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The Effect of Traditional Primary Processing of the Shea Fruit on the Kernel Butter Yield and Quality

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ABSTRACT

The influence of three traditional unit operations (fruit storage, par-boiling duration and nut drying method) in the primary processing of the shea fruit in Ghana for the marketable kernel was assessed. Mouldiness in kernels Butter Yield (BY) and Free Fatty Acid (FFA) were evaluated as standard quality parameters. All kernels irrespective of the duration of par-boiling attained the desired 7-7.5% moisture content in 7 days when solar dried while the mat and floor took 11 and 14 days to dry, respectively. Parboiled kernels longitudinally cut, indicated very mouldy kernels from the floor dried kernels resulting in significantly higher levels of FFA in the butter compared to those from mat and solar dried kernels. The moulds isolated and identified from the parboiled kernels were *Aspergillus tamari, Aspergillus wentii, Aspergillus terreus, Aspergillus versicolor, Aspergillus flavus, Fusarium avenaceum, Rhizopus stolonifer, Rhizoctonia* and *Penicillium* species. Non parboiled kernels, irrespective of the drying method had no mouldy nuts but high FFA (19.10-19.99%). Both parboiling duration and drying method significantly affected BY and FFA levels. Fruit storage before depulping negatively affected the quality of the resulting butter. Drying method had a significant effect on the shea kernel and butter quality. Solar and mat drying could therefore be adopted as part of the first step in the primary processing for good quality shea butter. Storage of fruits beyond three days before depulping adversely affected kernel and butter quality.

Key words: Parboiling, solar drying, floor drying, free fatty acids, moulds

INTRODUCTION

Shea butter is obtained from the kernel of the fruit of *Vitellaria paradoxa* GE Geertner and is second in importance only to palm oil in Africa (Hall *et al*., 1996). Kernels yield between 35 to 60% butter (Tano-Debrah and Ohta, 1994). Shea butter is used extensively in the food, pharmaceutical, cosmetic industries and often as Cocoa Butter Substitute (CBS) or Cocoa Butter Improvers (CBIs) by chocolate manufacturers and for margarine and baking purposes (Martin *et al*., 1987; Williams and Bolton, 1950; Hall *et al*., 1996). Large quantities of edible oils are also made from the shea kernel for local consumption (Collinson and Zewdie-Bosuener, 1999). Shea butter is highly prized by the pharmaceutical and cosmetic companies for its creamy texture and medicinal properties (Michael and Kofi, 2001). Despite its popularity and the fact that it is in great demand among chocolate, cosmetic and pharmaceutical companies, the butter from Ghana attracts very low market price because of its poor physicochemical qualities. Since the butter is extracted from the shea kernel, the kernel quality ultimately determines the butter quality. Traditionally, there are

eight unit operations in the primary processing of the shea fruit in Ghana for the marketable kernel viz collection of fruit, storage of fruit, de-pulping of nut, par-boiling, drying of nut, cracking of nut and separation of kernel, drying of kernel, bagging and storage of kernel. Among these, heat treatment (par-boiling) and drying have been reported as paramount (Lovett, 2004; Womeni, 2004). Parts of the processing line also expose the fruits, nuts and the kernel to external agents such as predators, soil, microorganisms, moisture and insects that affect the quality of the final product (the butter). The effects of these agents have however not been very well investigated. In the traditional methods of extraction, the yield is generally low and the butter attains a muddy-brown to greenish-grey colour, with a strong smell and taste as compared to practically no taste or smell and almost white coloured butter extracted by more refined methods (Williams and Bolton, 1950; Michael and Kofi, 2001). The traditionally extracted butter is also reported to have high iodine number, high acid number and high Free Fatty Acid (FFA) value (Adomako, 1985). The high acid number and FFA content have been reported to be indications of partial hydrolysis of the fat caused by fungal spoilage of the nuts and the kernel during processing and storage (Aye, 1989). Mouldy kernels usually come from nuts which have been par-boiled and not dried quickly and efficiently enough.

This study compared three drying methods (traditional drying on the floor, on raised raffia mat and solar drying) for shea kernel as well as influence of fruit storage before processing and par-boiling duration on nut, kernel and butter quality in terms of the level of free fatty acid and mould growth in the kernel as part of the steps in the post harvest processing of shea fruits.

