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AMINO ACID COMPOSITION OF THE RIPE FRUITS OF SOLANUM AETHIOPICUM AND SOLANUM MACROCARPON

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ABSTRACT

The two horticulturally important eggplant species with an African ancestry are the scarlet eggplant, *Solanum aethiopicum* and *gboma* eggplant, *Solanum macrocarpon* L. The amino acid composition of the fruits of *Solanum aethiopicum* and *Solanum macrocarpon* was determined on dry weight basis. The total essential amino acid ranged from 288 g kg^{-1} to 318 g kg^{-1} crude protein or from 48.9 % to 50.3 % of the total amino acid. The two samples had high correlation coefficient (r_{xy} = 0.9876). The predicted protein efficiency ratio was 1.90 - 2.30, essential amino acid index range was 0.81-0.90 and the lysine amino acid score based on whole hen's egg was 0.54-0.61. The quality of protein was high. Among the 17 amino acids determined, the *S. macrocarpon* was more concentrated in 15 (88.2 %) than the *S. aethiopicum;* the other two were the acidic amino acids (Asp and Glu).

KEY WORDS

Two garden eggs and amino acid composition

INTRODUCTION

The two horticulturally important eggplant species with an African ancestry are the scarlet eggplant, *Solanum aethiopicum* L., of which garden eggs are the best known representatives, and *gboma* eggplant, *Solanum macrocarpon* L. Both species are found throughout the warmer and non-acid parts of Africa where important fruity or leafy vegetables are[1].

NAKATI (The Shum group)

Plants of the Shum group used to be referred to as *Solanum zuccagnianum*. The name Shum is derived from *ndschum,* used in Cameroon, and from the somewhat similar *osun*, used by the Yoruba in south-western Nigeria. Then Shum group can be found in the higher rainfall zones of most West and Central African countries. It is of local importance especially in Uganda and south-eastern Nigeria. Ugandan people call it *nakati* and this is the most abundant leafy vegetable found in the Kampala markets. For this reason the vernacular name *nakati* is used here rather than the scientific name *S. aethiopicum* Shum group. In south-eastern Nigeria, where the crop is also common, the name is *anara*.

Solanum aethiopicum (garden eggs, *jakatu* or *nakati*) can be seen in almost every market in West and Central Africa where it is one of the five most important vegetables. The fruity forms are less important in East Africa. Garden eggs are also found in South America and the Caribbean[1].

GBOMA EGGPLANT (*Solanum macrocarpon* L.)

The name *gboma* means leaf-fruit in the *Ewe* language, in which garden eggs are called *agbitsa*. The Yoruba of south-western Nigeria refer to it as *igbagba*. In south-eastern Nigeria the Igbo call it *mafowo-bomonu* and in Cameroon it is called *anchia* or *nkeya. S. macrocarpon* fruit are becoming a luxury vegetable in the Caribbean for export to the USA and Europe, and are also becoming more popular in south- East Asia.

S. aethiopicum belong to *Solanum* subgenus *Leptostemonum* section *Oliganthes*. The *gboma* eggplant, *S. macrocarpon*, belongs to the same subgenus but a different section, *Melongena*. Crosses between *S. aethiopicum* and *S. macrocarpon* are possible, although difficulties are encountered, since F_1 hybrids are often relatively infertile[2]. The major differences between scarlet eggplant and *gboma* eggplant had been enumerated[1].

In Nigeria, *nakati* is frequently used in *egusi* soup, a popular dish, for example in the Enugu area, based on cucurbit seed kernels. In Uganda, *nakati* is mostly steamed rather than boiled and is often eaten as a supplement to *matoke* bananas. Some Ugandan people prefer to fry it[1].

All over the world, egg fruits are used as garnish to decorate some other meals possibly because of their varied beautiful colours and sometimes used as ornamentals. Despite the various uses of egg fruits, there is paucity of information on their chemical composition. Published works included: chemical composition of *S. melongena* fruit[3]; amino acid composition of leaf protein concentrates of *S. aethiopicum* and *S. macrocarpon*[4]; identification of some coumarins like scopoletine and aesculetin derivatives in the fruits of *S. gilo* and *S. melongena,* and fruit and leaves of *S. aethiopicum*[5]; proximate and mineral compositions of cooked and uncooked *S. melongena*[6]; determination of proximate, mineral, calculated fatty acids and energy, phytate (Phy), Phy: Zn, Ca: Phy, [Ca][Phy]/[Zn] molar ratios, Ca/P and Na/K in *S. gilo, S. aethiopicum, S. melongena, S. anguivi* and *S. inacum* fruits[7]. It is our intention here to report on the amino acid composition of *S. aethiopicum* and *S. macrocarpan* fruits. This is to improve information on them particularly on their nutritional attributes.

