Influence of Ohmic heating on the Proximate Composition and Consumer Acceptability Scores of African Breadfruit Seed Flour

Okocha, K S. [1]**; Nwabueze, T. U*[2]*; Onwuka, U. N*[3]*; Ishiwu, C, N*[1]*; Okoli, N. A*[4]*; Kalu, E. O; Ezegbe, C C*[1]*; Nwachukwu, O and IKOT, I. E*[3]*, Anene, N. M*[1]

[1]*Department of Food Science and Technology Nnamdi Azikiwe University Awka Anambra State, Nigeria*
[2]*Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Abia State Nigeria*
[3]*Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture Umudike, Abia State Nigeria*
[4]*Department of Crop Science and Horticulture Nnamdi Azikiwe University Awka Anambra State, Nigeria*

KEYWORDS

African breadfruit,
Aluminium electrodes,
Dehulling,
Ohmic heating,
Parboiling

ABSTRACT

This work compared the effect of Ohmic heating (115V, 100°C) using aluminum electrodes and some sodium salts with conventional heating as a possible heat source for parboiling operation as it affects the nutritional quality of the dehulled African breadfruit seeds. The protein content ranged from 15.75-19.60%, fat content ranged from 5.97-7.54%, starch content ranged from 1.6-2.9 mg/ml while samples Ohmic heated with sodium chloride had the highest overall consumer acceptability score of 8.3 (on a 9-point hedonic scale), thus adjudged the best in this study.

*CORRESPONDING AUTHOR

sk.okocha@unizik.edu.ng

INTRODUCTION

The African breadfruit plant (*Treculia africana*) Decne is an evergreen tropical tree crop that bears large seeded fruits. It is well known in Southern Nigeria where the edible seed is of great socioeconomic value and forms an important part of diets. It contains between 13.4 and 23.3% proteins, 53.7 and 62.6% carbohydrates, 10.4 and 18.9% fats, and a wide array of nutritive elements (Ca, Zn, Fe, Mg), and antinutrient components of the seed (phytate, oxalate, tannin, and hydrogen cyanide) are drastically reduced during seed processing via fermentation, toasting, and boiling (Oyetayo and Oyetayo 2020). It is increasingly becoming commercially important in Southern Nigeria hence, Baiyeri and Mbah (2006) described it as an important natural resource which contributes significantly to the income and dietary intake of the poor. African breadfruit (*Treculia africana*) locally referred to as Ukwa in Igbo language; it is one of the many treasured economical plants. Its seed is commonly called “Afon” by the Yoruba, “barafuta” by the Hausa, “Ize” by the Benin, “eyo” by the Igala, and “Ukwa” by the Igbos of Nigeria (Emenonye and Nwabueze, 2016). The seeds are roasted and are useful as thickeners in soups and are eaten as snacks. The extracted seeds of *Treculia africana* are identified to become extremely healthy whenever it is correctly processed (Ejiofor *et al*., 1998). Diverse food forms could be produced from the seeds on the basis of custom, tradition, ethnic background (Nwabueze and Okocha, 2008).

In recent decades, technologies utilizing electrical energy directly into food (Ohmic heating) processing have attracted renewed interest in the food industry (Alkanan *et al.,* 2021). Ohmic heating, also known as Joule heating or electrical resistance heating, is performed by passing an alternating electric current through the food material. Heat is internally generated within a material due to resistance against the applied electrical current (*Makoto et al*., 2015). Microwave, infrared, infrared-microwave, microwave energy with halogen lamp heating, hot air assisted microwave heating, dielectric heating (Sumnu *et al.,* 2005) has been exploited in food processing operations. Whereas, food materials have been heated through various medium, Ohmic heating (OH) has long been exploited in industrialized countries as it brings about minimally processed food. This technique provides high-quality food and is also used in many applications such as pasteurization, sterilization, cooking, thawing, fumigation, extraction, and fermentation, in addition to the new trend for its use in military fields and food for long-term space missions (Alkanan *et al*., 2021). Studies have shown that the use of this technique does not lead to significant effects on the nutritional, functional, and synthetic properties and sensory characteristics of food products compared to traditional techniques (Alkanan, 2021). Ohmic heating is a high-temperature short-time (HTST) method, thus decreasing the possibility of high-temperature over-processing and its likely associated loss of nutrients and bioactive compounds. Another advantage of Ohmic heating is that it keeps delicately structured foods such as strawberries intact (Xiao *et al.,* 2017).

