BAOBAB (*Adonsonia digitata*) -THE WILD PROTEIN SIDE

Quirino **Dawa***, Hua **Yufei**

State Key Laboratory of Food Science and Technology, School of Food Science and Technology, Jiangnan University, 1800 Lihu Road, 214122 Wuxi, Jiangsu Province, China.
*E-mail: qdawa@yahoo.com

Abstract
Wild fruits are consumed in many resource constrained communities around the world,these fruits provide many nutrients. Details of the nutritional contribution of wild plants and fruits to the diet have been outlined in various research and review papers. Besides their nutritional contribution, some of these wild plants have also been documented to be of high commercial value. Baobab seeds and leaves have noteably been reported to contain considerable amounts of protein.The pulp,leaves and seed have antioxidation capacity that can help a long way in the development of novel functional food ingredients. Baobab is used in many products and dishes but the presence of anti-nutritional factors reduces the bioavailability of baobab protein. Through proper processing techniques, the protein is made available for absorption in the body,while preventing any loss of antioxidant capacity. Extensive studies focussing on the improvement of functional properties that have been done on conventional plant crops such as legumes, oilseeds and cereals need to be conducted on baobab. Research publications and reviews on baobab have mainly focused on, agronomy, general nutrient composition analysis and medicinal properties of the tree.This review covers the nutritional significance of baobab as a protein source and its potential use as a functional ingredient in the food industry.

Keywords: baobab seed, functional properties, leaves, protein, food ingredient

Submitted: 26.10.2013 Reviewed: 09.01.2014 Accepted: 25.03.2014

1. INTRODUCTION

Wild plants are consumed by rural communities in most parts of the world to meet their food and nutritional needs (Emmanuel et al., 2011; Glew et al.,2005; Leakey,1999). ingredient in the United States of America (Leakey,1999; Gruenwald, 2009; Buchmann et. al., 2010; Addy,2009; De Smedt et al.,2011; The Commission of the European Communities, 2008).

Protein from drought tolerent wild plant sources such as baobab is crucial in areas with low and unpredictable rainfall patterns and commercialization of the tree and its products could help in the alleviation of poverty in rural resource constrained areas (Kalinganire et. al,2007; Venter and Witkowski, 2013). There are many research publications and reviews on baobab focussing on species taxonomy, agronomy, nutrient composition analysis, phytochemistry and pharmacology but not specifically on protein (Kamatou et.al,2011; Sena et. al,1998; Osman, 2004; Chadere et. al, Some of these wild plant species such as, *Sclerocarya birrea* (marula), found in the Southern African plateau, is of high commercial value and baobab (*Adonsonia digitata*) fruit pulp has been authorised for import in Europe and approved as a food 2009; Adejuyitan et. al,2012; Selvarani and Hudson, 2009; De Caluwé et al.,2010; Nour et al.,1980). This review focusses on the protein aspect of baobab and its potential use in the food industry. Baobab (*Adonsonia digitata*) mainly grows naturally as a wild tree, it is found in the Sahelian, Soudano-Sahelian, Soudanian zones, sub-Saharan Africa, Madagascar and Australia (Chadere et. al, 2009; Drake, 2006; Wickens and Lowe, 2008). The tree can reach a height of 25 m and 10–28 m circumference, it produces fruit with many hard round or ovoid seeds, in a dry, acidic pulp and shell, it also has hairy and sometimes hairless leaves (Osman, 2004;Wickens,1982; Gebauer et. al,2002; Sidibe and Williams, 2002; Baum,1995).

Protein content of baobab
Baobab leaves, seeds and pulp contain protein,vitamins, lipids, carbohyrates and minerals (Kalinganire et. al, 2007; Booth and Wickens,1988; Chadere et al.,2009).
Assogbadjo et al.(2012) reported that baobab seeds contain higher amounts of crude lipid and protein than all the other parts. Higher protein content values were reported in baobab seeds;28.7%-36.3% (Murray et al.,2001; Arnold et al.,1985; Saka,1995),while lower values15.12 % and 18.4±0.5% were reported by Lockett et al.(2000) and Osman (2004) respectively. Ezeagu (2005), also reported that baobab seeds have a low content of protein when compared with soybean and cowpea,but despite this, the seeds displayed a potential for use as a food supplement (Mwale et al., 2008; Chimvuramahwe et al., 2011).

