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EFFECT OF SOAKING IN SALT SOLUTIONS ON WATER ABSORPTION, pH AND COOKING TIME OF AFRICAN YAM BEAN SEEDS (*SPHENOSTYLIS STENOCARPA* HOCHST EX. A. RICH HARMS)

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ABSTRACT

The effect of soaking African yam bean (AYB) seeds in water and various concentrations of sodium sesquicarbonate ($Na_2CO_3.NaHCO_3.2H_2O$) and sodium chloride (NaCl) on the water absorption, pH of soak solution and the cooking time of the pulse was investigated. Hydration coefficient (HC) increased in all the solutions tested as soaking progressed from the 6th to the 18th hour (maximum hydration time) before a decrease occurred at the 24th hour of soaking. At the same concentration of both salts, HC was generally higher in samples soaked in $Na_2CO_3.NaHCO_3.2H_2O$ (akanwu) compared to those soaked in NaCl. pH was found to decrease in all the soak solutions tested and the drop in pH occurred over time of soaking. At the same concentration of both salts and for the same period of soaking ranging from 6 - 36 hours, the pH drop was higher in the akanwu-soaked samples compared to those soaked in sodium chloride.

Soaking, irrespective of the medium and salt concentration highly reduced the bean cooking time which decreases as salt concentration increases, and hence the soaking process is of economic and practical importance to food vendors in Nigeria. At the same salt concentration (1.0% $^{w}/_{v}$) and at each of the soaking periods (6, 12, 18, 24,30 and 36 hours) investigated, the percentage reduction in cooking time was highest in akanwu-soaked samples compared to those soaked in sodium chloride.

Key words: Water absorption, pH, cooking time, AYB soaking, salt solutions.

INTRODUCTION

Soaking has been shown to be a useful and essential step in the home cooking of legume seeds especially in areas of high altitude (Silva, 1980), and has been reported to decrease the trypsin inhibitor and hemagglutinin activity in *Phaseolus vulgaris* (Kakade and Robert, (1966). In Egypt, lentil seeds are usually soaked before cooking (Abou-Samaha *et al*, 1985). The African yam bean (AYB) seed is an excellent source of proteins (21-29% on dry matter basis). Although the protein level of AYB is lower than that of soybean which is 38%, amino acid analyses indicate that its lysine and methionine levels are equal to or better than those of soybean (Evans and Boulter, 1974). When properly cooked the AYB is very filling and lasting, giving a lot of staying power and causing the consumer of its meal to drink much water probably as an aid to digestion (Ezueh, 1984).

Constraints on the use of the AYB seeds as food especially for people of low socio-economic status (the hungry masses) have been the laborious traditional methods of preparation, long cooking times of 4-6 hours (Okigbo, 1973) and the presence of antinutritional factors such as trypsin inhibitors which have been shown to be inactivated by heat treatment (Onyeike et al, 1991). In most Nigerian homes, the absence of electricity, the factor of low socio-economic status (most people now live below the poverty line), the negative effect of austerity measures and structural adjustment programme limit the use of otherwise simple gas cookers. The use of firewood in the cooking process is also becoming inadequate due to rapid deforestation without a corresponding aforestation leading to more use of kerosene stoves for cooking. The addition of salts such as NaC1, $NaHCO_3$ and Na_2CO_3 to the soaking medium was found to lower the cooking times and gave the cooked black beans better sensory properties (Varriano-Marston and De-Omana, 1979). Morris (1963) had earlier reported that the hard to cook phenomenon in legumes stored for long periods of time required long soaking and cooking to soften the seeds.

The purpose of this investigation was therefore to assess the effect which soaking in water and various concentrations of sodiumsesquicarbonate and sodium chloride would exert on the seed weight/hydration, pH of soak solution and the extent of reduction in the bean cooking time as a function of fuel and energy economy.

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MATERIALS AND METHODS

MATERIALS:

The uninfested marble-coloured African yam bean (AYB) seeds were purchased from Afor Oru market in Ahiazu Mbaise, Imo State. They were sorted to remove broken ones and extraneous materials, cleaned, wrapped with polyethylene bag, sealed in an air-tight container and stored for 4 days in a refrigerator (4°C) until they were required for use. Tap water from the University of Port Harcourt water supply was used in preference to distilled water since the latter is not used for drinking and cooking purposes by the consumers of AYB meal.

