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Turkey-Hen Amino Acid Composition of Brain and Eyes

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Abstract. The amino acids composition of the brain and eyes of the mature Turkey-hen (*Meleagris gallopavo* L.), were determined on dry weight basis. Total essential amino acids ranged from 35.1-36.0 g/100 g as 49.5-49.8% of the total amino acids. The amino acid score showed that lysine ranged from 0.76-0.91 (on whole hen's egg comparison), 0.85-1.03 (on provisional essential amino acid scoring pattern), and 0.81-0.98 (on suggested requirement of the essential amino acid of a preschool child). The predicted protein efficiency ratio was 1.94-2.41, whilst essential amino acid index range was 1.06-1.08 and the calculated isoelectric point range was 3.97-4.18. The correlation coefficient (r_{xy}) was positively high and significant at r = 0.01 for the total amino acids, amino acid scores (on the whole hen's egg comparisons made) and the isoelectric point. On the whole, the eyes were better in 12/18 or 66.7% parameters of the amino acids than the brain of Turkey-Hen.

Keywords: amino acids, brain, eyes, turkey-hen

Introduction

Turkey with reference to birds, was originally a prefix to the terms cock, hen and poult (a young bird), but now stands on its own and denotes the species *Meleagris gallopavo*. Native to North America, these birds are now farmed and used for table poultry around the globe (Schorger, 1966).

The nomenclature of Turkey in modern European languages and scientific Latin, reflects confusion about the origin and nature of the bird on their arrival from the new world. They were confused in European minds with guinea-fowl, and probably peacocks too. Linnaeus used *Meleagris*, the Roman name for guinea-fowl, when naming the genus to which turkeys belong. Europeans called turkeys by names reflecting a supposed eastern origin, including coq d'Inde (cock of India), later corrupted to dinde or dindon in French. The English, who may have had their first birds through the agency of the Levant or Turkey merchants, settled on Turkey-cock (Davidson, 1999).

In their natural state they live in flocks, roosting in swampy areas and feeding on woodland berries and seeds. They are awkward in flight but run fast. It is thought to have been domesticated late in the 2nd millennium BC, somewhere, in Central America. By the time of the Spanish conquest, it was reared as a table bird and eaten by royalty. The earliest full description of turkeys in the new world was given by Shagún (1590) who recommended the meat of the hen as fat and savoury, and recorded several modes of preparation, including in TAMALES (Davidson, 1999).

Due to the emphasis placed on the nutritive value of food by consumers, a great need exists for information on the nutritional qualities of Turkey meat. Some work has been reported on different organs analyses of the Turkey-hen. Adeyeye and Ayejuyo (2007) reported on the proximate, amino acid and mineral composition of Turkey-hen muscle and skin; effect of salts on the food properties of Turkey-hen (*Meleagris gallopavo* L.) muscle flour (Adeyeye, 2011a); comparative study on the characteristics of egg shells of some bird species (including turkey) (Adeyeye, 2009a); determination of amino acids profiles of the organ meats of the Turkey-hen (Adeyeye, 2012) and the comparison of the amino acids profiles of whole eggs of duck, francolin and Turkey consumed in Nigeria (Adeyeye, 2013). In this part of the world, the head of the Turkey is usually reserved and given to the preschool child (2-5 years old) for consumption after cooking. The present study was therefore, undertaken in attempt to gain some information on the amino acid of the head organs (brain and eyes) of Turkey-hen. The Turkey sample used was the white plumage Turkey-hen bird.

Materials and Methods

Preparation of samples. Prior to butchering, food was withheld for a day to help ensure the digestive system was empty. Head was held on the stump and the Turkey head removed with an axe. At the end of bleeding, the Turkey was plucked. When all the feathers had been

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removed, the head was rinsed and dried in the oven. After drying, the eyes and brain were separately extracted, ground, sieved and kept in freezer in McCartney bottles pending analysis. Five birds (all free range) were used in the study.

Crude protein determination and fat extraction. The micro-Kjeldahl method as described by Pearson (1976) was followed to determine the fat-free protein. The fat was extracted with a chloroform/methanol (2:1 v/v) mixture using Soxhlet extraction apparatus (AOAC, 2006).

Amino acid analysis. Defatted samples between (30-35 mg) were weighed into glass ampoule, 7 mL of 6 MHCl added and hydrolysed in an oven preset at 105±5 °C for 22 h. Oxygen was expelled in the ampoule by passing nitrogen gas into it. Amino acid analysis was done by ion-exchange chromatography (Moore *et al*., 1958) using a Technicon sequential multisample amino acid analyzer (Technicon Instruments Corporation, New York, USA). The period of analysis was 76 min, with a gas flow rate of 0.50 mL/min at 60 °C, and the reproducibility was ±3%. Tryptophan was not determined due to cost. Norleucine was used as the internal standard.

Estimation of isoelectric point (pI). Theoretical estimation of isoelectric point (pI) was determined using the equation of Olaofe and Akintayo (2000) and information provided by Finar (1975).

