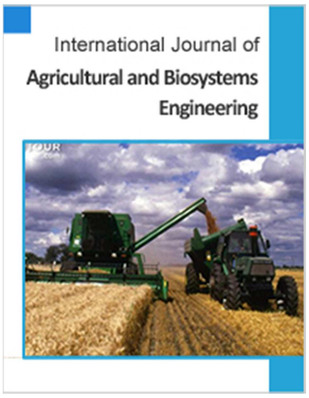
International Journal of Agricultural and Biosystems Engineering
2017; 2(6): 67-73
http://www.aascit.org/journal/ijabe

American Association for Science and Technology



Saline Bath System for Separation of Palm Kernels from Shells

Lateef Ayodele Sanni*, **Taiwo Ohiare**, **Raifu Olanrewaju Ibrahim**

Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

Email address

ldsanni@yahoo.com (L. A. Sanni)

*Corresponding author

Citation

Lateef Ayodele Sanni, Taiwo Ohiare, Raifu Olanrewaju Ibrahim. Saline Bath System for Separation of Palm Kernels from Shells. *International Journal of Agricultural and Biosystems Engineering*. Vol. 2, No. 6, 2017, pp. 67-73.

Keywords

Palm Kernels,
Shells,
Separation,
Clay-Water,
Saline Bath

Received: September 1, 2017
Accepted: November 22, 2017
Published: December 23, 2017

Abstract

Separation of palm kernels from cracked shells of the oil palm fruit is a difficult step in the production of palm kernel oil. An appraisal of the traditional clay-water bath separation method showed that the method was based on the difference in specific gravity of the palm kernels and the shells. The method was efficient but it was associated with many disadvantages which made it unsuitable for commercial production. Non-availability of clay and need for continuous agitation of the clay solution were among the disadvantages of the method. True density and bulk density of palm kernels and shells ranged from 1.03 – 1.07 g/cm^3 and 0.65 – 0.66 g/cm^3, and 1.16 – 1.43 g/cm^3 and 0.52 – 0.55 g/cm^3, respectively. Sodium chloride was used to replace clay soil and the separation of palm kernels and shells in the saline solution was efficient. All the palm kernels floated at salt concentration of 250 g/dm^3 to 300 g/dm^3 and all the shells sank to the bottom of the saline solution at all concentrations from 0 g/dm^3 to 300 g/dm^3. Increasing the quantity of mixture of palm kernels and shells reduced the separation efficiency slightly. Conceptual design of a saline bath system was developed for production of clean palm kernels on a commercial scale.

1. Introduction

The oil palm fruit (*Elaeis guineensis*), is a rich source of two distinct types of oil which are used for various domestic and industrial applications. The red palm oil is obtained from the fibrous mesocarp of the fruit and the palm kernel oil (PKO) is obtained from the endosperm (palm kernel) which is tightly embedded in the hard endocarp (palm nut) as shown in Figure 1. Both oils are made up of triglycerides but they are chemically and physically different from each other, because the red palm oil is rich in palmitic acid (C16 fatty acid) and PKO is rich in both lauric acid and myristic acid which are C12 and C14 fatty acids, respectively [1].