Sodium sesquicarbonate (akanwu) and sodium chloride were purchased from Choba market near the University of Port Harcourt. Akanwu is known as Nnu anwuru, kanwa, Ikang, Karu, Kaun and other names in various Nigerian languages depending on the ethnic group or tribe. It is a naturally-occurring alkaline rock salt whose aqueous solution has a pH of 11.0 as measured. It is misnamed "potash" in Nigeria because of the erroneous belief that it is a complex potassium salt (Uzogara et al, 1988). However, akanwu is over 98% trona ($Na_2CO_3.NaHCO_3.2H_2O$) with trace amount of calcium, magnesium, iron, zinc, sulphur, chlorine, silicon, phosphorous, potassium and aluminium (Makanjuola and Bettlestone, 1975). The akanwu was ground to a fine (100-mesh screen) powder, oven dried (105°C for 4 hr), cooled in a desicator and stored in an air-tight stoppered glass sample bottle until it was required for use.

Sodium chloride (common salt) is known in various parts of Nigeria as Nnu (Ibo), Iyo (Yoruba), Gishiri (Hausa), Inung (Efik and Ibibio), Uwanka (Urhobo), Lo (Ogoni), Arah (Ikwerre in Rivers State), etc. The pure common salt sodium chloride was purchased and used as such in the soaking studies.

METHODS

Determination of the hydration coefficient of the African yam bean seeds:

Whole dry bean seeds were weighed and soaked in plain tap water, akanwu and sodium chloride solutions of concentrations 0.20, 0.40, 0.60, 0.80 and 1.00% respectively at a bean to water ratio of 1:10 $^{w}/_{v}$ for periods of 6, 12, 18, 24, 30 and 36 hr at room temperature (29 ± 1°C). The soaked samples were drained, blotted dry with filter paper to remove surface water, weighed and the amount of water absorbed determined as hydration coefficient (HC) according to the method of Hulse et al (1977) as shown below:

$$\text{Hydration coefficient (HC)} = \frac{\text{weight of seeds after soaking}}{\text{weight of seeds before soaking}} \times 100.$$

Determination of p^H of Soak Solution:

The p^H of tap water and of the salt solutions used in sample soaking was determined prior to soaking by the use of a p^H meter. The AYB seeds were then weighed and soaked in water and various salt solutions for periods ranging from 6-36 hr at a bean to water ratio of 1:10 $^{w}/_{v}$. At the end of the soaking period, the seeds were removed and the p^H of the resulting solution measured.

Determination of the cooking time of AYB seeds: After soaking, the beans were blotted dry with Whatman No. 1 qualitative filter paper to remove surface water and the soak solution was discarded. Each sample lot of the soaked beans was separately added to boiling water (98°C) to cook and timing commenced with water added between boiling to avoid complete drying out.

The beans were cooked to tenderness in boiling water on a kerosene stove. Tenderness was determined by feeling between the fingers as done in most Nigerian homes. The degree of tenderness was scored on a scale of 0-5 with a rating of 5 for very soft beans and a rating of 0 (zero) for very hard beans. Determination was on the individual beans that made up the sample lot. To eliminate bias and obtain generalizable information, tenderness of the cooked AYB seeds was confirmed by 30 University of Port Harcourt students of both sexes composed by simple random sampling technique. The time needed to achieve a rating of 4 (soft) and which caused a splitting of over 95% of the AYB seeds during the cooking process was taken as the cooking time. As a control and for the purpose of comparison, unsoaked AYB seeds were subjected to the same cooking process in boiling tap water.

RESULTS

The results of the comparative effect of soaking in various akanwu and sodium chloride solutions on the hydration coefficient (HC) and p^H of soak solutions are embodied in Table 1. In all the solutions of both salts tested, HC generally increased with soaking time up to the 18th hour (maximum hydration time), then decreased by the 24th hour and slightly increased from the 30th to the 36th hour of soaking. For the same concentration of either of the salts and at the same period of soaking, there was a higher level of water absorption by the akanwu soaked samples compared to those soaked in sodium chloride. As the concentration of each salt increased at any given soaking time the HC generally decreased as lower salt concentrations generally caused increased water absorption.