MATERIALS AND METHODS

Collection and treatment of samples

Solanum species were purchased from the Iworoko Ekiti market, Ekiti State, Nigeria. Non-edible parts (stalk) were removed, good ones sorted out after physical examination and oven-dried to constant dry weight and ground into flour and kept in a deep freezer -4 ^{0}C) in McCartney bottles pending analysis.

Sample analysis

Defatting

About 2.0 g of each sample was weighed into the extraction thimble and the fat extracted with chloroform/methanol mixture (2:1 v/v) using a Soxhlet apparatus[8]. The extraction lasted for 5-6 h.

Hydrolysis of samples

About 30 mg of the defatted sample was weighed into glass ampoules. 7 ml of 6 M HCl were added and oxygen expelled by passing nitrogen gas into the samples. The glass ampoules were sealed with a Bunsen flame and put into an oven at 105±5 ^{0}C for 22 h. The ampoule was allowed to cool; the content was filtered to remove the humins. The filtrate was then evaporated to dryness at 40 ^{0}C under vacuum in a rotary evaporator.

Each residue was dissolved with 5 ml acetate buffer (pH 2.0) and stored in a plastic specimen bottle, and kept in the deep freezer.

Amino acid analysis

Amino acid analysis was by ion exchange chromatography (IEC) [9] using the Technicon Sequential Multisample (TSM) Amino Acid Analyser (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 ml min^{-1} at 60 ^{0}C with reproducibility consistent within ± 3 %. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. The amino acid values reported were averages of two determinations. Tryptophan was not determined. Norleucine was the internal standard.

Estimation of quality of dietary protein

The amino acid score was calculated under three different standards.

(a) Scores were calculated based on the whole hen's egg[10].

(b) The scores were calculated using the following formula (based on amino acid *scoring pattern of FAO/WHO* [11]*:*

Amino acid score = Amount of amino acid per test protein [mg g^{-1}]/ Amount of amino acid per protein in reference pattern [mg g^{-1}].

(c) Amino acid scores based on suggested pattern of requirement for preschool child (2-5 years) [12].

The predicted protein efficiency ratio (P-PER) was determined by using one of the equations developed by Alsmeyer *et al* [13]; i.e. P-PER = - 0.468 + 0.454 (Leu) - 0.105 (Tyr).

The essential amino acid index (EAAI) was calculated using the ratio of test protein to the reference protein for each of the eight essential amino acid plus histidine in the equation that follows:

$$\text{Essential amino acid index} = \sqrt[9]{\frac{\text{mg lysine in 1g test protein}}{\text{mg lysine in 1g reference protein}} \times \text{etc. for all 8 essential amino acids + His}}$$

Methionine and cystine were counted as a single amino acid value in this equation, as were phenylalanine and tyrosine[14].

The isoelectric point (pI) was calculated from the amino acid results[15, 16].

Determination of the total essential amino acid (TEAA) to the total amino acid (TAA) i.e. (TEAA/TAA); total sulphur amino acid (TSAA); percentage cystine in TSAA (% Cys/TSAA); total aromatic amino acid (TArAA), etc.; the Leu/Ile ratios as well as the percentage of their differences were calculated.

Statistical analysis

Calculations made were the mean, standard deviation, coefficient of variation in percent F-test setting the confidence level at $p < 0.05$, correlation coefficient and linear regression[17].

RESULTS AND DISCUSSION

Table 1 shows the amino acid (AA) compositions for each of the *Solanum* species. Glutamic (Glu) acid and aspartic (Asp) acid had the highest concentrations among their groups and are both acidic AA. Leucine (Leu) was the highest essential amino acid (EAA) concentration in both samples. The coefficient of variation (CV %)

Table 1
Amino acid composition (g kg^{-1} crude protein) of Solanum macrocarpon and Solanum aethiopicum