The content of protein in the leaf ranges from 13-15% (Becker, 1983; Yazzie et al., 1994; Nordeide et al., 1996). Based on the WHO reference standard, the essential amino acid score for baobab leaves is close to or above the 100% mark,with threonine scoring the lowest, making it the limiting amino acid (Sena et al.,1998). Data from Glew et al. (1997) and Addy and Eteshola (1984), showed that tryptophan was the limiting amino acid in baobab seeds. In proteins where the amino acid pattern is unbalanced, all the essential and limiting amino acids can be met if the protein is consumed in large amounts (Harper and Yoshimura,1993).

All these reported differences in nutritional composition of baobab parts is influenced by, genetics, soil, storage conditions, physiochemical characteristics of soil as well as other factors (Eromosele et al., 1991;Chadare, 2009;Assogbadjo et al., 2012; Cuni Sanchez et al., 2011). Pea protein content was found to be sensitive to, soil fertility as well as environmental stress factors (Robertson et al., 1962; Singh et al.,1972; McLean et al., 1974). But no factors have been directly associated with protein content in baobab parts. Deliberate efforts such as, applying the appropriate fertilizer amounts and type (Assogbadjo et al., 2012) can be made to improve the protein content levels in the seeds and leaves.

Baobab protein availability
The utilization of protein from baobab seed is limited by the presence of anti-nutrient components (Igboeli et al.,1997). Although the amount of antinutritional components present in baobab are reported to be below toxic levels (Vanderjagt et al.,2000;Nkafamiya, 2007), long-term feeding of raw soy flour or a fraction with trypsin inhibitor was shown to result in hyperplastic and neoplastic nodules of the pancreas, including carcinomas in rats. Mamalian species' response to carcinogenic effect of prolonged feeding of trypsin inhibitor is not the same (Liener and Hasdai,1985; Birk,1996; Liener, 1995). No allergies associated with baobab and related species including any cross-reactivity with known allergens have been reported to date. Baobab can serve as alternative to tree nuts and peanuts that cause allergenic reactions in some individuals (Van Putten, 2011; Taylor,1985; Roux et al., 2003;Sampson,2004). Isolation and characterisation of these anti-nutritive factors in baobab could reveal some benefits such as the anticarcinogenic properties in Bowman-Birk protease (Kennedy, 1998a; Kennedy, 1998b; Vanderjagt et al.,2000).

Effect of processing on baobab protein availability
The application of proper processing techniques enhances food nutritional quality by, inactivating or destroying anti-nutritional factors and unfolding and/or denaturing protein in seeds (Addy and Eteshola ,1984;Shekib et al.,1988; Uzogara et al.,1990;Geervani and Theophilus, 1980;Liener, 1976; Walker and Kochar,1982). The antitrypsin activity that was analysed in some wild plants including baobab seeds, was extensively or completely resistant to boiling.The residual antitrypsin is of concern when the baobab seeds are used as ingredients in infant formulas or weaning foods (Vanderjagt et al., 2000; Liener, 1995). Cooking, results in loss of antioxidant

properties therefore other processing techniques need to be investigated to prevent such losses (Tarwadi and Agte, 2005). Fermentation reduces the content of protein and carbohyrates in baobab seed and breaksdown protein complexes namely, protein-tannin, tannin-enzyme and protein-phytate. It also brings desirable flavour through the action of Bacillus spp. (Addy et al., 1995; Nnam and Obiakor ,2003; Kazanas and Fields, 1981; Chadare et al.,2011;Sarkar et al.,2002;Parkouda et al.,2009).

Baobab use and products

Baobab pulp, seeds and leaves are used in many dishes and products such as, drinks, sauces, fermented products and others (Gruenwald, 2009; Venter and Witkowski, 2013; Nordeide et al.,1996). No single plant food can generally provide an individual with all the necessary nutrients but when prepared with other foods they contribute significant amounts of nutrients in the diet (Humphrey et al., 1993; Cook et al.,2000; Avallone et al., 2008). Baobab products such as baobab milk (baobab juice with baoab seed kernals) is very nutritious (Obizoba and Anyika, 1993) because baobab seed kernals contain more protein than groundnuts and are rich in calcium,iron,lysine and thiamine (Booth and Wickens,1988). The product can also be made from the fruit pulp alone or it can be mixed with acha (*Digitaria exilis*) flour-Acha is a grain crop which can be used as a staple food with 7% protein content (Dachi and Gana, 2008). The fruit pulp has high anti-oxidation properties,the leaves and seeds also have antioxidation capacity albeit lower than the fruit pulp (Nour et al.,1980; Besco et al., 2007). Through further research, these baobab parts can be used as functional ingredients.

