NATIONAL AGRICULTURAL AND FOOD CENTRE
RESEARCH INSTITUTE FOR ANIMAL PRODUCTION NITRA

Slovak J. Anim. Sci., 56, 2023 (3): 20–28
ISSN 1337-9984, E-ISSN 1338-0095
SciCell

PREDICTION OF AMINO ACID CONTENTS OF CASSAVA ROOT FROM CRUDE PROTEIN AND ESSENTIAL AMINO ACIDS

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ABSTRACT

This study aimed at predicting and evaluating the variation in the amino acids of cassava roots from their crude protein. Nutrient composition of cassava roots was found from previous studies and descriptive statistics; correlations and prediction models were developed using stepwise multiple regression analyses. The results show that variations were occurred among the amino acid content of cassava roots from different sources. The amino acid component with the highest coefficient of variance was tryptophan (364.2 %), while the least was alanine (38.41 %). Glutamine had the highest mean value (0.25 %), while the least value was in cysteine (0.01 %). Positive and negative correlations were observed between the amino acid content at 1 and 5 % levels of significance. Equations generated for total essential amino acid (TEA) and total amino acid (TAA) revealed that r^2 increased as the number of variables increased. Prediction equations generated values for TEA and TAA of cassava roots, which were much close to the actual values obtained.

Key words: prediction; cassava; amino acid; essential amino acid; correlation coefficient

INTRODUCTION

The main products of cassava are roots, leaves and peels. These products have been used to replace cereal grains by poultry nutritionists, in order to eradicate inadequate nutrition and high cost of feed, which are the key factors affecting productivity. There is abundant production of cassava in many tropical countries, which can be fed to farm animals such as cattle, pigs and poultry (McDonald *et al*., 2002). The use of cassava and cassava by-products, as feedstuff for poultry, is limited because of its low protein content, which directly affects its amino acid content. Therefore, its use in poultry diets would require its supplementation with high protein sources, such as fish meal and soybean meal, which are also very expensive. The supplementation must be done accurately with proper knowledge of cassava's chemical composition and nutritional profile. However, chemical composition varies widely and is influenced by a variety; a significant variation in the chemical composition among leaves of different cassava varieties has been documented by Oresegun *et al*. (2016).

Factors influencing variations in the chemical composition of cassava are differences in processing techniques and improved analytical methods. In addition, the application of fertilizers may lead to variability

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Received: June 29, 2023
Accepted: September 21, 2023

https://doi.org/10.36547/sjas.833

in the chemical composition of cassava and its by-products. However, for rapid assessment of the nutritive value of cassava products it is necessary to develop reliable system of predictions of the individual or total amino acids from the chemical composition of the cassava because such prediction equations are not available in the literature. Prediction models have been employed to determine the contents of indispensable amino acids (IAA) and total amino acids (TAA) in maize and wheat based on their chemical compositions (Adebiyi, 2014). This study was undertaken to evaluate variation among amino acids of cassava roots and prediction models from their essential amino acids.

MATERIAL AND METHODS

Data collation and analysis

Nutrient compositions of cassava roots were compiled from previous studies (Table 1) and analysed using SPSS statistical package (SPSS, 1999). Descriptive statistics and correlations among chemical components and the associated probability values for cassava root were carried out. Prediction models for determining the total essential amino acid (TEA) and total amino acid (TAA) contents of cassava root from their crude protein and amino acid content were developed using stepwise multiple regression analyses (Adebiyi, 2014).

Criteria for selection

Maximum improvement in adjusted r^2 (adj r^2) crude protein was the model selection criteria. The best subset for each response variable was identified using a balance between maximum improvement in adj r^2, lowest crude protein values and lowest number of explanatory variables possible. The adj r^2 indicates the best of some models based on the largest variance explained, adj r^2 increase with the addition of an extra predictor variable, which improves the model more than expected by chance. Model validation was carried

Table 1. Sources of the data and countries of origin (Cassava root)