Estimation of predicted protein efficiency ratio (P-PER). The predicted protein efficiency ratio (P-PER) was estimated by using the equation from Alsmeyer *et al*. (1974).

Estimation of dietary protein quality. The amino acid scores were calculated using three different procedures:

(i) scores based on amino acid values compared with whole hen's egg amino acid profile (Paul and Southgate, 1978);
(ii) scores based on essential amino acid scoring pattern (FAO/WHO, 1973);
(iii) scores based on essential amino acid suggested pattern of requirements for preschool child (FAO/WHO/UNU, 1985).

Estimation of amino acid index (EAAI). The essential amino acid index (EAAI) was determined by using the method of Steinke *et al*. (1980).

Leucine/Isoleucine ratio. The leucine/isoleucine ratios, their differences and their percentage differences were calculated.

Statistical analysis. Statistical analysis was carried out to determine the mean, standard deviation (SD) and the coefficients of variation percent (CV %). A summary of the amino acids profile into factors A and B was also carried out (Oloyo, 2001).

Results and Discussion

Table 1 shows that amino acid of the eye was slightly concentrated (on pair wise comparisons) than the corresponding amino acid in the brain in 11/17 (64.7%) (amino acid) or 12/18 (66.7%) (amino acid plus protein) parameters, of the nine essential amino acids determined, 5/9 or 55.6% were more concentrated in the eyes than the brain on pair wise comparisons. The most concentrated essential amino acid (EAA) in the samples was Leu (7.02 g/100 g (protein) in the brain and 6.02 g/100 g (protein) in the eyes. The coefficient of variation per cent (CV %) ranged between 3.32-15.8 in the amino acids, with Tyr having the least CV % and Ala having the highest CV %. From literature, the EAA with Cys and Tyr values had been given for the brain of cattle, pig and sheep (Fornias, 1996); in g/100 g protein. With these literature values, the present EAA results in the

Table 1. Amino acid composition (g/100 g protein) of the eyes and brain of Turkey-Hen (dry weight)

Amino acid	Brain	Eyes	Mean*	SD	CV %
Lys[a]	4.69	5.66	5.18	0.69	13.3
His[a]	1.85	2.14	2.00	0.21	10.3
Arg[a]	4.49	5.18	4.84	0.49	10.1
Asp	7.96	7.00	7.48	0.68	9.08
Thr[a]	4.01	3.41	3.71	0.42	11.4
Ser	2.40	3.25	2.83	0.60	21.3
Glu	11.3	12.8	12.1	1.06	8.80
Pro	2.24	2.60	2.42	0.25	10.5
Gly	4.66	3.81	4.24	0.60	14.2
Ala	2.70	3.38	3.04	0.48	15.8
Met[a]	2.35	2.80	2.58	0.32	12.4
Cys	0.71	0.79	0.75	0.06	7.54
Val[a]	3.21	2.99	3.10	0.16	5.02
Ile[a]	3.51	3.79	3.47	0.45	13.0
Leu[a]	7.02	6.02	6.52	0.71	10.8
Phe[a]	4.35	4.05	4.20	0.21	5.05
Tyr	2.91	3.05	2.98	0.099	3.32
Try[a]	-	-	-	-	-
Protein (fat free)	61.4	66.2	63.8	3.39	5.32

[a] = essential amino acid; - = not determined; * = mean value is grand mean values of the amino acids; SD = standard deviation; CV % = coefficient of variation per cent.

brain can be described as follows: Leu (7.02), Ile (3.15), Lys (4.69), Met (2.35), Cys (0.71), Phe (4.35), Tyr 2.91), Thr (4.01), Val (3.21), His (1.85) and total (34.25). The value of 34.25 g/100 g protein in the brain of Turkey-hen was close to the value of 34.81 g/100 g protein in African giant pouch rat brain and 35.79 g/100 g protein in the guinea fowl hen brain. In the eyes, the total EAA in the eyes of Turkey-hen was 34.7 g/100 g protein, in the eyes of guinea fowl total was 36.62 g/100 g and in the eyes of African giant pouch rat total was 35.31 g/100 g protein. (Try was not determined in the present samples.)