Baobab protein functionality

Proteins and polysaccharides are categories of biopolymers commonly used as functional ingredients. The interaction of proteins and polyssacharides leads to the creation of food products (Rodríguez Patino and Pilosof, 2011;Benichou et al., 2002; Makari and Doxastakis, 2006). Insoluble complexes that lead to phase seperation are sometimes formed in solutions containing polysaccharides and protein (Schmitt et al., 1998). The protein - polysaccharide interaction in baobab milk and other such products need to be studied further. To understand the chemistry and functionality of proteins,characterisation of proteins is very important (Horax et al.,2011). Protein structure modifications improve protein solubility,suface activity and foaming properties (Lopez-Fandino,2006; Van der Plancken,2007; Murray,2007;Rodriguez Patino, 2007).

2. CONCLUSIONS

Wild plants are part of the diet for people in areas where environmental conditions do not favour conventional crop farming systems. Indepth studies on the leaf and seed protein characteristics and functionality are yet to be conducted, as well as investigations on benefits that could be associated with antinutritive factors that are present in the seeds.

Processing techniques that enhance protein availabity and prevent loss of antioxidation capacity should also be explored.

Factors that affect the protein content levels baobab parts need to be investigated so that appropriate measures should taken to improve the protein content in the baobab parts.

3. REFERENCES

[1] Emmanuel, T.V., Njoka, J., Catherine, L.W., Lyaruu, H.V.M.- Nutritive and anti-nutritive qualities of mostly preferred edible woody plants in selected drylands of Iringa district, Tanzania. Pakistan J. Nutr, 10 (8), pp. 786-791, 2011.

[2] Glew, R.S., VanderJagt, D.J., Bosse, R., Huang, Y-S, Chuang, L-T, Glew, R.H. -The nutrient content of three edible plants of the Republic of Niger. J. Food Comp Anal, 18, pp. 15–27, 2005.

[3] Leakey, R.R.B. -Potential for novel food products from agroforestry trees: A review. Food Chem, 66, pp. 1-14, 1999.

[4] Gruenwald, J.- Novel botanical ingredients for beverages. Clin. Dermatology, 27,pp. 210–216, 2009.

[5] Buchmann, C., Prehsler, S., Hartl, A., Vogl, C.R.- The importance of baobab (*Adansonia digitata L.*) in rural West African subsistence—suggestion of a