MATERIALS AND METHODS

Source of materials: The experiment was carried out at the Cocoa Research Institute of Ghana sub-station, Bole, 9°01' N, 2°29' W, 309 m above sea level. Fresh Ripe Fruits (RF) were obtained from the Upper West region of Ghana.

Sample preparation: Samples of shea fruits were de-pulped and the nuts washed in water to remove all adhering pulp material. The depulped nuts were spread on raffia mats to drain and air dry.

Parboiling: Samples of dried nuts were divided into four groups and parboiled for 0, 20, 30 and 40 min by submerging the nuts into boiling water with constant stirring. The nuts were then collected from the boiling water, placed in baskets and allowed to drain. The drained nuts were spread out on raised raffia mats to cool.

Drying: After cooling, each group of parboiled nuts was divided into three and dried using a locally designed Solar Dryer (SD), Raised Mat (MD) and on Concrete Floor (FD) (Fig. 1). The nuts were so dried for five days after which they were re-weighed and cracked. The kernels were carefully removed from the shell and weighed. Thereafter, the weight recordings of the kernel were taken daily for seven days. At the end of the seven days, samples were taken for moisture content determination. The experimental samples were dried for a further seven days during which period 48 h weight recordings were taken and at the end samples were again taken for moisture content determination, fat extraction and analysis.

Fruit storage experiment: Freshly dropped shea fruits were collected from the C.R.I.G. plots at Bole and de-pulped on 0, 3 and 8 days after collection. The nuts were parboiled for 20, 30 and

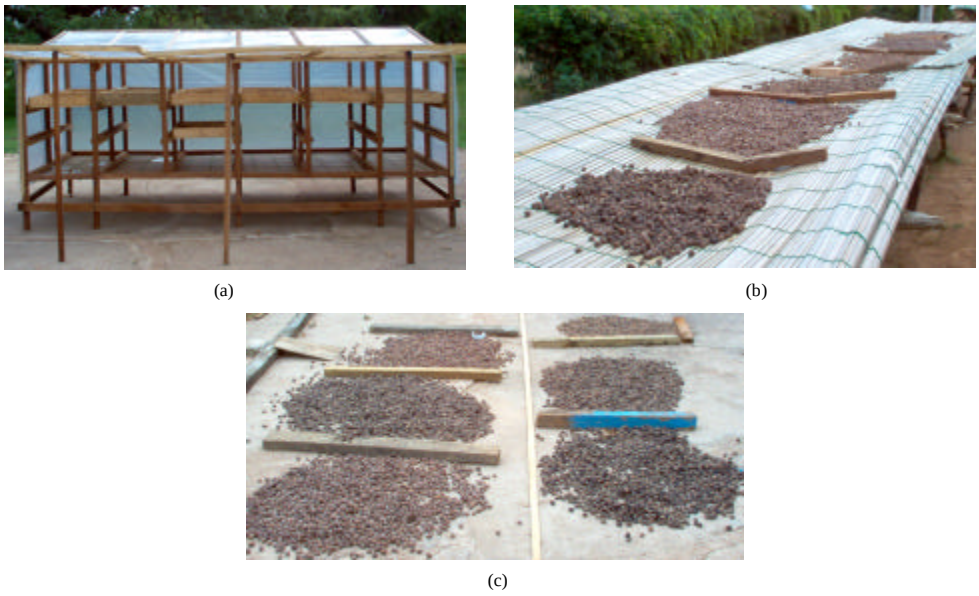

Fig. 1(a-c): Locally improvised solar dryer with (a) one Side Opened (SD); (b) Drying of kernels on raised Mats (MD) and (c) kernels dried on floor as usually practiced (FD)

40 min, drained and sun dried for 6 days. After drying, the nuts were cracked using a wooden mallet. Separated kernels were dried in the sun on raised mats to moisture content of 5-8%. Samples were taken for fat extraction and analysis and moisture content determinations.

Moisture and fat content determination: Kernel samples were taken and cut into pieces with clean stainless steel knives. About 15-20 g of the sample was weighed into petri dish. The dry weight of the samples was determined in triplicate according to the Association of Analytical Chemist (A.O.A.C) method (AOAC, 2005). Fat content determination was done using the soxhlet-extraction method (AOAC, 2005). The results were expressed as a percentage of dry matter (DM%).

