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FINAL REPORT

"The Solar Box Cooker and Food Quality: A Quantitative Analysis"

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Philander Smith College
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The National Food and Nutrition Commission
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Funded By: US Agency for International Development

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SUMMARY

Fuelwood consumption is continually increasing in many areas of the world resulting in deforestation and growing shortages of available fuelwood. Since fuelwood is the major energy source in these areas for cooking, these shortages are also causing a considerable burden of time and money for many. The development of cooking methods which utilize alternate energy sources is therefore most important in reducing the increased burden being experienced in food cooking and in decreasing the pressures on deforestation caused by the overcutting of trees for fuelwood.

A solar box cooker (SBC) has been recently developed which has the advantages of utilizing only sunlight as the energy source and of being inexpensive to make, lightweight, efficient, and convenient to use. The SBC has been shown to successfully cook a variety of foods including legumes, cereals, and vegetables. In this study, we examined the effect of cooking in the SBC on nutrient retention in foods in order to provide quantitative data needed in further assessing the SBC's utility. Such data was not previously available. The study included a variety of foods which permitted a more general assessment. Samples of raw foods and of those cooked in the SBC were analyzed and compared for contents of ascorbic acid, niacin, riboflavin, thiamin, carotene, protein, amino acids, available lysine, and moisture. Comparisons were made for two cooking time periods. Although nutrient retention was found to vary among the different foods tested and the various nutrients which were examined, the results have shown that cooking foods in the SBC maintains the nutrient content of foods as well or better than other cooking methods. Thus, the SBC can be used without negatively impacting on food quality and nutritional benefit.

Our study also included field testing of the SBC in Zambia in order to assess its utility in an environment with potential for actual use. In experimentation to develop cooking strategies, the SBC was found to successfully cook a variety of locally consumed foods. It was also shown that the SBC can be used to pasteurize water from local sources which were contaminated with either coliform or Escherichia Coli bacteria. This has important implications for improving water quality thereby reducing the health hazards associated with use of contaminated water. In a preliminary assessment of the acceptability of the SBC among the Zambians involved in the field testing, the response was very favorable. These participants noted the following advantages of the SBC: inexpensiveness, lack of needing to purchase or gather wood or charcoal, ability to cook foods without burning them, and ease of use.

Based on the results of our study, we feel strongly that use of the SBC should be actively promoted. Although the SBC cannot be used as the sole method of cooking due to the need for sunlight, it does offer an attractive alternative which can significantly contribute to a reduction in the dependency on scarce and/or expensive fuel sources for cooking and water pasteurization. SBC's should be made available in a larger demonstration project in which assessment of its use is monitored over an appropriate period of time for this larger group. Results from such an effort would be important in determining the actual impact of the SBC in this environment and would provide information needed in analyzing the feasibility of commercially producing the Cooker. Local production of the Cooker and its successful marketing will be important in achieving sustainable use.

INTRODUCTION

A problem of major significance in many areas of the world is the increased consumption of fuelwood with resultant shortages and ecological damages. Fuelwood is the major energy source in developing countries for cooking foods. In Africa, for example, around 90% of the population use fuelwood for cooking (1). And the consumption of fuelwood energy by households is typically ten times the total consumption of commercial energy for all purposes (including transport and electricity generation) in the low income countries. In Niger this usage is estimated to be as high as 99% of household energy consumption. However, the rate of consumption of fuelwood exceeds the rate of additions to supply, not only in Africa but in other areas as well. In 1979 fuelwood consumption in developing countries (excluding China) was 1,300 million m^3, already 100 million m^3 short of requirements (2). An estimated 250 million people live in areas of fuelwood shortage. By the year 2000 potential demand, at present per caput levels, is estimated to rise to 2,400 million m^3, but actual needs to satisfy minimum requirements may reach 2,600 million m^3. Because of the shrinking of the resource base, fuelwood production may be only 1,500 million m^3---1,100 million m^3 short of requirements. As a result, some 3,000 million people are expected to face acute fuelwood shortages by the end of the century, with the result that many poor people will not be able to cook their food adequately. This can have serious nutritional and health consequences. Programs countering fuel scarcity have concentrated on planting trees, teaching better charcoal-making techniques, promoting more efficient stoves, and finding alternate fuels. But reforestation efforts are unable to keep up with demand, and better efficiency can only have a limited effect on overall wood consumption, since wood continues to be consumed in greater amounts as more and more people depend directly on it. The burning of dung or fossil fuels as substitutes for fuelwood has its own drawbacks, primarily because collecting agricultural and animal waste can cheat soils of valuable nutrients, and gas and kerosene are too expensive for many families in developing countries.

A solar box cooker (SBC), originally developed by Barbara Kerr and Sherry Cole, offers tremendous potential for aiding in the solution of the fuel problem in food preparation. This SBC utilizes only sunlight as the energy source, and it is compact, lightweight, efficient, and inexpensive to make. Solar energy (sunlight) enters the box and is absorbed as heat energy by the dark cooking vessels and walls and floor of the chamber. Temperatures are achieved which are sufficient to cook a variety of foods. The inexpensiveness and the lack of need to be moved or repositioned during the day while being used for cooking give the SBC major advantages over other types of solar cooking devices such as the slant-faced cooker developed by Telkes (3) and the parabolic-concentrator cooker developed at the University of Wisconsin (4).

Dr. Robert H. Metcalf and his colleagues have successfully developed strategies for cooking a large variety of foods in the SBC (5). Foods were divided into three cooking categories. The effect of this cooking method on food quality (ie., nutrient content) had, however, not been determined. This is a critical

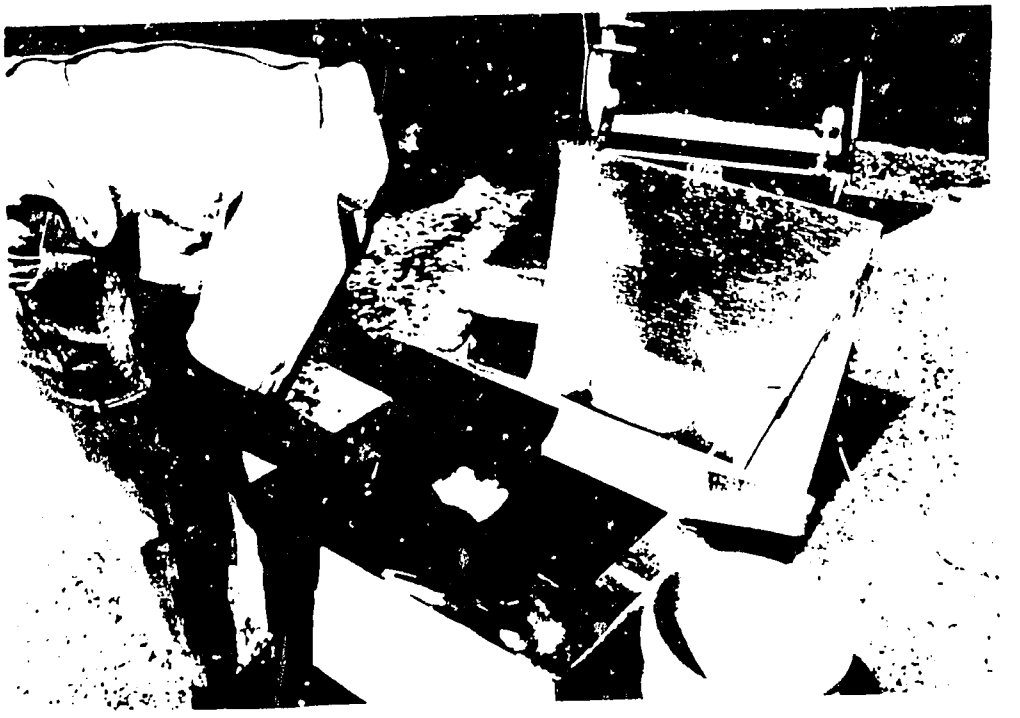
area especially in the absence of oversupplies of foods. Although nutrient content in foods has been shown to be affected by several variables such as method of cooking, amount of added water, type of food, stability of the nutrient, and time of cooking, there does not yet exist a method for predicting quantitatively the effects of processing variables on nutrient retention in any given foods (6,7). This study was, therefore, undertaken to provide quantitative data on the SBC's effect on food quality. Contents of protein, amino acids, and vitamins were measured in cooked food samples and compared with those of raw samples. Foods were selected from each of the three cooking categories, and they represented several food groups (legumes, cereals, and vegetables). Many of them are common to developing countries.

MATERIALS AND METHOD

SBC Construction:

The Kerr-Cole Eco-Cooker (Kerr Enterprises, Inc., Tempe, AZ) was made of three basic components: a well-insulated large cardboard box which contained the cooking area; a removable cardboard lid with a glass window; and a hinged, adjustable reflector shield attached to the lid. The main insulating material of the SBC was multiple layers of regular aluminum foil glued onto cardboard with a equal mix of water and white glue. All components were made from standard appliance shipping cardboard. The insulated cardboard box had four components. (i) The first was an outer box, foiled on the inner side only. (ii) The second was an inner box, covered on both sides with aluminum foil. The inner box rested on a foiled cardboard support piece. (iii) The third component was side insulators, foiled on both sides, extending diagonally from the inside bottom of the outer box to the outside top of the inner box. (iv) The fourth was four straddling pieces for each side of the SBC. The straddlers covered the outside of the outer box (extending over the tops of the outer box), side insulators, and inner box, and then foiled to cover completely one side of the inner box and form one wall of the cooking chamber. The outside corners were attached together by tying strings placed through holes on adjacent straddlers which had been drilled near the bottom and side of each straddler. A tray with shallow sides and made of aluminum metal, blackened with a nontoxic paint, was placed in the bottom of the cooking area. This tray absorbed sunlight and converted it to infrared heat rays. The back reflector on the cardboard lid had its bottom covered with foil, and when raised exposed the cooking area of the box. The lid is propped up by a piece of wood. A safety shield, which was made of flexible glass polymer fiber designed for solar purposes (type 540, Filcon Division, Vistrom Corp., Hawthorne, CA), was placed on top of the glass and was held above the glass by silicon caulk drops attached to the bottom of the shield.

Student assistant, Linda Applewhite, preparing food in the SBC.



Sample, selection, and cooking:

The following foods were included in this study: lentils, mung beans, navy beans, black beans, amaranth, blackeyed peas, split peas, pinto beans, barley, okra, sweet potatoes, corn, egg plant, rutabaga, turnips, kidney beans, millet, acorn squash, yellow squash, oats, brown rice, white rice, white potatoes, pumpkin, quinoa, and zucchini squash. Foods were purchased from local vendors. Exceptions were quinoa, which was kindly donated by Dr. Robert Metcalf, and pumpkin, which was purchased in Zambia. An attempt to include other Zambian-produced foods was unsuccessful due to customs restrictions.