Amino acid	*S. macrocarpon*	*S. aethiopicum*	SD[a]	CV %[b]
Lys	37.8	33.5	3.0	8.4
His	21.8	20.1	1.2	5.71
Arg	50.1	47.5	1.8	3.69
Asp	69.5	72.3	2.0	2.82
Thr	22.1	18.5	2.5	12.3
Ser	21.4	18.5	2.1	10.5
Glu	97.0	106	6.4	6.27
Pro	16.3	13.2	2.2	14.9
Gly	37.0	29.1	5.6	16.9
Ala	41.0	32.3	6.2	16.9
Cys	8.6	8.0	0.4	4.82
Val	41.6	39.0	1.8	4.47
Met	8.6	7.0	1.1	14.1
Ile	31.7	30.1	1.1	3.56
Leu	66.4	57.0	6.6	10.7
Tyr	23.8	21.1	1.9	8.44
Phe	37.7	35.3	1.7	4.66

SD[a] = Standard deviation, CV %[b] =Coefficient of variation percent.

were generally low between the two samples with the highest value of 16.9 being recorded for both Gly and Ala and lowest of 3.69 recorded for Arg. On the whole the F-test result showed that F-calculated< F-table at $p<0.05$, i.e., no significant differences existed between the two samples. The correlation coefficient (r_{xy}) was high at 0.9876 whereas the regression (Rc) was – 0.50. This means on the whole the AA parameters were more concentrated in *S. macrocarpon* than in *S. aethiopicum.*

Table 2 shows the concentrations of total AA (TAA), total essential AA (TEAA), total acidic AA (TAAA), total neutral AA (TNAA), total sulphur AA (TSAA), total aromatic AA (TArAA) and their percentage levels. All the CV % values were low although % TAAA was 28.3. In Table 3 the limiting AA of all the acids were shared between Ser and Met with similar values of 0.27 (27.0 %) in *S. macrocarpon* whereas in *S. aethiopicum* Met was the limiting AA with a value of 0.22 (22.0 %) which was also close to Ser with a value of 0.23 (23.0 %). The highest scores in both samples were recorded in Gly with a value of 1.23 (*S. macrocarpon*) and 0.97 (*S. aethiopicum*). All the CV % values were low with the highest being 17.3. The r_{xy} was 0.9568 and the Rc was 0.02. Table 4 shows the AA scores based on provisional AA scoring pattern[11]. The limiting AA here was the Met + Cys for both *Solanum* species; in *S. macrocarpon* it was 0.49 (49.0 %) and 0.43 (43.0 %) in *S. aethiopicum* respectively. The CV % levels ranged from 3.90-11.4 and the r_{xy} was 0.9864 with Rc value of -0.03. Table 5 shows the AA scores based on suggested pattern of requirement for preschool child (2-5 years) [12].

The limiting AA in *S. macrocarpon* was shared between Lys (0.65) and Thr (0.65) whereas Thr (0.54) was the limiting AA in *S. aethiopicum*. The CV % ranged from 3.60 – 22.0; r_{xy} was 0.9924 and Rc was - 0.10.

The observation for Glu and Asp acids in Table 1 was similar to the observation in three species of Nigerian fishes [18], in *Cola acuminata* and *Garcinia kola* [19] as well as in the leaf concentrates of *S. aethiopicum* and *S. macrocarpon* [4]. Leu in the *Solanum* fruit samples occupied the same position as in the *Solanum* leaf concentrates. In fact the pattern of the amino acids profile in the samples generally followed the pattern in the leaf concentrates on a one-to-one correlation of each specie.

Arginine (47.5-50.1 g kg^{-1} crude protein, cp) is essential for children and reasonable levels were present in the samples; this same assertion also goes for His with a value range of (20.1-21.8 g kg^{-1}). The Lys contents of the samples (33.5-37.8 g kg^{-1} cp) which were slightly close to the content of the reference egg protein (62 g kg^{-1} cp) and may therefore serve in some food complementation.

The contents of TEAA of 318 and 288 g kg^{-1} cp without tryptophan (which was not determined) (Table 2) were greater than half value of egg reference protein (566 g kg^{-1} cp) [19]. Our current TEAA results are favourably compared to some literature values

Table 2

EAA, non-EAA, acidic, basic, and neutral, sulphur and aromatic amino acid contents (g kg^{-1} crude protein) of the garden egg samples

