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Evaluation of the modified-ceylon copra kiln for accelerated production of ball copra

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Abstract: This study attempted to investigate the effect of kiln drying on the rate of formation of ball copra. Three samples containing fifty partially dried-coconuts were placed as a single layer in three compartmentalized blocks namely, Front: Blok-1, Middle: Block-2, and Rear: Block-3 in the copra bed of the modified-Ceylon copra kiln. From each of the three blocks, thirty coconuts were selected randomly for labeling and their fresh weights were recorded. The samples were subjected to intermittent drying in the kiln by thirty five firing cycles using charcoal dust as the fuel source. The temperature distribution pattern of the three blocks during the first six firing was monitored at three hourly intervals. The weight losses of individual coconuts in each block were measured after the completion of each firing. The results showed that, there was a significant ($p<0.05$) effect of copra bed temperature on the weight losses of the samples. The first ever ball copra formation was detected in the Block-3 after the completion of the 12th firing. The percentages of ball copra formed at the end of 35th firing were 44%, 78%, and 94%, in Block-1, Block-2, and Block-3, respectively. Analytical studies indicated that the quality indices of ball copra were comparable to those of the edible white copra.

Key Words: Ball copra, coconut processing, copra quality, coconut products, Kiln drying

Introduction

Sri Lanka has long been known for manufacture of copra for oil and other edible purposes. In the commercial sector, copra is traded either as milling copra or edible copra. Although edible copra constitutes a small per cent of the total annual production, there could be better prospects for export market owing to the increasing demand for edible copra by people living in the colder climate regions of south Asia. In general, edible copra are classified into two different kinds namely, cup copra and ball copra. Cup copra is usually processed in the Ceylon copra kiln using fully-matured coconuts as raw material (Nathanael, 1966). In this process, coconuts are split-opened into two halves and loaded onto the copra bed after a pre-sun drying in a cemented open yard for six to seven hours. Although pre-sun drying of the coconut halves in an open yard could contribute to the fuel saving, it would increase the chances of microbial contamination in the end product (Head, 1991). In the kiln drying process of edible copra manufacture, there are concerns with regard to the deposition of smoke and lack of uniformity in the dehydration. This would eventually affect the quality of the edible copra in terms of discoloration, under drying, scorching or case-hardening (Rodrigo et al., 1996).

When taking food safety into consideration, edible copra, as it is meant for direct human consumption, has to be produced more hygienically to meet better quality standards. Hence, attempts were made in the past to improve the quality of cup copra to an acceptable level. A notable development in this regard was the initiative taken to re-design the Ceylon copra kiln by making adjustments to its dimensions. As such the height of the compartment of the kiln was lowered from 1.8 to 1.2 m while the width was increased from 1.3 to 2.0 m. The kiln with the new dimensions was called the Modified-Ceylon copra kiln and subjected to field level testing to determine its efficiency to process better quality edible copra (Jayasundera et al., 2004). Although the modified system brought some improvements to copra drying, there is much more to be done for its optimization.

If edible copra is preferred in the form of ball copra, most of the above mentioned quality related problems could be overcome. Ball copra, in essence, is a substance formed within a fully matured whole nut due to natural dehydration of coconut water (Rethinum and Bosco, 2003). When coconut is in its tender stage, its cavity is filled entirely with coconut water. During the different stages of maturity, water inside the cavity undergoes various biochemical changes to help build up the white coconut meat on the surface of the cavity. When the nut reaches