Sources	Countries of origin
Ngiki et al. (2014)	Adamawa, Nigeria
Akinfala et al. (2002)	Ife, Nigeria
Tien Dung et al. (2005)	China
Khieu Borin (2005)	Uppsala
USDA (2015)	Adopted from published literature
FAO (2001)	Rome
Gil and Buitrago (2002)	Adopted from published literature
FAO (1990)	Rome
Lei and Park (2017)	South Korea
Egena (2006)	Adopted from published literature
Khajareen and Khajareen (2007)	Adopted from published literature
Olugbemi et al. (2010)	Tanzania
Nagid and Sousa (2007)	Brazil
Ochetim (1991)	Western Samoa
Apata and Babalola (2012)	Ilorin, Nigeria
Agunbiade et al. (2001)	Adopted from published literature
Emmanuel et al. (2012)	Ghana
Akapo et al. (2014)	Nigeria
Kenneth (2013)	Bahamas
Idrisu et al .(2017)	Ghana
Somendrika et al. (2017)	Srilanka
Diarra and Devi (2015)	Samoa
Chauynarong et al. (2009)	England
Animal Feed Resources Information System (2023) (www.feedipedia.org)	Adopted from published literature
Ospina (2002)	Adopted from published literature
Ceballos et al. (2006)	Adopted from published literature

USDA: United State Department of Agriculture; FAO: Food and Agriculture Organization.

out using mean information from the data set used in developing the models. Table 1 shows the sources of the data and the country of origin used for this study.

RESULTS

Table 2 shows the descriptive statistics of amino acid components of cassava root. The prominent variable with a higher coefficient of variance in amino acid content of cassava root was tryptophan (364.2 %), methionine (143.84 %), tyrosine (178.13 %) and histidine (135.79 %), while the least observable variables were alanine (38.41 %), threonine (38.79 %) and serine (39.72 %). The mean values observed for total amino acid and total essential amino acid in the root were 1.38 % and 0.46 %, respectively. From the list of amino acid content in the root, arginine (0.12 %) and glutamine (0.25 %) had the higher mean values, while the least value was observed in cysteine (0.01 %).

Correlation matrix between essential amino acid, total essential amino acid, total amino acid and crude protein for cassava roots

The result in Table 3 revealed that valine is the only variable that has proof of negative correlation with crude protein (r = -0.482) at $p < 0.05$ of all the essential amino acids. Likewise, total essential amino acid and total amino acid are both negatively correlated with crude protein (r = -0.439, r = -0.463 respectively) at $p < 0.05$. Moreover, TAA correlated favourably with phenylalanine (r = 0.443), cysteine (r = 0.473), proline (r = 0.425) at $p < 0.05$ and with tryptophan (r = 0.857) at $p < 0.01$.

Table 2. Descriptive statistics of the amino acid compositions (%) of cassava root

	Root					
	N	Max	Min	Mean	SD	CV
Arginine	24	0.34	0.03	0.12	0.09	76.41
Histidine	24	0.21	0.00	0.03	0.04	135.79
Isoleucine	25	0.08	0.01	0.03	0.02	62.93
Leucine	23	0.13	0.00	0.06	0.03	56.22
Lysine	28	0.30	0.01	0.06	0.05	86.08
Methionine	27	0.20	0.00	0.03	0.04	143.84
PHEN/ALA	24	0.13	0.00	0.05	0.03	59.52
Threonine	27	0.07	0.01	0.04	0.02	38.79
Tryptophan	20	1.15	0.01	0.07	0.25	364.21
Valine	25	0.12	0.02	0.04	0.03	58.64
TEA	28	1.61	0.09	0.46	0.28	61.80
Alanine	23	0.09	0.02	0.06	0.02	38.41
Aspartate	21	0.16	0.02	0.09	0.04	41.11
Cysteine	24	0.07	0.00	0.01	0.02	129.22
Glutamic	23	0.51	0.04	0.25	0.12	47.36
Glycine	23	0.08	0.01	0.04	0.02	49.27
Proline	23	0.20	0.00	0.04	0.04	98.38
Serine	23	0.09	0.01	0.05	0.02	39.72
Tyrosine	22	0.29	0.00	0.03	0.06	178.13
MET/CY	1	0.04	0.04	0.04	0.00	0.00
TYRO/PH	1	0.02	0.02	0.02	0.00	0.00
TAA	28	3.41	0.18	1.38	0.69	49.83

TAA: Total amino acid, TEA: Total essential amino acid. Values are expressed in % dry matter basis; N – sample number; SD – standard deviation; CV – coefficient of variation (%) Max – maximum; Min – minimum; PHEN/ALA: Phenylalanine; MET/CY: Methionine/Cysteine; TYRO/PH: Tyrosine/Phenylalanine.