The FAO/WHO/UNU (1985) standards for preschool children (2-5 years) were (g/100 g protein): Leu (6.6), Phe + Tyr (6.3), Thr (3.4), Try (1.1), Val (3.5), Ile (2.8), Lys (5.8), Met +Cys (2.5), His (1.9) and total (33.9 with His) and 32.0 (no His). Based on this information, the brain would provide enough or even more than enough of the Phe + Tyr, Ile, Leu, Thr, Met + Cys, His and total EAA while the eyes would provide enough or even more of Phe + Tyr, Thr, Ile, Met + Cys, His and total EAA. (Tryptophan was not determined.) Histidine is a semi-essential amino acid particularly useful for children growth. The value of Ile was 3.15-3.79 g/100 g protein in the samples. It is an essential amino acid for both old and young. Maple syrup urine disease is an inborn error of metabolism in which brain damage and early death can be avoided by a diet low in Ile and two other EAA, Leu and Val. Isoleucine was higher than the preschool standard (3.15-3.79 g/100 g protein *versus* 2.8 g/100 g protein), Leu was lower in the eyes (6.02-7.02 g/100 g protein *versus* 6.6 g/100 g protein), whereas, Val was low in both samples (2.99-3.21 g/100 g protein *versus* 3.5 g/100 g protein). Methionine is an EAA with value range of 2.35-2.80 g/100 g protein in this report or 3.06-3.59 g/100 g protein with Cys. Methionine is needed for the synthesis of choline. Choline forms lecithin and other phospholipids in the body. When the diet is low in protein, for instance in alcoholism and kwashiorkor, insufficient choline may be formed; this may cause accumulation of fat in the liver (Bingham, 1977). Phenylalanine formed a value range of 4.05-4.35 g/100 g protein in the samples. It is the precursor of some hormones and the pigment melanin in hair, eyes and tanned skin. In a normal diet, deficiency in Phe hardly occurs: for example, four large slices of bread supply the estimated adult needs for Phe and Tyr. Tyrosine is the precursor of some hormones (like the thyroid hormones) and the brown pigment melanin formed in hair, eyes and tanned skin. Tyrosine is found in all food proteins and reduces the requirement for Phe. Daily requirement of Phe is 31 mg/kg with a maintenance pattern of 4.3 (Rose, 1949). Tyrosine biosynthesis in mammals occurs by hydroxylation of Phe. Much of the dietary requirement for Phe is, in fact, due to the need for Tyr. If the latter is fed, the dietary requirement for Phe is reduced substantially. In this sense, Tyr bears the same relationship to Phe as cysteine does to Met. In normal metabolism, the only known fate of Phe, other than utilisation for protein synthesis, is its conversion to Tyr. The liver enzyme system catalysing this hydroxylation is Phenylalanine hydroxylase, a mixed-function hydroxylase that utilises tetrahydrobiopterin as the reduced cofactor.

Problems could arise with addition of phenylalanine/tyrosine in food. These include:

(i) Hereditary lack of Phe hydroxylase results in phenylketonuria. In the absence of this enzyme, minor pathways of Phe metabolism, little used in normal individuals, become prominent. Transamination from Phe yields phenylpyruvic acid, of which as much as 1-2 g/day may be excreted in the urine. The accumulation of phenylpyruvic acid also leads to formation and urinary excretion of Phenyllactic acid, *o*-hydroxyphenylacetic acid, and phenylacetic acid, the last as phenylacetylglutamine (White *et al*., 1973).

(ii) Phenylpyruvic acid is termed as keto acid because of its molecular structure; hence, the disease is known as phenylketonuria or PKU. People with the disease are called phenylketonurics. Infants diagnosed PKU must be put on a diet severely limited in Phe, avoiding excess Phe from milk, meats, other sources of rich protein. Phenylalanine is an EAA, a minimum amount of it must be available. Supplemented Tyr may also be needed to compensate for the absence of the normal conversion of Phe to Tyr (Eubanks *et al*., 2009).

(iii) High levels of tyrosine. Due to a temporary insufficiency of an enzyme necessary for its normal metabolism-sometimes it accumulates in the blood stream of babies. Permanent deficiency of the enzyme-hypertyrosinaemia, a rare inborn error of metabolism- can cause liver and kidney failure unless treated with a synthetic diet low in Phe and Tyr. Food containing tyramine, a derivative of tyrosine, must be avoided when certain tranquillisers are taken. Tyramine occurs naturally in cheese, extracts, baked beans, alcohol and yogurt. It is normally detoxicated by a group of enzymes called the monoamine oxidases

(MAO), but certain antidepressant drugs inhibit their action. These foods must not be eaten in conjunction with MAO inhibiting drugs: an alarming rise in blood pressure with sometimes fatal result has been recorded (Bingham, 1977). Valine, an EAA is restricted in the treatment of maple syrup urine disease.

Table 2 presents parameters on the quality of the protein of the samples. The EAA ranged between 35.1-36.0 g/100 g protein of the samples with a variation of 0.43% (least CV %). These values were more than half the average of 56.6 g/100 g protein of the egg reference protein (Paul and Southgate, 1978). The total sulphur amino acid (TSAA) of the samples was 3.06 g/100 g protein (brain) and 3.59 g/100 g protein (eyes). The values of 3.06-3.59 g/100 g protein were close to the value of 5.8 g/100 g protein recommended for infants (FAO/WHO/UNU, 1985). The aromatic amino acid (ArAA) range suggested for infant protein (6.8-11.8 g/100 g protein) (FAO/WHO/UNU, 1985) was very favourably comparable with current report of 9.11-9.24 g/100 g protein showing that the samples protein could be used to supplement sorghum flour (Adeyeye, 2008a), whole wheat flour (Adeyeye, 2011b) and pearl millet (Adeyeye, 2009b). The TSAA of the eyes and brain of African giant pouch rat ranged as 3.61-3.62 g/100 g protein, whilst the ArAA ranged as 7.45-7.87 g/100 g protein (Oyarekua and Adeyeye, 2011), whereas, the corresponding values in the brains and eyes of guinea fowl were 3.15-3.47 g/100 g protein (TSAA) and 7.32-8.93 g/100 g protein, respectively (Adeyeye and Aremu, 2010). The percentage ratio of EAA to the total amino acid (TAA) in the samples ranged between 49.5-49.8%. These values were well above the 39% considered adequate for ideal protein food for infants, 26% for children and 11% for adults (FAO/WHO/UNU, 1985).