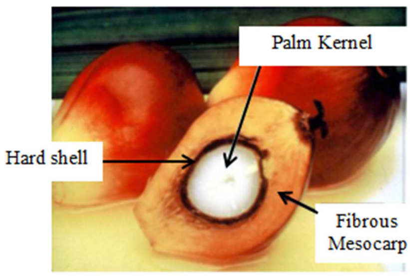


Figure 1. *Cross-section of the oil palm fruit.*

The preponderance of lauric acid in PKO is responsible for its low melting point and hardness at room temperature. This property makes PKO a valuable raw material in the food and oleo-chemical industries and a major trade commodity in both local and international markets ([2, 3]. Palm oil alone accounts for the largest proportion of world oil production and Nigeria is one of the major producers after Indonesia and Malaysia [4]. Low export of oil palm products from Nigeria can be partly attributed to high local consumption due to high population and the poor quality of oil palm products caused by lack of access to appropriate processing technologies by local farmers. The production and processing of oil palm fruits remain a predominant enterprise among farmers in the oil palm producing areas of Nigeria. According to [5], about 80% of oil palm processing in Nigeria is carried out by small scale processors and only 3% of the processors are engaged in PKO production, because they do not have access to appropriate processing machines required for PKO extraction. Most of the processors are more preoccupied with extraction and sale of the palm kernels to middlemen who supply the palm kernels to the big PKO production mills. The flow chart of Figure 2 shows the steps involved in the extraction of palm kernels and PKO from palm nuts [6]. The extraction of clean palm kernels from palm nuts is of utmost importance in the production of high quality PKO.

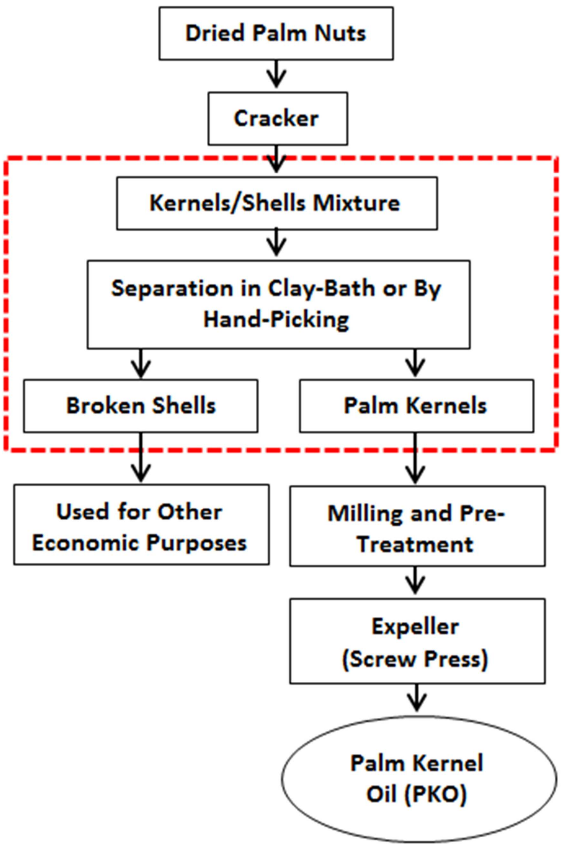


Figure 2. *Traditional process for extracting PKO from palm nuts.*

In a typical setting in Nigeria, the palm nuts are spread outdoor on the ground for days or weeks to be sun-dried. The dried palm nuts are then poured into the hopper of a locally fabricated mechanical cracker which breaks the hard nuts so that the palm kernels can be detached from the broken shell fragments. After the cracking process, a mixture of palm kernels and broken shells is produced. In many remote villages in Nigeria, the separation of the palm kernels from the broken shells is carried out by hand-picking – a method which is slow, tedious and certainly not adequate for commercial production. A faster and more popular traditional method is the use of clay-water bath for bulk separation of the palm kernels from shells [7]. The clay-water bath method is based on the difference in specific gravity between the shells and kernels [1]. The clay-water bath separation method is efficient and widely practiced in Nigeria, but the method is beleaguered with problems relating to poor hygiene, drudgery, low product quality and low productivity. Dry mechanical separators have been developed [8, 9, 10] and works are on-going to improve their efficiencies [1]. Improved mechanical clay-water separators have also been developed but the use of clay-water as the medium of separation is a challenge. The specific gravity of the clay-water has to be maintained by constant mechanical or manual agitation to prevent settlement of the clay at the bottom of the bath [11].