Amino acid	*S. macrocarpon*	*S. aethiopicum*	SD	CV %
Total amino acids	632	589	31	5.08
TNEAA	315	301	10	3.25
Total EAA with His	318	288	21.1	6.97
No His	296	268	19.9	7.06
% TNEAA	49.8	51.1	0.92	1.82
% Total EAA With His	50.3	48.9	0.93	1.88
No His	46.8	45.5	9.2	1.99
TNAA	356	310	32.5	9.76
% TNAA	56.3	52.5	2.69	4.94
TAAA	167	178	7.8	4.51
%TAAA	26.3	30.3	2.81	28.3
TBAA	110	101	6.4	6.03
%TBAA	17.3	17.2	0.12	17.3
TSAA	17.2	15.0	1.2	2.63
%TSAA	2.72	2.55	0.12	4.56
% Cys in TSAA	50.0	53.3	2.33	4.52
TArAA	61.5	56.4	3.6	6.12
% TArAA	9.72	9.58	0.10	1.04
P-PER	2.30	1.90	0.28	13.5
Leu/Ile ratio	2.09	1.89	0.14	7.11
Leu-Ile (diff.)	34.7	26.9	5.5	17.9
% Leu-Ile (diff.)	52.3	47.2	3.61	7.25
pI	3.65	3.33	0.23	6.48
EAAI	0.90	0.81	0.06	7.44

TArAA - total aromatic amino acid; P-PER - predicted protein efficiency ratio.
pI - isoelectric point; EAAI - essential amino acid index.
TNEAA - total non- essential amino acid; EAA - essential amino acid.
TNAA - total neutral amino acid; TAA - total acidic amino acid.
TBAA - total basic amino acid; TSAA - total sulphur amino acid.

from plant sources: 312 g kg^{-1} cp in *Parkia biglobosa* seeds [20], it is 221 g kg^{-1} cp in the endosperm of ripe coconut[21], 336 in *Anacardium occidentale* but much better than in *Cola acuminata* (137 g kg^{-1} cp) and in *Garcinia kola* (53.1g kg^{-1} cp)[19]. The contents of TSAA were generally lower than 58 g kg^{-1} recommended for infants[12]. The ArAA range suggested for ideal infant protein (68-118 g kg^{-1} cp)[12] has current values close to the minimum, i.e. 56.4-61.5 g kg^{-1} cp. The ArAA are precursors of epinephrine and thyroxin[22].

The percentage ratios of TEAA to the TAA in the samples were 50.3 % and 48.9 % which were well above the 39 % considered to be adequate for ideal protein food for infants, 26 % for children and 11 % for adults [12]. The TEAA/TAA percentage contents were strongly comparable to that of eggs (50 %) [23]; 43.6 % reported for pigeon pea flour [24]; 43.6 %- 44.4 % reported for beach pea protein isolate [25]; 55.3 % reported for coconut endosperm [21]; 46.8 % in *P. biglobosa* [20]; 51.0 % reported for *A. occidentale,* 38.4 % reported for *C. acuminata* and 47.1 % reported for *G. kola* [19].

Many vegetable proteins contain substantially more Cys than Met; this is in contrast to the observation in most animal proteins. For example, (Cys/TSAA) % were 36.3 in *Macrotermes bellicosus* [26]; 25.6 in *Zonozerus variegatus* [27]; 35.5 % in *Archachatina marginata*, 38.8 % in *Archatina archatina* and 21.0 % in *Limicolaria* sp. respectively [28] and 29.8 % in *Gymnarchus niloticus* (Trunk fish) [29]. In plants, the following (Cys/TSAA) % had been reported: 62.9 % in coconut endosperm [21]; in *P. boglobosa* it was 44.4 %; in *G. acuminata* it was 44.3 %, in G. kola it was 37.8 % and in *A. occidentale* it was 50.5 % respectively [19] and the values in our report ranged from 50.0 % - 53.3 %. Thus for animal protein diets (and some plant proteins), or mixed diets containing animal protein, cystine is unlikely to contribute up to 50 % of the TSAA [9]. Although FAO/WHO/UNU[12] did not give any indication of the proportion of TSAA

Table 3

Amino acid scores of the garden egg samples based on whole hen's egg

Amino acid	*S. macrocarpon*	*S. aethiopicum*	SD	CV %
Lys	0.61	0.54	0.05	8.93
His	0.91	0.84	0.05	5.75
Arg	0.82	0.78	0.03	3.75
Asp	0.65	0.68	0.02	3.03
Thr	0.43	0.36	0.05	12.5
Ser	0.27	0.23	0.03	12.0
Glu	0.81	0.88	0.05	5.88
Pro	0.43	0.35	0.06	15.4
Gly	1.23	0.97	0.19	17.3
Ala	0.76	0.60	0.11	16.2
Cys	0.48	0.44	0.02	4.35
Val	0.55	0.52	0.02	3.70
Met	0.27	0.22	0.04	16.7
Ile	0.57	0.54	0.02	3.64
Leu	0.80	0.69	0.08	10.8
Tyr	0.60	0.53	0.05	8.93
Phe	0.74	0.69	0.03	4.17

which can be met by Cys in man, for rats, chicks and pigs, the proportion is about 50 %. Information on the agronomic advantages of increasing the concentration of sulphur containing AA in staple foods shows that Cys has positive effects on mineral absorption, particularly on zinc [30, 31].

