x 0.70 = TFA (8)

Statistical analysis was carried out using both descriptive (Mean, standard deviation and coefficient of variation percent) and inferential (Chi-square) methods (Oloyo, 2001).

RESULTS AND DISCUSSION

The results of investigation of the proximate composition (g/100g) of the stockfish samples are presented in Table 1. The levels of moisture content in the samples (6.20 – 9.40 g/100g) were comparatively higher than the following literature values (g/100g): mean values of organs of duck (2.88 ± 1.40) (Adeyeye, 2020), pouch rat (3.23 ± 2.02) (Adeyeye and Adesina, 2018) and *Numidia meleagris* (2.99 ± 1.75) (Adeyeye and Adesina, 2014). High levels of moisture content in the stockfish samples would affect the preservation quality of the samples as high moisture content promotes microbial activities in the samples during storage thereby exposing the samples to microbial attack. The least value of moisture content observed in the skin might be due to skin being the most exposed to heat treatment during processing.

The total ash content of the samples ranged from 6.55 g/100g in skin (SK) to 10.0g/100g in eyes (EY) and a mean value of 8.31 ± 1.09 g/100g. Total ash content could be used to roughly estimate the mineral content of any given sample; the higher the total ash, the higher the mineral content. High levels of ash in the samples could therefore predict the samples to be good sources of mineral elements.

Table 1: Proximate composition (g/100g) of stockfish body parts

Parameters	MS	BD	GL	BN	HD	SK	EY	Total	Mean±SD	CV%	χ^2
MC	8.60	9.40	7.80	8.70	8.40	6.20	8.80	55.9	7.99±1.13	14.1	0.962
Crude protein	80.8	78.3	81.0	79.6	79.9	84.7	79.4	564	80.5±2.05	2.55	0.313
Crude ash	7.40	8.45	8.40	8.55	8.80	6.55	10.0	58.2	8.31±1.09	13.1	0.855
Crude fat	3.20	3.85	2.80	3.15	2.90	2.55	3.80	22.3	3.80±0.49	15.5	0.457
Crude fibre	< 0.01	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	ND	ND	ND	ND
CHO	< 0.01	< 0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	ND	ND	ND	ND
DM	91.4	90.6	92.2	91.3	91.6	93.8	93.2	644	92.0± 1.13	1.23	0.084
OM	84.0	82.2	83.8	82.8	82.8	87.3	83.2	586	83.7± 1.19	2.02	0.205

MC = Moisture content; CHO = Carbohydrate; DM = Dry matter; OM = Organic matter; MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye; SD = Standard deviation; CV% = Coefficient of variation percent; χ^2 = Chi-square, α = 0.05 df n-1 [where n-1 = 7-1 = 6 (df= 6)], χ^2 at α = 0.05; critical value 12.59; hence values of χ^2 were not significantly different from each other for each parameter.