cautionary approach to international market export of baobab fruits. Ecol. Food Nutr, 49, pp.145–172, 2010.
[6] Addy, R. Baobab fruit approved as food ingredient in US. 2009. Available at: http://www.nutraingredients-usa.com/content/view/print/2595742009 [Accessed on: 28/03/2013].
[7] De Smedt, S., Alaerts, K., Kouyate, A.M., Van Damme, P., Potters, G., Samson, R. -Phenotypic variation of baobab (*Adansonia digitata L.*) fruit traits in Mali. Agroforest. Syst, 82,pp. 87–97, 2011.
[8] The Commission of the European Communities.-Commission decision of 27 June 2008 authorising the placing on the market of baobab dried fruit pulp as a novel food ingredient under Regulation (EC) No 258/97 of the European Parliament and of the Council. Official J. Eur. Union, pp. 38-39, 2008. (Absrt.)
[9] Kalinganire, A., Weber, J.C, Uwamariya, A., Kone, B. -Improving rural livelihoods through domestication of indigenous fruit trees in the parklands of the Sahel, in Akinnifesi FK, Leakey RRB, Ajayi OC, Sileshi G, Tchoundjeu Z, Matacala P, Kwesiga FR (Eds). Indigenous Fruit Trees in the Tropics: Domestication, Utilization and Commercialization. CABI, Wallingford,pp. 186-200, 2007.
[10] Venter, S.M., Witkowski, Ed T.F. -Fruits of our labour: Contribution of commercial baobab (*Adansonia digitata* L.) fruit harvesting to the livelihoods of marginalized people in northern Venda, South Africa. Agroforest. Syst, 87,pp.159–172, 2013.
[11] Kamatou, G.P.P., Vermaak, I., Viljoen, A.M. - An updated review of Adansonia digitata: A commercially important African tree. S. Afr J. Bot., 77, pp.908–919, 2011.
[12] Sena, L.P., Vanderjagt, D.J., Rivera, C., Tsin, A.T.C., Muhamadu, I., Mahamadou, O., Millson, M.,Pastuszyn, A., Glew, R.H. -Analysis of nutritional components of eight famine foods of the Republic of Niger. Plant Food Hum Nutr., 52, pp.17–30, 1998.
[13] Osman, M.A.- Chemical and nutrient analysis of baobab (*Adansonia digitata*) fruit and seed protein solubility. Plant Food Hum Nutr., 59, 29–33, 2004.
[14] Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R., Van Boekel, M.A.J.S. -Baobab food products:A review on their composition and nutritional value. Crit. Rev Food Sci., 49,pp.254–274,2009.
[15] Adejuyitan, J.A., Abioye, A.O., Otunola, E.T., Oyewole, Y.N. -An evaluation of some properties of baobab fruit powder and Ogi mixes. Transnational J. Sci. Tech., 2 (7),pp.91-102, 2012.
[16] Selvarani, V., Hudson, J.B. -Multiple inflammatory and antiviral activities in *Adansonia digitata* (baobab) leaves, fruits and seeds. J. Med. Plants Research, 3(8),pp.576-582, 2009.
[17] De Caluwé, E., Halamová, K., Van Damme, P. -*Adansonia digitata* L. – A review of traditional uses, phytochemistry and pharmacology. Afrika focus, 23,pp.11-5, 2010.
[18] Nour, A.A. , Magboul, B.I., Kheiri, N.H. -Chemical composition of baobab fruit (*Adansonia digitata* L.).Trop. Sci., 22,pp.383-388, 1980.
[19] Drake, E.. A book of baobabs. Aardvark Press, Cape Town, 2006.
[20] Wickens G.E., Lowe, P.-The baobabs: Pachycauls of Africa, Madagascar and Australia. Springer, UK, 2008.
[21] Wickens, G.E.-The baobab, Africa's upside-down tree. Kew Bull, 37(2), pp.171–202, 1982.
[22] Gebauer, J., El-Siddig, K., Ebert, G. -Baobab (*Adansonia digitata* L.): A review on a multipurpose tree with promising future in the Sudan. Gartenbauwissenschaft, 67 (4),pp.155-160, 2002.
[23] Sidibe M., Williams, J.T. - Baobab. *Adansonia digitata*.International Centre for Underutilised Crops, Southampton, UK, 2002.
[24] Baum, D.A. -A systematic revision of Adansonia (Bombacaceae). Ann.Mo Bot. Gard, 82, pp.440–471, 1995.
[25] Booth, F.E.M., Wickens, G.E. -Non-timber uses of selected arid zone trees and shrubs in Africa. FAO Conservation Guide 19. Rome, Italy,1988.
[26] Assogbadjo, A.E., Chadare, F.J., Kakaï, R.G., Fandohana, B., Baidu-Forson, J.J.-Variation in biochemical composition of baobab (*Adansonia digitata*) pulp, leaves and seeds in relation to soil types and tree provenances. Agr. Ecosyst Environ, 157,pp.94– 99, 2012.
[27] Murray, S.S., Schoeninger, M.J., Bunn, H.T., Pickering, T.R., Marlett, J.A. - Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. J. Food Comp. Anal., 14,pp.3-13, 2001.
[28] Arnold, T.H., Well, M.J., Wehmeyer, A.S. -Koisan food plants:Taxa with potential for economic exploitation,in Wickens GE, Goodin JR, Field DV (Eds). Plants for Arid Lands. George Allen and Yunwin, London, pp. 69-86, 1985.
[29] Saka, J.D.K. The nutritional value of edible indigenous fruits: Present research status and future directions,in Maghembe JA, Ntupanyama Y, Chirwa PW (Eds) Improvement of indigenous fruit trees of the Miombo Woodlands of Southern Africa. ICRAF Nairobi, Kenya, pp. 50-57, 1995.
[30] Lockett, C. T., Calvert, C.C., Grivetti, L.E. -Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought. Study of rural Fulani, Northeastern Nigeria. International Journal of Food Sciences and Nutrition, 51,pp.195-208,2000.
[31] Ezeagu, I.E. - Baobab (*Adansonia digitata L.*) Seed protein utilization in young albino rats I:

Biochemical ingredients and performance characteristics. Anim Research Int, 2(1), pp.240 – 245, 2005.
[32] Mwale, M., Mupangwa, J.F., Mapiye, C., Saina, H., Chimvuramahwe, J. Growth performance of guinea fowl keets fed graded levels of baobab seed cake diets. Int. J. Poult. Sci 7,pp.429–432, 2008.
[33] Chimvuramahwe, J., Musara, J.P., Mujuru, L., Gadzirayi, C.T., Nyakudya, I.W., Jimu, L., Katsvanga, C.A.T., Mupangwa, J.F., Chivheya, R.- Effect of feeding graded levels of *Adansonia digitata* (baobab) seed cake on the performance of broilers. J. Anim Plant Sci.,11(3),pp.1442-1449, 2011.
[34] Becker, B. -The contribution of wild plants to human nutrition in the Ferlo (Northern Senegal). Agroforest. Syst., 1,pp.257-267,1983.
[35] Yazzie, D., Vanderjagt, D.J., Pastuszyn, A., Okolo, A.,Glew, R.H. -The amino acid and mineral content of baobab (*Adansonia digitata L.*) leaves. J. Food Comp Anal., 7,pp.189–193,1994.
[36] Nordeide, M.B., Hatloy, A., Folling, M., Lied, E., Oshaug, A. –Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in southern Mali. Int J. Food Sci. Nutr, 47, pp.455–468, 1996.
[37] Glew, R.H, VanderJagt, D.J., Lockett, C., Grivetti, L.E., Smith, G.C., Pastuszyn, A., Millson, M. - Amino acid, fatty acid and mineral composition of 24 indigenous plants of Burkina Faso. J. Food Comp Anal., 10,pp.205-217, 1997.
[38] Addy, E.O.,Eteshola, E. -Nutritive value of a mixture of tigernut tubers (*Cyperus esculentus L.*) and baobab seeds (*Adansonia digitata L.*). J. Sci. Food Agric 35, pp.437-440, 1984.
[39] Harper A.E., Yoshimura, N.N.-Amino acid balance and use in the body. Nutrition, 9,pp.460-469, 1993.Available at: http://www.oralchelation.com/technical/amino1.htm#11. Accessed May 24, 2013.
[40] Eromosele, I.C., Eromosele, C.O., Kuzhkuzha, M. - Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. Plant foods Hum. Nutr., 41,pp.151-154, 1991.
[41] Cuni Sanchez, A., De Smedt, S., Haq, N., Samson, S.- Comparative study on baobab fruit morphological variation between western and south-eastern Africa: Opportunities for domestication.Genet. Resour Crop Evol.,58,pp.1143–1156, 2011.
[42] Robertson, R.N., Highkin, H.R., Smydzuk, J.,Went, F.W. -The effect of environmental conditions on the development of pea seeds. Aust J. Biol Sci., 15,pp.1–15,1962.
[43] Singh, B., Campbell, W.F., Salunkhe, D.K. -Effects of striazines on protein and fine structure of cotyledons of bush beans. Am J. Bot.,59,pp.568–572, 1972.