Table 2. EAA, non-EAA, acidic, neutral, sulphur and aromatic amino acid contents (g/100 g protein) of the eyes and brain of Turkey-hen (dry weight)

Amino acid	Brain	Eyes	Mean	SD	CV %
Total amino acids (TAA)	70.5	72.7	71.6	1.56	2.17
Total non-essential amino acid (TNEAA)	35.4	36.7	36.1	0.92	2.55
Total EAA					
-with His	35.1	36.0	35.6	0.64	1.79
-no His	33.3	33.9	3.36	0.42	12.6
% TNEAA	50.2	50.5	50.4	0.21	0.42
% Total EAA					
-with His	49.8	49.5	49.7	0.21	0.43
-no His	47.2	46.6	46.9	0.42	0.90
Total neutral amino acid (TNAA)	39.7	39.9	39.8	0.14	0.36
% TNAA	56.3	54.9	55.6	0.99	1.78
Total acidic amino acid (TAAA)	19.3	19.8	19.6	0.35	1.81
% TAAA	27.4	27.2	27.3	0.14	0.52
Total basic amino acid (TBAA)	11.0	13.0	12.0	1.41	11.8
% TBAA	15.6	17.9	16.8	1.63	9.71
Total sulphur amino acid (TSAA)	3.06	3.59	3.33	0.37	11.3
% TSAA	4.34	4.94	4.64	0.42	9.14
% Cys in TSAA	23.2	22.0	22.6	0.85	3.75
Total aromatic amino acid (TArAA)	9.11	9.24	9.18	0.09	1.00
% TArAA	12.9	12.7	12.8	0.14	1.10

The percentage of EAA/TAA for the samples could be favourably compared with other animal protein sources: 46.2% in *Zonocerus variegatus* (Adeyeye, 2005a), 43.7% in *Macrotermes bellicosus* (Adeyeye, 2005b), 54.8% in *Gymnarchus niloticus* (Trunk fish) (Adeyeye and Adamu, 2005), 48.1-49.9% in brain and eyes (African giant pouch rat) and in the brain and eyes of guinea fowl, 47.5-52.2%, whereas, it is 50% for egg (FAO/WHO, 1990). The total EAA in these results were close to the value of 44.4 g/100 g protein in soybean (Yuwai *et al*., 1991), melon and gourd oilseeds with respective values of 53.4 g/100 g protein (Olaofe *et al.,* 1994). The percentage of total neutral amino acid (TNAA) ranged from 54.9-56.3, indicating that they formed the bulk of the amino acids; total acidic amino acid (TAAA) ranged from 27.2-27.4% which were far lower than % TNAA, whilst the percentage range in total basic amino acid (TBAA) was 15.6-17.9, which made them the third largest group among the samples.

Most animal proteins are low in Cys, for examples: 36.3% in *M. bellicosus* (Adeyeye, 2005b); 25.6% in *Z. variegatus* (Adeyeye, 2005a); 35.5% in *Archachatina marginata*, 38.8% in *Archatina archatina* and 21.0% in *Limicolaria* sp., respectively (Adeyeye and Afolabi, 2004); 23.8-30.1% in three different Nigerian fishes (Adeyeye, 2009c); 27.3-32.8% in female fresh water crab body parts (Adeyeye, 2008b); 13.3-15.9% in male fresh water crab body parts (Adeyeye and Kenni, 2008); 26.0-26.5% in Turkey-hen meat (Adeyeye and Ayejuyo, 2007) in their (Cys/TSAA) % values. The present results corroborated these observations with values of 23.2

(brain) down to 22.0% (eyes). In other brain/eyes (Cys/TSAA) % values, it was 34.6 (brain) down to 20.6% (eyes) in guinea fowl (Adeyeye and Aremu, 2010) and also 28.2 (brain) down to 20.8% (brain) in African giant pouch rat (Oyarekua and Adeyeye, 2011). In contrast, many vegetable proteins contain substantially more Cys than Met, examples (Cys/TSAA) %: 62.9% in coconut endosperm (Adeyeye, 2004); in *Anacardium occidentale* it is 50.5% (Adeyeye *et al*., 2007); 58.9-72.0 in sorghum (raw, steeped, germinated) (Adeyeye, 2008a); 45.8-52.6 (raw, steeped, germinated) wheat (Adeyeye, 2011b); 51.2-53.1 (raw, steeped, germinated) pearl millet (Adeyeye, 2009b). Thus, for animal protein diets or mixed diets containing animal protein, Cys is unlikely to contribute up to 50% of the TSAA (FAO/ WHO, 1991). The percentage of Cys in TSAA had been set at 50% in rat, chick and pig diets (FAO/WHO, 1991). Cys can spare with Met in improving protein quality and has positive effects on mineral absorption, particularly zinc (Mendoza, 2002; Sandstrom *et al*., 1989).

