genation of trans fatty acids of dietary origin (Gurr and James, 1975) or partial hydrogenation of polyunsaturates (Christie, 1978).

The effect of monensin on suppression of chain enlongation, as speculated above regarding 20:1ω9c, may be nonexistent, based on examination of the composition of polyunsaturated fatty acids. No differences were seen between control and monensin-fed tissues either in the concentrations of ω6 fatty acids that arise from enlongation and dehydrogenation of dietary 18:2ω6c or in the concentrations of ω3 fatty acids that arise similarly from dietary 18:3ω3c.

Enhanced concentrations of the 17-carbon acids by monensin (Tables II and III) may arise from de novo fatty acid synthesis from propionate; increased propionate output over acetate, as was discussed in the introduction, is a manifestation of monensin incorporation into bovine feed. The normal saturate 17:0, its desaturation product 17:1ω8c, and the branched ai17:0 all may arise from de novo synthesis from propionate (Vernon, 1980), and concentrations of all these acids are greater in tissue from monensin-fed animals than in control tissue. The same pattern observed for the 17-carbon acids is seen for the sums of all odd-chain normal saturates and branched saturates.

CONCLUSIONS

The sparsity of variations in bovine lipid content and fatty acid composition suggests that monensin has only a minor effect on lipid metabolism in cattle. Those variations in fatty acid composition that were detected may have resulted from alterations in biohydrogenation and de novo fatty acid synthesis.

Registry No. Monensin, 17090-79-8.

Supplementary Material Available: Normalized fatty acid composition (Table IV) and fatty acid composition by weight per tissue portion (Table V) (6 pages). Ordering information is given on any current masthead page.

LITERATURE CITED

Bergen, W. G.; Bates, D. B. *J. Anim. Sci.* **1984**, *58*, 1465–1483.
Christie, W. W. *Prog. Lipid Res.* **1978**, *17*, 111–205.
Gurr, M. I.; James, A. T. In "Lipid Biochemistry: An Introduction", 2nd ed.; Chapman and Hall: London, 1975.
Harfoot, C. G. *Prog. Lipid Res.* **1978**, *17*, 1–19.
Marmer, W. N. In "Vegetable Lecithins"; List, G.; Szuhaj, B., Eds.; American Oil Chemists' Society: Champaign, IL, 1984; in press.
Marmer, W. N.; Maxwell, R. J. *Lipids* **1981**, *16*, 365–371.
Marmer, W. N.; Maxwell, R. J.; Phillips, J. G. *Lipids* **1983**, *18*, 460–466.
Marmer, W. N.; Maxwell, R. J.; Williams, J. E. *J. Anim. Sci.* **1984**, *59*, 109–121.
Maxwell, R. J.; Marmer, W. N. *Lipids* 1983, *18*, 453–459.
Miller, R. G., Jr. In "Simultaneous Statistical Inference"; Springer-Verlag: New York, Heidelberg, and Berlin, 1981; pp 67–70.
Ostilie, S. C.; Wagner, D. G.; Sims, P. 1981 Animal Science Research Report, Oklahoma Agricultural Experiment Station, 1981, pp 165–167.
Potter, E. L.; Raun, A. P.; Cooley, C. O.; Rathmacher, R. P.; Richardson, L. F. *J. Anim. Sci.* **1976**, *43*, 678–683.
Raun, A. P.; Cooley, C. O.; Potter, E. L.; Rathmacher, R. P.; Richardson, L. F. *J. Anim. Sci.* **1976**, *43*, 670–677.
Richardson, L. F.; Raun, A. P.; Potter, E. L.; Cooley, C. O.; Rathmacher, R. P. *J. Anim. Sci.* **1976**, *43*, 657–664.
Schelling, G. T. *J. Anim. Sci.* **1984**, *58*, 1518–1527.
Vernon, R. G. *Prog. Lipid Res.* **1980**, *19*, 23–106.

Received for review April 26, 1984. Accepted September 24, 1984.

Ukwa Seed (*Treculia africana*) Protein. 1. Chemical Evaluation of the Protein Quality

Michael A. Makinde,* Babajide O. Elemo, Uche Arukwe, and Peter Pellett[1]

Amino acid analyses of defatted breadfruit seed (Ukwa) were made. The defatted seed contains 19% protein, which is higher than that for cereals and similar to most pulses. The amino acid content and calculated chemical score indicate that Ukwa seed is adequate in furnishing most essential amino acids in the human diet with sulfur-containing amino acids and tryptophan as the limiting amino acids. Ukwa seed is particularly high in aromatic amino acids. It is a potential source of good protein.