The predicted protein efficiency ratio P-PER (Table 2) ranged between 1.90-2.30 which were favourably comparable to 2.0 in *P. biglobosa* [20], 2.88 in whole hen's egg [10], 2.50 in reference casein [32]; but better than 1.21 (cowpea), 1.82 (pigeon pea) [33]; 0.27 (sorghum *ogi*), 1.62 (millet *ogi*)[32] but lower than 4.06 (modified corn *ogi*)[32]. The Leu/Ile ratio ranged from 1.89-2.09 with percentage difference of 47.2-52.3. Clinical,

Table 4

Amino acid scores of the garden egg samples based on provisional amino acid scoring pattern

Amino acid	*S. macrocarpon*	*S. aethiopicum*	SD	CV %
Lys	0.69	0.61	0.06	9.23
Thr	0.55	0.46	0.06	11.8
Val	0.83	0.78	0.04	4.93
Met + Cys	0.49	0.43	0.04	8.70
Ile	0.79	0.75	0.03	3.90
Leu	0.95	0.81	0.10	11.4
Phe + Tyr	1.03	0.94	0.06	6.12
Total	0.80	0.71	0.06	8.00

Table 5

Amino acid scores of egg samples based on suggested pattern of requirement for preschool child (2-5 years)

Amino acid	*S. macrocarpon*	*S. aethiopicum*	SD	CV %
Lys	0.65	0.58	0.05	8.06
His	1.15	1.06	0.29	22.0
Thr	0.65	0.54	0.07	11.7
Val	1.19	1.11	0.06	5.22
Met + Cys	0.69	0.60	0.06	9.23
Ile	1.13	1.08	0.04	3.60
Leu	1.01	0.86	0.11	11.7
Phe + Tyr	0.98	0.90	0.06	6.38
Total	0.91	0.82	0.06	6.90

biochemical and pathological observations in human rat experiments showed that high Leu in the diet impairs the metabolism of Try and niacin and is responsible for the niacin deficiency in sorghum eaters [34]. Leu could be counteracted by increasing the intake of niacin or Try and also with supplementation with Ile [35]. The present Leu/Ile ratios were low in value. The calculated isoelectric point (pI) ranged from 3.33 to 3.65. This is a good starting point in predicting the pI for proteins in order to enhance a quick precipitation of protein isolate from biological samples [15]. The low pI values could be a function of TAAA (167-178 g kg^{-1} cp or 26.3 - 30.3 %). The essential amino acid index (EAAI) (Table 2) can be useful as a rapid tool to evaluate food formulations for protein quality. Our EAAI results range was 0.81-0.90 which was lower to 1.26 reported for the soy flour[36].

Table 6
Summary of the amino acid profiles into factors A and B

	Garden egg fruits (Factor A)		Factor B means
	S. macrocarpon	*S. aethiopicum*	
Amino acid composition (Factor B)			
Total essential amino acid	31.8	28.8	30.3
Total non-essential amino acid	31.5	30.1	30.8
Factor A means	31.7	29.5	30.6

The AA scores are in Tables 3, 4 and 5. The EAA most often acting in a limiting capacity are Lys, Met + Cys, Thr and Try [37]. In Table 4, Met + Cys were the limiting AA (LAA) in both samples. In *S. macrocarpon* Met + Cys was 0.49 or 49.0 % whereas in *S. aethiopicum* the score was 0.43 or 43 %. In order to fulfil the daily need for all the EAA in the samples, it would require in the diet. In Table 5 Thr was the LAA in both samples. The same discussion as under Table 4 could also be applied here.

CONCLUSION

In summary, this study indicates that the amino acid profiles of *Solanum macrocarpon* and *Solanum aethiopicum* have very close composition (see Table 6 particularly under factor B means). Both are good sources of many of the essential amino acids. *Solanum* fruits are often eaten together with yam; under this condition the *Solanum* species would complement the protein quality of the yam.

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