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its full-maturity, the volume of the nut water in the cavity gets reduced creating an air gap inside. The air gap inside the cavity would be expanded when the nut water gets reduced during the post harvest storage of coconut (Thampan, 1982; Banzon and Valesco, 1982). Unless the nuts are used for processing, the above changes inside the cavity of nuts may continue uninterruptedly for several months until the whole nut-water inside the cavity is fully absorbed by the kernel. Upon reaching this stage, kernel inside the cavity may have become partially dried-copra and within weeks of time the dried kernel inside the cavity could slowly get-detached from the coconut shell leading the formation of ball copra. This stage could be well-recognized with a sound inside the cavity upon shaking. As the process takes for several months, the ball copra manufacturing becomes tedious and can not sustain continuous supply. Due to this reason, there has been considerable interest to find a cut-short of the time duration of ball copra formation. But the literature dealing with accelerated production of ball copra is scanty. If an alternative method is proposed, it could not only save the time but it may also help to improve the productivity of this industry. For this, adopting a kiln drying system such as the modified-Ceylon copra kiln could be mostly advantageous as the biomass generated by the coconut industry could be used as the fuel. For a developing country like Sri Lanka copra processing by kiln drying is the most economical when compared to other sophisticated technologies. Hence, the objective of this study is to evaluate the modified-Ceylon copra kiln for accelerated production of ball copra.

Materials and Methods

Materials

Good quality seasoned coconuts with husk were obtained from the Bandirippuwa estate of the Coconut Research Institute of Sri Lanka, Lunuwila. Samples of naturally cured ball copra and edible cup copra were collected from the whole sale dealers from Colombo. All the chemicals used were of analytical grade unless otherwise specified.

Ball copra processing and experimental design

The ball copra processing was conducted on a selected compartment of the modified-Ceylon copra kiln described previously by Thanaraj et al. (2006). The compartment with the dimension of 1.2 m x 2.0 m x 3.7 m (Length x Width x Height) was subdivided into three blocks namely, Block-1: front portion, Block-2: middle portion, Block-3: rear portion. Fifty partially dried-coconuts of three weeks of seasoning were placed in each block to spread as a single layer with thirty of them being labeled. The initial whole nut weight of each labeled coconut was recorded before the commencement of the kiln drying. Experiment was conducted as a intermittent drying with each firing cycle lasting for 21 hrs with a cooling interval of 2 hrs duration. Weight measurements of labeled coconuts were taken at the end of each cooling cycle. The fuel input for a firing cycle was 30 kg of charcoal dust spread in two parallel rows along the edges of the walls of the kiln chamber. The firing cycles were continued until the formation of ball copra.

Temperature measurement

The temperature distribution on the perforated-drying platform of the compartment was recorded during the first six firing cycles by locating thermometers fixed on to water containing glass bottles (50 ml) placed at the middle of each block (Front: block-1, Middle: block-2 and Rear: block-3). The temperature readings were recorded at three hourly intervals during each firing cycle (Jayasundara et al., 2004).

Weight loss measurement

The weight loss of each labeled coconut in the three different blocks was recorded during the cooling time after each firing cycle.

Quantification of ball copra formation

On completion of each firing cycle, the percentage of coconuts turning into ball copra was recorded for each block separately.

Analytical methods

Quality parameters of copra namely, moisture content, color, and free fatty acid (FFA) content were determined according to the SLS 612:1983. Protein, sugar, fiber and ash contents were determined according to the Pearson Laboratory Techniques in Food Analysis (Pearson, 1972). Microbiological parameters namely, total plate count and yeast and mould count were determined according to the SLS 516 - Part I and II: 1991.

Statistical analysis

Data were statistically analyzed by one-way analysis of variance (ANOVA) using MINITAB statistical package at 0.05 probability level.