Table 3. Correlation matrix of crude protein and amino acids of cassava roots

	CP	Argin	Histid	Isoleucine	Leucine	Lysine	METH	PHEN/ALA	Threonine	Trypto	Valine	TEA	TAA
CP	1												
Argin	0.011	1											
Histid	0.014	0.043	1										
Isoleucine	-0.387	-0.068	0.082	1									
Leucine	-0.151	0.210	0.245	0.366	1								
Lysine	0.062	-0.186	-0.029	-0.061	-0.199	1							
Methionine	0.033	-0.071	-0.084	-0.110	-0.317	0.958**	1						
PHEN/ALA	-0.246	0.301	0.141	0.405*	0.855**	-0.243	-0.303	1					
Threonine	-0.071	-0.468*	0.110	0.216	0.127	0.845**	0.683**	-0.135	1				
Trypto	-0.364	-0.104	-0.097	0.538*	-0.319	-0.051	0.021	0.176	0.068	1			
Valine	-0.482*	-0.068	0.048	0.790**	0.000	-0.127	-0.116	0.143	-0.065	0.916**	1		
TEA	-0.439*	0.196	0.115	0.445*	0.006	0.156	0.244	0.332	0.160	0.919**	0.447*	1	
TAA	-0.463*	0.241	0.179	0.366	0.243	0.087	0.143	0.443*	0.290	0.857**	0.275	0.909**	1

CP: Crude protein; ARGIN: Arginine; HISTID: Histidine; METH: Methionine; PHEN/ALA: Phenylalanine; TRYPTO: Tryptophan; TEA – total essential amino acids, TAA – total amino acid, $^{*}P < 0.05$, $^{**}P < 0.01$

Regression equation for predicting the essential amino acid content of cassava roots from their crude protein composition

The results in Table 4 show that differences determined in the crude protein of cassava roots varied from r^2 0.0001 to 0.232. The r^2 obtained for TEA and TAA were 0.19 and 0.22, respectively. The least r^2 was obtained in methionine (0.12 + 0.001 (CP), while valine has the most prominent r^2 (0.232) followed by tryptophan with r^2 0.133; the estimated equations were 0.076 – 0.012 (CP) and 0.307 – 0.086 (CP), respectively.

Regression equation for predicting the composition of individual essential amino acid from an essential amino acid in roots

Table 5 shows the best prediction models for essential amino acids in cassava roots (% DM). The first four principal components predicted with the highest proportion of variation in roots were isoleucine (0.98), tryptophan (0.97), leucine (0.97) and valine (0.96). The predicted equations were: -0.017 + 1.50 (met) + 0.35 + 0.35 + 0.072 (Try), -0.36 + 10.66 (Val) + 0.76 (Arg) - 3.40 (Leu) + 3.77 (Iso), -0.004 + 0.80 (Lys) - 0.03 (Try) + 0.92 (Phen/Ala) - 0.65 (Iso) - 0.044 (Arg), and 0.035 + 0.072 (Try) - 0.066 (Arg) + 0.120 (Leu). Arginine had the least r^2 of 0.62 and the equation generated was 0.37 - 5.78 (Thr).

Model subsets for predicting TEAA and TAA in cassava roots

Table 6 shows the best model subset for the total amino acids of cassava roots. The root estimated equation with the highest r^2 was obtained in models with 5, 4 and 3 variable predictors having r^2 varied from 0.917 to 0.960. The equation generated from slope and intercept with five variables was 0.45 + 2.75 (Try) + 20.26 (Leu) + 2.43 (Arg) + 1.64 (histidine) + -10.82 (phen/alanine). The least r^2 (0. 718) was obtained in one variable predictor with equation 1.41 + 1.76 (Try). Tryptophan and leucine were the most prominent component predictors in cassava root, though did not take part in one variable predictor.

Table 7 shows that tryptophan, phenylalanine, histidine, arginine, lysine and threonine had a 99 % explanation for predicting the TEA of cassava root. Tryptophan was the most prominent component that occurred in all the prediction models in this study. Also, histidine and phenylalanine occur frequently in 5, 4 and 3 variable predictors with r^2 0.999, 0.990,

Table 4. Prediction models for amino acid contents of cassava roots (% DM)

Amino Acid	Adj.r^2	Equations
TEA	0.19	0.77 – 0.11 (CP)
TAA	0.22	2.17 – 0.28 (CP)
Arginine	0.0001	0.12 + 0.001 (CP)
Histidine	0.0002	0.03 + 0.001 (CP)
Isoleucine	0.15	0.051 – 0.007 (CP)
Leucine	0.023	0.068 – 0.005 (CP)
Lysine	0.004	0.052 + 0.003 (CP)
Methionine	0.001	0.022 + 0.001 (CP)
Phenyl/alanine	0.06	0.065 – 0.007 (CP)
Threonine	0.005	0.045 – 0.001 (CP)
Tryptophan	0.133	0.307 – 0.086 (CP)
Valine	0.232	0.076 – 0.012 (CP)