After the palm kernels have been recovered from the clay-water, both the clay and palm shells form a murky mixture at the bottom of the bath and are disposed of together. In this work, an appraisal of the traditional clay-water bath separation method was carried out and gravimetric properties of palm kernels and shells from the Tenera variety of oil palm fruits were determined. An improved system using salt-water solution as the separation medium was conceptualized with the aim of recovering clean palm shells for other useful purposes [12, 13, 14] instead of dumping them away to constitute nuisance to the environment.

2. Materials and Methods

2.1. Appraisal of Clay-Water Bath Separation Method

An oil palm processing centre located in *'Gbo-Gbo'* village - a small farming community about 7 km from Obafemi Awolowo University, Ile-Ife, was used for the appraisal. The Rapid Rural Appraisal (RRA) technique described by [15] was used. The clay-water bath separation process was observed in-situ, and conversation in local Yoruba language was used to get relevant information about the knowledge, attitudes and practices (KAP) of the handlers. Photographs of the processes were taken and the information gathered was used as design considerations for the conceptualization of an improved saline bath system.

2.2. Determination of Gravimetric Properties of Palm Kernels and Shells

A batch of cracked mixture of palm kernels and shells was collected from a processing centre at *Gbo-gbo* village. Samples of palm kernels and broken shells were manually separated and cleaned. Bulk density of both kernels and shells was determined using the method described by [16] in which a cylindrical can of known volume and weight was filled with each material. For each experiment the can was tapped on a table five times after which it was weighed with its full content. The weight of material in the can was determined and the bulk density of each sample was calculated using Equation 1. For each material the experiment was repeated 10 times.

$$\text{Bulk density} = \frac{\text{weight of material in can}}{\text{volume of can}} \quad (1)$$

True density of palm kernels and broken shells was determined by the water displacement method as reported by [17]. Twenty randomly selected samples of each material were weighed and thinly coated with vegetable oil to prevent water absorption. Each sample was submerged with a metal sponge sinker of known weight and volume, into a measuring cylinder containing 500 ml of distilled water. Net volumetric water displacement by each sample was recorded. This technique was suitable because each immersion experiment lasted for maximum of 2 minutes and absorption of water by the samples was negligible. The true density of each material sample was determined using Equation 2 and each experiment was repeated 10 times.

$$\text{True density} = \frac{\text{weight of materials}}{\text{volume of water displaced}} \quad (2)$$

2.3. Investigation of Saline Solution as Alternative to Clay-Water

A transparent measuring cylinder was partially filled with 2 litres of clean tap water. A weighed sample of common salt (NaCl) was added and stirred thoroughly using a non-absorbent plastic rod until all the salt particles dissolved. A 300 g mixture of palm kernels and shells containing 100 palm kernels was poured into the saline solution and stirred. The system was allowed to settle for 2 minutes and the number of floating palm kernels was recorded. The experiment was performed in salt solutions with concentrations of 0 g/dm^3 to 300 g/dm^3 at increment of 25 g/dm^3. The experiments were repeated by pouring 600 g of palm kernel and shell mixtures containing 200 kernels each. The palm kernel separation efficiency by each salt-water solution was determined using Equation 3. The data gathered was used to plot graphs of kernel separation efficiency versus NaCl concentration.

$$\text{Separation efficiency (\%)} = \left(\frac{\text{number of floating palm kernels}}{\text{number palm kernels in sample}}\right) \times 100 \quad (3)$$

2.4. Conceptual Design of a Saline-Bath System for Separating Palm Kernels from Shells

The problems associated with the traditional clay-bath method were used as considerations for the design of an improved saline-bath system. The process recommended by [18] was used to develop a preliminary design concept of a saline-bath system for separating palm kernels. A schematic drawing of the design concept was done using Microsoft Word Shapes software. The design concept of the saline bath system was based on the differences in the specific gravities of palm kernels, shells, saline solution and fresh water.