Foods were cooked in the SBC according to the strategies described by Metcalf and coworkers (5). These strategies divide foods into three cooking categories (easy-to-cook, medium-to-cook, and difficult-to-cook). In the easy-to-cook category, foods can be cooked when the food temperature is 80°C or greater for 2 hrs. Medium-to-cook foods require temperatures of 80°C or greater for about 3 hrs, and difficult-to-cook foods require 3 hrs at 90°C or more for cooking. A list of foods by cooking category is given in Table I. Cooking strategies were also related to solar potential (described in terms of C-Scale points). For examples, difficult-to-cook foods can be cooked only if the number of C-Scale points for a given day exceeds 200, and medium-to-cook foods only if the number exceeds 150. For the present study, legumes were soaked overnight before cooking. Samples were cooked either with no added water or with only minimal amounts added. Dark vessels were utilized for cooking all samples. Cooking was for periods of 3, 4, or 5 hrs and of 7 hrs. The minimal time period was required for doneness which was evaluated with taste-testing by two students. Although the time of cooking required to attain doneness varied with different foods, it was found that a common cooking time could be utilized to reach doneness for foods within a given cooking category. The 7-hr cooking time period was included to simulate all-day cooking.

TABLE I

Cooking Categories of Foods:

Easy-to-cook	Medium-to-cook	Difficult-to-cook
Amaranth	Acorn squash	Kidney beans
Barley	Black beans	Navy beans
Brown rice	Blackeyed peas	Pinto beans
Millet	Corn	Split peas
Oats	Egg plant	
Okra	Lentils	
Pumpkin	Mung beans	
Quinoa	Rutabaga	
White rice	Sweet potatoes	
Yellow squash	Turnips	
Zucchini squash	White potatoes	

Chemicals:

Cysteic acid, α-aminoadipic acid, methionine sulfone, 1-fluoro-2,4-dinitrobenzene, ε-DNP lysine, ascorbic acid, carotene (synthetic and natural), niacin, thiamin, and riboflavin were purchased from Sigma Chemical Co., St. Louis, MO. Taka-diastase was purchased from Pfaltz and Bauer, Inc., Stamford, CT. Amino Acid Standards H was purchased from Pierce Chemical Co., Rockford, IL. PIC-A reagent and C_{18} Sep-Pak were purchased from Waters' Associates, Milford, MA. Ultrex 6N HCl was purchased from J.T. Baker Chemical Co., Phillipsburg, NJ. Kjeltabs (K_2SO_4, $CuSO_4$) were purchased from Tecator Co., Hoganas, Sweden. Kjel-Sorb (boric acid solution) was purchased from Fisher Scientific Co., Fair Lawn, NJ. The following chemicals were purchased from J.T. Baker Chemical Co. and were of HPLC grade: sodium acetate, glacial acetic acid, acetonitrile, methanol, and chloroform. All othe reagents were of analytical grade. Millex HV and Millex SR filters were purchased from Millipore Co., Bedford, MA; Acro LC filters from Gelman Sciences, Inc., Ann Arbor, MI. Water used in HPLC analyses was filtered through the Millipore Milli-Q system (Millipore Co.)

Instrumentation:

A Model 338F isotemp oven (Fisher Scientific Co., Fair Lawn, NJ) was used for sample drying. Grinding of food samples was carried out in a Cemotec 1098 sample mill (Tecator Co., Hoganas, Sweden). Nitrogen determinations were done with the Kjeltec System (Tecator Co.) consisting of the Model 1002 distilling unit, Model 1607 digestor, and Multi-Burette E 485 titrator. The HPLC system consisted of Waters' (Waters' Associates, Milford, MA) Model 680 gradient controller, Model 510 pumps, U6K injector, Model TCM column temperature control system, Model 441 absorbance detector, and Model 420-AC fluorescence detector, and Hewlett Packard's (Palto Alto, CA) Model 3392A integrator with the following columns: Waters' Pico-Tag (3.9mm x 15cm), μ-Bondapak-C_{18} (3.9mm x 30cm), and C_8-Radial-PAK (18mm x 10cm) and Whatman's (Clifton, NJ) Partisil 10 SAX (4.6mm x 250mm).

Analytical procedures:

The moisture content of food samples was determined by the AOAC method (8). Protein content was determined by the Kjeldahl Nitrogen method using the Kjeltec (Tecator) system with Cu-catalyst as outlined in the manufacturer's instructions. A conversion factor of 6.25 was used for all samples with following exceptions: oats, millet, barley (5.83); amaranth (5.85); brown rice, white rice (5.95). Amino acid analysis was carried out by Waters' (Waters' Associates) Pico-Tag method for food analysis and included performic acid oxidation. Available lysine was estimated using the method developed by Peterson and Warthesen (9). This method utilizes HPLC and is a modification of the dinitrophenyl derivative method of Carpenter (10).

Ascorbic acid (vitamin C) content was estimated by the method of Rissolo **et al.** (11). Samples were extracted with metaphosphoric acid, and the amount of ascorbic acid was determined by anion-exchange HPLC with UV detection at 254 nm. Sample clean-up was done with Waters' C_{18} Sep-Pak. For carotene content determinations, samples were extracted with acetone, partitioned into hexane, and saponified with potassium hydroxide (12). Analysis was conducted by reversed-phase HPLC (13). The elution solvent system was chloroform-acetonitrile (8:92) with UV detection at 436 nm. Extraction of samples with calcium hydroxide was

used in determinations of niacin content. Quantitation was done by reversed-phase HPLC with UV detection at 254 nm (14). Riboflavin (vitamin B_2) and thiamin (vitamin B_1) were determined simultaneously by the method described by Fellman et al. (15). Samples were subjected to acid extraction followed by enzyme digestion with taka-diastase. Reversed-phase HPLC with fluorescent detection was utilized to quantify the amounts of the two vitamins following conversion of thiamin to thiochrome and preconcentration with Waters' C_{18} Sep-Pak.

RESULTS AND DISCUSSION

Foods of various types were cooked in the SBC in an effort to assess the effect of this cooking method on food quality. These foods included cereals (white rice, brown rice, oats, barley, amaranth, quinoa, corn, and millet), legumes (black beans, blackeyed peas, kidney beans, lentils, mung beans, navy beans, pinto beans, and split peas), and vegetables (rutabaga, sweet potates, turnips, white potatoes, acorn squash, egg plant, okra, pumpkin, yellow squash, zucchini squash). Many of these foods are consumed in developing countries. They provide varying amounts of various vitamins and other nutrients (16). For examples, pumpkins, sweet potatoes, acorn squash, and okra are resonably good sources of carotene; and many of the cereals and legumes are reasonably good sources of niacin, riboflavin, and thiamin. Legumes are also good sources of protein. Cooking, which was found to be easy and efficient, was conducted according to the strategies developed by Metcalf and coworkers (5). These strategies categorize foods according to ease-of-cooking. Foods from each of the three cooking categories were included in this study (see Table I).

Metcalf and coworkers also developed the C-Scale as a method which permits a comparison of the solar potential on various types of days throughout the year and in various parts of the world (5). The method involves multiplying the value for the type of day (0-4: 0, no sunshine; 4, complete sunshine) by the maximum sun altitude (maximum degrees above the horizon which the sun reaches at solar noon) for the day. The product obtained is from 0-360 and is expressed as C-Scale points. The successful cooking of various foods is correlated with C-Scale points since the number of points reflect oven temperatures obtainable. For example, legumes in the difficult-to-cook category were cooked on days in which the C-Scale points were in the range of 250-310 and maximum oven temperatures were 125°-140°C.

The effect of SBC cooking on nutrient retention was assessed for each of the foods. Samples of raw foods and of cooked ones were analyzed and compared for contents of ascorbic acid, niacin, riboflavin, thiamin, carotene, protein, amino acids, available lysine, and moisture. Comparisons were made for two cooking time periods. Minimal cooking times for each category are indicated in the tables. The longer cooking time period was 7 hrs for all categories. This longer time period was included in order to assess the effect on nutrient reten-

tion under simulated all-day cooking conditions. The SBC offers the convenience of allowing most foods to remain in the cooker all day during the cooking process.

Protein content:

The effect of cooking on protein content was minimal in the food samples which were examined. Amounts of protein are shown in Table II for foods in the three cooking categories. Values were determined for raw samples and for those cooked in the minimal and extended cooking time periods. Losses during the cooking process did not exceed 10% even for the extended cooking time. Most losses were no more than 2-4%. Protein content in foods has generally been shown to be little affected by the cooking process. Studies by numerous investigators of the effect of conventional cooking on nutrient content in a variety of legumes (including blackeyed, kidney, and pinto beans) and in potatoes found that the protein content in cooked foods was essentially unchanged relative to raw samples (17-22). Similar results were found with other cooking methods (eg., microwaving, autoclaving, or dry heat).

TABLE II

Amount of Protein (g/100g, DWB) in Uncooked and Cooked:

SAMPLE	Raw	Cooking times			
		3 hrs	4 hrs	5 hrs	7 hrs
Kidney beans	24.9	-	-	24.7	24.0
Navy beans	24.6	-	-	24.0	24.2
Pinto beans	22.8	-	-	23.1	22.2
Split peas	27.0	-	-	26.3	26.1
Acorn squash	5.8	-	6.2	-	5.2
Black beans	22.9	-	22.8	-	22.5
Blackeyed peas	26.1	-	26.0	-	26.4
Egg plant	14.3	-	13.9	-	13.9
Lentils	27.3	-	26.9	-	26.8
Mung beans	26.6	-	26.3	-	26.0
Rutabaga	10.5	-	10.2	-	10.0
Turnips	12.4	-	12.0	-	11.7
Amaranth	14.5	14.4	-	-	13.9
Barley	10.4	10.1	-	-	10.0
Brown rice	8.6	8.3	-	-	8.6
Millet	11.0	10.6	-	-	10.9
Oats	17.6	17.5	-	-	17.1
Okra	18.3	18.1	-	-	17.8
Pumpkin	9.0	9.2	-	-	-
Quinoa	14.9	15.1	-	-	14.4
White rice	7.9	8.0	-	-	7.6
Yellow squash	16.2	15.8	-	-	15.1
Zucchini squash	21.2	19.7	-	-	20.0

Amino acid content:

Amino acid contents in raw and in cooked food samples are shown in Tables III-V for foods in each of the cooking categories. Only minimal losses were found for the amino acids in cooked samples. With lysine and the sulfur amino acids, cysteine and methionine, which are usually limiting amino acid in plant-based proteins, losses were usually between 5-10% at minimal cooking times. The general trend was additional loss with longer cooking time; however, this loss was usually less than 5%. Chung et al. (21) found average losses of 17 individual amino acid in Colossus Peas were 5.2% in conventionally cooked samples. Average losses in microwave cooking were 9.6%. Loss of lysine was 5.5% in conventional cooking and 7.7% in samples cooked by microwave. Cysteine loss varied from 9.1% in conventional cooking to 18.2% in microwave cooking. In two varieties of chick pea, reduction of lysine in both varieties was found not to exceed 3% in autoclaving; conventional cooking for 2 hrs caused a reduction of approximately 5-8% (23).