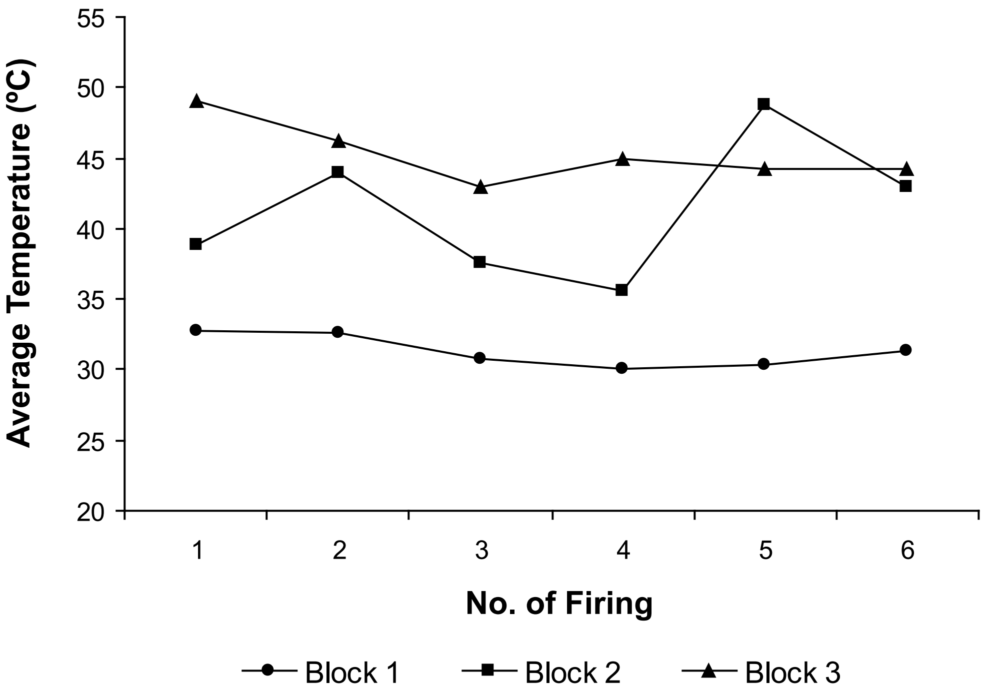

Figure 1. Average temperature distribution of the copra bed

Results and Discussion

Temperature distribution in the copra bed

Heating is the most important factor influencing the effectiveness of any drying process. Therefore, it is important to see the effect of copra bed temperature on the rate of formation ball copra. The initial temperature of the bed was as low as 30^{o}C, but it was progressively increasing up to the maximum of 60^{o}C. Based on the first six firing cycles, the average temperatures observed on Block-1, Block-2 and Block-3 were 32.8^{o}C, 48.8^{o}C and 49^{o}C, respectively. This was actually on the lower side, but could be further increased by augmenting the amount of charcoal dust used per firing cycle. This would, eventually, facilitate the reduction of the total drying time or the number of firing cycles required for ball copra formation. Hence, conducting further batch trials to work out the drying time requirement for different levels of temperature would be beneficial though maximum permissible temperature for ball copra formation is still not known. A similar kind of an exercise was previously undertaken for the processing of milling copra meant for oil production, where the average drying time requirement was determined for drying temperatures of 40, 50, 60, 70, 80, 90, and 100^{o}C (Guarte et al., 1996). But this should be done with the concurrent monitoring of the quality of the final product since quality degradation due to over drying is a major concern. Like in many other food drying operations, the copra bed temperatures exceeding its permissible limit could be disadvantageous (Leon et al., 2002; Mujumdar, 1997). It is already reported that in the processing of cup copra, the drying temperature exceeding 80ºC was found to cause some Maillard type of browning (Guarte et al., 1996). Hence, determining the maximum permissible temperature would be worthwhile because since heating could either affect the quality of ball copra or might lead to nut cracking.

In a typical Ceylon copra kiln system as described previously by Thanaraj et al. (2006), intermittent drying is adopted as continuous drying may be practically not feasible. During the intermittent drying, the heat supply and air flow inside the kiln may be taking place in a cyclic manner in combination with heat transfer by radiation (Baini and Langrish, 2007). In this, the heat convection cycles could be operating from two opposing directions; the first one due to the air flow coming through the front opening of the kiln while the second one is due to the air flow coming through the back vent hole of the firing chamber. The front convection could usually become more dominant than the back convection due to the higher air flow rate coming through the front opening. This imbalance could eventually drive the heat flow more lenient towards the back of the drying chamber, resulting in enhanced heating on the block-3 (Figure 1). The data analysis of the temperature distribution of the copra bed clearly showed that the mean temperature