[44] McLean, L.A., Sosulski, F.W.,Youngs, C.G. - Effects of nitrogen and moisture on yield and protein in field peas. Can J. Plant Sci., 54, pp.301–305, 1974.
[45] Igboeli, L.C., Addy, E.O.H., Salami, L.I.- Effects of some processing techniques on the antinutrient contents of baobab seeds (*Adansonia digitata*). Bioresource Technol.,59,pp.29-31, 1997.
[46] Vanderjagt, D.J., Freiberger, C., VU, H-T.N., Mounkaila, G., Glew, R.S.,Glew R.H. -The trypsin inhibitor content of 61 wild edible plant foods of Niger. Plant Food Hum Nutr.,55,pp. 335–346, 2000.
[47] Nkafamiya, I.I., Osemeahon, S.A., Dahiruand, D., Umaru, H.A. -Studies on the chemical composition and physicochemical properties of the seeds of baobab (*Adasonia digitata*). Afr. J. Biotech, 6 (6), pp.756-759, 2007.
[48] Liener I.E.,Hasdi, A. -The effect of the long-term feeding of raw soybean on the pancreas of the mouse and hamster in Friedman M (Ed). Nutritional and Toxicological Significance of Enzyme Inhibitors in Foods. Plenum Press. N.Y., pp. 189–197, 1985.
[49] Birk, Y. - Protein protease inhibitors in legume seeds – overview. Arch. LantinoAm. Nutr., 44 (Suppl 1),pp. 26S–30S,1996.
[50] Liener, I.E. -Possible adverse effects of soybean anticarcinogens. J. Nutr.,125, pp.774S–750S, 1995.
[51] Van Putten, M.C., Kleter, G.A., Gilissen, L.J.W.J., Gremmen, B., Wichers, H.J., Frewer, L.J. -Novel foods and allergy: Regulations and risk-benefit assessment. Food Control, 22,pp.143-157, 2011.
[52] Taylor,S.L.- Food allergies. Food Technol., 39,pp.98–105, 1985.
[53] Roux,K.H., Teuber,S.S., Sathe S.K. Tree nut allergens. Int. Arch Allergy Imm., 131, pp.234–244, 2003.
[54] Sampson, H.A. Update on food allergy. J. Allergy Clin. Immun., 113, pp.805–819, 2004.
[55] Kennedy, A.R. -The Bowman–Birk inhibitor from soybeans as an anticarcinogenic agent. Am J. Clin Nut.,68,pp.1406S–1412S, 1998a.
[56] Kennedy, A.R.-Chemoprotective agents: protease inhibitors. Pharmacol. Therapeut, 78,pp.167–209, 1998b.
[57] Shekib, L.A., El-Iraqui, S.N., Abobakr, T.M.- Studies on amylase inhibitors in some Egyptian legume seeds. Plant Food Hum Nutr.,38,pp.325-332,1988.
[58] Uzogara, S.G., Morton, I.D.,Daniel, J.W.-Changes in some antinutrients of cowpeas (*Vigna unguiculata*) processed with 'kanwa' alkaline salt. Plant Food Hum Nutr., 40, pp.249-258, 1990.
[59] Geervani, P., Theophilus, F.-Effect of home processing on the protein quality of selected legumes. J. Food Sci., 42, pp.1269–1275, 1980.
[60] Liener, I.E. -Legume toxins in relation to protein digestibility – A review. J. Food Sci., 41,pp. 1076–1081, 1976.