Available lysine:

Direct measurement of total lysine does not always reflect the nutritional availability of this amino acid. This unavailability is due the derivatization of its ε-amino group (24). A separate analysis was, therefore, conducted to estimate available lysine in the food samples. The results are shown in Tables VI-VIII. Although reduced amounts of available lysine were found for all cooked samples, retention of the nutrient exceeded 80% in all samples cooked in the minimal time periods. The values ranged from 81-96%. For those samples cooked in the longer time period (7 hrs), retention values ranged from 71-86%. Similar results were found for all cooking categories. Average retentions values for difficult-to-cook foods were 89% for foods cooked for 5 hrs and 82% for those cooked 7 hrs. The comparable values were 89% and 81% for medium-to-cook foods and 91% and 83% for easy-to-cook foods. Retention values were also similar among food groups (90% and 82% for the legumes, 90% and 82% for the cereals, and 87% and 78% for the vegetables). Bender et al. (25) found losses of 7-21% in legumes (including blackeyed, red kidney, and mung beans) conventionally cooked 1-2 hrs and losses of 21-29% when cooking was extended to 8 hrs. Comparable results were found for samples that were autoclaved. However, Addo and Hill (19) found that there was a slight increase in the amount of available lysine in cooked blackeyed beans and red kidney beans.

TABLE III

Amino Acid Content (g/100g, DWB) in Uncooked and Cooked Foods (Difficult-to-Cook):

SAMPLE	Amino Acid																
	ala	arg	asp	cys[a]	glu	gly	his	ile	leu	lys	met[a]	phe	pro	ser	thr	tyr	val
Split peas																	
raw	1.27	2.41	3.21	0.35	4.69	1.17	0.61	1.04	1.86	1.94	0.27	1.23	1.09	1.22	0.96	0.76	1.25
cooked, 5 hrs	1.25	2.38	3.18	0.32	4.64	1.18	0.60	1.05	1.83	1.93	0.29	1.22	1.05	1.20	0.94	0.78	1.26
cooked, 7 hrs	1.22	2.34	3.22	0.34	4.61	1.14	0.58	1.02	1.87	1.90	0.26	1.20	1.03	1.24	0.91	0.75	1.22
Kidney beans																	
raw	1.08	1.59	3.17	0.23	3.99	0.97	0.69	1.11	2.05	1.73	0.33	1.37	1.08	1.39	1.14	0.67	1.26
cooked, 5 hrs	1.10	1.55	3.14	0.19	3.95	0.99	0.66	1.12	2.01	1.69	0.32	1.39	1.05	1.39	1.10	0.65	1.24
cooked, 7 hrs	1.12	1.55	3.10	0.18	3.93	0.94	0.64	1.08	2.00	1.67	0.30	1.35	1.10	1.34	1.12	0.62	1.23
Navy beans																	
raw	1.02	1.60	3.03	0.24	3.80	0.92	0.61	1.19	1.98	1.81	0.32	1.39	1.05	1.31	0.98	0.68	1.25
cooked, 5 hrs	1.06	1.55	3.07	0.21	3.72	0.87	0.59	1.16	1.98	1.75	0.30	1.34	1.03	1.30	0.95	0.66	1.28
cooked, 7 hrs	0.98	1.63	3.10	0.23	3.69	0.86	0.55	1.22	1.93	1.71	0.35	1.32	1.00	1.26	0.89	0.65	1.20
Pinto beans																	
raw	0.97	1.39	2.75	0.21	3.51	0.84	0.60	0.97	1.85	1.49	0.29	1.20	1.05	1.22	0.95	0.65	1.19
cooked, 5 hrs	0.95	1.34	2.81	0.20	3.44	0.81	0.57	0.97	1.80	1.44	0.25	1.24	1.01	1.19	0.93	0.52	1.16
cooked, 7 hrs	0.95	1.24	2.70	0.20	3.42	0.78	0.55	0.94	1.88	1.41	0.25	1.18	1.00	1.15	0.90	0.59	1.14

[a]Cys and Met were determined from oxidized samples as cysteic acid and methionine sulfone, respectively.

TABLE IV

Amino Acid Content (g/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

SAMPLE	Amino Acid																
	ala	arg	asp	cys[a]	glu	gly	his	ile	leu	lys	met[a]	phe	pro	ser	thr	tyr	val
Lentils																	
raw	1.26	2.36	3.44	0.31	4.79	1.22	1.93	1.25	2.19	2.13	0.22	1.46	1.25	1.38	1.11	0.86	1.47
cooked, 4 hrs	1.21	2.40	3.50	0.29	4.68	1.18	1.90	1.19	2.17	2.08	0.20	1.48	1.19	1.35	1.08	0.81	1.45
cooked, 7 hrs	1.25	2.33	3.40	0.26	4.65	1.15	1.88	1.21	2.25	2.06	0.19	1.43	1.20	1.32	0.99	0.79	1.42
Mung beans																	
raw	1.08	1.59	3.00	0.20	4.55	1.07	0.84	1.07	1.99	1.87	0.34	1.39	1.14	1.22	0.89	0.71	1.28
cooked, 4 hrs	1.04	1.55	2.96	0.17	4.60	1.03	0.89	1.04	1.95	1.84	0.32	1.36	1.10	1.25	0.91	0.73	1.25
cooked, 7 hrs	1.02	1.53	3.05	0.19	4.51	1.00	0.82	1.10	1.95	1.80	0.31	1.30	1.11	1.20	0.87	0.76	1.21
Black beans																	
raw	0.96	1.39	3.06	0.22	3.55	0.88	0.63	1.09	1.87	1.57	0.39	1.28	0.97	1.19	0.98	0.61	1.25
cooked, 4 hrs	0.93	1.42	3.01	0.20	3.49	0.83	0.61	1.06	1.89	1.53	0.36	1.25	0.95	1.16	0.95	0.58	1.22
cooked, 7 hrs	0.90	1.34	3.00	0.19	3.61	0.86	0.58	1.11	1.80	1.49	0.40	1.21	0.92	1.20	0.93	0.60	1.19
Blackeyed peas																	
raw	1.07	1.44	2.81	0.27	3.32	0.98	0.60	1.05	1.81	1.75	0.32	1.35	0.96	1.18	0.99	0.67	1.20
cooked, 4 hrs	1.07	1.50	2.74	0.24	3.28	0.95	0.63	1.02	1.78	1.72	0.30	1.32	0.91	1.15	0.98	0.69	1.17
cooked, 7 hrs	1.10	1.47	2.78	0.22	3.25	1.02	0.58	1.07	1.75	1.70	0.28	1.30	0.90	1.11	0.99	0.66	1.15

[a]Cys and Met were determined from oxidized samples as cysteic acid and methionine sulfone, respectively.

TABLE V

Amino Acid Content (g/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

SAMPLE	Amino Acid																
	ala	arg	asp	cys[a]	glu	gly	his	ile	leu	lys	met[a]	phe	pro	ser	thr	tyr	val
Oats																	
raw	0.97	1.21	1.51	0.43	3.75	0.83	0.34	0.71	1.34	0.64	0.29	0.92	0.99	0.73	0.56	0.59	0.98
cooked, 3 hrs	0.95	1.19	1.55	0.40	3.55	0.80	0.37	0.69	1.36	0.60	0.28	0.94	0.95	0.69	0.52	0.56	0.95
cooked, 7 hrs	0.91	1.15	1.54	0.39	3.60	0.78	0.32	0.66	1.31	0.58	0.26	0.89	0.94	0.70	0.52	0.54	0.98
Millet																	
raw	1.02	0.47	0.71	0.19	2.45	0.24	0.25	0.59	1.76	0.33	0.25	0.57	0.89	0.65	0.44	0.28	0.66
cooked, 3 hrs	1.00	0.45	0.68	0.17	2.40	0.26	0.25	0.56	1.73	0.30	0.23	0.54	0.85	0.61	0.44	0.31	0.63
cooked, 7 hrs	1.04	0.48	0.67	0.17	2.37	0.25	0.23	0.55	1.70	0.31	0.22	0.52	0.85	0.60	0.41	0.30	0.62
Barley																	
raw	0.54	0.61	0.71	0.22	3.04	0.53	0.25	0.58	0.77	0.39	0.20	0.66	1.24	0.49	0.42	0.37	0.60
cooked, 3 hrs	0.55	0.58	0.70	0.21	2.95	0.49	0.27	0.53	0.75	0.41	0.19	0.63	1.25	0.45	0.39	0.35	0.63
cooked, 7 hrs	0.50	0.57	0.75	0.19	2.90	0.46	0.22	0.55	0.72	0.38	0.22	0.65	1.22	0.45	0.38	0.30	0.57
Brown rice																	
raw	0.41	0.50	0.62	0.10	1.35	0.46	0.18	0.35	0.69	0.28	0.22	0.42	0.40	0.44	0.30	0.36	0.54
cooked, 3 hrs	0.39	0.48	0.57	0.12	1.29	0.43	0.20	0.33	0.65	0.27	0.20	0.39	0.43	0.43	0.32	0.40	0.51
cooked, 7 hrs	0.42	0.45	0.60	0.09	1.30	0.45	0.20	0.32	0.70	0.25	0.19	0.44	0.37	0.40	0.30	0.43	0.50
Amaranth																	
raw	0.83	1.15	1.31	0.18	2.39	1.74	0.40	0.28	0.88	0.74	0.27	0.55	0.80	1.21	0.59	0.27	0.77
cooked, 3 hrs	0.79	1.20	1.34	0.15	2.40	1.69	0.37	0.26	0.85	0.70	0.29	0.51	0.75	1.18	0.56	0.25	0.70
cooked, 7 hrs	0.80	1.12	1.25	0.15	2.34	1.81	0.35	0.25	0.83	0.68	0.25	0.50	0.72	1.20	0.55	0.30	0.74
Okra																	
raw	0.63	0.80	1.30	0.16	2.45	0.34	0.25	0.65	0.98	0.68	0.15	0.51	0.32	0.40	0.63	0.77	0.75
cooked, 3 hrs	0.59	0.80	1.26	0.15	2.37	0.30	0.30	0.63	0.94	0.70	0.13	0.55	0.30	0.36	0.60	0.80	0.72
cooked, 7 hrs	0.55	0.76	1.23	0.10	2.40	0.25	0.30	0.60	1.00	0.65	0.15	0.50	0.30	0.35	0.62	0.73	0.70

[a]Cys and Met were determined from oxidized samples as cysteic acid and methionine sulfone, respectively.