Despite the advantages of Ohmic heating of food products its use has been limited by the following:

- Lack of suitable electrode materials (Ruan *et al.,* 2001)
- Cost of electrical energy (Varghese *et al.,* 2014)
- Fear of electrocuting (Llave *et al.,* 2018)
- Improved performance at frequencies above 50 Hz (Shynkaryk *et al.,* 2010)

Although the technology of Ohmic heating appears to be promising and highly effective, there is little information in literature concerning the effect of this technique on a myriad of food products especially seeds, pulses and legumes. Unfortunately, in developing countries like Nigeria little is known about the usefulness of Ohmic heating in processing food materials. This work would compare the effect of Ohmic heating using aluminum electrodes and some sodium salts with convectional heating, thus drawing attention on the applicability of Ohmic heating as a possible heat source for parboiling operation on the dehulling of seeds, legumes and pulses using breadfruit as a model sample.

MATERIALS AND METHODS

Source of Materials

African breadfruit seeds were obtained from the breadfruit orchard of the Department of Forestry, Michael Okpara University of Agriculture Umudike in Abia State, while reagents were purchased from Hoslab Umuahia.

Experimental Design

The experimental Design was modeled as a randomised block design experiment having two variable (Convectional heating and Ohmic heating). Where the Ohmic heating experiment was carried out using 0.5% w/w of sodium salts *(Sodium chloride, Sodium sulphate, Sodium thiosulphate and Sodium metabisulphate at 0.5% w/w)* at 115volts for 15min at 100^{o}C using aluminum electrodes.

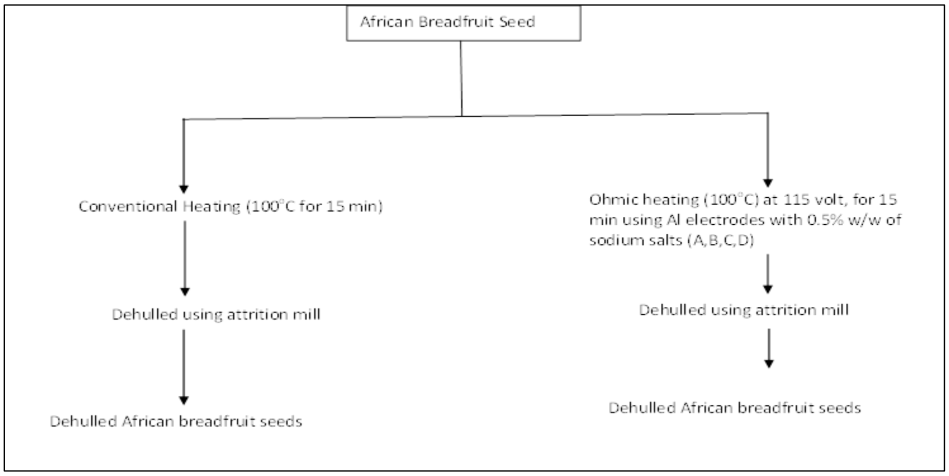

Fig 1: Production of dehulled African breadfruit seed flour

Note: Salt A = Sodium chloride; Salt B = Sodium sulphate; Salt C = Sodium thiosulphate; Salt D = Sodium metabisulphate. All the samples (Dehulled African breadfruit seeds) were oven dried (100^{o}C) milled and sieved with a 300 mill micron sieve and stored for further analysis.