3. Results and Discussion

3.1. Traditional Clay-Water Bath Separation Method

Drying and cracking of palm nuts preceded the use of clay-water bath for separating palm kernels from shells. Figure 3 shows the traditional clay-water bath separation method in which the floating kernels were scooped out using a small perforated bowl. Ten activities in the process line were identified and their disadvantages are recorded in Table 1. The use of clay water solution was based on the difference in specific gravity of the shells and that of palm kernels. This was why the shells sank to the bottom and the kernels floated to the surface of the clay-water solution. The clay-water bath separation method was efficient but associated with several disadvantages which made it unattractive for large scale commercial processing. According to the processors, availability of clay was the biggest challenge they faced [19].

Figure 3. *Clay-water bath method of separating palm kernels.*

Table 1. *Activities and disadvantages of traditional clay-water bath method of separation.*

Steps	Handling Method	Observed Problems/Disadvantages
STEP 1 Drying of palm nuts	*Palm nuts were dried by spreading them out on the ground for weeks or months*	(i) Major source of dirt that reduced the effectiveness of cracking (ii) The high incidence of dirt after cracking increased the time and labour required for cleaning the kernels produced (iii) The presence of dirt and partially broken shells in the kernels affected expression and the quality of the palm kernel oil produced (iv) The market value of palm kernels was reduced due to dirt and shell content.
STEP 2 Cracking of palm nuts	*A locally fabricated centrifugal cracker was used to crack the palm nuts in batches*	(i) A fraction of the cracked mixture contained partially cracked nuts (ii) The mixture of kernels and broken shells were heaped on the ground which further introduced dirt (iii) The mixture was not packed immediately and was exposed to rodents and theft
STEP 3 Collection of mixture	*After mechanical cracking the mixture of kernels, shells and dirt was loaded into baskets or old oil drums in readiness for separation.*	(i) Loading of the bulky mixture was labour intensive and ergonomically stressful (ii) Separation in clay bath was done in small batches and off-loading was time consuming (iii) Rodents fed on the exposed kernels before and after separation which caused high loss (iv) Only limited quantity of stock could be handled leading to delayed cracking and reduced capacity
STEP 4 Sourcing for clay soil	*Villagers traveled afar in search of clay soil or ant hills to dig for clay.*	(i) Where clay soil was not available, processors scavenge the bushes in search of ant hills as alternative to clay soil (ii) Apart from traveling long distances to get ant hills, processors faced the risk of being bitten by dangerous reptiles (iii) Much time and energy was spent in digging and pulverizing the clay soil or ant hill (iv) Separation of palm kernels was delayed for as long as clay was absent and this reduced production capacity (v) Sand, clay particles and other impurities increased the dirt content of palm kernel/shell mixture
STEP 5 Mixing of clay and water	*The processor (mostly women and children) pulverized the clay soil in water to form a heavy colloidal suspension*	(i) Pulverizing the clay soil in water was time wasting (ii) Much time and energy was spent in removing solid impurities from the clay bath (iii) The clay water was not completely free of dirt (iv) Sand and clay particles settled at the bottom of the water forming a thick layer which reduced the free space required for shells and kernels to separate (v) Processing was further delayed and unhygienic (vi) About 3 buckets of water was used and this reduced the amount of palm kernels that could be separated per batch (vii)Serious environmental pollution was engendered by improper waste management
STEP 6 Mixing of kernel/shell mixture with clay water	*About 3 kg of shell-kernel-dirt mixture was poured in the clay water for separation*	(i) Due to the shallow head of free clay solution, the whole mixture was manually stirred with both hands for the kernels and light dirt particles to float, while the shells and dense particles of sand, metals and other admixtures settled at the bottom (ii) Much time and energy was required for proper mixing (iii) The process was messy and unhygienic (iv) Plenty of dirt floated with kernels (v) The kernels constituted only about one third of the batch, therefore only a small quantity of kernels was recovered from clay bath per batch (vi) The process took about 10 minutes and the kernels were prone to high moisture absorption
STEP 7 Recovery of palm kernels	*The processor used a small perforated bowl to scoop off the palm kernels and some dirt from the surface of the clay bath*	(i) The process was time consuming and laborious (ii) The dirt particles were scooped together with the kernels, which made further cleaning necessary (iii) It was ergonomically inappropriate due to prolonged bending of the back bone (iv) Thin layer of clay stuck to the surfaces of the kernels (v) The process exposed the kernels to further moisture absorption
STEP 8 Washing and cleaning of recovered palm kernels	*The palm kernels and dirt and fine clay particles was dumped in another bowl of fresh water and a small perforated bowl was used to agitate the mixture*	(i) Both kernels and dirt were washed together and increased handling time and moisture absorption (ii) The fresh water for washing soon became cloudy and led to improper washing and poor quality of the kernels (iii) Identification and removal of spoilt kernels was difficult (iv) Palm kernels were allowed to drain
STEP 9 Drying and cleaning of palm kernels	*The palm kernels were spread out on a mat to dry under the sun for days or weeks depending on weather condition.*	(i) Only small quantity of kernels was handled and the production capacity was therefore limited (ii) Both kernels and dirt were dried together. A few dirt was hand-picked instinctively (iii) During drying the kernels were cleaned by winnowing to remove light particles while heavier ones were hand picked (iv) The cleaning process was time consuming and labour intensive (v) Damaged kernels were difficult to identify and separate from good ones due to similarity in appearances. The percentage of broken kernels was high (vi) Further loss of palm kernels occurred during winnowing and due to exposure to rodents
STEP 10 Disposal of shell/clay mixture	*The mixture of clay soil, shells and other admixtures at the bottom of the clay bath were dumped off in nearby bush or farm lands.*	(i) Continuous dumping of the waste on nearby farmlands was a major environmental pollution. (ii) The shells which could be used for other economic purposes were dumped off along with the mud because separation was difficult.

