SELECTION OF AN IDEAL MESH SIZE FOR THE CRACKING UNIT OF A PALM KERNEL PROCESSING PLANT

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ABSTRACT
One of the main problems associated with cracking of palm nut is the mixture of small Tenera and the big Dura variety nuts. In general, low yield of about 40% is obtained from cracking the mixture of Dura-Tenera nuts. In cracking the mixture, most of the Tenera nuts are not cracked when a large sieve size is used. When the sieve size is small, the Dura kernels get broken, thereby affecting the quality of the processed kernel oil. Hence the objective of this work was to develop a model for selecting a suitable sieve size that can be used to crack the nut in order to increase productivity and also improve the quality of the palm kernel oil. Series of experiments carried out confirmed the need for separation of nuts before cracking and also the need to select an ideal sieve size for each type of nut. In conclusion, it was established that separating the two nut varieties before cracking led to a significant ($p< 0.01$) increase in cracking efficiency of up to about 90% thereby increasing the productivity by 40% and making an economic gain of GH¢ 1.07 (US$0.98, October, 2008) per every 50 kg nut processed.

Keywords: *Cracking efficiency, Dura nut, Oil palm, Mesh size, Tenera nut*

INTRODUCTION

The different varieties and types of the oil palm (*Elaeis guineensis*) can be distinguished with respect to the quantity and quality of the extractable oil. A simple classification is based on its internal structure, especially the thickness of its shell. The fruit may belong to one of the following three varieties; namely Dura, which has a shell thickness of 2 mm to 8 mm; Tenera, which has a thin shell of 0.5 to 4 mm thick and Pisifera, which is shell-less and has little commercial use. The Pisifera is mostly used in the breeding of commercial palms (Asiedu, 1990).

Evidence from both scientific and empirical research suggests that about 25 percent of food grown in the tropics is lost before it can be utilised (Adzimah and Seckley, 2009). Indeed post harvest losses represent the waste of all human energy and other inputs expended in the cultivation and harvesting of the crop. Processing of crops, therefore, is a widely acknowledged alternative approach, which can be used as an effective means of reducing post harvest losses (Oke, 2007).

Palm oil, which is derived from the outer pulpy layer of the palm fruit, is composed mainly of palmitic acid (a saturated fatty acid) and oleic acid (an unsaturated fatty acid) (Geoffrey, 2003). Both acids are roughly in equal proportions. On harvesting, fats in the mesocarp of the palm fruit constitute 70 – 75 per cent of the dry matter. In addition, there is about 1 percent palmitoleic acid, and traces of lauric and lanoline acids (Koya and Faborode, 2006). Apart from the fatty acids, the major constituents of palm oil are the fat-soluble carotenoids, chiefly carotene, which gives the palm oil its red colourations. The carotene content can be as high as 1000 ppm (parts per million). The carotenoids are responsible for the high amount of vitamin A in palm oil (Koya and Faborode, 2006).

The two main products obtained from palm kernels besides the hard shells are the palm kernel oil and palm kernel cake. The characteristic feature of palm kernel oil is its high content of saturated fatty acids, primarily lauric acid. Due to its high proportion of saturated fatty acids, palm kernel oil does not readily turn rancid (Bergert, 2000).

One major problem associated with the processing of palm kernel is how to obtain greater yield that depends on the quality of cracked nuts, which is affected by the process of cracking the nuts. This problem mainly occurs when different types of kernel are mixed together for cracking, that is, when the bigger Dura nuts are mixed with smaller Tenera nuts (Boateng *et al.*, 2008).

Dadzie, (2007), redesigned and mechanised the layout of the cracking unit of an existing oilseed processing machine being used by the Golden Web factory Ltd, Suburb of Kumasi to improve its productivity. It was noted that, using the new design of two sieve sizes in the factory (small and large) for the cracking of the separated varieties increases the efficiency (6 - 15%). That is, when the large Dura nuts outnumber the smaller Tenera nuts, the latter comes out as uncracked nuts among the mixture of shell and kernel. Greater yield could therefore be achieved for the cracking of the nuts, if the nut can be separated into different sizes and cracked separately using an ideal sieve size. Hence the objective of this work is to develop a model that can be used to select a suitable sieve size for cracking palm kernel depending on the variety so as to increase production efficiency and increase the quality of the palm kernel oil.