The data in Table 3 depicted the differences in the amino acid concentration values (g/100 g protein) between the brain and the eyes. Values in Lys, His, Arg, Ser, Glu, Pro, Gly, Ala, Met, Cys, Ile, Tyr and protein were more concentrated in the eyes than in the brain; this gave a value of 12/18 or 66.7%. Among the essential amino acids, 5/9 or 55.6% members were more positively concentrated in the eyes than the brain. For all the amino acids, where values in eyes were better than the brain, better concentrated values were in the percentage range of 4.81-35.4%; on the EAA side, range was 6.90-20.7%.

In Table 4, some specialised amino acid quality parameters in the samples were shown. The CV % values were generally higher than in Tables 1 and 2; they ranged from 1.32-38.0. In all the parameters reported, the brain was higher in predicted protein efficiency ratio (P-PER), Leu/Ile ratio, Leu-Ile (difference) and % Leu-Ile (difference), whereas, eyes had higher values in essential amino acid index (EAAI) and the isoelectric point (pI). The predicted protein efficiency ratio (P-PER) was 2.41 (brain) and 1.94 (eyes). These results were highly comparable to the following literature values: 2.27 (skin) and 1.93 (muscle) of Turkey-hen (Adeyeye and Ayejuyo, 2007); it is 2.22 (*Clarias anguillaris*), 1.92 (*Oreochromis niloticus*) and 1.89 (*Cynoglossus senegalensis*) (Adeyeye, 2009c); 1.82 (brain) and 2.33 (eyes) of guinea fowl (Adeyeye and Aremu, 2010); 1.58 (brain) and 2.08 (eyes) of African giant pouch rat (Oyarekua and Adeyeye, 2011) but lower than in the values from various parts of fresh water female crab: 3.4 (whole body), 3.1 (flesh), 2.6 (exoskeleton) (Adeyeye, 2008b); fresh male crab: 2.9 (whole body), 2.8 (flesh), 2.4 (exoskeleton) (Adeyeye and Kenni, 2008); 4.06 (corn *ogi*) and reference casein with PER of 2.50 (Oyarekua and Eleyinmi, 2004); 2.56 (cattle brain), 3.04 (pig brain) and 2.68 (sheep brain) (Fornias, 1996). Other literature values were 1.21 (cowpea), 1.82 (pigeon pea) (Salunkhe and Kadam, 1989); 1.62 (millet *ogi*) and 0.27 (sorghum *ogi*) (Oyarekua and Eleyinmi, 2004); greater than 0.00 (raw sorghum), 0.23 (steeped sorghum) and 0.29 (germinated sorghum) (Adeyeye, 2008a). The Leu/Ile ratio was low in both

Table 3. Differences (g/100 g protein) between the amino acids composition of the eyes and brain of Turkey-hen (dry weight)

Amino acid	Brain	Eyes	Difference*
Lys	4.69	5.66	-0.97 (20.7%)
His	1.85	2.14	-0.29 (15.7%)
Arg	4.49	5.18	-0.69 (15.4%)
Asp	7.96	7.00	+0.96 (12.1%)
Thr	4.01	3.41	+0.60 (15.0%)
Ser	2.40	3.25	-0.85 (35.4%)
Glu	11.3	12.8	-1.50 (13.3%)
Pro	2.24	2.60	-0.36 (16.1%)
Gly	4.66	3.81	+0.85 (18.2%)
Ala	2.70	3.38	-0.68 (25.2%)
Met	2.35	2.80	-0.45 (19.1%)
Cys	0.71	0.79	-0.08 (11.3%)
Val	3.21	2.99	+0.22 (6.85%)
Ile	3.15	3.79	-0.64 (20.3)
Leu	7.02	6.02	+1.00 (14.2%)
Phe	4.35	4.05	+0.3 (6.90%)
Tyr	2.91	3.05	-0.14 (4.81%)
Try	-	-	-
Protein	61.4	66.2	-4.8 (7.82%)

* = negative values mean amino acid value in eye is higher than in the brain and *vice versa* for the positive sign; same sign runs before and within the brackets.