Heating Methods

Convectional heating

Weigh 500g of African breadfruit seeds were sorted, wash under running water and conventionally parboiled at 100^{o}C for 15min. The seeds were cracked with a corona corn hand mill (*Ref. 121, Medellin-Colombia*) while still hot by adjusting the plates of the mill to allow the least impart between an un-parboiled seed and the plate. Cracked/dehulled seeds were sorted manually and oven dried (*Memmet, D 91126, Schwabach-Germany*) at 60^{o}C to constant weight, while seed pieces, undehulled whole seeds, undehulled seed pieces were separated and weighed for further analysis. The sample was milled with a locally fabricated disk mill and sieved with a 300μm pore size sieve. The flour produced serves as the control which was stored at ambient temperature (28-30^{o}C) for further analysis.

Ohmic heating

About 500 g of African breadfruit seeds were sorted, wash under running water and were Ohmic heated at 115 volts for 15 min at 100^{o}C using aluminum electrodes and sodium salts (*Sodium chloride, Sodium sulphate, Sodium thiosulphate and Sodium metabisulphate at 0.5% w/w*). The seeds were cracked with a corona corn hand mill (*Ref. 121, Medellin-Colombia*) while still hot by adjusting the plates of the mill to allow the least impart between an un-parboiled seed and the plate. Cracked/dehulled seeds were sorted manually and oven dried at 60^{o}C to a constant weight, while seed pieces, undehulled whole seeds, undehulled seed pieces were separated and weighed for further analysis. The samples were milled with a commercial mill. The milled sample was sieved with a 300 μm pore size sieve and stored at ambient temperature for further analysis.

Determination of Proximate Composition

Samples were evaluated for % moisture, % ash, % fat, % crude fibre % crude protein and % carbohydrate would be determined using the equation:

% carbohydrate = 100 – (% moisture + % ash + % fat + % crude fibre + % crude protein) as described by AOAC (2000).

Determination of Carbohydrate Components (Starch, Amylose and Amylopectin)

Starch content (mg/ml) was determined by the method of Radley (1976) as reported by Onwuka (2005).

Amylose content (%) was determined using the rapid calorimetric procedure as described by Onwuka (2005), while amylopectin (%) = 100 - % amylose.

Sensory evaluation

A consumer sensory panel of 20 semi-trained sensory panelists evaluated the quality features of the flour samples. They rated the samples on a 9-point Hedonic scale appearance, texture, flavour, saltiness and overall acceptability, with 9 representing strongly like and 1 representing extremely dislike.

Statistical Analysis

The Statistical Package for Social Science (SPSS) version 23.0 software was used to analyze the data. Duncans Multiple Range Test was used to detect significant differences ($p<0.05$) among the sample means using Analysis of Variance (ANOVA) and Least Significant Difference (LSD) for separation of significant means.

Plate 1: African breadfruit seed

Plate 2: Manual cracking of Conventional/Ohmic heated African breadfruit

Plate 3: Cracked, Dehulled kernel (whole and pieces) African bread fruit seeds

Plate 4: Dehulled African breadfruit seed (whole and pieces)

Table 1: Proximate composition of African breadfruit seed from conventional and ohmic heating

Proximate (%)	*Conventional heating 100°C*	*Ohmic Heating Aluminium electrode*				
		A	B	C	D	*LSD*
Moisture	3.58^{a}	3.42^{a}	3.93^{a}	4.13^{a}	3.88^{a}	3.2356
Protein	18.69^{a}	17.21^{a}	19.23^{a}	19.60^{a}	15.75^{a}	7.5965
Fat	7.54^{e}	6.07^{b}	6.63^{c}	5.97^{a}	7.43^{d}	0.0586
Crude Fibre	0.15^{a}	2.03^{b}	3.67^{d}	4.90^{e}	2.63^{c}	0.1847
Ash	2.61^{b}	1.20^{a}	8.40^{d}	2.80^{bc}	3.10^{c}	0.3360
Carbohydrate	67.45^{b}	70.05^{b}	58.14^{a}	67.21^{b}	62.60^{ab}	8.7122