In this study, it was established that separating the Dura and Tenera nut varieties before cracking resulted in a significant ($p < 0.01$) increase in cracking efficiency of up to about 90%. Thus increasing the economic productivity by almost 40%.

MATERIALS AND METHODS

The kernels were cracked using a locally manufactured cracker. The cracking machine is capable of cracking about 12 tonnes of kernel in 24 hours of continuous operation. After cracking, the feed stock is winnowed to remove the dust in the shell/kernel mixture for easy and efficient separation to take place. Figure 1(a) shows fixed impellers of the cracking machine.

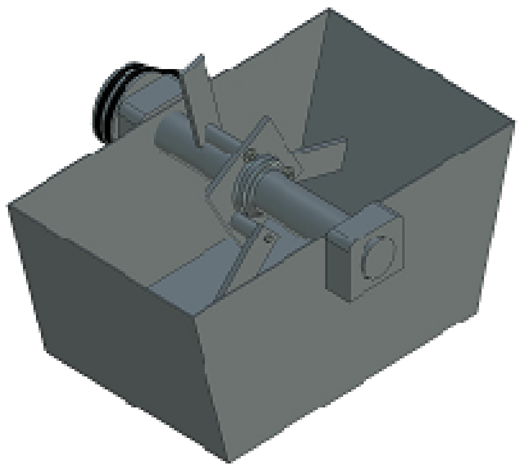

Figure 1(a)

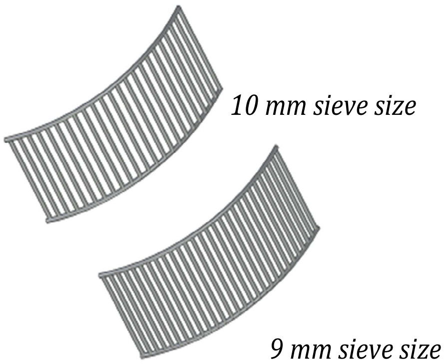

Figure 1(b)

Figure 1: Inner parts of the cracking machine showing (a) the impellers and (b) two of the designed sieves used for the Experiment

The separation of the kernel from the shells is done using the clay bath method. The clay-water concentrate is mixed in large pots into which the shell-kernel stock is poured and stirred by swirling action for about three minutes for the kernel to float and the shells to sink to the bottom. The suspended kernel is scooped and washed for further processing while the shells are collected from time to time. The shell is used as fuel to fire the boiler or to dry the kernel.

Series of experiments were performed to establish the need for separating the nuts before cracking by selecting an ideal sieve for each of the constituents. The experiment was performed using weighing scales, cracking machine with the provision to change the sieves and a constant speed of 1500 rpm, and a clay-bath. The palm nuts were weighed and then introduced into the machine. The cracking action occurs when the nuts are fed to the rotating impeller which hits the nuts and through its centrifugal force, cracks it. Five different mesh sizes (9, 10, 12, 13 and 15 mm) were used for the initial experiment. After the model development, the identified appropriate sieve sizes of 10 and 14 were used to crack the Tenera and Dura nuts, respectively. Figure 1(b) shows sieve size 9 and 10 mm used to perform the experiments.

Determination of suitable sieve size

Three sacks full of 50 kg each of the Dura-Tenera mixture were separated into Dura nuts and Tenera nuts only. Each variety containing 50 kg was cracked using the sieves of 9, 10, 12, 13, and 15 mm mesh size. After cracking, the clay bath system in a pot was used to separate the kernel from the shells. A kernel yield (W_1) and shell fraction (W_2) in grams from the sample were collected for each of the varieties and sieve size combination and analysed to find the cracking efficiency. The kernel yield samples were separated into uncracked nut (W_3) and broken kernel (W_4). The shell samples were also separated into the shell (W_5) and the whole nut (W_6).

Estimation of cracking efficiency, percentage broken kernel and whole nut in shell

The cracking efficiency, (σ), is defined as the fraction of the quantity of non defective kernel over the total kernel sample.