Oil analysis

Free fatty acid (FFA) determination: Soxhlet extracted fats were used for the determination of the FFA by the method of IOCCC (1996). Briefly, 5 g of extracted shea butter was melted and dissolved in 50 mL of diethylether and 95% ethanol mixture (1:1, v/v) and titrated against standardized 0.1 N alcoholic KOH solution using 1 mL phenolphthalein as indicator. FFA (oleic acid%) was calculated using the formula below:

$$\text{FFA (oleic acid\%)} = 0.564 \times V$$

where, V = Volume of KOH used in titration.

Isolation of moulds: One hundred shea nuts were washed in distilled water and surface sterilized in 10% Clorox (2 min), blotted dry with tissue paper, peeled and cut into two. These were then

plated on Malt Extract Agar (MEA) containing Chloramphenicol (100 mg L^{-1}) to suppress bacteria growth and plates incubated at 28±2°C for 72 h. Pure cultures of the isolated mould were then grown on fresh MEA plates, until sporulation for identification.

Identification of moulds: The isolates were identified to species level using the compound microscope using standard references (Barnett and Hunter, 1972; Nelson *et al*., 1983; Samson *et al*., 1995; Mathur and Kongsdal, 2003). The identification of the various moulds was done based on their colony and cell morphologies such as colour, mycelia, conidia and sporulating structures.

Statistical analysis: The data was log transformed prior to analysis to stabilize the variances and normalize the residuals. Analysis of variance was performed on the transformed data using Genstat (9.2). The Least Significant Difference Test (LSD) was employed to determine differences between means at a 5% significance level.

RESULTS AND DISCUSSION

The length of parboiling did not significantly affect the time it took for kernels to attain 7% moisture content (Fig. 2, 3). The method of drying however had a significant effect on the length of time needed for the kernels to attain the maximum of 7.0% moisture content. The solar drier was the most efficient, with a drying time of 7 days, followed by the mat (11 days) and the floor (14 days). Average temperature within the solar dryer was 40 compared to 35°C outside. This could probably have accounted for the faster drying in the solar dryer relative to the mat and floor dried treatments. Samples dried in the solar dryer appeared cleaner with a pleasant aroma than those dried on the raised mats which also looked better than the floor dried samples. Most of the floor dried samples were mouldy and started to develop rancid odour.

Due to the presence of lipase and germination enzymes in the living shea seed (Lovett, 2004), the primary objective in post-harvest processing is to quickly kill and dry seed in a controlled manner to produce a dry kennel that is chemically stable for storage without further chemical processes affecting the lipid content leading to rancidity. Boiling however induced physical changes in the structure and colour of the shea kernel and the possible formation of volatile aromatic

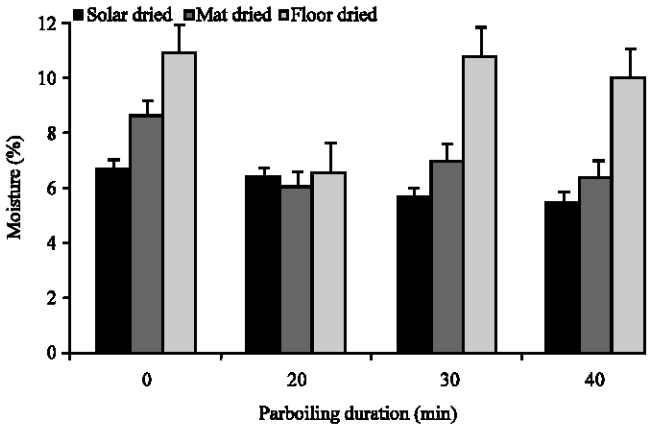

Fig. 2: Moisture content of variously par-boiled kernels 7 days after drying using three different methods. Bars represent standard errors

compounds. Increase in parboiling time however resulted in darker kernels which were easily visible on a cut cross section (Fig. 4). Nuts which were not parboiled were difficult to crack and the shell and kernels were also difficult to separate and retained most of the kernel testa. The ease of cracking and separation of the kernels from the shells depended upon the duration of the