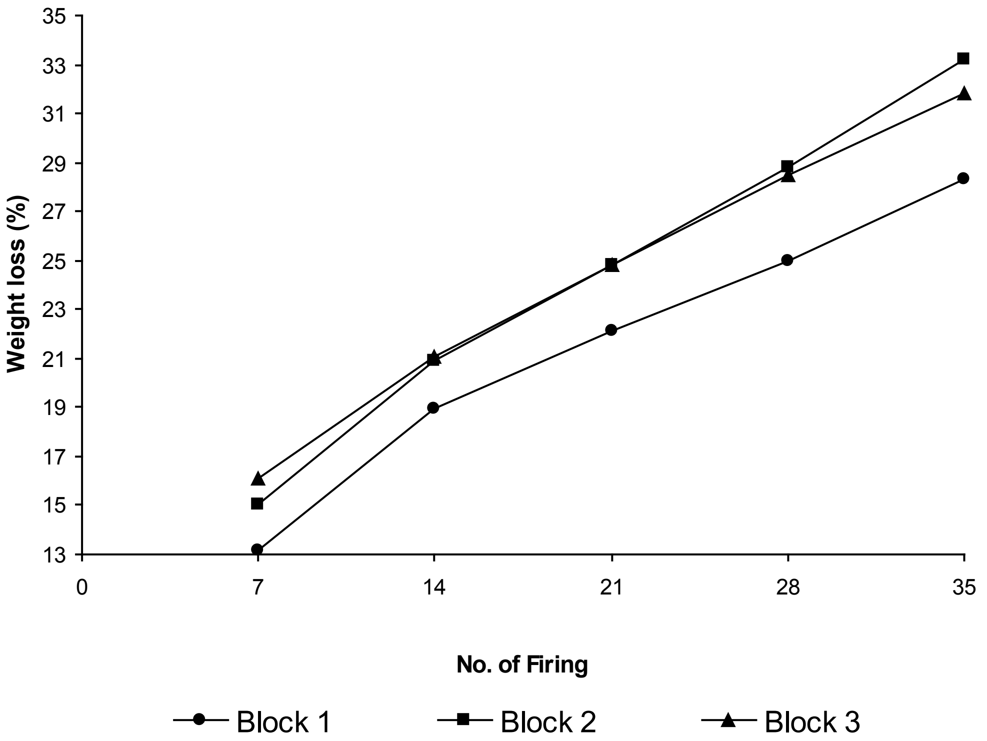

Figure 2. Average weight loss after different firing at each block

of the Block-1 was significantly ($p<0.05$) lower than those of the Block-2 and Block-3. However, no significant difference was found between the mean temperatures of the Block-2 and the Block-3 (Figure 1). The difference in the mean temperature of each block could be due to an imbalance between the air flow rates of the two convection cycles occurring from the front and back of the chamber (Leon et al., 2002; Cardenas, 1968). The observed non uniformity in the temperature distribution of the copra bed could actually lead to the non uniformity in the formation of ball copra in a given batch of coconuts. Apart from this, the non uniformity in drying could also lead to some other undesirable consequences. For instance, coconuts lying in the low heating block may be subjected to lower moisture removal. As a result, they may have higher moisture entrapped in their husk, which could make a favorable condition for them to undergo either germination or spoilage by micro flora growing on the embryo part. Once an embryo is formed in a coconut, various biochemical reactions would start to operate (Islas-Flores et al., 2000; Islas-Flores et al., 1998). This would ultimately lead to the deterioration of the kernel, making it unsuitable for ball copra.