A=Sodium Chloride, B= Sodium Sulphate, C= Sodium Thiosulphate, D= Sodium Metabisulphate. Means in the same row with different superscript are significantly different at $(p<0.05)$

RESULTS AND DISCUSSION

Proximate composition of African breadfruit seed from conventional and Ohmic heating

The results of proximate composition of the different treatments are summarized in Table 1. Significant differences $(p <0.05)$ were not observed for moisture and protein content for all the treatments. Although the protein content of some of the ohmic heated samples (15.75, 17.21) were lower than that of convectional heating (18.69). This could be attributed to slight leaching and dehulling losses, although the protein content was relatively high and as such would be adequate to prevent protein energy malnutrition in people with breadfruit as their main protein source.

Furthermore, the fat content (%) of Ohmic heated samples was lower (5.97, 6.07, 6.63, 7.43, 7.43) as against 7.54 for conventionally heated sample: the brine of Sodium thiosulphate during the ohmic heating process produced the least fat content followed by Sodium chloride followed by Sodium sulphate and finally Sodium metabisulphate. Crude fibre contents (%) for Ohmic heated samples were significantly higher $(p <0.05)$ than that of the control. Thus, we suggest that Ohmic heating could be of benefit during defattening operations and could retain fibre in foods where high fibre content is targeted.

Table 2 shows that the starch content was higher (2.9 mg/ml) for conventional heating as against ohmic heating (1.6 mg/ml). Although there was no literature to explain this observation but we reasoned that the significant difference $(p<0.05)$ in carbohydrate components (Starch, Amylose, Amlopectin) could be due to the vigorous volumetric heating during ohmic heating.

Table 2: Carbohydrate Components of African breadfruit seed flour from conventional and Ohmic heating

CHO Components	*Conventional heating 100°C electrode*	*Ohmic Heating Aluminium*				
		A	B	C	D	*LSD*
Starch (mg/ml)	2.9^{b}	1.6^{a}	1.6^{a}	1.6^{a}	1.6^{a}	0.6113
Amylose	39.49^{b}	12.73^{a}	14.11^{a}	13.19^{a}	13.46^{a}	4.6008
Amylopectin	60.51^{a}	87.27^{b}	85.89^{b}	86.81^{b}	86.54^{b}	16.258

A=Sodium Chloride, B= Sodium Sulphate, C= Sodium Thiosulphate, D= Sodium Metabisulphate. Means in the same row with different superscript are significantly different at $(p<0.05)$

The vigorous heating (Ohmic heating) promoted leaching of soluble nutrients (starch and amylose). It was also observed that ohmic heated samples have higher amylopectin content with no significant difference ($p>0.05$) amongst the Ohmic heated samples; this could be an indication of some levels of starch modification. Amylopectins are branched starch fraction which are resistant to retrogradation.

Products that have high amylopectin are said to possess outstanding paste clarity, high water-binding capacity, and resistance to gel formation and retrogradation; they are helpful in production of salad dressings, sauces, and pie fillings and in some canned goods; they are useful because of resistance to irreversible gel formation and syneresis on freezing and especially for many products stored in the frozen state (Cereal processing, 2010).

Table 3: Effect of Conventional / Ohmic heating on the Consumer Acceptability Scores of dehulled African breadfruit seed flour

Treatment	Appearance	Texture	Flavour	Saltiness	Overall Acceptability
C/H	7.4^{a}	7.4^{a}	7.3^{a}	6.9^{ab}	7.0^{a}
O/H (A)	7.9^{b}	7.8^{b}	8.1^{b}	8.4^{c}	8.3^{c}
O/H (B)	7.7^{ab}	7.7^{ab}	7.2^{a}	7.0^{b}	7.7^{b}
O/H (C)	7.6^{ab}	7.5^{ab}	7.3^{a}	6.6^{a}	7.3^{a}
O/H (D)	$7.b^{b}$	7.5^{ab}	7.4^{a}	8.2^{c}	8.2^{c}