Table 1 EFFECT OF SOAKING RAW AYB SEEDS IN VARIOUS AKANWU AND SODIUM CHLORIDE SOLUTIONS ON THE HYDRATION COEFFICIENTS AND pH OF THE SOAK SOLUTION

Akanwu Conc(%)	Soaking time (hr.)	Hydration Co eff.(%)	pH of Soak Solution			Colour of Soak Solution (Visual observation)	Sodium Chloride Conc.(%)	Soaking Time (hr.)	Hydration Co eff.(%)	pH of Soak Solution			Colour of Soak Solution (Visual observation)
			Initial	Final	Decrease in pH					Initial	Final	Decrease in pH	
0.20	6	168.2	10.2	9.90	0.30	Light Brown	0.20	6	166.5	5.40	5.30	0.10	Light Brown
0.20	12	179.1	10.2	9.50	0.70	Brown	0.20	12	178.0	5.40	5.30	0.10	Light Brown
0.20	18	181.3	10.3	8.80	1.50	Dark Brown	0.20	18	180.1	5.40	5.20	0.20	Yellowish Brown (amber)
0.20	24	167.8	10.0	7.25	2.75	Dark Brown	0.20	24	170.0	5.40	5.20	0.20	Amber
0.20	30	176.7	10.0	7.20	2.80	Dark Brown	0.20	30	175.1	5.40	5.15	0.25	Brown
0.20	36	178.8	9.90	7.10	2.80	Dark Brown	0.20	36	177.3	5.40	5.15	0.25	Brown
0.40	6	162.5	10.3	10.2	0.10	Brown	0.40	6	161.8	5.50	5.40	0.10	Light Brown
0.40	12	180.0	10.3	10.0	0.30	Brown	0.40	12	177.0	5.60	5.50	0.10	Light Brown
0.40	18	180.8	10.3	9.70	0.60	Dark Brown	0.40	18	179.0	5.50	5.35	0.15	Amber
0.40	24	177.2	10.3	9.50	0.80	Dark Brown	0.40	24	175.0	5.50	5.30	0.20	Amber
0.40	30	175.4	9.90	7.80	2.10	Dark Brown	0.40	30	176.0	5.50	5.30	0.20	Brown
0.40	36	176.0	10.0	7.35	2.65	Dark Brown	0.40	36	176.0	5.50	5.30	0.20	Brown
0.60	6	164.4	10.3	10.2	0.10	Brown	0.60	6	161.0	5.50	5.30	0.20	Light Brown
0.60	12	168.5	10.2	9.90	0.30	Brown	0.60	12	176.9	5.50	5.30	0.20	Light Brown
0.60	18	181.2	10.3	9.70	0.60	Dark Brown	0.60	18	180.0	5.50	5.30	0.20	Amber
0.60	24	174.2	10.2	9.50	0.70	Dark Brown	0.60	24	174.0	5.50	5.25	0.25	Amber
0.60	30	174.2	9.90	7.85	2.05	Dark Brown	0.60	30	172.6	5.50	5.25	0.25	Brown
0.60	36	174.7	9.90	7.40	2.50	Dark Brown	0.60	36	174.4	5.50	5.20	0.30	Brown
0.80	6	159.3	10.3	10.1	0.20	Brown	0.80	6	160.1	5.55	5.35	0.20	Light Brown
0.80	12	172.4	10.3	10.0	0.30	Brown	0.80	12	176.2	5.55	5.35	0.20	Light Brown
0.80	18	175.4	10.2	9.90	0.30	Dark Brown	0.80	18	178.3	5.55	5.30	0.25	Amber
0.80	24	175.2	10.2	9.85	0.35	Dark Brown	0.80	24	172.0	5.55	5.30	0.25	Amber
0.80	30	173.1	9.80	8.40	1.40	Dark Brown	0.80	30	172.0	5.60	5.30	0.30	Brown
0.80	36	174.5	9.70	7.70	2.00	Dark Brown	0.80	36	172.7	5.58	5.25	0.35	Deep Brown
1.00	6	165.7	10.2	10.00	0.20	Brown	1.00	6	159.5	5.60	5.40	0.20	Light Brown
1.00	12	171.8	10.2	9.90	0.30	Brown	1.00	12	170.3	5.60	5.40	0.20	Light Brown
1.00	18	176.2	10.2	9.80	0.40	Dark Brown	1.00	18	174.0	5.60	5.30	0.30	Amber
1.00	24	169.8	10.2	9.80	0.40	Dark Brown	1.00	24	165.8	5.70	5.35	0.35	Amber
1.00	30	170.2	10.0	8.65	1.35	Dark Brown	1.00	30	167.0	5.60	5.20	0.40	Brown
1.00	36	171.9	10.0	8.10	1.90	dark Brown	1.00	36	170.5	5.60	5.10	0.50	Dark Brown