TABLE VI

Available Lysine (g/100g, DWB) in Uncooked and Cooked Foods (Difficult-to-Cook):

SAMPLE	Raw	Cooking times 4 hrs	7 hrs
Kidney beans	1.54 ± 0.14	1.34 ± 0.12	1.25 ± 0.13
Navy beans	1.66 ± 0.14	1.54 ± 0.17	1.41 ± 0.16
Pinto beans	1.36 ± 0.12	1.22 ± 0.14	1.07 ± 0.10
Split peas	1.78 ± 0.19	1.50 ± 0.12	1.46 ± 0.16

TABLE VII

Available Lysine (g/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

SAMPLE	Raw	Cooking times 4 hrs	7 hrs
Black beans	1.46 ± 0.13	1.26 ± 0.10	1.15 ± 0.10
Blackeyed peas	1.40 ± 0.16	1.32 ± 0.14	1.15 ± 0.09
Lentils	1.89 ± 0.17	1.80 ± 0.20	1.63 ± 0.15
Mung beans	1.61 ± 0.15	1.43 ± 0.13	1.29 ± 0.11

TABLE VIII

Available Lysine (g/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

SAMPLE	Raw	Cooking times 3 hrs	7 hrs
Amaranth	0.61 ± 0.08	0.57 ± 0.09	0.48 ± 0.07
Barley	0.33 ± 0.03	0.30 ± 0.05	0.27 ± 0.03
Brown Rice	0.23 ± 0.03	0.22 ± 0.04	0.19 ± 0.03
Millet	0.28 ± 0.04	0.24 ± 0.03	0.24 ± 0.05
Oats	0.60 ± 0.05	0.55 ± 0.05	0.51 ± 0.05
Okra	0.62 ± 0.07	0.53 ± 0.07	0.51 ± 0.08
Pumpkin	0.49 ± 0.05	0.45 ± 0.06	-
Quinoa	0.65 ± 0.05	0.59 ± 0.10	0.55 ± 0.07

Ascorbic acid:

With foods cooked in the SBC, vitamin retentions were found to vary with the vitamin and with the food. The results for ascorbic acid are given in Tables IX and X. Retention values remained higher than 65% varying from 68-91% with samples cooked 3 or 4 hrs. Cooking 7 hrs resulted in some additional losses varying from 6-22%. However, total losses did not exceed 50% in the food samples tested. Comparisons between the two cooking categories showed similar results (average retention values of 86% and 70% in medium-to-cook foods and 80% and 66% in easy-to-cook foods). Figure 1 shows the effect of cooking time on retention of the vitamin for several of these foods. Ascorbic acid has been found to be usually unstable to cooking. Hewston et al. (26) found retentions of this vitamin ranging from only 30-50% in 20 common foods. Retention values of 48-94% for Ghanian starchy roots and tubers (including sweet potatoes) and starchy fruits and values of 63-97% for vegetables (including okra) have been reported (27). Similar results were observed by Gomez (28). Boiled potatoes and sweet potatoes retained 58-65% of their ascorbic acid content, whereas leafy vegetables retained only averages of 10-25%. Hudson et al. (29) compared the effect of various cooking methods on ascorbic acid content in broccoli. Losses varied from 22-42%. Boiling was the method most destructive when compared with microwaving and steaming. In Colossus Peas, loss of 16% was reported for samples conventionally cooked and 11% for those cooked by microwave (21). In examining the effects of cooking time, Noble (30) found average retention values of ascorbic acid in eight vegetables cooked for 50 min (longer period) and 5 min (shorter period) in boiling water were respectively, 35-44% and 66-78%.

TABLE IX

Ascorbic Acid Content (mg/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

SAMPLE	Raw	Cooking times	
		4 hrs	7 hrs
Acorn squash	78 ± 6	61 ± 7	52 ± 7
Rutabaga	270 ± 31	230 ± 25	213 ± 23
Sweet potatoes	78 ± 6	71 ± 9	64 ± 5
Turnips	325 ± 30	283 ± 29	211 ± 18
White potatoes	69 ± 5	58 ± 8	47 ± 7

TABLE X

Ascorbic Acid Content (mg/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

SAMPLE	Raw	Cooking times 3 hrs	Cooking times 7 hrs
Okra	270 ± 31	230 ± 25	213 ± 23
Pumpkin	80 ± 7	69 ± 8	-
Yellow squash	211 ± 19	167 ± 15	139 ± 15
Zucchini squash	366 ± 42	249 ± 27	194 ± 18

Carotene:

Carotene was found to be stable to this cooking method in those foods tested. In most foods, retentions were greater than 90% even with the longer cooking time period (Tables XI and XII). A 25% loss in vitamin content was, however, observed with black beans which were cooked 7 hrs. In a study involving 20 common foods cooked conventionally, carotene was found to be the most stable vitamin (26). Low retentions of 33% were noted for carotene in cooked green fall cabbage and of 67% in green spring cabbage. In other studies involving a variety of foods, no significant change in carotene content was found to occur in conventional cooking (21, 31, 32). Additionally, the method of cooking (eg., microwaving, baking, boiling, steaming) had no significant effect.

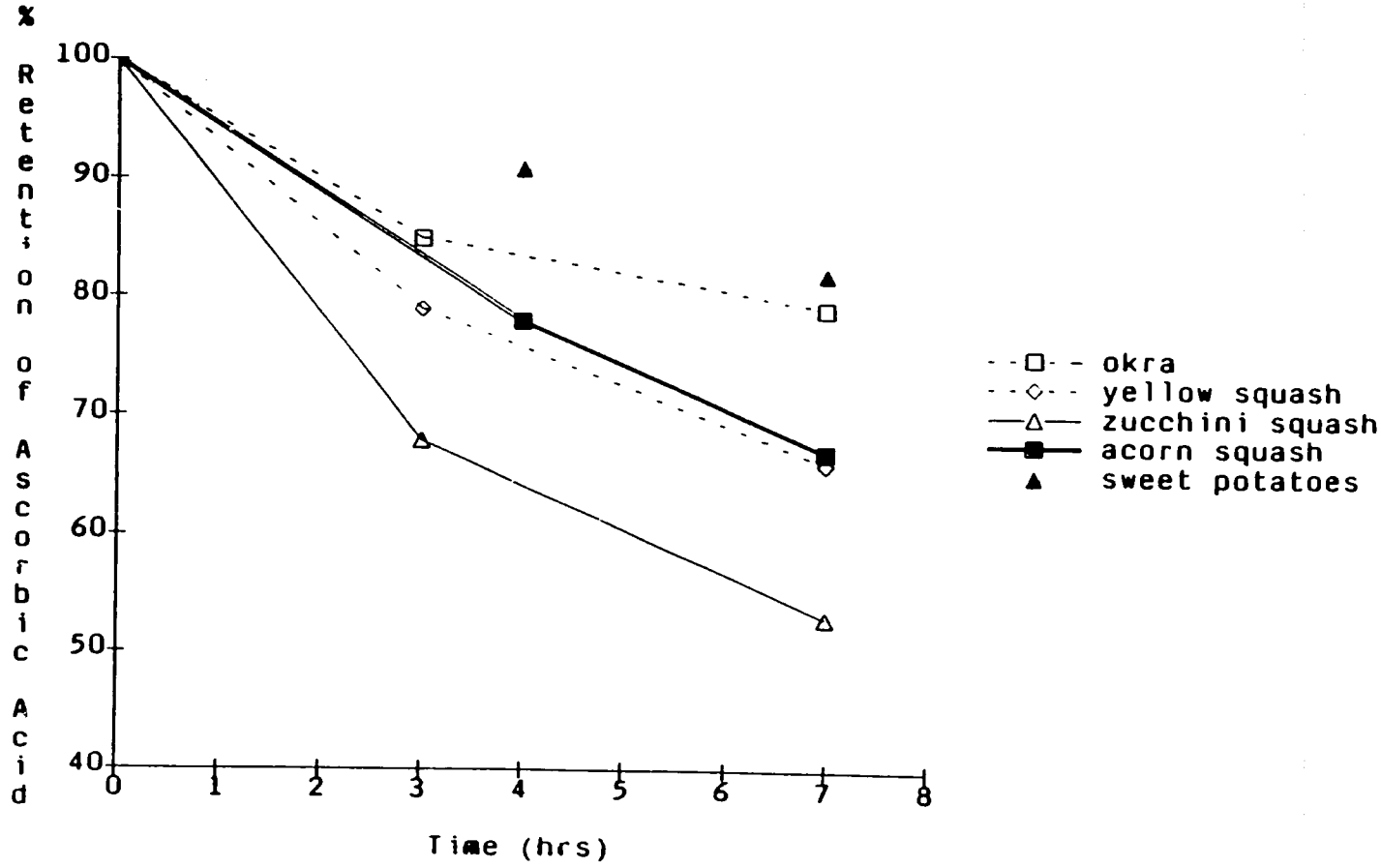
TABLE XI

Carotene Content (µg/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

SAMPLE	Raw	Cooking times 4 hrs	Cooking times 7 hrs
Acorn squash	1850 ± 119	1758 ± 155	1827 ± 142
Black beans	16 ± 3	18 ± 4	12 ± 3
Blackeyed peas	33 ± 4	33 ± 2	30 ± 3
Egg plant	450 ± 47	435 ± 40	418 ± 40
Lentils	29 ± 5	32 ± 5	25 ± 4
Mung beans	225 ± 21	216 ± 19	233 ± 20
Split peas	120 ± 14	115 ± 17[§]	124 ± 15
Sweet potatoes	35713 ± 1445	34642 ± 1776	33995 ± 1560

[§]Cooking time was 5 hrs.

Figure 1



Percentage of retention of AA in vegetables during cooking in SBC.

TABLE XII

Carotene Content (μg/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

SAMPLE	Raw	Cooking times	
		3 hrs	7 hrs
Okra	3060 ± 238	2815 ± 259	2943 ± 260
Pumpkin	12600 ± 835	12096 ± 780	-
Yellow squash	1450 ± 140	1379 ± 130	1291 ± 112
Zucchini squash	1550 ± 139	1395 ± 145	1442 ± 150

Niacin:

Niacin retention in cooked foods varied with the food sample. Tables XIII-XV give the results for foods in each of the cooking categories. With foods in the difficult-to-cook category, retention values of niacin varied from 77-91% (average retention value of 83%) in samples cooked 5 hrs. An additional 2 hrs of cooking resulting in only minimal additional losses (2-11%). Similar results were found with foods in the medium-to-cook category. Retention values ranged from 70-102% (average value of 83%) for samples cooked in the minimal time period (4 hrs). Retention values were slightly higher for foods in the easy-to-cook category, varying from 86-101% (average value of 88%) for sample cooked 3 hrs. Additional losses with longer cooking time for food samples in these two categories varied from 2-13%. These results can also be viewed in terms of food group. Retention of niacin content at both cooking time periods was slightly higher in cereals (average values, 93% and 86%) than that in legumes (average values, 83% and 77%). Plots of retention values versus cooking times for several of these foods are shown in Figures 2 and 3. Augustin et al. (33) found an average retention value for niacin of approximately 70% (ranging from 56-81%) in a group of nine types of legumes (including black turtle, navy, dark red kidney, and pinto beans) that were cooked conventionally. In another study with legumes, losses of niacin were found to be approximately 25-55% (20). With a group of tropical root crops (including sweet potatoes), losses of approximately 20% were reported (34). In oven-baked Irish potatoes, 98% of the vitamin was retained (35). Time of cooking and method of cooking have been shown to affect niacin retention. Vitamin content decreased slightly with increasing cooking time in one variety of chick pea (23). However, in another study with a group of four types of legumes, no consistent relationship between niacin content and cooking time was found (20). Niacin content was reported to be slightly higher in blackeyed peas cooked in steam as compared with those boiled (36). Lanier and Sistrunk (31) found overall retention was greatest in sweet potatoes which were baked and lowest in those boiled.