This can be computed as

$$\sigma = \left[1 - \left(\frac{w_3 + w_4}{w_1}\right)\right]100\% \quad (1)$$

The percentage broken kernel (α) is defined as the fraction of the broken kernels in the kernel sample. This is expressed as

$$\alpha = \frac{w_4}{w_1} \times 100\% \quad (2)$$

The percentage whole nut in the shell sample (β) is also defined as quantity of whole nuts in the shell sample. This is expressed

$$\beta = \frac{w_6}{w_2} \times 100\% \quad (3)$$

Evaluation of appropriate sieve size

To ascertain the results for the production of the palm kernel oil, a sack of 50 kg Dura/ Tenera nuts mixture were divided into three equal parts and labelled samples A, B and C. Sample A was separated into the Dura nuts and Tenera nuts. The Dura nuts were cracked using a sieve with a size of 14 mm mesh based on the identified appropriate mesh size established which falls within the range selected for the Dura nuts while a sieve with a size of 10 mm mesh was also used to crack the Tenera nuts which also falls within the range selected for the Tenera nuts. The Dura-Tenera mixture of Sample B were cracked using a sieve with a size of 10 mm mesh while the Dura-Tenera mixture of Sample C were cracked using a sieve 14 mm mesh. For the sample A, after cracking the two types of nuts, they were then combined to represent the value for sample A. The cracking efficiency, the percentage broken kernel and the percentage whole nut in shell were determined for each sample. These processes were repeated for four (4) additional sacks of Dura/Tenera nut mixtures. Analysis of variance was used to determine differences in cracking efficiency, percentage broken kernel and percentage whole nut in shell for each sample.

RESULTS AND DISCUSSION

Appropriate sieve size

Using the 9 mm mesh size sieve, the results obtained for the Dura-Tenera mixture were 146 g for the whole kernel in nut and 264 g for the broken kernel, which leads to low quality and low efficiency. This is illustrated in Table 1.

Table 1: Different kernel fraction yield obtained by using various sieve sizes for different nut types

Type of Nut	Sieve Size (mm)	Uncracked Nuts W_3 (g)	Broken Kernel W_4 (g)	Whole Nut W_6 (g)
	9	146	264	18
	10	120	270	24
Mixture	12	103	277	38
	13	74	301	44
	15	70	344	61
	9	6	415	19
	10	18	358	21
Dura Nut	12	36	256	24
	13	58	173	17
	15	67	122	8
	9	21	48	18
	10	33	99	33
Tenera Nut	12	67	128	54
	13	135	150	62
	15	208	170	74

Separating the mixture into the Dura and the Tenera nuts, gives a high quality and high efficiency for the Tenera nut but low quality and low efficiency for the Dura nut. However, using the 15 mm mesh size sieve, the results obtained for the Dura/Tenera mixture were 70 g for the whole kernel in nut and 344 g for the broken kernel, which also leads to low quality and efficiency. But, separating the mixture into the Dura and the Tenera nuts, gives a low quality and efficiency for the Tenera nut but high quality and efficiency for the Dura nut. Similarly the weight of whole nuts lost to the shell for the Dura nuts was found to be 19 g when using the 9 mm mesh size sieve but decrease dramatically to 8 g when using the 15mm mesh size sieve. Conversely, for the Tenera nut, 18g was obtained for 9 mm whilst 74 g for the 15 mm mesh size sieve. The nuts lost to the shells in the mixture were found to be 18 g and 61 g for the 9 mm and 15 mm respectively. Hence separating the mixture and selecting an ideal sieve will increase the efficiency and the quality of the palm kernel oil.

Figure 2 illustrates the relationship between sieve size and the cracking efficiency for the separate Dura and Tenera nuts and their mixture. The cracking efficiency for the Dura nuts was found to increase from 47.38% to 76.38 % while the cracking efficiency for the Tenera nut decreases from 91.38% to 52.75%. The mixture gave the lowest value indicating that majority of the smaller size nuts pass through the sieve without cracking or the larger size nuts were broken.

For the mixture, the cracking efficiency increases with sieve size up to 12 mm and then decreases. This means that using the smaller sieves, majority of the kernel are broken due to the presence of the Dura nut and also using the larger sieve size, the Tenera nuts escape through the mesh size without cracking. This contributes to low yield of kernel production during the cracking of Dura-Tenera nuts mixture. However, the 12 mm mesh size is an optimum sieve size suitable for the mixture. From the results, it is advisable to separate the nuts into its constituent before cracking. Also since the broken kernel contributes to the oil quality and the cracking efficiency, σ; it is important to determine its effect on the selection of the sieve size for each type of nut.