3.2. Properties of Palm Kernels and Shells Affecting Separation in Liquid Media

True and bulk densities of shells and palm kernels of the oil palm fruits were determined and recorded in Table 2. The results show that the average true density of the shells (1.27 g/cm^3) was higher than that of palm kernels (1.04 g/cm^3). This was why the shells sank and the kernels floated when mixed with clay water. Conversely, bulk density of the shells was lower than that of kernels. The kernels were round and smooth and therefore more closely packed than shells. The shells were more irregular in shape and had sharp edges and rough surfaces which must have been responsible the high porosity during packing. The sharp and flat edges of the shells could have aided their sinking, while the sphericity of the kernels aided floating. The results agreed with those of [20]. The difference in true density between palm kernels and palm shells is the strongest factor for their separation in a liquid bath.

Table 2. *Gravimetric properties of shell and palm kernel.*

Material	Property	Experimental Replication	Unit	Mean value	Minimum value	Maximum value
Broken Shells	True density	10	g/cm^3	1.27	1.16	1.43
	Bulk density	10	g/cm^3	0.53	0.52	0.55
Palm Kernels	True density	10	g/cm^3	1.04	1.03	1.071
	Bulk density	10	g/cm^3	0.66	0.65	0.66

3.3. Sodium Chloride as Substitute for Clay in Liquid Separation

The scarcity of clay in many oil palm producing communities and the many disadvantages associated with its use in clay-water bath separation necessitated the investigation into the use of common salt (sodium chloride) as a cheap substitute. Sodium chloride dissolved faster in water with minimum effort when compared with mixing of clay soil with water to form a suspension. Below the saturation point of the salt-water solution, the salt remained dissolved and there was no need for continuous manual or mechanical agitation as was the case in previous mechanical clay-water separators [11]. Figure 4 shows the effect of sodium chloride concentration on separation efficiency. The separation efficiency increased with increase in salt concentration in a sigmoidal relationship and all the palm kernels floated and were separated from shells at salt concentration ranging between 250 g/dm^3 and 300 g/dm^3. There was a slight decrease in separation efficiency when the quantity of palm kernel/shell mixture was increased from 300 g to 600 g. The decrease in separation efficiency was due to the reduction in free space in the salt solution caused by the increase in the quantity of shell/kernel mixture.