Table 2. Reduction in cooking time of AYB seeds soaked in water and various akanwu and sodium chloride solutions.

Soaking time (hr)	Reduction in Cooking Time (%)*										
		Akanwu (%)				Sodium Chloride (%)					
	H_2O	0.20	0.40	0.60	0.80	1.00	1.0	2.0	4.0	6.0	8.0
0	0.0	-	-	-	-	-	-	-	-	-	-
6	30.3	42.5	45.8	50.2	53.5	55.7	50.3	54.6	56.8	61.3	62.4
12	38.6	50.7	53.0	57.9	60.7	63.5	53.0	59.1	60.7	62.9	64.6
18	46.9	53.5	56.8	61.8	65.1	69.0	55.7	60.2	62.4	65.1	67.4
24	50.2	56.3	61.3	65.7	68.5	72.9	57.9	64.0	66.2	69.0	71.2
30	51.3	60.2	64.6	67.6	70.1	75.1	64.0	67.4	70.1	71.8	73.4
36	52.4	61.4	67.4	70.1	73.4	76.8	65.7	69.6	72.3	73.4	77.9

Cooking time of raw (unsoaked) African yam bean (AYB) seeds was 180.7 ± 2.50min.
* Values are means of duplicate determinations.

For each concentration of either akanwu or sodium chloride, the p^H of soak solution decreased with soaking; the decrease was higher in the akanwu-soaked than in the sodium chloride-soaked samples and the drop in p^H generally increased over time of soaking. The intensity of colour (by visual observation) of each of the soak solutions increased over soaking time (Table 1). The results of soaking AYB seeds in tap water and various akanwu and sodium chloride solutions on the cookability of the African yam bean (AYB) seeds are shown in Figures 1 and 2. The African yam bean seeds were found to cook in plain tap water for 180 minutes (3 hours)

Soaking for 18 hours was found adequate for the AYB seeds to acquire maximum hydration. The soaking process, irrespective of the medium and salt concentration caused a marked reduction in the cooking time of the seeds. The reduction increased as soaking period increased particularly in akanwu, then sodium chloride solutions compared with tap water (Table 2). The reduction in cooking time also occurred in a concentration-dependent manner (Table 2). It was at the 24th hour of soaking that AYB seeds soaked in plain tap water achieved 50% reduction in cooking time whereas this was achieved by the 6th hour of soaking in 0.60% akanwu solution and 6th hour of soaking in 1.0% sodium chloride solution.

DISCUSSION

This investigation establishes that for the African yam bean (AYB) seeds (Sphenostylis stenocarpa) maximum water absorption occurred at the 18th hour of soaking in water, akanwu and sodium chloride solutions irrespective of salt concentration. The water absorbed is thought to have aided the enzymatic hydrolysis of the sugars and other macromolecules in the sample. This may have been responsible for the presence of white-coloured leachates observed at the bottom of the conical flask used in sample soaking resulting in decrease in seed weight by the 24th hour of soaking. It is indeed more plausible to think that the colouration may result from disruption of cell membranes due to the high osmotic pressure build up. The Slight increase in the weight of the seeds and the hydration coefficient as soaking progressed from the 30th to the 36th hour is attributable to the active reabsorption of the leachates