Table 4. Some specialized amino acid quality parameters in the samples

Parameter	Brain	Eyes	Mean	SD	CV %
P-PER	2.41	1.94	2.18	0.33	15.3
Leu/Ile ratio	2.23	1.59	1.91	0.45	23.7
Leu-Ile (difference)	3.87	2.23	3.05	1.16	38.0
% Leu-Ile (difference)	55.1	37.0	46.1	12.8	27.8
EAAI	1.06	1.08	1.07	0.01	1.32
Isoelectric point (pI)	3.97	4.18	4.08	0.15	3.64

samples (1.59-2.23) with CV % of 23.7, hence, no concentration antagonism might be experienced in the Turkey-hen samples when used as protein source in food. The essential amino acid index (EAAI) ranged from 1.06 (brain) -1.08(eyes) and CV % of 1.32. EAAI is useful as a rapid tool to evaluate food formulations for protein quality, although it does not account for differences in protein quality due to various processing methods or certain chemical reactions (Nielsen, 2002). The EAAI of defatted soybean is 1.26 (Nielsen, 2002); this is a bit higher than the present results. In the results of the isoelectric points (pI), there was a shift from 3.97 (brain) up to 4.18 (eyes). This type of shift was also seen in turkey meat: from 4.41 (skin) to 5.01 (muscle) (Adeyeye and Ayejuyo, 2007); from 4.64 (brain) down to 4.32 (eyes) in guinea fowl (Adeyeye and Aremu, 2010); 4.28 (brain) down to 4.25 (eyes) in African giant pouch rat (Oyarekua and Adeyeye, 2011). The calculation of pI from amino acids would assist in the production of the protein isolate of organic product without going through the process of determining the functionality of the organic product.

Table 5 shows the amino acid scores (AAS) of the samples based on whole hen's egg profile (Paul and Southgate, 1978). The score values were very close with the variation ranging from 2.85-21.9%. The least or limiting amino acid score was Ser in both samples with values as 0.30 (brain) and 0.41 (eyes) but highest variation of 21.9%. The Turkey-hen head organs (brain and eyes) generally showed good comparisons with the amino acid profile of the whole hen's egg. The highest score in the samples was glycine (1.27-1.55) and CV % of 14.0. The highest EAA score in the brain was shared between Phe and Leu, each having a score of 0.85 but different CV % with 5.17 (Phe) and 10.7 (Leu). The highest EAA score in the eyes was Lys (0.91). The least score in the two samples was Ser with values of 0.30-0.41 with CV % value of 21.9 (being the highest CV %).

Table 6 depicts the essential amino acid scores (EAAS) based on the provisional amino acid scoring pattern (FAO/WHO, 1973). The EAAS greater than 1.00 or equal to 1.00 in the brain were Thr, Leu and Phe + Tyr whereas they were Met + Cys, Lys and Phe + Tyr in the eyes. The limiting amino acid (LAA) in the brain was Val (0.64) whereas it was also Val in the eyes (0.60). Although this would have been described as the LAA, however, the EAA most often acting in a limiting capacity are methionine (and cysteine), lysine, threonine and tryptophan (FAO/WHO/UNU, 1985). Since Try was not determined, Thr would be limiting in the eyes (0.85). (Just as in the eyes of guinea fowl, where Thr was also limiting at 0.85.) To make corrections for LAA in the eyes if they serve as sole sources of protein food therefore, it would be 100/85.0 × protein of eyes; or 1.18 × protein of eyes. The highest EAAS in the brain was Phe + Tyr (1.21) and also Phe + Tyr (1.18) in the eyes. The CV % values were generally close ranging between 1.78 and 13.5.

Table 7 presents the EAAS based on suggested requirement of the EAA of a preschool child (FAO/ WHO/ UNU, 1985). Greater numbers of scores were > 1.00 than as seen in Table 6. Here, in the brain, Thr, Met +

Table 5. Amino acid scores of the Turkey-hen head organs based on whole hen's amino acid profile

Amino acid	Brain	Eyes	Mean	SD	CV %
Lys	0.76	0.91	0.84	0.11	12.7
His	0.77	0.89	0.83	0.08	10.2
Arg	0.74	0.85	0.80	0.08	9.78
Asp	0.74	0.65	0.70	0.06	9.16
Thr	0.79	0.67	0.73	0.08	11.6
Ser	0.30	0.41	0.36	0.08	21.9
Glu	0.94	1.07	1.01	0.09	9.15
Pro	0.59	0.68	0.64	0.06	10.0
Gly	1.55	1.27	1.41	0.20	14.0
Ala	0.50	0.63	0.57	0.09	16.3
Cys	0.39	0.44	0.42	0.04	8.52
Val	0.43	0.40	0.42	0.02	5.11
Met	0.73	0.88	0.81	0.11	13.2
Ile	0.56	0.68	0.62	0.08	12.5
Leu	0.85	0.73	0.79	0.08	10.7
Tyr	0.73	0.76	0.75	0.02	2.85
Phe	0.85	0.79	0.82	0.04	5.17
Total	0.71	0.74	0.73	0.02	2.93

Table 6. Amino acid scores of the Turkey-hen eyes and brain based on the provisional essential amino acid scoring pattern