[61] Walker A.F., Kochar, N. -Effect of processing including domestic cooking on nutritional quality of legumes, in proceedings of the nutrition society. Publisher Nutrition Society, pp. 41–51, 1982.
[62] Tarwadi, K., Agte, V. -Antioxidant and micronutrient quality of fruit and root vegetables from the Indian subcontinent and their comparative performance with green leafy vegetables and fruits. J. Sci. Food Agri., 85,pp.1469–1476, 2005.
[63] Addy, E.O.H., Salmi, L.I., Igboeli, L.C., Remawa, H.S. -Effect of processing on nutrient composition and anti-nutritive substances of African locust bean (Parkia filicoidea) and baobab seed (*Adansonia digitata*). Plant Food Hum Nutr., 48, pp.113-117, 1995.
[64] Nnam, N.M., Obiakor, P.N. -Effect of fermentation on the nutrient and antinutrient composition of baobab (*Adansonia digitata*) seeds and rice (Oryza sativa) grains. Ecol. Food Nutr., 42,pp.265-277, 2003.
[65] Kazanas, N., Fields, M.L. Nutritional improvement of sorghum by fermentation. J. Food Sci., 49, pp.819-821, 1981.
[66] Chadare, F.J., Jonkman, J., Wolkers-Rooijackers, J., Nout, M.J.R., Hounhouigan, J.D., Zwietering, M.H. Microbiota of *Tayohounta*, a fermented baobab flavour food of Benin. Afr. J. Biotech., 10(69),pp.15607-15615, 2011.
[67] Sarkar, P.K., Hasenack, B., Nout, M.J.R. -Diversity and functionality of *Bacillus* and related genera isolated from spontaneously fermented soybeans (Indian Kinema) and locust beans (African Soumbala). Int J. Food Microbiol, 77(3), pp.175-186, 2002.
[68] Parkouda, C., Nielsen, D.S., Azokpota, P., Ouoba, L.I.I., Amoa-Awua W.K., Thorsen, L., Hounhouigan, J.D., Jensen, J.S., Tano-Debrah, K., Diawara, B., Jakobsen, M.- The microbiology of alkaline-fermentation of indigenous seeds used as food condiments in Africa and Asia. Crit Rev. Microbiol, 35,pp.139–156, 2009.
[69] Humphry, C.M., Clegg, M.S., Keen, C.O., Grivetti, L.E.-Food diversity and drought survival.The Hausa example. Int J. Food Sci. Nutr 44,1-16, 1993.
[70] Cook, J.A., VanderJagt, D.J., Pastuszyn, A., Mounkaila, G., Glew, R.S., Millson M., Glew, R.H. -Nutrient and chemical composition of 13 wild plant foods of Niger. J. Food Comp Anal.,13,pp.83-92, 2000.
[71] Avallone, S., Tiemtore, E.T-W., Mouquet-Rivier, C., Trèche, S. -Nutritional value of six multi-ingredient sauces from Burkina Faso. J. Food Comp. Anal., 21, pp.553– 558, 2008.
[72] Obizoba, I.C., Anyika, J.U. -Nutritive value of baobab milk (gubdi) and mixtures of baobab *(Adansonia digitata* L.) and hungry rice, acha *(Digitaria exilis)* flours. Plant Food Hum Nutr., 46,pp.157-165,1993.
[73] Booth, F. E. M., Wickens, G.E. -Adansonia digitata L. Non-timber uses of selected arid zone trees and shrubs in Africa. Food and Agriculture Organization (FAO) Conservation Guide, 19,pp.13-17,1988.
[74] Dachi, S.N., Gana, A.S. -Adaptability and yield evaluation of some Acha (*Digitaria exilis* and *Digitaria iburua* Kippis Stapf) accessions at Kusogi – Bida, Niger State, Nigeria. Afr J. Gen. Agric., 4(2),pp.73-77, 2008.
[75] Besco, E., Braccioli, E., Vertuani, S., Ziosi, P., Brazzo, F., Bruni, R., Sacchetti, G., Manfredini, S. -The use of photochemiluminescence for the measurement of the integral antioxidant capacity of baobab products. Food Chem.,102, pp.1352-1356, 2007.
[76] Rodríguez Patino, J.M., Pilosof, A.M.R.- Protein-polysaccharide interactions at fluid interfaces. Food Hydrocolloid, 25, pp.1925-1937, 2011.
[77] Benichou, A., Aserin, A., Garti, N. -Protein-polysaccharide interactions for stabilization of food emulsions. J. Disper. Sci. Technol, 23(1-3), pp.93-123, 2002.
[78] Makari, E.A., Doxastakis, G.I. -Study of emulsions stabilized with *Phaseolus vulgaris* or *Phaseolus coccineus* with the addition of Arabic gum, locust bean gum and xanthan gum. Food Hydrocolloid, 20,pp.1141–1152,2006.
[79] Schmitt, C., Sanchez, C., Desobry-Banon, S., Hardy, J. -Structure and technofunctional properties of protein-polysaccharide complexes: A review. Crit. Rev Food Sci., 38,pp.689-753, 1998.
[80] Horax, R., Hettiarachchy, N., Kannan, A., Chen, P. -Protein extraction optimisation, characterisation, and functionalities of protein isolate from bitter melon (*Momordica charantia*) seed. Food Chem., 124,pp.545–550, 2011.
[81] Lopez-Fandino, R.- Functional improvement of milk whey proteins induced by high hydrostatic pressure. Crit. Rev Food Sci.46,pp.351–363, 2006.
[82] Van der Plancken, L., Van Loey, A., Hendrickx, M.E. -Foaming properties of egg white proteins affected by heat or high pressure treatment. J. Food Eng 78,pp.1410–1426, 2007.
[83] Murray, B.S. -Stabilization of bubbles and foams. Curr Opin Colloid In., 12, pp.232–241, 2007.
[84] Rodríguez Patino, J.M., Conde, J.M., Linares, H.M., Jimenez, J.J.P., Sanchez, C.C., Pizones, V. -Interfacial and foaming properties of enzyme-induced hydrolysis of sunflower protein isolate. Food Hydrocolloid, 21, pp.782–93, 2007.