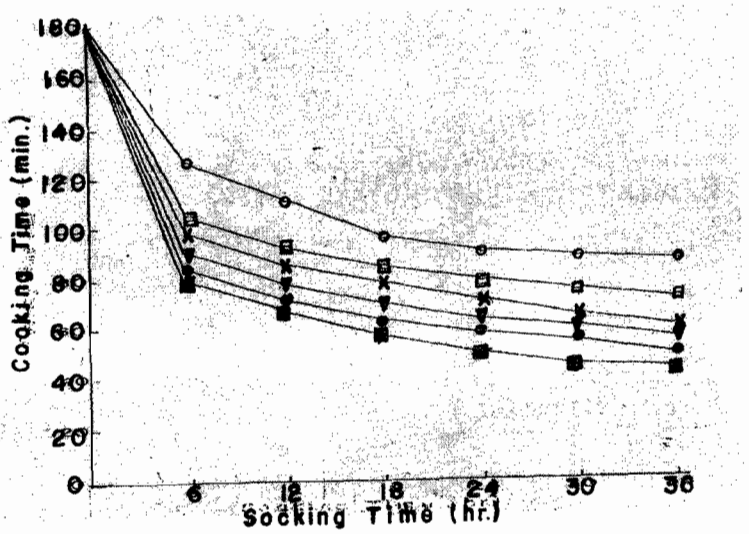

Fig. 1. Plots of Cooking Time of the African Yam Bean Seeds Cooked in Boiling Tap Water Against Soaking Time in Various Akanwu[a] Solutions. a: Sodium sesquicabonate or Na_2CO_3. $NaHCO_3$. $2H_2O$
Plain Tap water; 0.20% Akanwu; 0.40% Akanwu
0.60% Akanwu; 080% Akanwu; 1.00% Akanwu

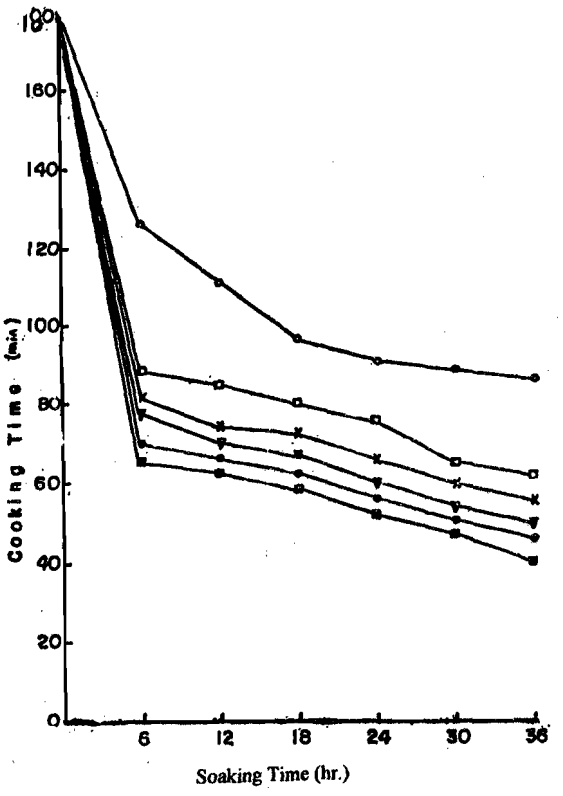

Fig. 2:

Plots of Cooking Time of the African Yam Bean Seeds Cooked in Boiling Tap Water Against Soaking Time in Various Sodium Chloride Solutions.

o—o Plain tap water; □—□ 1.0% Nacl.; x—x 2.0%Nacl.; ▽—▽ 4.0% Nacl.; ●—● 6.0% Nacl.; ■—■ 8.0% Nacl.

by the seed sample and the latter may have taken in more water because of the disruption of the membrane system. As the concentration of each salt increased at a particular soaking period, the HC generally decreased. For instance, as NaC1 concentration increased (0.20, 0.40, 0.60, 0.80 and 1.00%) for a 6 hour soaking schedule, the HC decreased (166.5, 161.8, 161.0, 160.1, and 159.5) respectively (Table 1). This indicates that HC generally increased at lower salt concentrations. It has been suggested that lower concentrations of kanwa (akanwu) alkaline rock salt solution were more effective in softening cowpeas (*Vigna unguiculata*) than the higher levels probably because of the decreased viscosities and increased water absorption at lower salt concentrations (Uzogara et al, 1988).