The ever increasing problem of feeding the fast growing population of Nigeria as well as the population of farm livestock has continued to pose a very serious problem. Treculia *africana* (breadfruit seed), locally called "Ukwa", is a popular traditional food among the Igbos of the Southern part of Nigeria. There are many different ways of preparing Ukwa seed as part of the daily menu. The seed can be roasted until the testa becomes brittle for easy removal, and the cotyledon can then be eaten. The seed can also be blanched to ease the removal of the hard testa and then cooked, mashed, and served with yam. It can also be made into Ukwa porridge.

Although the seed is widely consumed only among the Igbos, very little information is available in the literature on its chemical composition in relation to its nutritive value and its possible application in food processing. Recent work on the seed has shown that Treculia seed contains about 4–7% total lipid content (Nwaokorie, 1983). With evidences of gross inadequate availability and consumption of protein foods in Nigeria coupled with both population explosion and urbanization, the nutritional problems resulting from inadequate protein consumption will remain if efforts are not made toward finding other available and cheaper sources of protein. This paper therefore reports

Department of Biochemistry, Nutrition Unit, College of Medicine, University of Lagos, P.M.B. 12003, Lagos, Nigeria.
[1]Present address: Department of Food Science and Nutrition, University of Massachusetts, Amherst, Massachusetts.

0021-8561/85/1433-0070$01.50/0

Table I. Solubility Classification of Protein: Osborne Method[a]

types of protein	dry weight, g	% protein extracted
albumins	0.125	3.125
globulin	0.120	3.0
glutelins	0.283	7.075
prolamins	none	none

[a] Total protein extracted (dry wt) = 0.528. Quantity of sample used = 4 g. Percentage of protein extracted = 0.528/4 × 100/1. Out of this percentage protein extracted, glutelins constituted 53.3 %, albumins constituted 23.8%, and globulins constituted 22.8%.

Table II. Amino Acid Composition of *T. africana* (Ukwa) Protein

amino acids	mg/16 g of N	amino acids	mg/16 g of N
aspartic acid	105	isoleucine	56
threonine	52	leucine	74
serine	67	tyrosine	56
glutamic acid	137	phenylalanine	76
proline	47	lysine	62
glycine	72	histidine	38
alanine	40	ammonia	18
half-cystine	8	arginine	79
valine	61	tryptophan	2
methionine	9		

Table III. Chemical Score and Limited Amino Acid in Defatted Ukwa Seed Protein[a]

essential amino acid	chemical score	limiting amino acids
histidine	224	
isoleucine	133	
leucine	106	
lysine	122	
total SAA	65	
total arom AA	181	
threonine	149	
valine	127	
tryptophan	18	tryptophan

[a] Based on mg of amino acid/g of protein and NAS/NRC (1980) reference pattern.

one effort to unveil the potential of Ukwa seed as a cheap source of protein. We also report the results of the study on isolation and partial characterization of Ukwa seed protein relevant to its probable application in food formulation. Its potential nutritional role in the dietary formulations both for man and livestock is discussed.

MATERIALS AND METHODS

Preparation of Defatted Ukwa Flour. Ukwa seeds were obtained from local markets. The seeds were poured into boiling water and blanched 30–60 s. Blanching softens the seed and eases the removal of the testa. The cotyledons were then dried overnight in a Kottlermann 2716 air oven at 50 °C. The dried seeds were ground into flour with a Waring Blendor and filtered with a 100-mesh sieve. The big particles that could not pass through the sieve were returned to the Blendor and ground until all particles were able to pass through. This seed flour was defatted by using the methanol–chloroform (2:1 v/v) method of Bligh and Dyer (1959).

Chemical Analysis: Total Nitrogen and Amino Acid Determination. The total nitrogen content of the defatted seed was determined by the semimicro Kjedahl method (AOAC, 1970), and crude protein was calculated ($N \times 6.25$). For amino acid analysis, 2.5-g samples of dried defatted seeds were weighed in duplicate into 125-mL Erlenmeyer flasks and digested with 6 M HCl in an autoclave for 6 h at 15 lb of pressure (Evans and Bondemer, 1967). The hydrolysate was dissolved in 50 mL of distilled water and its amino acid content determined with the Technicon amino acid analyzer by using the Spackman et al. (1958) procedure as modified by Piez and Morris (1960). Tryptophan was determined by the procedure of Mertz and Villegas (1971) as modified by Makinde et al. (1976).