Effect of heating on the weight loss

The weight of a matured coconut could vary from 1.0 to 2.0 kg depending on the variety. It is estimated that an average coconut of the Sri Lankan tall variety is composed of about 45% husk, 13% shell, 22% meat and 20% water (Liyanage, 1996; Peries, 1996). During ball copra formation weight loss may occur due to the moisture loss from the husk, nut shell, and the kernel. The weight loss of nuts could be influenced by factors such as condition of the drying air, air flow rate, loading density, nature of the product, etc.. In fact, loading density determines the drying capacity of the kiln compartment. But placing coconut one above the other rather than a single layer may tend to limit the area of exposure of the coconut surface to the drying air, resulting in poor drying (Leon et al., 2002). Hence, a single layer loading was preferred in this study. When considering the nature of the product, weight loss is said to be faster for fresh coconuts. Since partially dried coconuts were used in this study, the rate of loss in the weight of coconuts was comparatively lower. As illustrated in the Figure 2, the rate of loss in the weight of coconuts was higher only up to the end of 14th firing, but it tended to decrease slightly afterwards. This could be due to

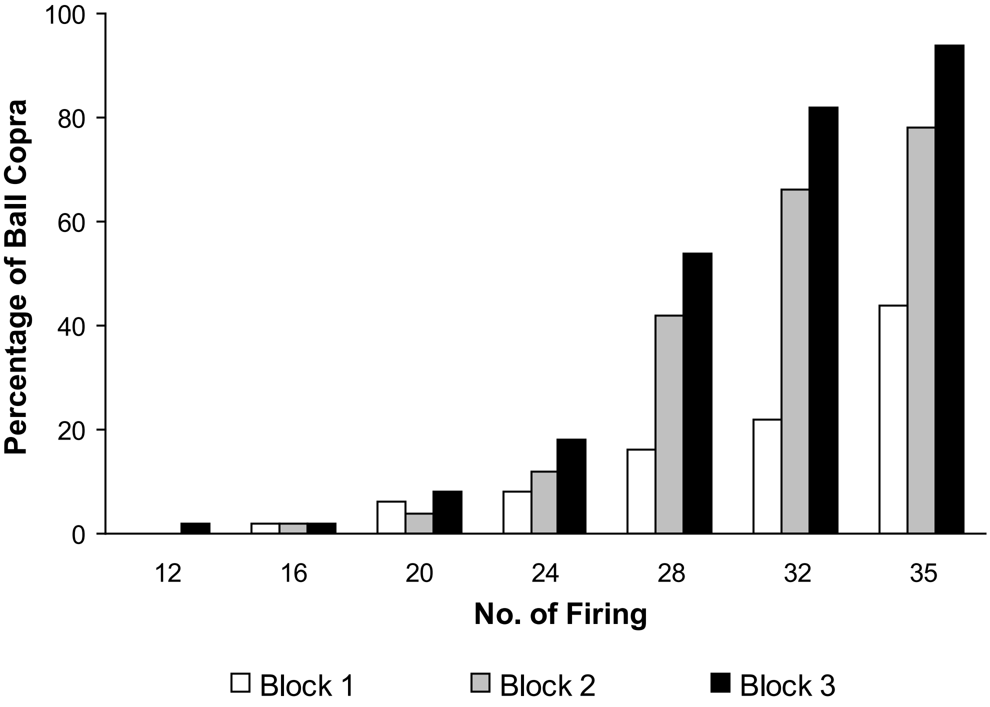

Figure 3. Percentage of ball copra formed at each block

some hindrance occurring to moisture removal at the surface of the coconut husks. In general, moisture removal could be slowed down when the surface tissues become over dried. This is usually attributed to the shrinkage of the surface cell structure leading to the reduction in the water diffusion coefficient (Fish, 1958; Leon et al., 2002). Further, it could be seen that there was a significant ($p<0.05$) effect of the temperature variation in different blocks on the weight loss of nuts. It was clear that the weight loss in the Block-1 was significantly lower than those observed in the Block-2 and the Block-3. However, there was no significant difference in weight losses between the samples in the Block-2 and Block-3. After the completion of the 35th firing, the average weight losses recorded in the Block-1, Block-2 and Block-3 were 28.35%, 33.18% and 31.88%, respectively.