The relationship of the percentage broken kernel to the sieve size is presented in Figure 3. For the Tenera nuts, the percentage broken ker-

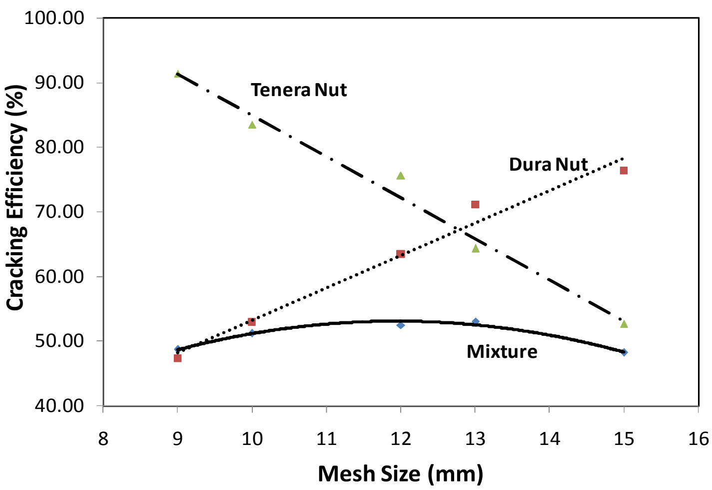

Figure 2: Cracking Efficiency of separate Dura and Tenera and their mixture using different sieve sizes

nel increases with increasing sieve size but decreases with increasing sieve size for the Dura nut. Thus indicating that using a small sieve size for the Dura nut will decrease the quality of oil obtained from the production of the palm kernel oil.

Figure 4 illustrates the loss of the kernel to the shell as given by the percentage whole nuts in shell. This is influenced by the sieve size as presented. The mixture and Tenera nuts only, shows the percentage whole nut in shell increases with increasing sieve size. However for the Dura nuts, the percentage whole nut lost to shell increases up to a sieve size of 12 mm mesh size and then decrease to the mesh size of 15 mm. This indicates that using the larger mesh size, many of the Tenera nuts will pass through the sieve. However, this will increase the quantity of uncracked nut lost to the shell

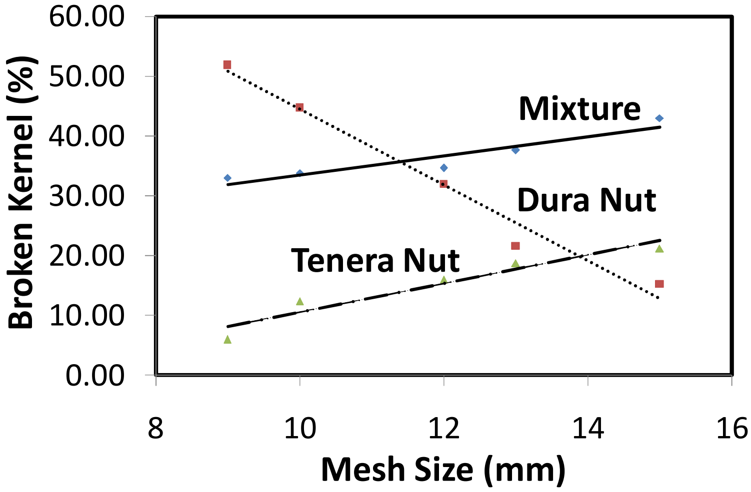

Figure 3: Percentage broken kernel of separated Dura and Tenera and their mixture using different sieve sizes

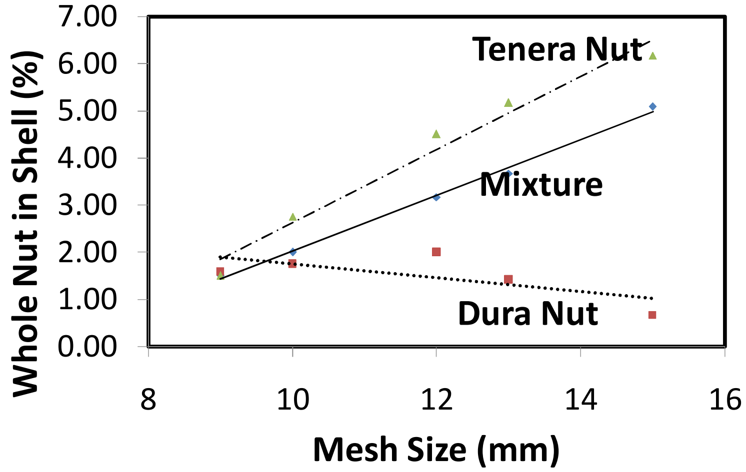

Figure 4: Percentage nut in shell of separated Dura and Tenera and their mixture using different sieve sizes

thereby reducing the amount of oil produced.