The total ash contents in this study were higher than1.17-1.33g/100g in differently fed catfish (Solomon and Oluchi, 2018), 1.65g/100g in pouch rat (Adeyeye and Adesina, 2018), 1.66g/100g in duck (Adeyeye, 2020) and 4.40 g/100g in Nigerian local cheese (Adeyeye *et al.*, 2021). The crude protein contents of the samples were very high, confirming the literature reports that fish is a very good source of protein. Crude protein levels in this study (78.3 – 84.7 g/100g) were higher than 19.09-20.75g/100gin differently fed catfish (Solomon and Oluchi, 2018),33.4g/100g in Nigerian local cheese (Adeyeye *et al*., 2021), 44.3g/100g and 38.4g/100g in *Clariasgariepinus* and *Oreochromis niloticus* respectively (Fawole *et al.,* 2007). The protein content (g/100g) in eyes and skin in this study are 79.4 and 84.7 respectively. These values were well above the literature reports for similar organs in duck, pouch rat and *N. meleagris* with the following values (g/100g): duck: eyes (18.2) and skin (3.24) (Adeyeye, 2020); pouch rat: eyes (7.11) and skin (2.70) (Adeyeye and Adesina, 2018); *N. meleagris* eyes (17.7) and skin (1.08) (Adeyeye and Adesina, 2014). Another interesting scenario is that for duck, pouch rat and *N. Meleagris*, crude protein was more concentrated in eyes than skin but in this study, there is higher level of crude protein in the skin than in the eyes. The crude fat content of the stockfish samples were relatively low in the range 2.55 – 3.85g/100g with mean value of 3.80$\pm$ 0.492. These values were lower than 5.35g/100g and 6.26g/100g in adult bee and maize weevil respectively (Adeyeye and Olaleye, 2016), 14.2g/100g in beef jerky meat (Adeyeye *et al.,* 2020) and 18.4g/100g in Nigerian local cheese (Adeyeye *et al*., 2021). This is not surprising as stockfish is one of the lean fishes expected to have low fat content. Crude fat in this study are (g/100g): muscle (3.20) and skin (2.55) whereas Adeyeye and Ayejuyo (2007) reported the following for similar organs in turkey (g/100g): muscle (2.12) and skin (12.1).However, crude fat in this study was higher than 1.16-1.91g/100g in the muscle of different fish species from Muthupettal mangroves (Suganthi *et al*., 2015).Both crude fibre and carbohydrate were reported in trace amounts (<0.01g/100g). High concentrations of protein could largely be responsible for the very low contents of crude fibre, carbohydrate and the method of drying whereby the nutrients remain concentrated in the stockfish.

The dry matter levels in the samples (90.6 – 93.8g/100g) compare favourably to 92.3g/100g reported for Nigerian local cheese (Adeyeye *et al*., 2021). They were however lower than 95.2 - 95.5 g/100g reported by Adeyeye (2020) for duck organs. Moisture content is usually the predictor of dry matter in any food sample as they vary inversely with each other. The organ (SK) with least levels of moisture and total ash (6.20 g/100g and 6.55 g/100g respectively) had the highest value of organic matter (87.3 g/100g). The levels of organic matter (OM) in this study (82.2 – 87.3 g/100g) were higher than the values in *Bagrus bayad* (75.0g/100g) and *Hemichronis fasciatus* (76.0g/100g) (Abdullahi and Abolude, 2002). They are however lower than 98.97g/100g in ostrich muscle (Sales and Hayes, 1996) and 91.07g/100g in trunk fish (Adeyeye and Adamu, 2005). Generally, the descriptive and inferential statistical analyses of the proximate profiles show that there is agreement among the samples in most of the parameters determined. This is evident in the low values of coefficient of variation percent (CV%) (1.23 – 15.5%) as well as the Chi-square results which ranged from 0.0836 – 0.9623, showing that the values were not significantly different. This implies that any of the body parts examined could likely perform similar biochemical functions of others. Profiles of energy contributions from crude fat and crude protein are presented in Table 2. In the total energy contributed by fat, BD had the highest value (142kJ/100g or 34.7kcal/100g) with 17.2% of total value. The least value was observed in SK (94.5kJ/100g) with percent value of 11.5% whereas the highest total energy contributed by protein was observed in SK (1440kJ/100g or 339kcal/100g) with 15.0% of total value from all samples. BD contributed the least energy from protein with 1331kJ/100g or 313kcal/100g and 13.9% of total value from all samples.

Table 2: Energy contributions from fat and protein in proximate composition of stockfish body parts

Energy contribution	MS	BD	GL	BN	HD	SK	EY	Total
Fat								
kJ/100g	118	142	104	117	107	94.5	141	824
kcal/100g	28.8	34.7	25.2	28.4	26.1	23.0	34.2	200
% Value	14.3	17.2	12.6	14.2	13.0	11.5	17.1	ND
Protein								
kJ/100g	1374	1331	1377	1353	1358	1440	1350	9583
Kcal/100g	323	313	324	318	320	339	318	2255
% Value	14.3	13.9	14.4	14.1	14.2	15.0	14.1	ND
Total (kJ/100g)	1492	1473	1481	1470	1465	1535	1491	10407
Total (kcal/100g)	352	348	349	346	346	362	352	2455

MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye; ND = Not determined

Generally, the total energy contributed by both fat and protein ranged from 1465kJ/100g (346kcal/100g) in HD to 1535kJ/100g (362kcal/100g) in SK. Total energy in any food sample is usually obtained from contributions of fat, protein and carbohydrate. However, energy contribution from carbohydrate could not be used to compute the total energy value in this study due to trace amounts of carbohydrate. The total energy in this study was lower than 1720kJ/100g in Nigerian local cheese (Adeyeye *et al.*, 2021), 1713kJ/100g in muscovy duck-hen (Adeyeye, 2020) and 1660kJ/100g in beef jerky meat (Adeyeye *et al.*, 2020).

The percentage energy contributions by fat (PEF%), protein (PEP%) and energy contributions due to protein, assuming 60% utilization (UEDP%) are depicted in Table 3. The results showed that PEP% >> PEF% in each of the samples. The same trend had been observed in the following literature reports: five commonly eaten insects in southwestern Nigeria (Adeyeye and Olaleye, 2016); duck-hen organs (Adeyeye, 2020).

Table 3: Proportion of total energy due to fat (PEF%) and protein (PEP%) and (UEDP%) from fat and protein in the proximate composition

Energy contribution	Stockfish body parts						
Total energy	**MS**	**BD**	**GL**	**BN**	**HD**	**SK**	**EY**
kJ/100g	1492	1473	1481	1470	1465	1535	1491
kcal/100g	352	348	349	346	346	362	352
PEF%							
kJ/100g	7.91	9.64	7.02	7.96	7.30	6.16	9.46
kcal/100g	8.18	9.97	7.22	8.21	7.54	6.35	9.72
PEP%							
kJ/100g	92.1	90.4	93.0	92.0	92.7	93.8	90.5
kcal/100g	91.8	89.9	92.8	91.9	92.5	93.6	90.3
UEDP%							
kJ/100g	55.3	54.2	55.8	55.2	55.6	56.3	54.3
kcal/100g	55.1	54.0	55.7	55.1	55.5	56.2	54.2

MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye

However, reverse trend was observed in Nigerian local cheese (Adeyeye *et al.,* 2021) and beef jerky meat (Kilishi) (Adeyeye *et al.,* 2020). The PEF% values in this study are lower than recommended 30% of the total energy requirement (NACNE, 1983) and 35% for total energy intake (COMA, 1984). The levels of UEDP% were high in all the samples in both kJ and kcal models. The high UEDP% shows that the samples have enough protein (in terms of energy) that is enough to prevent protein energy malnutrition in adults and children fed solely on the samples as the main protein source.

Table 4 shows the distribution of fat into total fatty acid (TFA) and other lipids. Conversion of crude fat into total fatty acid was achieved by multiplying the crude fat values by 0.70 (Anderson, 1976). The TFA which could also be referred to as edible portion (Ep) (g/100g) ranged from 1.79g/100g EP in SK to 2.70g/100g EP in BN. Other lipids such as phospholipids, sterols, etc. ranged from 0.765 – 1.56g/100g Ep. The percentage value for the TFA in each sample was constant at 70.0% just like that of other lipids with constant value of 30.0%. The constant percentage values could be due to the same conversion factor used. Addition of energy from TFA and other lipids (kcal/100g) gave similar values with the total energy contributed by fat (kcal/100g) in each of the samples.