Amino acid	Brain	Eyes	Mean	SD	CV %
Lys	0.85	1.03	0.94	0.13	13.5
Thr	1.00	0.85	0.93	0.11	11.5
Met + Cys	0.87	1.03	0.95	0.11	11.9
Val	0.64	0.60	0.62	0.03	4.56
Ile	0.79	0.95	0.87	0.11	13.0
Leu	1.00	0.86	0.93	0.10	10.6
Phe + Tyr	1.21	1.18	1.20	0.02	1.78
Try	-	-	-	-	-
Total	0.93	0.93	0.93	0.00	-

Cys, Ile, Leu, Phe + Tyr and total (essential amino acids) had scores > 1.00 each; whereas in the eyes, His, Thr, Met + Cys, Ile, Phe + Tyr and total had scores ≥1.00 each. The CV % had similar scores as found in Table 6 having values of 1.24-13.4.

Table 7. Amino acid scores of the Turkey-hen eyes and brain based on the suggested requirement of the essential amino acid of preschool child

Amino acid	Brain	Eyes	Mean	SD	CV %
Lys	0.81	0.98	0.90	0.12	13.4
His	0.97	1.13	1.05	0.11	10.8
Thr	1.18	1.00	1.09	0.13	11.7
Val	0.92	0.85	0.89	0.05	5.59
Met + Cys	1.22	1.44	1.33	0.16	11.7
Ile	1.13	1.35	1.24	0.16	12.5
Leu	1.06	0.91	0.99	0.11	10.8
Phe +Tyr	1.15	1.13	1.14	0.01	1.24
Try	-	-	-	-	-
Total	1.04	1.06	1.05	0.01	1.35

Three different amino acid scores each had their scores less than 1.00 in the samples: for the brain we have Lys (0.81), His (0.97) and Val (0.92); for the eyes we have Lys (0.98), Val (0.85) and Leu (0.91). The highest score in the samples came from Met + Cys with values of 1.22 (brain) and 1.44 (eyes) and CV % of 11.7; in Table 6, Phe + Tyr had the highest scores in both samples: 1.21 (brain) and 1.18 (eyes) and CV % of 1.78. The recognized limiting amino acid in both samples was Lys with values of 0.81 (brain) and 0.98 (eyes) with respective corrections of 100/81.0 (1.23) × protein of brain and 100/98.0 (1.02) × protein of eyes.

The following values would show the position of the quality of the Turkey-hen brain and eyes protein: the EAA requirements across board are (values with His) (g/100 g protein): infant (46.0), preschool (2-5 years) (33.9), school child (10-12 years) (24.1) and adult (12.7) and without His: infant (43.4), preschool (32.0), school child (22.2) and adult (11.1) (FAO/WHO/UNU, 1985); from the present results based on these standards, 34.3 g protein (with His) and 32.4 (no His) in brain; 34.7 g protein (with His) and 32.6 g protein (no His) in eyes have been observed. While the present results would satisfy a high percentage of infant needs, they will satisfy the requirements of preschool children and above.

Table 8 reveals a brief summary of the amino acid profiles in two samples. Column (under Factor B means) shows that the values were very close with a range of 35.7-35.9 g/100 g protein. It is to be noted that both Factor A means and Factor B means terminated at a similar value of 35.8 g/100 g protein.

Table 8. Summary of the amino acid profiles into factors A and B means (g/100 g protein)

Amino acid composition (Factor B)	Samples (Factor A) Brain	Eyes	Factor B means
Total essential amino acid	35.1	36.7	35.9
Total non-essential amino acid	35.4	36.0	35.7
Factor A means	35.25	36.35	35.8

The statistical analysis of the data in Tables 1, 4 (pI only), 5, 6 and 7 was shown in Table 9. The correlation coefficient was positively high and significant at $r_{0.01}$ in data from Table 1 and 4 (pI only) and 5 but positively high but not significant at $r_{0.01}$ in the data from Table 6 and 7. This similar trend was observed in the coefficient of determination (r_{xy}^2) although with much lower values in data from Table 6 and 7. The regression coefficient (R_{xy}) was generally low but positive from values in Tables 1, 4, 5, 6 and 7. The general mean was calculated for each Table but it was interesting to note that the CV % started to decrease as one moved from Table 1, 4, 5, 6, 7; in the brain, it was Table: 1 (62.9%) > 4 (53.8%) > 5 (38.7%) > 6 (20.0%) > 7(13.5%) and in the eyes: 1 (62.4%) > 4 (52.1%) > 5 (30.3%) > 6 (19.8%) > 7 (18.9%). The coefficient of alienation (C_A) was low from Table 1, 4 and 5 (range of value = 0.2717-0.4398) but high from Table 6 and 7 (range of value = 0.7258-0.8001). The values of index of forecasting efficiency (IFE) were in the reverse order from the C_A; this is the expected since both C_A + IFE = 1.00 in each case of appearance. The r_{xy} value was highest in 1 and 4 at $r_{0.01}$ and n-2 degrees of freedom. The regression coefficient (R_{xy}) showed that for every unit increase in the brain amino acid parameter, the increase in the eyes was 0.1940 (Table 1), 0.1190 (Table 4), 0.2224 (Table 5), 0.2967 (Table 6) and 0.1777 (Table 7). The variance (r_{xy}^2) followed the pattern as seen in the r_{xy} with value trend as shown: Table 1 (r_{xy}^2) > Table 4 > Table 5 > Table 6 > Table 7. The grand mean, standard deviation