The higher HC in the akanwu-soaked samples compared to the sodium chloride-soaked ones at the same concentration of both salts indicates that the former may have a higher softening rate and cook to tenderness at a shorter time. The colour of the soak solution could be due to leaching out of pigments from the AYB seeds during soaking as noted for black beans by Silva et al, (1981). It could also be attributable to the formation of complexes between the AYB seed pigments and microelements in the soak

colour intensity as soaking progressed may also be due to the oxidation products of pigments leached out of the bean sample.

The fall in pH in the akanwu-soaked samples than in the corresponding sodium chloride-soaked ones may indicate that akanwu is a better tenderizer since it caused more release of the hydrolyzed biomolecules out of the sample into the soak solution as observed by visual inspection. The reduction in pH value with soaking is an indication of leaching out of acidic biomolecules from the AYB seeds into the soak solution. The pH drop observed in this soaking studies is attributable to the nature of the leachates or to the growth of lactic acid bacteria which convert fermentable sugars to lactic acid and other end products as reported for soaking studies on winged bean under tropical conditions by Kialasapathy et al (1985). It has also been reported that the longer the beans were soaked the greater was the loss of solids to the soak medium, and the rate of which decreased with soaking time (Lo et al, 1968).

In the case of akanwu as in Table 1, bacterial growth is thought to be highest at lower concentrations for the same soaking period (e.g. soaking for 18 hr at akanwu concentrations of 0.20, 0.40, 0.60, 0.80 and 1.00%) as evidenced by increased reduction in pH of soak solution. Reduction in pH could also be due to the spontaneous demethylation of pectic substances or to increased activity of pectin methylesterase or to the dissociation of protons of the amino acid side chains - the resulting charges on the macromolecules would thus influence water absorption (Varriano-Marston and De Omana, 1979). They also showed that the pH decrease may be caused by ionization of cellular components resulting in increased levels of protons (H^+) in the soak solution. It has however been shown in studies on pectic substances that some of these hydrogen ions (H^+) were contributed by the pectic acid which has a pka of 2.80 to 4.20 (Kertesz, 1951). It has been demonstrated that the amount of sodium in the soak water did not significantly affect water absorbed by black beans; the pH was the critical determinant (Varriano-Marston and De-Omana, 1979).

It can be seen from this study that the soaking of AYB seeds is very beneficial in reducing the cooking time, and this is of considerable economic and practical importance to the providers of food in Nigeria. From literature cited, AYB cooks for between 4-6 hours. Here, it was found to cook in plain tap water for 3 hours. Analysis of tap water samples at the University of Port Harcourt indicated that the water was salty as test of hardness showed the water to be hard and hence thought to contain the ions Na^+, Ca^{2+} and Mg^{2+}. It is possible that the presence of these ions in water may have enhanced softening and so bringing about reduction in the bean

time of the AYB seeds soaked in akanwu and sodium chloride solutions could be explained by the fact that the presence of sodium salts ($Na_2CO_3.NaHCO_3.2H_2O$ and NaC1) in the soaking medium and high pH increases the softening rate. Similar observation was made for black beans (Silva et al, 1981). Varriano-Marston and De-Omana (1979) demonstrated the mechanism of softening as affected by salts and showed that softening was due to ion exchange and probably also by chelation of ions responsible for cellular firmness - the net effect being the solubilization of pectic substances.

At the same concentration (1.0%) of akanwu and sodium chloride, the reduction in cooking time was higher in akanwu-soaked compared to sodium chloride-soaked samples (Table 2) confirming the merit of the former over the latter as a tenderizer. Sodium chloride on the other hand is reputed to serve two major functions in the preservation of vegetables namely retention of firmness of the vegetable and directing the course of microbial activities (Pederson, 1979). This firmness retention may account in part for the greater softening of AYB seeds cooked after soaking in 1.0% akanwu compared to the seeds cooked after soaking in 1.0% sodium chloride.

CONCLUSION

Irrespective of the medium and concentration of the salts used in soaking, the AYB seeds were found to have maximum water absorption at the 16th hour of soaking. At the same concentration of both salts, the drop in pH was more in akanwu-soaked compared to sodium chloride-soaked samples indicating that akanwu is a better tenderizer and thus causing greater softening of the cooked AYB seeds at a shorter time compared to sodium chloride and plain tap water.