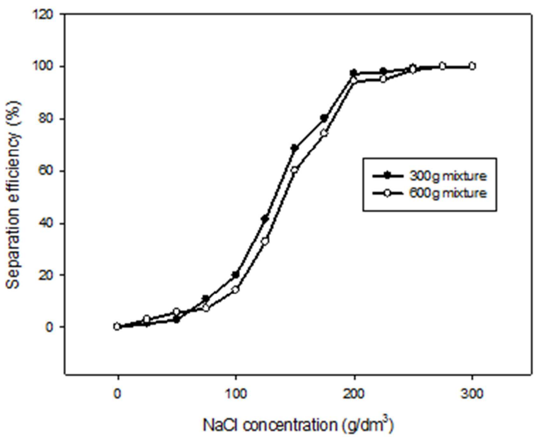


Figure 4. *Effect of salt concentration on separation efficiency.*

Clean palm kernels were recovered from the surface of the salt solution and clean shells were evacuated from the bottom without the encumbrances of dealing with murky mixture of clay soil, shells and other foreign admixtures associated with the clay-water bath. Also the salt concentration and specific gravity at which all the palm kernels floated remained constant for as long as no fresh water was added. The same salt water solution could therefore be reused to separate a larger quantity of palm kernels. The recovered shells could be dried and used for other economic purposes [12, 13, 14] instead of being dumped away with muddy mixture as was the case in clay-water bath method. The salt-water solution did not constitute a health hazard and the time, energy and risk involved in sourcing for clay soil were eliminated.

3.4. Conceptual Design of a Saline Bath System for Separation of Palm Kernels

The design concept of a saline bath system for the separation of palm kernels from shells is shown in Figure 5. Section A is the hopper in which the mixture of palm kernels and shells is poured. The neck of the hopper is inclined at angle that allows the mixture to move down by gravity and a shutter gate helps to control material flow rate. Sections B and Section C contain salt-water solution which is recycled by Pump 1. Section D and E contain fresh water which is recycled by Pump 2. As the mixture from Section A moves into Section B by gravity, the upward current of salt-water helps in dispersing the kernel/shell mixture. Due to differences in specific gravity, the shells sink to the bottom of Section B and the palm kernels float to the top and carried by the overflowing salt-water into Section C. An inclined screen covering Section C allows only liquid to pass through while the kernels roll down by gravity into the fresh water in Section D to be washed. The palm kernels sink to the bottom of Section D while other light admixtures are pushed to the top by the fresh water current from Pump 2. The screen covering Section E allows only fresh water to pass through and the admixtures roll/slide down by gravity and are discharged. The shells and palm kernels in Sections B and D can be evacuated in batches or continuously by mechanical means.