TABLE XIII

Niacin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Difficult-to-Cook)

SAMPLE	Raw	Cooking times 5 hrs	Cooking times 7 hrs
Kidney beans	2.92 ± 0.17	2.45 ± 0.12	2.31 ± 0.22
Navy beans	2.73 ± 0.21	2.10 ± 0.17	2.05 ± 0.16
Pinto beans	1.46 ± 0.16	1.15 ± 0.09	0.99 ± 0.10
Split peas	3.37 ± 0.19	3.07 ± 0.21	2.81 ± 0.21

TABLE XIV

Niacin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

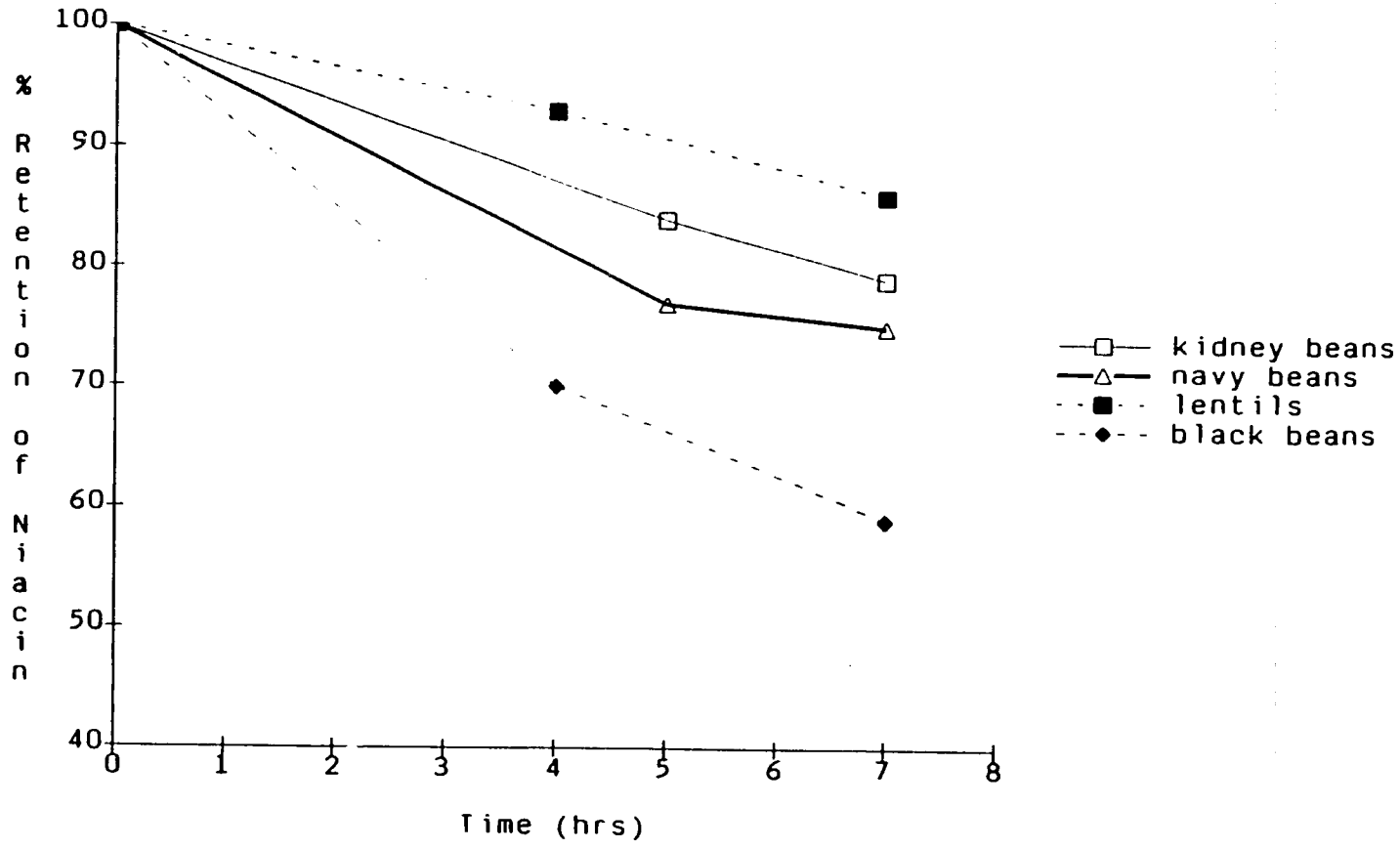
SAMPLE	Raw	Cooking times 4 hrs	Cooking times 7 hrs
Black beans	2.02 ± 0.19	1.41 ± 0.16	1.19 ± 0.12
Corn	2.61 ± 0.31	2.27 ± 0.20	1.93 ± 0.18
Lentils	2.64 ± 0.14	2.46 ± 0.19	2.27 ± 0.18
Mung beans	2.36 ± 0.11	2.15 ± 0.17	2.08 ± 0.19
White potatoes	8.15 ± 0.86	8.31 ± 0.77	7.42 ± 0.71

TABLE XV

Niacin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

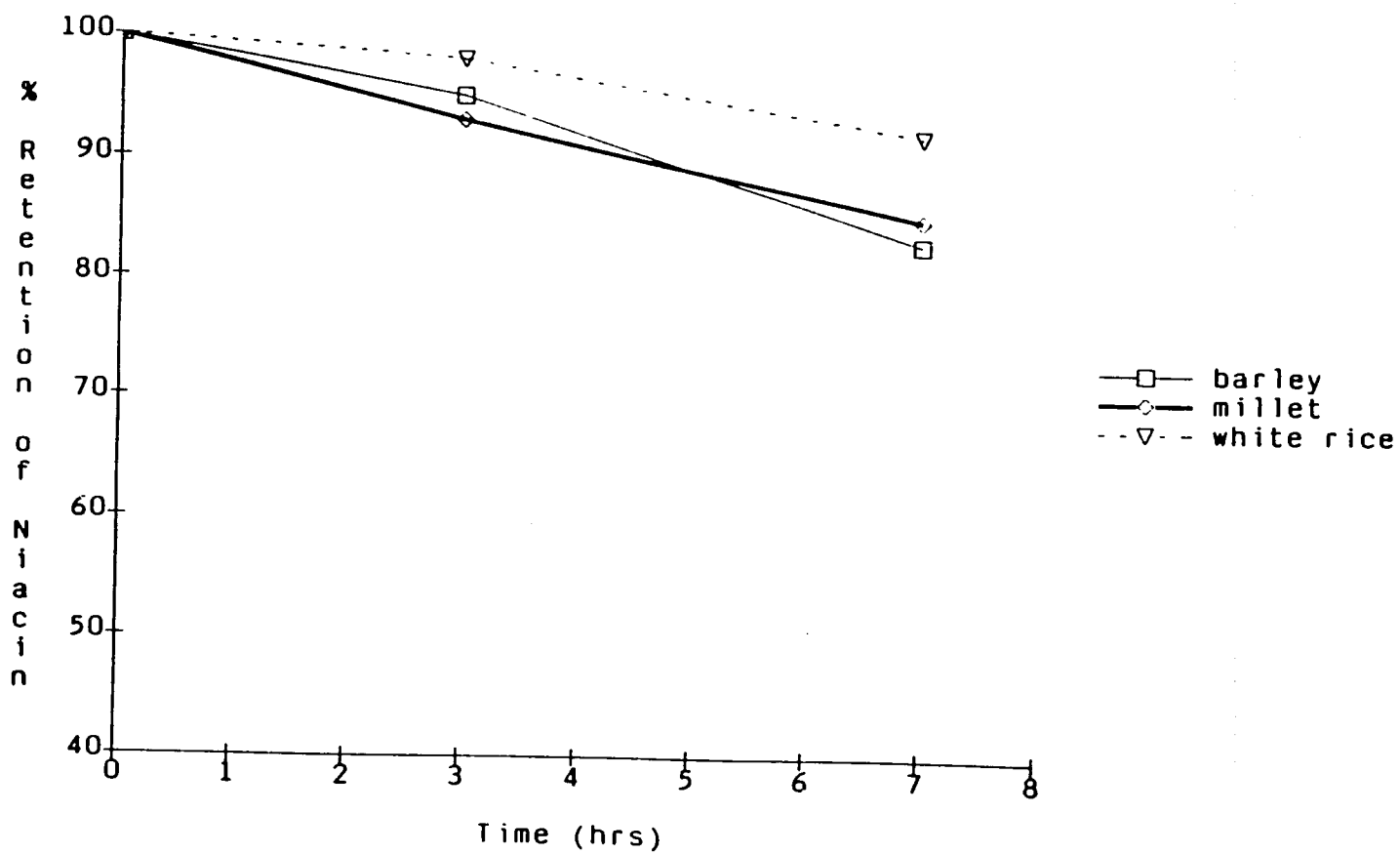
SAMPLE	Raw	Cooking times 3 hrs	Cooking times 7 hrs
Barley	3.69 ± 0.21	3.51 ± 0.18	3.06 ± 0.22
Brown rice	5.63 ± 0.43	5.70 ± 0.39	5.56 ± 0.31
Millet	4.29 ± 0.18	3.99 ± 0.24	3.65 ± 0.20
Oats	1.49 ± 0.16	1.28 ± 0.14	1.35 ± 0.12
Pumpkin	5.05 ± 0.43	4.70 ± 0.35	-
Quinoa	3.41 ± 0.27	3.00 ± 0.19	2.73 ± 0.20
White rice	4.39 ± 0.29	4.29 ± 0.28	4.04 ± 0.17

Figure 2



Percentage of retention of niacin in legumes during cooking in SBC.

Figure 3



Percentage of retention of niacin in cereals during cooking in SBC.

Riboflavin:

In comparing the riboflavin content in raw samples with that in cooked samples for those foods tested, retention of the vitamin was greater than 70% for all sample cooked in minimal time periods. Retention values were in the range of 73-100% (Tables XVI-XVIII and Figures 4 and 5). In samples cooked 7 hrs, the range of retention values was 60-98%. These values reflect additional losses of the vitamin of only 4-20%. Results were similar for foods from all three cooking categories. For foods in the difficult-to-cook category, the average retention value was 86% for sample cooked 5 hrs and 79% for those cooked 7 hrs. Average retentions in the other two categories were 86% and 79% (medium-to-cook) and 92% and 82% (easy-to-cook). Overall retention of riboflavin was slightly higher in vegetables included in this study (average value, 91%) compared with legumes (average value, 77%) or cereals (average value, 80%). An average retention value of 76% (range of 66-88%) was reported for riboflavin in a group of nine types of legumes (including black turtle, navy, kidney, and pinto beans) which were cooked conventionally (33). Hewston **et al.** (26) found that riboflavin was retained to the extent of 60-90% in boiled vegetables. In oven-baked Irish potatoes, retention of the vitamin was reported to be 107% (35). For four common Indian pulses, losses of riboflavin were found to vary in the range of approximately 15-40% in conventionally cooked samples (37). Cooking losses could not, however, be related to time taken for cooking. In comparing cooking methods, values of the retention of the vitamin in Colossus Peas were reported to vary from 40% in microwave cooking to 58% in conventional cooking (21). Baked sweet potatoes were reported to contain a higher riboflavin content relative to those cooked by other methods (31). Hudson **et al.** (29) observed lower retention of the vitamin in boiled broccoli (58%) compared with samples which had been cooked by other methods (steamed, 83%; microwaved, 83%).