When intending to cook AYB seeds with akanwu, soaking should be done in 0.60% $^{w}/_{v}$ solution for 6 hours or 0.40% $^{w}/_{v}$ solution for 12 hours. For sodium chloride cooking, soaking in 1.0% $^{w}/_{v}$ solution for 6 hours before cooking is recommendable. These lower salt concentrations at only 6 hour soaking schedule resulted in up to 50% reduction in the bean cooking time. Moreover, prolonged soaking apart from being unacceptable to consumers who want the AYB meal urgently, may also have the demerit of enhancing the growth of lactic acid bacteria which can convert fermentable sugars to lactic acid and other end products thus leading to loss of beneficial solids (proteins, carbohydrates and lipids) to the soak solution that is usually discarded.

REFERENCES

Abou-Samaha, O. R., El-Mahdy, A. R. And Moharran, Y. G., 1985. Effect of soaking on the quality of lentil seeds. Z. Lebensm Unters Forsch, 180: 485-490.

Evans, I. M. and Boulter, D., 1974. Amino acid composition of seed meals of yam bean *(Sphenostylis stenocarpa)* and lima bean *(Phaseolus lunatus).* J. Sci. Food Agric. 25 (8): 919-922.

Ezueh, M. I. 1984. African yam bean as a crop in Nigeria. World Crops 36 (6): 199-200.

Hulse, J. H., Rachie, K. O. And Billingsley, L. W. 1977. Nutritional standards and methods of evaluation of food legume breeders. International Development Research Centre (IDRC TS 7e), Ottawa, Canada, KIG 3 H 9, Ottawa.

Kakade, M. L. and Robert, J. E. 1966. Effect of soaking and germination on the nutritive value of beans. J. Food Sci. 31: 781-784.

Kertesz, L. I. 1951. The pectic substances. Interscience Publishers, Inc., New York.

Klalasapathy, K., Perera, P. A. L. and Mac-Neil, J. H. 1985. Soaking studies on winged bean *(Psophocarpus tetragonolobus* LDC) to process full fat flour and determine its shelf-life stability. J. Food Sci. 50 (5): 773-777.

Lo, W., Sterinkraus, K. H., Hand, D. B., Hackler, L. H. and Wilkens, W. F. 1968. Soaking soybeans before extraction as it affects chemical composition and yield of soymilk. Food Technol. 22: 138-141.

Makanjuola, A. A. and Bettlestone, J. G. 1975. Some chemical and mineralogical notes on kaun (trona). Nig. J. Minning and Geology. 10 (1,2): 31-41.

Morris, H. J. 1963. Cooking qualities of dry beans. Paper presented at the 6th Annual Dry Bean Conference, Los Angeles, C. A.

Okigbo, B. N., 1973. Introducing the yam bean *(Sphenostylis stenocarpa)* Hochst ex A. Rich) Harms. In: Proceedings of the first IITA Grain Legume Improvement Workshop, October 29-November 2, 1973, Ibadan, p. 224.

International Institute of Tropical Agriculture, Ibadan, Nigeria.

Onyeike, E. N., Abbey, B. W. and Anosike, E. O. 1991. Kinetics of heat inactivation of trypsin inhibitors from the African yam bean *(Sphenostylis stenocarpa)*. Food Chem. 40 (1): 9-23.

Pederson, C. S. 1979. Microbiology of Food Fermentation; 2nd edn., AVI Publishing Co. Inc., Wastport, CT.

Silva, C. A. B. 1980. Soaking and thermal processing effects on black bean quality. Diss. Abst. Int. BYI: 509 (C. F. FSTA 13 IIJ 1664, 1981 J).

Silva, C., Bates, R. P. and Deng, J. C. 1981. Influence of soaking and cooking upon the softening and quality of black beans. J. Food Sci. 46: 1716-1720.

Uzogara, S. G. ... and Daniel, J. W. 1988. Q... d mineral content of co... *iculata* L. Walp.) seeds pr... wa alkaline salt. Food Ch...

Vuriano-Marston, E. and De-Omana, E. 1979. Effects of Sodium salt solutions on the chemical composition and morphology of black beans *(Phaseolus vulgaris)*. J. Food Sci. 44: 531-536.