Table 9. Summary of the statistical analysis of the data in Tables 1, 4, 5, 6 and 7

Parameter	Sources of statistics (from Tables)				
	1	4	5	6	7
Correlation coefficient (r_{xy})	0.9624*	0.9523*	0.8981*	0.6879	0.5999
Coefficient of determination (r_{xy}^2)	0.9262	0.9069	0.8066	0.4732	0.3599
Regression coefficient (R_{xy})	0.1940	0.1190	0.2224	0.2967	0.1777
Mean (brain = A)	4.12	23.4	0.7188	0.9086	1.055
SD (A)	2.59	12.6	0.2785	0.1820	0.1429
CV % (A)	62.9	53.8	38.7	20.0	13.5
Mean (eyes = B)	4.28	24.6	0.7476	0.9286	1.0988
SD (B)	2.67	12.8	0.2266	0.1840	0.2080
CV % (B)	62.4	52.1	30.3	19.8	18.9
Coefficient of alienation (C_A)	0.2717	0.3051	0.4398	0.7258	0.8001
Index of forecasting efficiency (IFE)	0.7283	0.6949	0.5602	0.2742	0.1999

* = r_{xy} significant at r_{xy} = 0.066 at α = 0.01 and n-2 (15) df.

and CV % for all the amino acids in each of the samples could be seen in Table 9; it covered all the values from Table 1, 4, 5, 6 and 7. The overall amino acids from Table 1 gave mean values of brain/eyes as 4.12-4.2 g/100 g protein, SD as 2.59-2.67, CV % as 62.9-62.4; etc.

The coefficient of alienation (C_A) was low in Table 1 (0.27 or 27%), Table 4 (0.31 or 31%) and Table 5 (0.44 or 44%) but high in Table 6 (0.73 or 73%) and Table 7 (0.80 or 80%). The index of forecasting efficiency (IFE) was high in Table 1 (0.73 or 73%), Table 4 (0.69 or 69%) and Table 5 (0.56 or 56%), while others were low at 27-20% (Table 6 and 7, respectively). Low IFE versus high C_A makes prediction of relationship difficult. The C_A produces an index of lack of relationship while the IFE gives the reduction in the errors of prediction of relationship. The C_A and IFE values showed that a good relationship existed between the brain and eyes amino acid in turkey particularly with the results in Table 1, 4 and 5. High values of the IFE showed that the physiological activities of the brain could be carried out by the eyes and vice versa. The pattern of r_{xy} results from Table 1 and 2 were similar to those obtained for the amino acid profiles of the shell and flesh of *Penaeus notabilis* (Adeyeye *et al*., 2008); results in the Table 1, 4 and 5 were in agreement with the results in Tables 1, 2 and 4 in the brain and eyes of guinea fowl (Adeyeye and Aremu, 2010); similar results also came from the eyes and brain of the African giant pouch rat (Oyarekua and Adeyeye, 2011).

The comparison of the amino acids profile in the eyes and brain of Turkey-hen and the amino acid profiles on the eyes and brain of guinea-fowl hen could be seen in Table 10. The values of the organs in the two bird samples were highly comparable.

Table 10. Amino acid composition of the eyes and brain of Turkey-hen and Guinea fowl hen compared (g/100 g)

Amino acid	Brain		Eyes	
	Guinea fowl	Turkey	Guinea fowl	Turkey
Lys	5.04	4.69	5.51	5.18
His	3.03	1.85	2.50	2.14
Arg	7.10	4.49	4.75	5.18
Asp	9.96	7.96	7.00	7.00
Thr	3.20	4.01	3.40	3.41
Ser	2.26	2.40	3.16	3.25
Glu	14.0	11.3	14.2	12.8
Pro	3.93	2.24	3.00	2.60
Gly	3.26	4.66	3.60	3.81
Ala	4.50	2.70	3.69	3.38
Met	2.27	2.35	2.50	2.80
Cys	1.20	0.71	0.65	0.79
Val	3.06	3.21	4.10	2.99
Ile	3.26	3.15	3.74	3.79
Leu	5.80	7.02	6.90	6.02
Phe	5.60	4.35	4.12	4.05
Tyr	3.33	2.91	3.20	3.05
Try	-	-	-	-
Protein (Fat free)	60.7	61.4	64.4	66.2

Conclusion

This study had presented the amino acid data of the head organs (brain and eyes) of Turkey (*Meleagris gallopavo* L.) hen. It was found that the samples were good sources of high quality protein of almost adequate or more than adequate of essential amino acids, low Leu/Ile ratio and high protein efficiency ratio values thereby providing a probable premium quality meat.

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