TABLE XVI

Riboflavin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Difficult-to-Cook):

SAMPLE	Raw	Cooking times	
		5 hrs	7 hrs
Kidney beans	0.25 ± 0.02	0.20 ± 0.03	0.18 ± 0.01
Navy beans	0.26 ± 0.03	0.22 ± 0.02	0.21 ± 0.02
Pinto beans	0.21 ± 0.01	0.19 ± 0.02	0.18 ± 0.02
Split peas	0.28 ± 0.03	0.25 ± 0.02	0.23 ± 0.03

TABLE XVII

Riboflavin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook)

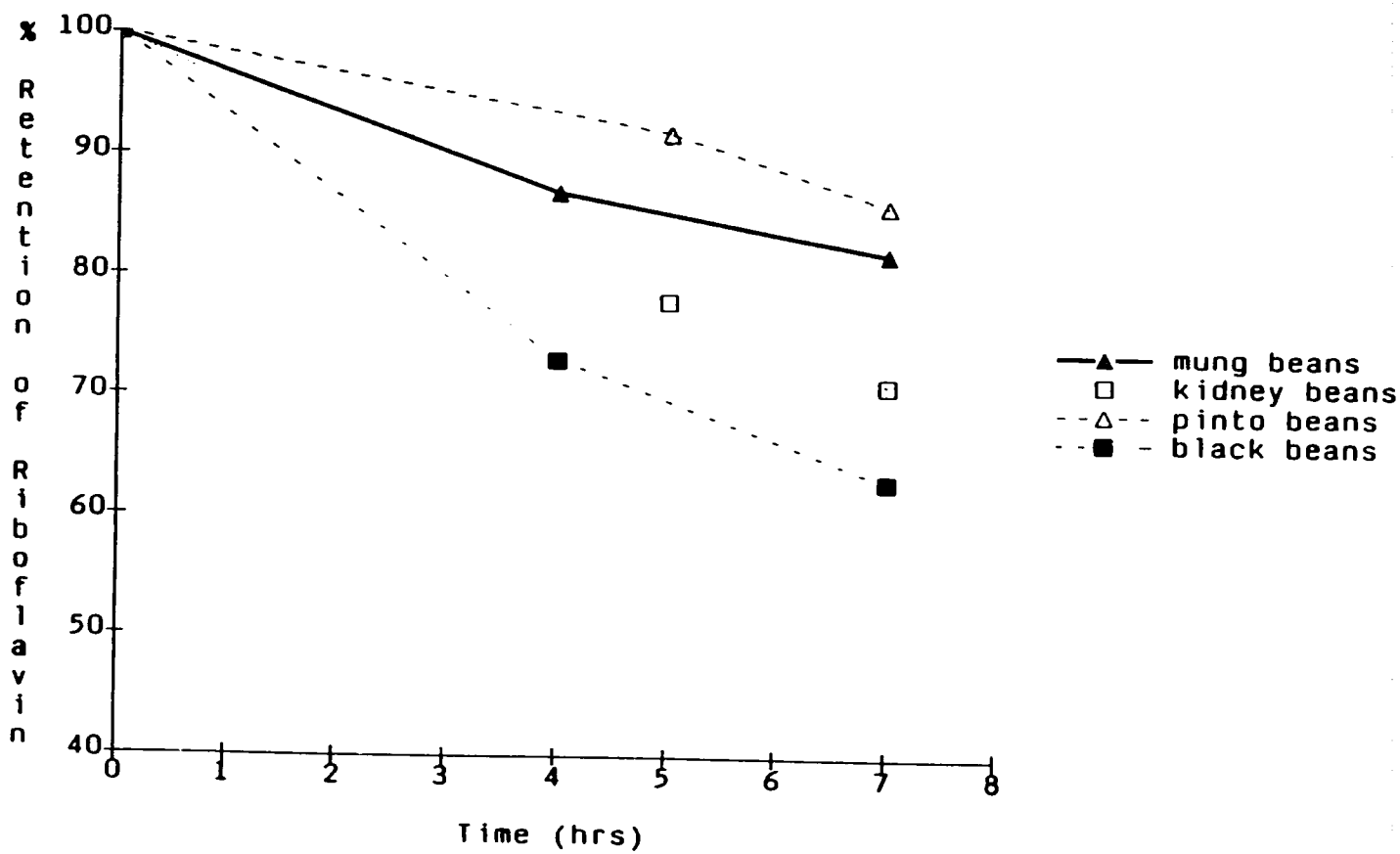
SAMPLE	Raw	Cooking times	
		4 hrs	7 hrs
Black beans	0.24 ± 0.03	0.17 ± 0.02	0.14 ± 0.02
Corn	0.18 ± 0.02	0.16 ± 0.01	0.13 ± 0.02
Lentils	0.29 ± 0.02	0.26 ± 0.03	0.23 ± 0.02
Mung beans	0.22 ± 0.01	0.19 ± 0.02	0.18 ± 0.01
Sweet potatoes	0.33 ± 0.04	0.30 ± 0.04	0.26 ± 0.02
White potatoes	0.15 ± 0.02	0.13 ± 0.01	0.14 ± 0.01

TABLE XVIII

Riboflavin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

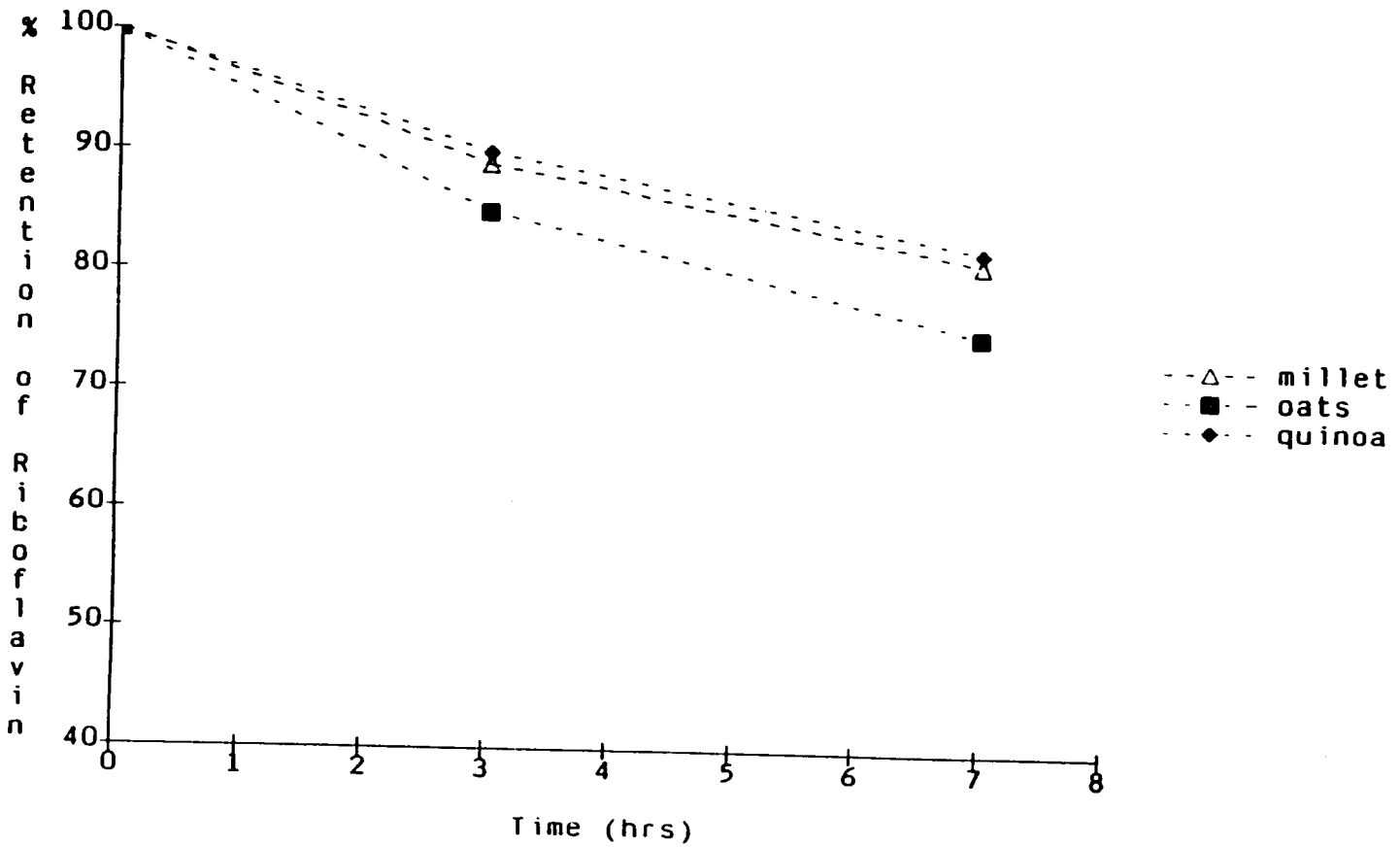
SAMPLE	Raw	Cooking times	
		3 hrs	7 hrs
Amaranth	0.15 ± 0.03	0.13 ± 0.02	0.11 ± 0.03
Barley	0.11 ± 0.01	0.10 ± 0.02	0.09 ± 0.01
Brown rice	0.12 ± 0.01	0.11 ± 0.01	0.10 ± 0.02
Millet	0.28 ± 0.02	0.25 ± 0.02	0.22 ± 0.02
Oats	0.12 ± 0.02	0.10 ± 0.01	0.09 ± 0.01
Okra	1.13 ± 0.15	1.02 ± 0.15	1.11 ± 0.21
Pumpkin	0.50 ± 0.06	0.49 ± 0.04	-
Quinoa	0.39 ± 0.03	0.35 ± 0.03	0.32 ± 0.04
White rice	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.02

Figure 4



Percentage of retention of riboflavin in legumes during cooking in SBC.

Figure 5



Percentage of retention of riboflavin in cereals during cooking in SBC.