CP: Crude protein; TEA: total essential amino acid; TAA: total amino acids; Adj.r^2: Adjusted r^2

Table 5. Best prediction models for essential amino acids in cassava root (% DM)

Amino Acid	Adj.r^2	Equations
Arginine	0.62	0.37 – 5.78 (Thr)
Isoleucine	0.98	-0.017 + 1.50 (Met) + 0.35 (Lys) + 0.20 (Try)
Leucine	0.97	-0.004 + 0.80 (Lys) – 0.03 (Try) + 0.92 (Phen/Ala) – 0.65 (Iso) – 0.044 (Arg)
Lysine	0.93	-0.006 + 0.71 (Thr) + 0.33 (Leu) + 0.24 (Iso)
Methionine	0.93	0.012 + 0.516 (Iso) – 0.104 (Val) – 0.088 (Lys)
Phenyl/Alanine	0.94	0.015 + 1.22 (Meth) + 0.78 (Leu) – 0.79 (Thr) + 0.031 (Try)
Threonine	0.85	0.030 + 0.592 (Lys) – 0.054 (Arg) – 0.171 (Leu)
Tryptophan	0.97	-0.36 + 10.66 (Val) + 0.76 (Arg) – 3.40 (Leu) + 3.77 (Iso)
Valine	0.96	0.035 + 0.072 (Try) – 0.066 (Arg) + 0.120 (Leu)

CP: Crude protein; Thr: Threonine; Met: Methionine; Lys: Lysine; Try: Tryptophan; Leu: Leucine; Iso: Isoleucine; Arg: Arginine; Thr: Threonine; Val: Valine; TEA: total essential amino acid; TAA: total amino acids

Table 6. Best model subset for the total amino acids of cassava roots and leaves

No. of Variables	Adj.r^2	Variables used
TAA		
1	0.718	Tryptophan
2	0.871	Tryptophan
		Leucine
3	0.917	Tryptophan
		Leucine
		Arginine
4	0.942	Tryptophan
		Leucine
		Arginine
		Histidine
5	0.960	Tryptophan
		Leucine
		Arginine
		Histidine
		Phenyl/Alanine

CP: Crude protein; Adj.r^2: Adjusted r^2; TAA: Total amino acids.

0.967 respectively, the equation for the five variable predictor was 0.06 + 1.07 (Try) +2.08 (phe) + 1.0 (hist) + 0.84 (Arg) + 2.74 (Lys). Moreover, r^2 0.865 for tryptophan depicted the least value, which was the only variable predicting the TEAA of cassava root with 0.41 + 1.05 (Try). It was noted that the higher the number of variables, the higher the r^2 values is.

The predicted and experimental values of the prediction model developed from the crude protein, individual amino acids and total essential amino acids of cassava roots

Table 8 shows the predicted and actual amino acid values for prediction models developed from crude protein and individual amino acids of cassava

Table 7. Best model subsets for the total essential amino acids of cassava root

No. of Variables	Adj.r^2	Variables used
TEA		
1	0.865	Tryptophan
2	0.943	Tryptophan Phenylalanine
3	0.967	Tryptophan Phenyl/Alanine Histidine
4	0.990	Tryptophan Phenyl/Alanine Histidine Arginine
5	0.999	Tryptophan Phenyl/Alanine Histidine Arginine Lysine
6	1.000	Tryptophan Phenyl/Alanine Histidine Arginine Lysine Threonine

TEA: Total essential amino acid; Adj r^2: Adjusted r^2.

Table 8. Predicted and actual amino acid values for prediction models developed from the crude protein and individual amino acids of cassava roots

Amino Acid	Actual	Predicted
TEA	0.460	0.465
TAA	1.383	1.395
Arginine	0.123	0.123
Histidine	0.029	0.033
Isoleucine	0.031	0.032
Leucine	0.056	0.054
Lysine	0.060	0.060
Methionine	0.025	0.025
Phenyl/Alanine	0.047	0.046
Threonine	0.042	0.042
Tryptophan	0.070	0.069
Valine	0.045	0.043

Values are expressed in or have been converted to a % dry matter basis. TEA: Total essential amino acid; TAA: Total amino acid.

roots. The regression equations generated from the predicted value were much close to the mean value obtained from the experimental values.