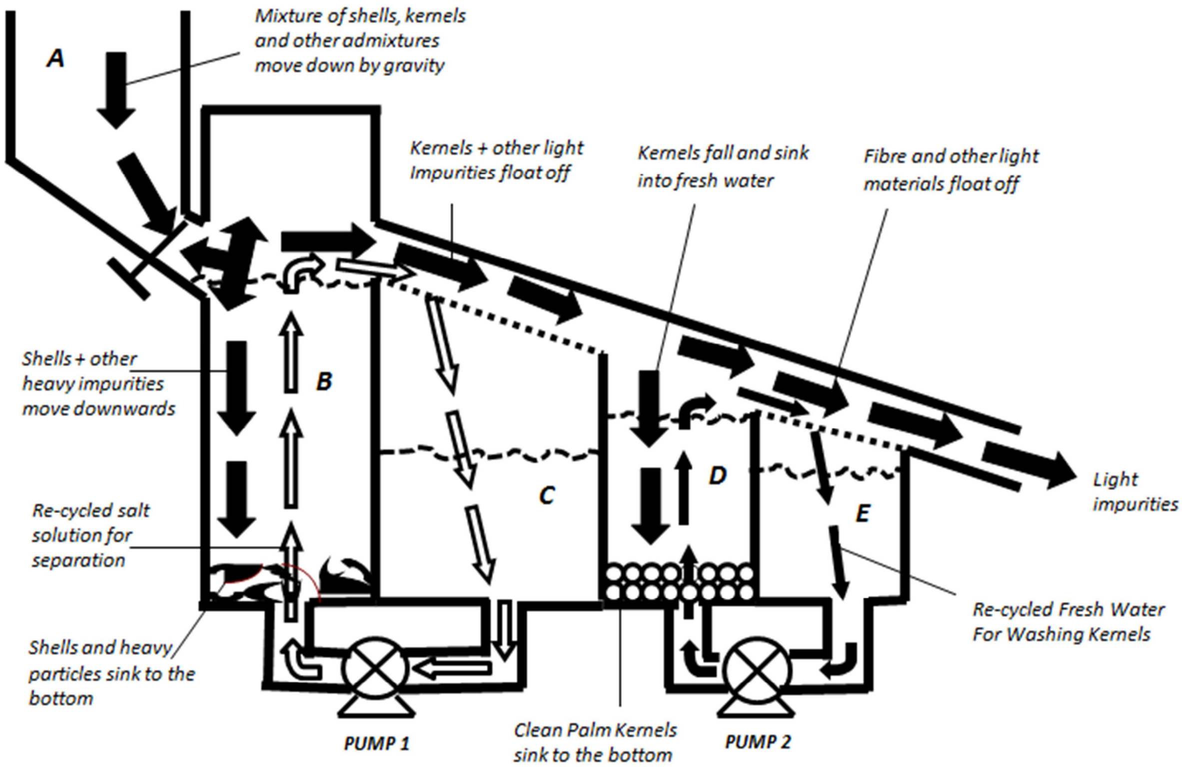


Figure 5. *Design concept of a saline bath system for separating palm kernels from shells.*

The design concept of the saline bath system is based on the same operational principle as the traditional clay-water bath method. The use of saline solution in place of clay water would make the system more hygienic and most of the disadvantages of the clay-water bath system would be eliminated. The resident time of kernels and shells in the saline bath would be shorter therefore the palm kernels would not absorb moisture as much as in the clay-water bath method. The salt concentration in the liquid would remain constant and could be re-used to separate several batches of palm kernel/shell mixture. The system could also be upgraded into a continuous-flow industrial system where both kernels and shells could be simultaneously evacuated and transported into a drying/storage bin.

4. Conclusion

The study has shown that sodium chloride is a good substitute to clay. Existing mechanical separators are capital intensive and not suitable for rural environment where most local farmers/processors are located. The design and fabrication of a saline bath system will be a cheaper and more appropriate alternative to the clay-water bath method. The fact that sodium chloride is cheap, available and hygienic makes the saline bath system a better option. The advantage of the saline bath system is that it can be upgraded to meet the target capacity of production. The system may also be combined with the dry separation system. The major disadvantage of the saline bath system is that drying of both palm kernels and shells is required, but its advantages outweigh the disadvantages of the traditional clay-bath method. Compared with dry mechanical separators, the saline bath system is more cost effective.

References

[1] Rohaya, M. H., Ridzuan, R., Che, R. C. M., Choo, Y. M., Nasrin, A., Numan, A. (2016) Dry separation of palm kernel and palm shell using a novel five-stage winnowing column system. *Technologies,* 4 (13).

[2] Pantzaris, T. P. (2000) Pocketbook of palm oil uses. 5th Edition. MPOB Bangi: 102-109.

[3] Gbadam, E. K., Anthony, S., Asian, E. K. (2009) Determination of some parameters for palm nut cracker. *European Journal of scientific Research*, 38 (2): 315-327.