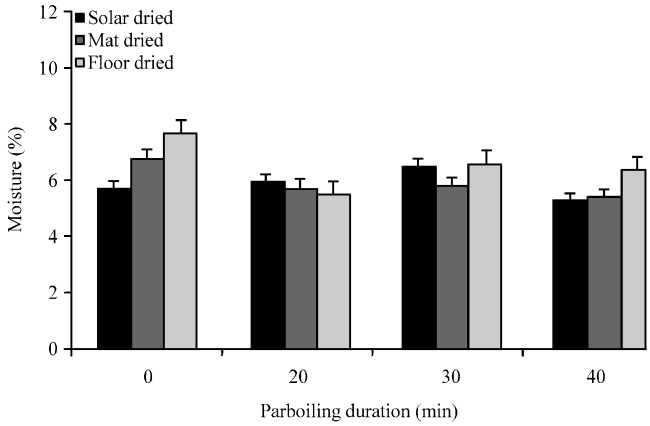

Fig. 3: Moisture content of variously par-boiled kernels 14 days after drying using solar, mat and floor drying methods. Bars represent standard errors

Fig. 4(a-d): Colour of kernels obtained from parboiled nuts (a) UNBK, unboiled; (b) PARB20, parboiled for 20 min; (c) PARB30, parboiled for 30 min and (d) PARB40, parboiled for 40 min

parboiling. The longer the parboiling, the easier the cracking and separation of the shell and the cleaner the kernel. Kernels from the fresh, un-boiled nuts had white to cream colour with lots of latex. This changed with duration of boiling. Kernels boiled for 20 min had cream to light brown colours and some latex. Those boiled for 30 min had light brown to brown colour with very little latex and those boiled for 40 min had slightly darker brown colour with no latex.

The floor dried kernels tend to have significantly high mouldy kernels (Table 1) compared to the solar and mat dried kernels. Kernels that were not parboiled did not have any mould problems irrespective of the drying method. Drying of the boiled shea nuts during rainy season in high ambient temperature and humidity greater than 65% therefore poses a lot of challenge. The nuts became quickly infected with a wide range of moulds. The moulds identified belonged to the genera *Aspergillus*, *Fusarium*, *Rhizopus*, *Rhizoctonia* and *Penicillium*. The most frequently encountered moulds were the *Aspergillus* and the *Rhizopus* species. Five *Aspergillus* species were isolated and identified. They were *A. tamari*, *A. wentii*, *A. terreus*, *A. versicolor* and *A. flavus*. All these *Aspergillus* species have the potential of producing mycotoxins especially aflatoxins which are carcinogenic and therefore could have health implications on the consumer. Other species isolated and identified were *F. avenaceum*, *Rhizopus stolonifer*, *Rhizoctonia* and *Penicillium* species. The moulds also affected the quality of those shea nuts. They increased levels of FFA and other volatile chemical compounds with unpleasant odour.

The adverse effect of non-parboiled nuts is revealed in Table 2. They tend to have significantly higher Free Fatty Acids (FFA) compared to the parboiled kernels. The values of 19.10-19.99% far exceeds the acceptable level of 5% for the industry. Non-parboiled kernels solar dried had significantly lower levels of FFA compared to the mat and floor dried kernels. This could be attributed to the faster drying experienced in the solar dryer, resulting in the faster deactivation of the lipases which are responsible for fat hydrolysis leading to rancidity. All floor dried parboiled samples however, had significantly higher ($p<0.05$) levels of FFA compared to the other two methods of drying. The level of FFA in the samples tended to significantly increase with length of

Table 1: Effect of parboiling time and method of drying on mouldy shea kernels (%)

	Duration of parboiling (min)				
Drying method	0	20	30	40	Mean
Floor dried	0.0 (-0.3)	8.0 (0.9)	14.0 (1.2)	5.0 (0.7)	6.8 (0.6)
Mat dried	0.0 (-0.3)	2.0 (0.4)	3.0 (0.5)	0.0 (-0.3)	1.3 (0.1)
Solar dried	0.0 (-0.3)	2.0 (0.4)	1.0 (0.2)	0.0 (-0.3)	0.8 (0.0)
Mean	0.0 (-0.3)	4.0 (0.6)	6.0 (0.6)	1.7 (0.1)	2.9 (0.2)
LSD (p = 0.05)	0.2				

Values in parenthesis are Log (X+0.5)

Table 2: Effect of parboiling time and method of drying on free fatty acid content of shea kernels (%)