Extraction of Proteins from Ukwa Seed. Free amino acids, albumins, globulins, prolamins, and glutelins were extracted from defatted meal by using the Osborne (1924) method as modified by Sodek and Wilson (1971). Four grams of sample served as the starting material.

Samples were extracted 3 times with 10 mL of distilled water (0 °C) centrifuged at 1000*g* and the supernates pooled for analysis of free amino acids. The residue was treated in the same pattern for albumins (3 × 10 mL of 0.5M NaCl at 20 °C), globulins (3 × 10 mL of 70% aqueous ethanol at 20 °C), and prolamins and glutelins (3 × 10 mL of 0.2% NaOH at 20 °C for 30, 60, and 120 min). Residues were washed with distilled water after each extraction sequence.

Weights of the protein fraction were determined by precipitation with trichloroacetic acid (5% for albumins and 25% for the other fractions). Results are shown in Table I.

Protein homogeneity was established through cellulose acetate paper electrophoresis (Ellis and Simpson, 1955). Barbital buffer (pH 8.6) was used in development while Ponteux S dye was used in staining.

RESULTS

On analysis, *T. africana* seeds were found to contain 5% oil and 13% crude protein while defatted Ukwa seed flour contains 19% protein. The total amino acid content as determined by the Technicon amino acid analyzer is

Table IV. Essential Amino Acid Content of Defatted Ukwa Seed Protein Compared to Some Other Legume Seed Proteins Maize and Egg

	mg of amino acids/16 g of nitrogen							
amino acids	defatted Ukwa seed	FAO/WHO (1973)[a]	NAS/NRC (1980)[b]	Harosoy soybean[c]	cowpeas[c]	whole Maize[d]	Egg[e]	kidney[c] beans
histidine	38		17	26	29	23	24	26
isoleucine	56	40	42	42	40	40	63	42
leucine	74	70	70	80	76	196	88	81
lysine	62	55	51	65	68	25	67	67
total SAA	17	35	26	10	10	19	60	9
total arom, AA	132	60	73	49	53	44	99	53
threonine	52	40	35	37	37	47	51	42
valine	61	50	48	46	48	54	68	51
tryptophan	2	10	11	18	14	6	34	15

[a] FAO/WHO (1973). [b] NAS/NRC (1980). [c] Amino acid composition of Harosoy soybean, cowpea, and Kidney beans (Evans and Bandemer, 1967, p 1077). [d] Amino acid composition of whole maize (Bressani and Mertz, 1958). [e] Amino acid contents of foods and biological data on proteins (FAO, 1970).

presented in Table II. The essential amino acid content is compared with standards set by FAO/WHO (1973), NAS/NRC (1980), whole egg (FAO, 1970), whole maize (Bressani and Mertz, 1958), and cowpea (Evans and Bandemer, 1967).

The calculated chemical score of the essential amino acids and limiting amino acid is presented in Table III.

DISCUSSION

Table IV, Ukwa seeds appear to be low in sulfur-containing amino acids, while it is very high in aromatic amino acids when compared to provisional FAO/WHO (1973) requirements. Ukwa seed will supply just about half the requirement of sulfur-containing amino acids, methionine and cystine, recommended by FAO/WHO (1973). However, the sulfur-containing amino acid content is higher than for most pulses (Evans and Bandemer, 1967). All the other essential amino acids and especially both phenylalanine and tyrosine exceed FAO/WHO (1973) and NAS/NRC (1980) requirements.

The calculated chemical score of the amino acids also indicate that tryptophan is the only limiting amino acid in Ukwa seed with levels being lower than that for maize (Table IV).

Fortification of Ukwa seed protein with tryptophan will greatly improve the nutritive quality. The protein content of 19% of the defatted meal compared favorably with that of most pulses (22%), suggesting that this protein can be employed favorably in mixed diets (FAO, 1970). However, toxicological studies are under way to confirm its food value and nutritional quality before use in dietary formulations.

The protein content of Ukwa seed flour coupled with the excellent amino acid profile provides another source of high-quality plant protein as a Nigerian dietary staple. Finally, findings from toxicological studies in progress will further confirm this nutritional quality of Ukwa seed flour.