It is evident that the cracking efficiency, the percentage broken kernel and the percentage whole nut in shell are affected by the sieve size. The choice of sieve size also depends on the palm nut variety or the mixture. Hence, a model was developed relating the three efficiencies to the sieve size so that the point of intersection for the three can be used to select the appropriate sieve size for nut type or mixture. Since the computed values obtained for the three efficiencies have a wide range, the result for each efficiency were normalised by dividing each value by the least value. The computed normalised values for the three efficiencies for the Tenera nuts and Dura nuts are presented in Figures 5 and 6.

From Fig. 5, it is seen that the cracking efficiency line intersects the percentage broken kernel and the percentage whole nut in shell at almost the same point with a mesh of size 9.6 mm. The percentage broken kernel intersects the percentage whole nut in shell at the point where the mesh size is 10 mm. This means that, for a high production rate and high quality oil, a sieve with a size between 9.5 mm and 10 mm mesh size is ideal for the cracking of the Tenera nuts after the separation of the two nuts. Hence a sieve of 10 mm mesh size was used to evaluate the cracking efficiency, percentage broken kernel and percentage whole nut.

From Figure 6, the cracking efficiency line intersects the percentage broken kernel and the percentage whole nut in shell at the points where sieve sizes are 14.5 mm and 15.5 mm respectively. The percentage broken kernel curve also intersects the percentage whole nut in shell at the point where the sieve size is 13.5 mm. This means that, for a high production rate and high quality oil, a sieve with a size between 13.5 mm and 15.5 mm is ideal for cracking Dura nuts after the separation of the two nuts. Therefore a sieve of 14 mm mesh size was used to evaluate the cracking efficiency, percentage broken kernel and percentage whole nut.

Evaluation of cracking efficiency, percentage broken kernel and percentage whole nut

Table 2 presents the ANOVA for cracking efficiency (CE), broken kernel (PBK) and whole nut (PWN) in shell percentages for separate Dura and Tenera nuts and their mixture. Out of the 50 kg sample split into three equal parts of A, B and C, the sample A was cracked using sieve of 14 mm and 10 mm for the separated Dura and Tenera nuts, respectively; and the mixture of Dura-Tenera cracked with sieve size of 10 mm and 14 mm for sample B and C, re-

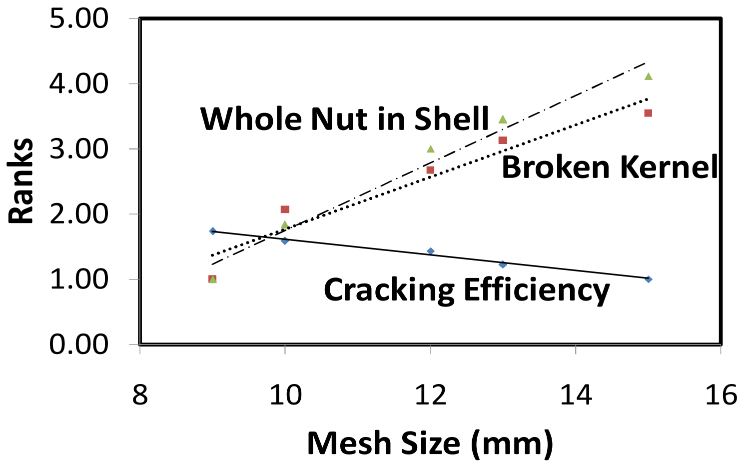

Figure 5: Normalized cracking efficiency, broken percentage and whole nut in shell variation with sieve size for the Tenera nuts