C/H =Conventional heating. O/H=Ohmic heating, A=Sodium Chloride, B= Sodium Sulphate, C= Sodium Thiosulphate, D= Sodium Metabisulphate, Scored on a 9 point hedonic scale with 1 = dislike extremely, 2 = disliked very much, 3 = dislike moderately, 4=dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely. Sores (9-7) = Positive / Liked; (6-4) = Neutral; (3-1) = Negative / Disliked. For each attribute, means in the same column with different superscripts are significantly different at $p < 0.05$.

Table 3 shows the result obtained from the Consumer acceptability scores of breadfruit flour produced from conventional/ohmic heating. We observed no significant difference ($P<0.05$) for the appearance of the flour samples. All the samples were liked (positive) (9-7) although, conventional heated dehulled African breadfruit seed had lower (7.4) appearance (sensory score) as against Ohmic heated samples (7.6-7.9). Whereas, no similar work come be sited. However, a few cooking experiments between conventional cooking and Ohmic cooking shows that Ohmic heated cauliflower had higher sensory scores (Appearance and Texture) when compared with that of conventional heating (Sandrine *et al.,* 2001). Lighter and less red colour for Ohmic cooked beef muscle '*biceps femoris*' (Markus *et al.,* 2009) and a good visually sensory quality for Ohmic cooked meatballs (Ilkin, 2013) have been reported.

From Table 3 the different treatments showed a slight significant difference at $p > 0.05$ for Texture. Van der Veer (1985) has enumerated the various functions of sodium chloride to include: (i) A functional role of improving texture. (ii) Reduction of growth of pathogens and organisms that spoil food products and reduce their shelf life. (iii) Improving taste and flavor.

Table 3 went further to shows the possibility of using Ohmic heating to improve the texture, flavour and saltiness of dehulled African breadfruit seeds flour. The overall acceptability showed that dehulled African breadfruit seed Ohmic heated (OH) (parboiled) with sodium chloride was mostly accepted, followed by samples Ohmic heated parboiled with Sodium metabisulphate, Sodium sulphate, Sodium thiosulphate and conventionally heated samples respectively.

CONCLUSION

The results revealed that the two parboiling methods (conventional and Ohmic heating) did not significantly ($p>0.05$) affect the protein content of the flour sample. Crude fibre contents were higher for Ohmic heated samples. African Breadfruit seed Flours samples produced with Sodium chloride salt had the highest overall acceptability score of 8.3 followed by the African Breadfruit seed Flour samples produced with of Sodium metabisulphate (8.2) while African Breadfruit seed Flours sample parboiled via conventional heating had the least overall acceptability of 7.0.

REFERENCE

AOAC (2000). The Association of Official Analytical Chemists, Official Methods of Analysis 17th Edition, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Alkanan, Z. T., Altemimi, A. B., Al-Hilphy, A. R. S., Watson, D. G., and Pratap-Singh, A. (2021). *Ohmic Heating in the Food Industry: Developments in Concepts and Applications during 2013–2020. Applied Sciences, 11(6)*: *2507.* doi:10.3390/app11062507

Baiyeri, K.P. and Mbah, B.N. (2006). Effects of soilless and soil-based Nursery media on seedling Emergency, Growth and Response to Water stress of African breadfruit (Treculia africana Decne). *African Journal Biotechnology* 5 (15): 1400-1405.

Cereal processing (2010). Encyclopædia Britannica. *Encyclopaedia Britannica Ultimate Reference Suite.* Chicago: Encyclopædia Britannica.

Denis, A. C. and Desmond, J. M. (2009). Ohmic cooking of whole beef muscle – Optimisation of meat preparation. Meat Science **81**: (4) 693–698.

Emenonye, A and Nwabueze, T. (2016). Characterization of Volatile Components of African Breadfruit (*Treculia africana*) Seed Oil. *Food and Nutrition Sciences*. 07. 609-615. 10.4236/fns.2016.77062.