[4] Oil World (2015) Independent Global Market Analyses and Forcasts. ISTA Mielke GMBH, Hamburg, Germany.

[5] Taiwo, K. A., Owolarafe, O. K., Sanni, L. A., Jeje, J. O., Adeloye, K., Ajibola, O. O. (2000) Technological assessment of palm oil production in Osun and Ondo States of Nigeria. *Technovation*. 20: 215-223.

[6] Sanni, L. A. and Adegbenjo, A. O. (2002) Properties of palm nuts and fibre residue that influence mechanical separation after palm oil extraction. *Proceedings of International Conference on Promotion of Appropriate Agro-Processing Technologies in West Africa.* Ile-Ife, Nigeria: 186-196.

[7] Ibrahim, M. H, Daud, W. R. W. and Talib, M. Z. M (1997) Drying Characteristics of Palm Kernel. *Drying Technology*, 15 (3&4): 1103-1117.

[8] Koya, O. A., Faborode, M. O. (2006) Separation theory for palm kernel and shell mixture on a spinning disc. *Biosystems Engineering,* 95 (3): 404-412.

[9] Rohaya, M. H., Nasrin, A. B., Mohd Basri, W., Choo, Y. M., Ridzuan, R., Ma, A. N., Ravi, N. (2009) Maximizing the recovery of dry kernel and shell via a 4-stage winnowing column. Proceedings of the Malaysian Palm Oil Board. International Palm Oil Congress, Kuala Lampur, Malaysia, 9-12 November 2009.

[10] Olasunboye, A., Koya, O. (2014) A rotary separator for the dry mixture of palm kernel and shell. *Innovative Systems Design and Engineering.* 5 (7): 32-41.

[11] Okoronkwo, C. A., Ngozi-Olehi, L. C., Nwafo, O. C. (2013) The adaptation of clay-bath and hydro-cyclones in palm nut cracked-mixture separation to small-scale oil palm processing industry. *International Journal of Mordern Engineering Research,* 3 (4): 2023 – 2026.

[12] Oti, O. P., Nwaigwe, K. N., Okereke, N. A. A. (2017) Assessment of palm kernel shell as a composite aggregate in concrete. Agricultural Engineering International: *CIGR Journal,* 19 (2): 34-41.

[13] Dagwa, J. M., Builders, P. F., Achebo, J. (2012) Characterization of palm kernel shell powder for use in polymer matrix composites. *International Journal of Mechanical and Mechatronics Engineering.* 12 (4): 88-93.

[14] Fono-Tamo, R. S., Idowu, O. O., Koya, F. O. (2014) Development of pulverized palm kernel shells based particleboard. *International Journal of Material and Mechanical Engineering.* 3 (3): 54-61.

[15] Crawford, I. M. (1997) Rapid Rural Appraisal. In: Marketing, Research and Information Systems. Food and Agriculture Organization of the United Nations. Rome, Italy.

[16] Sanni, L. A., Ogunsina, B. S., Oladigbo, C. (2008) Development of rotary pulverizer for cassava cake in gari production. *Journal of Food Process Engineering.* 31 (6): 783-797.

[17] Omobuwajo, T. O., Omobuwajo, O. R., Sanni, L. A. (2003) Physical properties of calabash nutmeg (*Monodora myristica*) seeds. *Journal of Food Engineering.* 57 (4): 375-381.

[18] Khurmi, R. S. and Gupta, J. K. (2005) A textbook of Machine Design. 15th Edition. Schand and Company Ltd., New-Delhi, India.

[19] Cornelius R. O. (1983) Farm products and machineries. 2nd Edition. Granada Publishing Limited, London: 245-250.

[20] Koya, O. A., Faborode, M. O. (2005) Mathematical modelling of palm nut cracking based on Hertz's theory. *Biosystems Engineering.* 91 (4): 471-478.