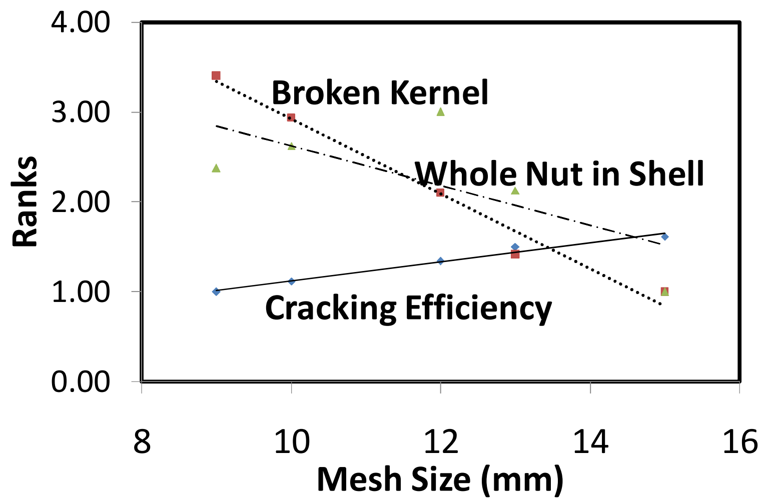

Figure 6: Normalized cracking efficiency, broken percentage and whole nut in shell variation with sieve size for the Dura nuts

spectively. The analysis shows significant differences in CE, PBK and PWN for the different sample types.

Table 2 shows a significantly ($p<0.01$) higher cracking efficiency for separated nuts sieve with appropriate sieve size (Sample A) compared to the mixture separated with any sieve size (Sample B or C). Also, the broken kernel percentage and whole nut in shell are significantly lower for separated nuts sieved with appropriate sieve size (Sample A) compared to the mixture separated with any sieve size (Sample B or C). Thus indicating that when the Dura-Tenera nuts mixtures are separated and an ideal sieve size is selected for the cracking, the cracking efficiency increases to almost 90%, thereby increasing the production by 40%. Also the percentage broken kernel is reduced to a value of 4.3% and this will lead to increase in palm kernel oil quality.

COST BENEFIT ANALYSIS

Given an expected kernel oil yield of 16.33 %

Table 2: Cracking efficiency, broken kernel and whole nut in shell in percentages for different samples

*Sample	Cracking Efficiency (%)	Broken Kernel (%)	Whole Nut in Shell (%)
A	87.5	4.3	5.7
B	43.4	12.7	8.4
C	59.7	8.9	5.1
Significance level	0.00	0.00	0.00
LSD	1.648	1.034	0.705

*Sample A (separated Dura and Tenera sieved with 14 mm and 10 mm, respectively); Sample B (mixture of Dura-Tenera sieved with 10 mm); and Sample C (mixture of Dura-Tenera sieved with 14 mm)

Table 3: Lost Income per 50 kg unseparated Dura-Tenera nut Mixture

	Oil (kg)	Unit Price GH¢	Amount GH¢
Expected income per 50 kg nut (16.33 %)	8.17	1.2	9.80
40 % oil lost due to not separating nuts and sieving with 10 mm mesh (A)	3.27	1.2	3.92
Additional labour cost for separating 50 kg nut (B)			2.85
Lost of income per 50 kg nut (A-B)			1.07

with a standard deviation of 0.77 and using five replicates each for separated Dura, and Tenera and the mixture of nut and the unit price of GH¢1.20 per kg of kernel oil then it can be estimated that one expects a reduced income of GH¢1.07 (Table 3) if the 50 kg Dura-Tenara mixture is not separated and sieved with 10 mm mesh size. This could amount to a reduced income of over GH¢20.00 if one processes on the average twenty 50 kg bags daily. However, sieving with a 14 mm mesh may not lead to any income reduction.

CONCLUSION AND RECOMMENDATION

This study establishes the need to separate nuts before cracking and also selecting an ideal sieve size for each type of nut. To obtain high production efficiency and good quality oil, a mesh size from 13.5 mm to 15.5 mm is ideal for the cracking of the Dura nuts and 9.5 mm to 10 mm mesh size is ideal for the cracking of the Tenera nuts after the separation.

Separating the Dura-Tenera nuts mixture into Dura nuts and Tenera nuts and selecting an ideal sieve size for each type of nuts increases the cracking efficiency by 40%. The consequent increase in palm kernel oil production is high enough to offset the additional cost incurred in separating the nuts. Separating also gives a better oil quality since the amount of broken kernel is reduced by as much as 6 %.

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