Table 4: Distribution of total fatty acid and other lipids from crude fat of stockfish body parts

Sample	Crude fat	TFA (%)	Other lipids (%)	TFAenergy (kcal)	Other lipids energy (kcal)
MS	3.20	2.24 (70.0)	0.960 (30.0)	20.2	8.64
BD	3.85	2.70 (70.0)	1.16 (30.0)	24.3	10.4
GL	2.80	1.96 (70.0)	0.840 (30.0)	17.6	7.56
BN	3.15	2.21 (70.0)	0.945 (30.0)	19.8	8.51
HD	2.90	2.03 (70.0)	0.870 (30.0)	18.3	7.83
SK	2.55	1.79 (70.0)	0.765 (30.0)	16.1	6.89
EY	3.80	2.66 (70.0)	1.14 (30.0)	23.9	10.3

MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye

The approximate sample weight equivalents to the energy requirements of both adults and infants from the proximate composition are shown in Table 5. The daily energy requirement for infant is 740kcal and range from 2500-3000kcal for adults depending on adults' physiological state (Bingham, 1978). This shows that for 2500kcal model, an adult would, need to consume between 691-723g and between 829-867g (for 3000kcal model) depending on the sample to cater for energy need per day. Infants would have to take between 204-214g (depending on the sample) in order to satisfy their energy needs per day. The present values for sample weight equivalents were lower than the literature reports: *Acanthurus monroviae* adult: 733g and 880g (for 2500kcal model and 3000kcal model respectively), infant: 220g; *Lutjanus goreensis*: adult: 735g and 882g respectively, infant: 221g (Adeyeye *et al.*, 2016).

Table 5: Approximate sample weight equivalent to the energy requirements of adults and infants from the proximate composition

Sample	Total energy	Adult energy requirement per day		Infant energy requirement per day
		2500 kcal Sample equivalent (g)	3000 kcal Sample equivalent (g)	740 kcal Sample equivalent (g)
MS	352	710	852	210
BD	348	718	862	213
GL	349	716	860	212
BN	346	723	867	214
HD	346	723	867	214
SK	362	691	829	204
EY	352	710	852	210

MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye

Table 6 depicts the required water for excretion of urea and sulphate formed as well as water deficit as a result of metabolism in each of the samples. The values of water (g) required for complete metabolism of 100 calories of food substances are: pre-formed water: 0.0g (for protein, fat and starch); water gained by oxidation: 10.3 (protein), 11.9 (fat) and 13.9 (starch); water lost in excreting end products: 300 (protein) and 0.00 (for both fat and starch); water deficit: 350 (protein) 48(fat) and 46 (starch). 1 calorie of protein requires 3ml of water for excretion of urea and sulphate formed from it (Albanese, 1959). In Table 6, the required water for excretion of urea and sulphate by-products formed (Q) ranged from 939-1017ml, whereas water deficit from metabolism ranged from 1096-1187ml. Therefore the required water balance for complete metabolism for each of the samples (T-Q) are (ml): MS(162), BD(157), GL(162), BN (159), HD (160), SK(170) and EY (159). Effect of the water deficit may not be mitigated by carbohydrate and fat due to their presence in relatively small amounts. However, water deficit in the samples could be made up for from water intake.

Table 6: Water requirement for complete metabolism from proximate composition of stockfish body parts

Parameters	**MS**	**BD**	**GL**	**BN**	**HD**	**SK**	**EY**
Protein (g/100g)	80.8	78.3	81.0	79.6	79.9	84.7	79.4
Energy contributed by protein (P) (kcal/100g)	323	313	324	318	320	339	318
Required water for excretion (= 3P)^X (ml)	969	939	972	954	960	1017	954
Water deficit (350/100 x P = T) (ml)	1131	1096	1134	1113	1120	1187	1113
Required water balance (= T- Q) (ml)	162	157	162	159	160	170	159

MS = Muscle; BD = Body; GL = Gill; BN = Bone; HD = Head; SK = Skin; EY = Eye; ^{x} = 1 calorie of protein requires 3 ml of water for by-products excretion

CONCLUSION

This study investigated the proximate composition of various organs of stockfish. Stockfish is a poor source of both crude fibre and carbohydrate but very rich in crude protein, having more than 75% of total in each of the samples. The total energy was high at 1465-1535kg/100g and was mainly contributed by protein. Total fatty acid from the crude fat was higher than other types of lipids in the samples. The required water balance from complete metabolic reactions in the body was relatively low in the samples because none was up to 200ml. Generally, there was little or no variation among the stockfish samples in most of the parameters determined.

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