Thiamin:

The effect of the cooking process on thiamin content for those foods tested in this study is shown in Tables XIX-XXI (see also Figures 6 and 7). For food samples which were cooked in the minimal time periods retention values were in the range of 50-100%. However, with most samples retention of the vitamin was greater than 80%. Extending the cooking time period to 7 hrs resulted in some additional losses in thiamin content for most samples. These losses did not, however, exceed 15%. Comparisons of the retention values in foods among the three cooking categories find these values to be similar. Average retention values were 87% (minimal cooking time period) and 80% (longer cooking time period) in difficult-to-cook foods, 90% and 79% in medium-to-cook foods, and 84% and 74% in easy-to-cook foods. Among the food groups, these average values are 86% and 77% in legumes, 84% and 82% in cereals, and 92% and 88% in vegetables. In several investigations in which the retention of thiamin in conventionally cooked legumes has been examined, retention values have been reported of approximately 60-85% (23), 65-80% (33), and 45-65% (20). In oven-baked Irish potatoes, 92% retention of the vitamin was reported (31). Lincoln **et al.** (38) found retention values of approximately 85-95% in a group of cereal products which were boiled 30 min. Relative to cooking method, retention of thiamin in Colossus Peas was found to vary from 80% in samples cooked by microwave to 61% for those conventionally cooked (21). Different retention values were also reported for broccoli cooked by various methods (29). Steamed broccoli retained the full amount of thiamin whereas retention in boiled and microwaved samples was 70%.

TABLE XIX

Thiamin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Difficult-to-Cook):

SAMPLE	Raw	Cooking times	
		5 hrs	7 hrs
Kidney beans	0.79 ± 0.05	0.68 ± 0.07	0.64 ± 0.05
Navy beans	0.84 ± 0.08	0.70 ± 0.06	0.67 ± 0.08
Pinto beans	0.81 ± 0.07	0.71 ± 0.09	0.62 ± 0.04
Split peas	0.84 ± 0.10	0.76 ± 0.07	0.71 ± 0.07

TABLE XX

Thiamin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Medium-to-Cook):

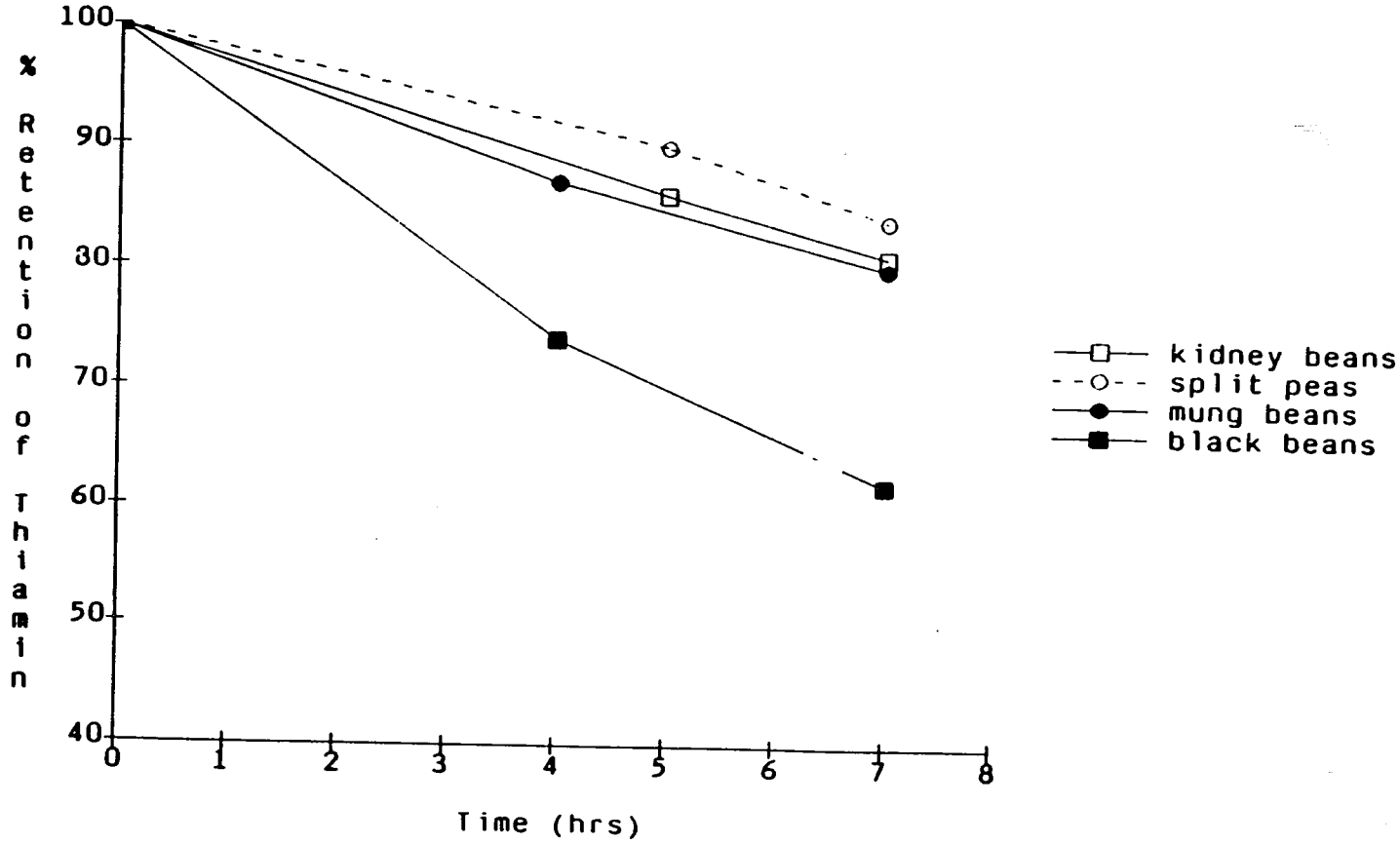
SAMPLE	Raw	Cooking times	
		4 hrs	7 hrs
Black beans	1.05 ± 0.11	0.78 ± 0.10	0.65 ± 0.06
Corn	0.35 ± 0.04	0.31 ± 0.04	0.26 ± 0.03
Lentils	0.64 ± 0.05	0.59 ± 0.07	0.49 ± 0.06
Mung beans	0.65 ± 0.06	0.56 ± 0.08	0.52 ± 0.04
Sweet potatoes	0.31 ± 0.05	0.33 ± 0.04	0.29 ± 0.04
White potatoes	0.43 ± 0.05	0.39 ± 0.03	0.36 ± 0.04

TABLE XXI

Thiamin Content (mg/100g, DWB) in Uncooked and Cooked Foods (Easy-to-Cook):

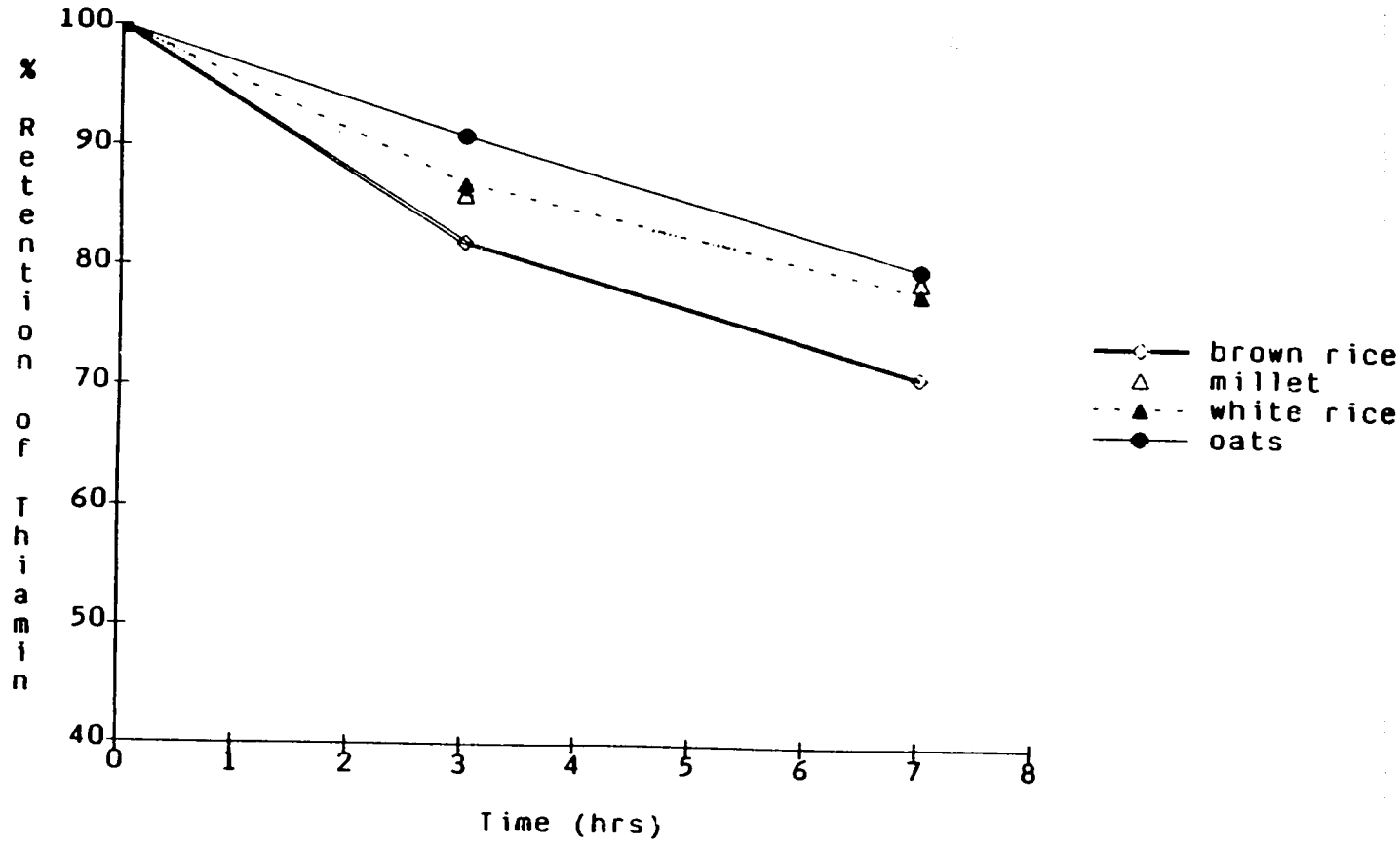
SAMPLE	Raw	Cooking times	
		3 hrs	7 hrs
Amaranth	0.04 ± 0.02	0.02 ± 0.01	0.04 ± 0.02
Barley	0.19 ± 0.03	0.18 ± 0.03	0.18 ± 0.02
Brown rice	0.47 ± 0.04	0.38 ± 0.03	0.33 ± 0.04
Millet	0.51 ± 0.06	0.44 ± 0.05	0.40 ± 0.06
Oats	0.55 ± 0.05	0.50 ± 0.06	0.44 ± 0.03
Okra	1.59 ± 0.23	1.40 ± 0.21	1.33 ± 0.15
Pumpkin	0.45 ± 0.04	0.39 ± 0.04	-
Quinoa	0.26 ± 0.04	0.23 ± 0.04	0.21 ± 0.05
White rice	0.48 ± 0.04	0.42 ± 0.04	0.37 ± 0.03

Figure 6



Percentage of retention of thiamin in legumes during cooking in SBC.

Figure 7



Percentage of retention of thiamin in cereals during cooking in SBC.