Ejiofor, M.N., Obiajulu, O.R., and Okafor, J.C. (1998). Diversifying Utilities of African Breadfruits (Treculia Africana Decne Subsp. Africana) as Food and Feed. International Tree Crops Journal 5,125-134.

Ilkin, Y. S. (2013). Microbiological and chemical properties of fig vinegar produced in Turkey. *African Journal of Microbiology Research,* 7(20), 2332–2338. doi:10.5897/ajmr12.2275

Llave, Y., Morinaga, K., Fukuoka, M., and Sakai, N. (2018). Characterization of ohmic heating and sous-vide treatment of scallops: Analysis of electrical conductivity and the effect of thermal protein denaturation on quality attribute changes. Innovative Food Science and Emerging Technologies. doi:10.1016/j.ifset.2018.09.007

Makoto, S., Yuki, I., Izumi, S, Makoto, K**.**, Mitsuharu, I., Kimiko, T., Shintaro, E and Yoshitaka, H (2015)**.** Characterization of Soymilk Prepared by Ohmic Heating and of Voltage Applied *Food Technology Research*, **21** (3): 439-444.

Markus, Z., James G. L., Denis, A. C. and Desmond, J. M. (2009). Ohmic cooking of whole beef muscle – Optimisation of meat preparation. Meat Science **81** (4): 693–698.

Nwabueze, T.U. and Okocha, K.S. (2008) Extraction Performances of Polar and Non-Polar Solvents on the Physical and Chemical Indices of African Breadfruit (Treculia africana) Seed Oil. *African Journal of Food Science*, 2, 119-125.

Onwuka, G. I. (2005). Food Analysis and Instrumentation (Theory and Practice).Naphthali Prints, Lagos, Nigeria, pp 34-38.

Onwuka, G.I. (2018). Food Analysis and Instrumentation (Theory and Practice)-Second edition.Naphtali Printers, Nigeria, pp. 299-314.

Oyetayo, F. L., and Oyetayo, V. O. (2020). *The African Breadfruit (Treculia africana) Decne Plant Seed. Nuts and Seeds in Health and Disease Prevention, 45–50.* doi:10.1016/b978-0-12-818553-7.00004-8

Ruan, R., Ye, X., Chen, P. and Doona, C.J. (2001). Ohmic heating. Woodhead Publishing Ltd. https://edisciplinas.usp.br/pluginfile.php/128439/mod_resource/content/1/cr1216_13.pdf. Retrived on line on 9th March 2023

Sandrine, C.E.G, François, Z and Adeline, G (2001). Processing and stabilisation of cauliflower by ohmic heating technology. *Innovative Food Science and Emerging Technologies* **2**(4): 279–287

Sumnu, G., Sahin, S., and Sevimli, M. (2005). Microwave, infrared and infrared-microwave combination Baking of cakes. *Journal of Food Engineering* **71** (2): 150-153 doi:10.016/j.jfoodeng.2004.10.02

Shynkaryk, M. V., Ji, T., Alvarez, V. B., and Sastry, S. K. (2010). Ohmic Heating of Peaches in the Wide Range of Frequencies (50 Hz to 1 MHz). Journal of Food Science, 75(7), E493–E500. doi:10.1111/j.1750-3841.2010.01778.x

Varghese, K. Shiby; Pandey, M. C.; Radhakrishna, K.; Bawa, A. S. (2014). *Technology, applications and modelling of ohmic heating: a review. Journal of Food Science and Technology, 51(10), 2304–2317.* doi:10.1007/s13197-012-0710-3

Xiao, H.-W., Pan, Z., Deng, L.-Z., El-Mashad, H. M., Yang, X.-H., Mujumdar, A. S., Zhang, Q. (2017). Recent developments and trends in thermal blanching – A comprehensive review. Information Processing in Agriculture **4** (2), 101-127. doi:10.1016/j.inpa.2017.02.001