LITERATURE CITED

AOAC (Association of Official Agricultural Chemists). "Official Methods of Analysis", 10th ed.; AOAC: Washington, DC, 1970.
Bligh, E. G.; Dyer, W. J. *Can. J. Biochem. Physiol.* **1959**, *37*, 911.
Bressani, R.; Mertz, E. C. *Cereal Chem.* **1958**, *35*, 227.
Ellis, S.; Simpson, M. E. *J. Biol. Chem.* **1955**, *220*, 939.
Evans, R. J.; S. L. *J. Agric. Food. Chem.* **1967**, *15*, 439.
FAO. "Amino Acid Contents of Foods and Biological Data on Proteins"; Food Policy and Food Science Service, Nutrition Division: Rome, Italy, 1970.
FAO/WHO. *FAO Nutr. Meet. Rep. Ser.* **1973**, *No. 52*.
Makinde, M. A.; Hare, L. B.; Lachance, P. A. *Nutr. Rep. Int.* **1976**, *15*, 95.
Mertz, E. C.; Villegas, E. Centro Intemational de Majoramento de Maize Trigo, Mexico, 1971, Research Bulletin No. 2.
NAS/NRC. "Pattem of amino acid requirements", 9th ed.; National Academy of Sciences, National Research Council; Washington, DC, 1980.
Nwaokorie, V. I. M.Sc. Thesis, University of Lagos, Lagos, Nigeria, 1983.
Osborne, J. B. "The vegetable proteins", 2nd ed.; Langmans, Green and Co.; London, 1924.
Piez, K. A.; Morris, L. *Anal. Biochem.* **1960**, *1*, 187.
Sodek, L.; Wilson, C. M. *J. Agric. Food Chem.* **1971**, *19*, 1144.
Spackman, D. H., Stein, W. H.; Moore, S. *Anal. Chem.* **1958**, *30*, 1190.

Received for review January 16, 1984. Revised manuscript received July 12, 1984. Accepted September 13, 1984.

Aerobic and Anaerobic Degradation of Aldicarb in Soils

Li-Tse Ou,* K. Sture V. Edvardsson, and P. Suresh C. Rao

Mineralization of aldicarb to CO_2 as well as formation of various metabolites and extractable and nonextractable ^{14}C were measured in [^{14}C]aldicarb-treated surface and subsurface soils. Surface soil samples were incubated under aerobic conditions, and subsurface soil samples were incubated under aerobic and anaerobic conditions. Total aldicarb, aldicarb sulfoxide, and aldicarb sulfone residue (TTR = total toxic residue) disappearance rates were also determined in soils held under aerobic conditions. These data were used to compute half-lives for aldicarb mineralization and TTR disappearance in soil. TTR disappearance in soils held under strict anaerobic conditions, despite slow mineralization, was more rapid than under aerobic conditions. Mineralization rates for surface soil samples were generally higher than for subsurface soil samples. Metabolites detected included aldicarb sulfoxide, aldicarb sulfone, aldicarb sulfoxide oxime, aldicarb sulfoxide nitrile, aldicarb sulfone oxime, TLC polar products, and two unknowns. Aldicarb sulfone and its hydrolysis products were not detected in soils incubated under strict anaerobic conditions.

Aldicarb [2-methyl-2-(methylthio)propionaldehyde *O*-(methylcarbamoyl)oxime] is widely used for the control of soil insect and nematode pests. This chemical is applied to soil in the form of granules containing 10 or 15% a.i. (trade name Temik). The insecticide is degraded in soil principally through oxidation and hydrolysis. Aldicarb is rapidly oxidized to aldicarb sulfoxide, which, in turn, is slowly oxidized to aldicarb sulfone. Aldicarb sulfoxide and aldicarb sulfone have a toxicity similar to that of their parent compound, aldicarb (Anonymous, 1983). Richey et al. (1977) used the term "total toxic residue" (TTR) to include the three toxic compounds. Aldicarb, aldicarb sulfoxide, and aldicarb sulfone also undergo hydrolysis to corresponding oximes that are further degraded to nitriles, acids, etc., and eventually to CO_2. Microbial degradation appears to be the main factor contributing to the disappearance of aldicarb in soils. Several species of common soil fungi were capable of oxidizing aldicarb to aldicarb sulfoxide (Jones, 1976). Microorganisms capable of utilizing aldicarb as a sole source of carbon and essential energy have not been reported.

Several studies reported that aldicarb disappeared from soils rapidly following first-order rate constants (k_1) of 0.078–0.80 day^{-1} (Bromilow et al., 1980; Leistra et al., 1976;

Soil Science Department, University of Florida, Gainesville, Florida 32611.

0021-8561/85/1433-0072$01.50/0