Nutrient retention in foods cooked in the SBC was found to vary relative to the food and to the nutrient. Foods from three food groups were included in the study. In general, longer cooking times resulted in some lowering of retention values. Minimal losses were observed for protein, amino acid, and carotene. Losses of ascorbic acid were greatest. However, these losses did not exceed 50%. Overall retention of available lysine was approximately 80-85%. For niacin, riboflavin, and thiamin overall retention was approximately 70-90%. Slightly higher retention of niacin was observed in cereal as compared with legumes. Retentions of riboflavin and thiamin were slightly higher for vegetables as compared with legumes or cereals. In comparing these results of nutrient retention in foods cooked in the SBC with many of the results reported in literature for foods cooked by other methods, foods cooked in the SBC were found to have either similar or better retention of nutrients. Foods cooked in the SBC require either no added water (samples with high moisture content) or only minimal amounts of added water (**eg.**, legumes and cereals). In a study by Martinsen and Ostrander (39), the amount of cooking water was found to affect the retention of vitamins. The thiamin content of carrots and cabbage cooked in a minimal amount of water ("waterless" cooking) was greater than thiamin content in these vegetables cooked by the standard boiling method. This relationship was observed with the ascorbic acid content of cabbage and peas and with the amount of riboflavin in carrots, cabbage, and peas. Deceased nutrient retention with increased volume of cooking water has also been reported by Krehl and Winters (40), by Sreeramulu (41), and by Fafunso and Bassir (42). Additionally, maximum oven temperatures in the SBC are lower than those of conventional ovens which should favor greater retention of nutrients since several of the nutrients, such as ascorbic acid, riboflavin, and thiamin, are heat labile (6).

The effect of solar cooking on nutrient retention in foods has also been reported by Jain and Bhat (43). The cooker was developed at the Agriculture Tools Research Centre in Bardoli, India. However, the description of the cooker was not given this report. Retention of thiamin, riboflavin, and ascorbic acid in seven commonly consumed Indian foods (including plain rice) was determined. Thiamin retention was found to be approximately 70-90%; retention of riboflavin was ap- proximately 80-90%. Only two of the foods were tested for ascorbic acid reten- tion. Retention of approximately 85% was observed. These foods were also cook- ed by sauce pan and by pressure cooking in order to compare the relative effect of the three cooking methods on nutrient retention. In almost all instances, solar cooking resulted in the lowest losses in nutrient content.

In summary, our study finds that cooking foods in the SBC maintains the nutrient content of foods as well or better than other cooking methods. A variety of foods, as well as a variety of nutrients, was included in this assessment. Thus, the use of the SBC can be promoted as an acceptable method of cooking which does not negatively impact on food quality.

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FIELD TESTING

In order to assess the utility of the SBC in an environment with potential of actual use, field testing of the Cooker was conducted in Zambia. In this country fuelwood is the principal source of energy, providing 80 per cent of the energy used in towns and cities and meeting virtually all energy requirements in rural areas (1). Zambia losses about 0.5 per cent of its woodlands every year; around large human settlements the loss is consideralbly higher. One of the main causes for this loss has been the overcutting of trees for fuelwood which has resulted in an increase in the amount of time and money needed in obtaining this fundamental resource. Development of an alternative to fuelwood for food cooking, such as the utilization of solar energy, should be of importance in addressing this increasing problem.

The field testing was carried out by David Kasonso, Head of the Food Science and Technology Unit, and others at the The National Food and Nutrition Commission (Zambia). The ability of the SBC to satisfactorily cook foods commonly consumed in this country was examined. This included the development of appropriate cooking strategies. Its utility in pasteurizing contaminated water samples taken from various local sources was examined as well. A preliminary assessment was also made of the potential to locally produce the Cooker. Additionally, families and observers were asked to response to whether they would utilize the Cooker.

Cooking Experimentation:

Testing for food cooking was conducted in two areas -- Lusaka, an urban location, and Solwezi, a rural location. The foods included in the tests were those common to these areas. In taste comparisons and assessment efforts, a total of 12 housewives and 15 observers were involved over the duration of the study. The time period involved was April through October. In Zambia, stable foods consist of maize, fingermillet, sorghum, and cassava. These are converted into flour before they are cooked in boiling water to form a thick paste known as nshima. Nshima is the major component of the Zambian diet and is eaten with various relishes which include vegetables, beans and oilseeds, fish, meat, insects, etc. Certain other foods are eaten as snacks. These include some products of the major stables (eg., maize samp may be eated in place of nshima) and other foods (eg., sweet potatoes, Livingstone potatoes, cassava tubers, pumpkins, etc.) Of late, particularly among the urban populations, rice and wheat products have become major components of their diets. Twenty-two foods were cooked in the SBC. Included were highly milled rice, green beans, dry kidney beans, groundnuts, sweet potatoes (yellow flesh variety and white flesh variety), Irish potatoes, fresh pumpkin, maize samp, pumpkin leaves, cassava tubers, cassava leaves, cabbage, carrots, whole sorghum, Livingstone potatoes, dry haricot beans, dry groundpeas, semi-fresh maize on the cob, fresh groundpeas (unshelled), maize samp with pounded groundnuts, peeled sweet potatoes with pounded groundnuts, and pounded cassava leaves with pound groundnuts.

In the cooking experiments, two portions of the same foods were prepared. One portion was cooked by conventional methods, and the other was cooked in the SBC. The food was later served to family members and observers who were requested to note any organoleptic differences. Cooking time periods varied from 1/2 to 4 hours depending upon the food and the type of day. Table XXII shows the cooking conditions for these foods. Most foods were prepared as commonly done for conventional cooking. However, beans were soaked overnight, and rice required less water than usual to avoid a taste of overcooking. On the whole, no major organoleptic differences were detected. Attempts to cook nshima in the SBC were unsuccessful. Although oven temperatures were sufficient to bring the water to boiling, the proper consistency of the nshima was not achieved. Efforts to develop an appropriate cooking strategy for nshima are, however, continuing beyond the duration this project time period. In some areas of Zambia families cook quantities of nshima in excess of what is needed for that day's consumption in order to eliminate the need to cook it every day. The SBC could provide a convenient way of reheating the leftover nshima.

TABLE XXII

Conditions for Cooking Foods in the SBC:

Sample	Type of Day	Cooking Time (hrs)
Pumpkin leaves	4	0.5
Maize samp	3	3
Carrots	3	1
Whole sorghum grain	2	2.5
Semi-dry groundnuts (shelled)	4	2
Cassava tubers	4	3
Sweet potatoes	3	2
Cassava leaves	3	1
Goundnuts	3	1.5
Irish potatoes	3	2.5
Green beans	3	2
Dry kidney beans	4	4
Cabbage	3	0.5
Fresh pumpkin	3	3
Livingstone potatoes	3	2.5
Dry haricot beans	4	4
Dry groundpeas (shelled)	3	4
Semi-fresh maize on the cob	2	1.5
Highly polished rice	4	1
Fresh groundpeas (unshelled)	4	2.5
Maize samp with pounded groundnuts	4	1.5
Sweet potatoes with pounded groundnuts	3	2
Pounded fresh cassava leaves with pounded groundnuts	2	1

David Kasonso and others from the National Food and Nutrition Commission demonstrating the SBC.

Water Pasteurization Experimentation:

Because of the health hazards of bacterial contamination in water sources, the SBC was also evaluated for its utility in the pasteurization of contaminated water. Results from an earlier study had shown that contaminated water could be pasteurized using the SBC (2). In this examination, samples in quantities of 5-15 liters were collected from 5 sources in the Lusaka area. Water from several of these sources are used for cooking and drinking. Each were tested for the presence of coliform bacteria. Samples that tested positive were also tested for contamination by Escherichia Coli. The analysis was done with the Colilert MPN system (Acess Analytical Systems, Bransford, CT), a rapid and specific method for evaluating water quality which does not require access to a microbiology lab or an extensive background in microbiology to compotently perform and interpret tests. (The method was modified in that time of incubation was 36 hours at room temperature. This modification was made in order to eliminate the need for a 37° incubator.) The presence of coliforms was detected in 4 of the samples (a yellow color change); Escherichia Coli was also detected in 3 of them indicating fecal contamination. After heating the contaminated samples to a temperature of at least 65°C in the SBC, they were again tested. All samples tested negatively for presence of either coliforms or Escherichia Coli which demonstrated that the SBC can be used successfully to eliminate these bacteria from contaminated water found in this area.

TABLE XXIII

Water Pasteurization in the SBC:

Water Source	Before heating		After heating	
	Coliforms	E. Coli	Coliforms	E. Coli
Stream (Lusaka Urban)	+	+	-	-
Stream (Lusaka Rural-Chongwe area)	+	+	-	-
Stream (Lusaka Rural)	+	+	-	-
Stream (Lusaka Rural-Old Mumbwa Road)	-	-		
Shallow well (Lusaka Rural)	+	-	-	-

Promotion of the Use of SBC by Families:

In assessing the acceptability for use of the SBC, some observations were made. All the people who participated in the field testing were not convinced that the Cooker could cook food and were even less convinced that it could cook food that they could eat. After using the SBC and evaluating foods cooked in it, nearly all the participants were so impressed with the SBC that they requested for the Cooker to remain with them or that it be given to them after field testing. Apart from a few participants, the majority were prepared to purchase the SBC if made available. The price that they were prepared to pay ranged widely from as low as ZK 100 to not more than ZK 1,000 (1 US$ = 12 ZK). The several advantages of the SBC, such as its inexpensiveness, its ability to cook without burning food, its ease of use, the lack of need to purchase wood or charcoal or spent time gathering it, etc., were noted. One big disadvantage that was bought out was that the Cooker has limited use during winter and can easily get damaged by rains during the wet season.

Assessment of the Potential to Locally Produce the Cooker:

The potential for reproducing the SBC locally was assessed and was found to exist in the country. Most of the components except the foil are locally available. Availability of foil is erratic. The Technological Development Advisory Unit (TDAU) is a specialised Unit within the School of Engineering at the University of Zambia (UNZA) and is a leading institution in as far as designing and modifying appropriate technologies is concerned. There is also the Small Industries Development Organisation (SIDO) which has enterprenuers who can readily manufacture the SBC for sale, if the market is assured.

In summary, field testing of the SBC in Zambia has shown that it can be utilized successfully to cook a variety of locally consumed foods. The SBC can also be utilized to pasteurize water contaminated with either coliform or Escherichia Coli bacteria, thereby having potential to contribute to the improvement of water quality. It can be used at least nine months of the year (April through December) in this environment. Because of the lower temperatures in the winter months (June and July), use may be restricted during this period. Although only a limited number of persons participated in the field testing, all participants were very impressed with the SBC and requested a cooker for their use. They noted several advantages of the SBC such as its inexpensiveness, the lack of needing to purchase or gather wood or charcoal, its ability to cook foods without burning them, and its ease of use. Thus, the results of this study demonstrate that the SBC can be an important additional mode of cooking available to people which can significantly contribute to reducing their dependency on scarce and/or expensive fuel sources. It's utilization can also be important in improving the quality of the water which is used for drinking and cooking.

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