	Duration of parboiling (min)					
Drying method	0	20	30	40	Mean	LSD (p = 0.05)
Floor dried	19.99	1.07	3.46	4.50	7.26	0.03
Mat dried	19.40	0.14	0.31	0.14	5.00	
Solar dried	19.10	1.51	0.26	0.27	5.29	
Mean	19.50	0.91	1.35	1.64		
LSD (p = 0.05)	0.04					
Interaction LSD (p = 0.05)	0.07					

(a) (b)

Fig. 5(a-b): Dried kernels; (a) DUNT, unboiled nuts and (b) BMK, mouldy kernels from improperly dried boiled nuts

parboiling for the floor dried kernels (Fig. 5). This vindicates processors practice of parboiling for short periods before floor drying. A similar trend could not be established for the solar and mat dried kernels which had FFA values with range of 0.14-1.51%. Womeni *et al.* (2006) and Bup Nde *et al.* (2009) however, recommends cooking sheanuts for a length of time (50-140 min), especially above 100 min before processing in order to obtain butter with low acid and peroxide values. This recommendation did not seem to have considered the effect of drying after parboiling as traditionally practiced. Butter was extracted directly from the boiled nuts. The results of this study suggest that mould growth might not be the only factor among others contributing to high FFA levels in shea butter. Boiling of the fresh nuts denatures the proteins binding the fibre and holding the moisture and lipids. In denaturing, the lipase enzymes which cause oxidation of kernel lipids during germination of the living seed are inactivated by the boiling and hence reduce the excess formation of FFA (Norris, 1982). Susceptibility to development of peroxides are however possible through inhibition and/or reduction of phenolic antioxidant compounds, especially catechins in the kernel after boiling (Masters, 2007; Yasmin *et al.*, 2008). Parboiling however important destroys the shea kernel mechanisms providing protection against fungal infection as well as butter quality, presumably as a result of auto-oxidation catalysed reactions in the presence of heat, UV or certain metals (Bup Nde *et al.*, 2009).

Length of parboiling and method of drying significantly ($p<0.05$) influenced the yield of shea butter from kernels (Table 3). Generally, parboiled kernels yielded higher percentage of fat than non parboiled kernels.

Effects of storage of fruits on primary processing: Traditionally, fruits are not picked/collected every day. Even when fruits are picked daily, some are missed out because of the weedy nature of the terrain and may be collected the next time round. Fruits after being picked are eventually heaped and left for a length of time to soften up and ease the depulping process. The effect of this practice is however seen in the results of this experiment. The nuts from the fully ripped fruits kept for 3 days before processing had mainly light brown to brown shining shells. Nuts from the fully ripped fruits kept for 8 days (some already de-pulped) before processing were mainly brown to dark dull brown in appearance and started to germinate. The long storage periods before de-pulping resulted in more infested, black and germinated kernels (data not presented) than those stored for shorter periods. This is translated into higher free fatty acids (Table 4) and hence the quality of the butter obtained. Fruits should not be kept too long before processing.

Table 3: Effect of parboiling time and method of drying on fat content of shea kernels (%)

	Duration of parboiling (min)					
Drying method	0	20	30	40	Mean	LSD (p = 0.05)
Floor dried	52.95	55.25	53.66	57.28	54.79	0.03
Mat dried	51.87	55.32	54.70	55.42	54.33	
Solar dried	53.08	54.62	53.88	54.34	54.23	
Mean	52.63	55.40	54.08	55.68		
LSD (p = 0.05)	0.03					
Interaction LSD (p = 0.05)	0.06					

Table 4: Effect of fruit storage before depulping on free fatty acid of butter (%)

	Duration of parboiling (min)					
Storage duration	0	20	30	40	Mean	LSD (p = 0.05)
Fresh fruits (3 days)	19.50	0.91	1.35	1.34	5.85	0.03
Old fruits (8 days)	20.18	2.06	1.53	3.54	6.83	
Mean	52.63	55.40	54.08	55.68		
LSD (p = 0.05)	0.06					

CONCLUSIONS

Overall, the result of this study demonstrated the impact of parboiling and method of drying on the quality of kernel and extracted shea butter. The first step of the primary processing from the picking or collection of the fresh fruits to the drying of the kernel are of critical importance to the final quality of the shea butter. The only way to reduce fungal problems is to ensure boiled nuts are dried quickly and efficiently on raised drying mats or inside solar-dryers which have been found to be effective in this study. The practice of storing fruits to soften up for depulping should be restricted to not more than three days before processing to improve processed nut, kernel and butter quality.

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