Detection of ball copra formation

Determining the duration of the drying process to form ball copra is the key important parameter of this experiment. It is estimated from the time of loading fresh coconut to the kiln until when the product is recovered as ball copra. It is commonly assumed that the disappearance of the sloshing sound of the water inside the cavity of the nut is the indication of the ball copra formation. Accordingly, the first ever ball copra formation was detected in the Block-3 after the completion of the 12th firing and the amount of coconuts converted into ball copra was only 2%. But in Block-1 and Block-2, the initial detection of the ball copra was made only after the completion of the 16th firing. According to the data presented in the Figure 3, there was a steady increase in the quantity of ball copra in all three blocks from the 20th firing onwards. At the end of the 35th firing, the percentages of ball copra formed in Block-1, Block-2, and Block-3 were 44%, 78%, and 94%, respectively. The observed variation in the percentage of ball copra in different blocks is well-connected to the location specific temperature variations of the copra bed. If uniformity of ball copra formation in all three blocks is desired, it may be necessary to get a deeper insight into the shortcoming in the heat transfer mechanism of the modified-Ceylon copra kiln with special reference to its air flow rate and direction. Particularly, air flow rate and the temperature distribution pattern of the copra bed have to be monitored after making changes to the dimensions of the backside vent hole of the drying chamber.

Quality of ball copra

Since ball copra is an edible item intended for direct consumption, its quality parameters have to be comparable to those of the white edible copra. In the present study, quality specification of white edible

Table 1. Mean values of the quality parameters of ball copra and white edible copra

Parameters	Ball copra	White edible copra
Moisture content (%)	5.07	6.05
Oil content (%)	61.06	63.45
Color	Creamy White	White
*Free fatty acid content (%)	0.44	0.33
*Total plate count (Micro organisms/gram)	2,591	6,909
*Yeast & Mould count (Yeast &Mould/gram)	1962	5,273
Total ash content (%)	1.26	1.39
Protein content (%) (6.25 x N)	6.00	5.72
Sugar content (%)	5.75	4.69
*Crude Fiber Content (%)	19.99	17.82

*Parameters which showed significantly different at $p<0.05$.

copra is taken as the reference because there are no established standards for ball copra in Sri Lanka. Among the quality indices of ball copra, moisture content is the most critical as it could influence the FFA content and microbiological parameters. Hence, maintaining the moisture content below 6% would be required to ensure product acceptance and safe storage (Nathanael, 1966). According to the results presented in Table 1, there were no significant ($p>0.05$) differences between ball copra and white edible copra with regard to moisture, oil, sugar, total ash, and protein contents. However, significant ($p<0.05$) differences were noted with respect to FFA content, crude fiber content, total plate count and the yeast and mould count. Particularly, the total plate count and the yeast and mould count of ball copra were lower mainly due to the fact that the ball copra processing is done using whole nuts without removing the husk and hence, the possibility of microbial contamination is very low. Moreover, the difference in processing method could also have some beneficial effect on sensory attributes such as color and smell. Usually, in the normal processing of edible cup copra frequent mixing up of drying coconut cups are required in order to reduce discoloration and over burnt patches (Thanaraj et al., 2006). As could be seen from the Table 1, color of the ball copra was creamy white indicating its superiority over the white edible copra. This also could have some definite influence on the consumer acceptance.

Conclusions

This study demonstrated that the ball copra formation could be expedited through a method of kiln drying. With kiln drying, the time duration for ball copra formation could be reduced from seven months to about two months. Quality analyses showed that the ball copra formed by kiln drying is comparable to edible white copra in terms of the physico-chemical and microbiological parameters. With regard to drying, there were location specific temperatures variations in the copra bed of the modified-Ceylon copra kiln that lead to the non uniformity in the drying of coconuts. In order to facilitate a uniform distribution in ball copra formation, the air flow and ventilation of the modified-Ceylon copra kiln is needed to be readjusted.

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