DISCUSSION

The amino acids in cassava root had greater variation resulting from differences in their constituents. The reasons for variation in the amino acid components of cassava and its by-products have been documented by various authors. According to Garcia and Dale (1999), the composition of cassava depends on the specific tissues (roots or leaves), geographic location, variety, age of the plant and environmental conditions. Ntawuruhunga and Dixon (2010) also reported that characteristics, which include leaf morphology, stem colour, branching habit and storage, root shape and colour, may influence nutrients in cassava and yield.

The higher variability noticed could also be due to the resultant effect of soil nutrients and other components (Gil and Buitrago, 2002). Furthermore, the coefficient of variation for tryptophan, tyrosine, methionine and histidine was higher for root, which could be linked to heritability. According to Ceballos *et al*. (2006), considerable variation in the proportion of amino acid components is also due to differences in genetic makeup.

The observed correlation characteristics revealed that only valine, TEA and TAA negatively correlated with crude protein, whereas TEA produced a positive correlation with isoleucine, valine, cysteine and tryptophan. This might be the result of changes in ash content due to available nutrients in the soil. It has been reported that ash content is highly dependent on the soil and area of the plantation (Siti Sarah and Aishah, 2016). In the same vein, TAA had a positive correlation with phenylalanine, proline, valine, serine, glycine and tryptophan in roots. This may be due to different analytical tools used and a wider variation in minerals content because of different factors such as synthetic fertilizers, manure, weather condition and disease resistance level.

These observed relationships among the CP, TAA and TEAA in this study might be due to their percentage proportion of chemical components and changes in protein level because of the developmental stage of roots and environment (Howelar, 1981). The equations, derived from crude protein, showed prediction ability with r^2 0.232, 0.22, 0.19 and 0.15 for valine, TAA, TEA and isoleucine in the root. The results indicate that the variability in chemical components of the amino acid of cassava could contribute to the predicted equation.

The quadratic equation, built for TEAA and TAA, revealed higher r^2 as the number of variables increased suggesting that the model is adequate. Among all the amino acids, tryptophan is the only variable predictor and one of the most common variables despite its hydrolysis during analysis (Nassar and Souza, 2007). Histidine and phenylalanine also occurred frequently for all the models, and this could be linked to the fact that they are essential amino acids that play vital roles in the biogenesis of proteins. Histidine comprises the alpha-amino group, carboxylic acid group and an imidazole side chain during protein metabolism. According to Maimann *et al*. (2000), amino acids are key focuses in it developing techniques for metabolic profiling. The study revealed variations in the chemical constituents of cassava and its by-product, as shown by the data collected from different sources. Adequate proof from this study also showed that the essential amino acids and total amino acid contents of cassava roots can be predicted from their crude protein and amino acid contents. These will help the nutritionists to assess, what is needed to establish reliable facts, by which efficient utilization of cassava as poultry feed can be accomplished.

CONCLUSION

The study shows that variation occurs in the chemical compositions of cassava roots from different sources. Positive and negative correlations existed between their chemical components and amino acid contents at 1 and 5 % levels of significance. The results show that the contents of essential amino acids and total amino acids of cassava roots can be predicted from their crude protein contents and the information obtained can be used to make adjustments in formulating diets and supplementary with appropriate amino acids for poultry.

ACKNOWLEDGEMENT

The authors are grateful for the research support received from the Africa Centre of Excellence in Agriculture and Sustainable Environment, Federal University of Agriculture Abeokuta Nigeria.

IMPLICATION

Cassava is predominantly grown in the Tropics; it has low crude protein, yet it could be replaced with maize to minimize cost and maximize poultry production if its nutrients profile is well known.

ETHICAL APPROVAL

Not applicable

AUTHOR'S CONTRIBUTIONS

Conceptualization: Olanloye, S. A., Fafiolu, O. A., Jegede A. V.

Methodology: Olanloye, S. A., Fafiolu, O. A., Egbeyale, L. T., Alade, A. A.

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Writing-review and editing: Jegede A. V., Alade, A. A., Ogunsola, I. A., Oluwatosin, O.

All authors have read and agreed to the published version of the manuscript.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

Data presented in this study are available on request from the corresponding author.

CONFLICT OF INTEREST

There is no conflict of interest.

FUNDING

The authors are grateful for the research grant received from the World Bank Africa Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, Abeokuta, Nigeria.

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