Design, Development and Evaluation of Minimal Processing Machine for Tender Coconut (*Cocos nucifera*)

by

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Abstract

This research involved designing and developing a prototype for minimal processing of tender coconut that could trim the outer husk to make a pentagonal shape coconut that could be cut open easily. The prototype consisted of a trimming unit and a power transmission system. The trimming unit consisted of a tender nut holder, shoulder-trimming knife, and bottom cutting knife. Shoulder trimming knife was set to the angle of 60° giving rise to minimum fibrous surface and short processing time. During operation, the tender coconut was placed vertically at the holder and clamped before the shoulder trimming took place. When the fruit rotated, the operator manually adjusted the trimming blades to trim the shoulder part of the fruit. The results show that the coconut trimming machine could trim 160 tender nuts. h^{-1} with a trimmed husk of 52.56 kg/h when the rotational speed was set at 428 rpm.

Introduction

Tender coconut water is a pure and healthiest natural beverage with many medicinal properties. The husk and hard shell of coconut is an exceptional package for the inside water which contains essential minerals, sugars, complex carbohydrates, ascorbic acid and vitamin-B complex, amino acids, phytohormones, electrolytes and cytokine (Harach and Jarimopas, 1995). It is an alternative to sports drinks and aerated beverages and low in calories. According to Sports Science Institute (USA), tender coconut water suitable for the budding sports drink market. Due to high perishable nature of tender coconut, it gets lost natural freshness within 24 to 36 h even under cold conditions unless treated scientifically (Geetha et al., 2016). Maturity and development of the tender coconut also strongly affects the fruit quality (Jarimopasa and Kuson, 2007).

The tender coconut is a bulky commodity due to husk that poses lot of transportation, packaging and handling problems. The average tender coconut weight is 1.5 kg of which the husk constitute of two-third of the volume of tender coconut or 65% of the total weight (Raju et al., 2002; Haseena et al., 2010). Hence, handling of tender coconuts will be easy if a major part of the husk is removed. But, the partial removal of husk resulted in rapid spoilage of nuts due to biochemical and enzymatic reactions are constrains in marketing of trimmed tender coconut in areas where coconut not grown (Haseena et al., 2010). To retain the wholesomeness, freshly harvested tender coconuts are transported to the processing house for trimming of individual nuts. The tender coconuts should be minimum six months old and the trimming process should allow the husk at least 1 cm thickness over the soft eye for minimal processing of tender coconut (Mohpraman and Siriphanich, 2012). The tender coconut is usually trimmed like pentagonal shape (conical shaped top with tapered cylindrical body and a flat base) to remove 50-60%

of the outer husk, and then shrink wrapped before being packed in corrugated boxes. The technology for preservation of trimmed tender coconut developed by Raju et al. (2002) involves dipping partially dehusked tender coconut in a citric acid (0.50%) and potassium metabisulphate (0.50%) solution for three minutes. They found that dipped tender coconut can be stored up to 24 days in refrigerated condition (5-7 °C). By using this process, tender coconut can be exported to distant place and served like other soft drinks.

Minimal processing of tender coconut reduces transportation cost and facilitates ease of packaging. Conventional trimming process requires skilled labour to shear the husk of tender coconut with sharp knife (Jarimopas and Ruttanadat, 2007). Hence, it is requires significant physical strength and extremely dangerous procedure. Other troubles related with conventional trimming process are the shortage of skilled labour, product is not uniform size, high production cost, and the time consumption (Yahya and Mohd Zainal, 2014). Consequently, several food engineers and coconut growers have attempted to develop tender coconut trimming machine (Harach and Jarimopas, 1995; Jarimopas and Pechsamai, 2002; Jarimopas and Ruttanadat, 2007; Jarimopas et al., 2009). Unfortunately, their machines were unacceptable by farmers, processors, exporters and traders due to low trimming capacity and complicate procedure involved during trimming process. Jarimopas and Ruttanadat (2007) developed a machine to trim tender coconut by horizontal lathe cutting mechanism. However, most of the operating time was wasted to reposition of the tender nut and readjustment of trimming knife for each trimming operation (Jarimopas et al., 2009).

In fact, many coconut growers, traders, exporters and entrepreneurs have expressed the interest to have machinery that is able to trim the tender coconut into a pentagonal shape (flat bottom, round body and pyramid top) as fast as can currently be done by labor. Therefore, there is an urgent need for minimal processing machine to trim the tender nuts in simple and safer way. The main aim of the present study was development and performance evaluation of minimal processing machine for tender coconut with vertical holding and trimming mechanism.

Materials and Methods

Raw Materials

Freshly harvested tender coconuts were obtained at Farm Office, Central Plantation Crops Research Institute (CPCRI), Kasaragod. Knowledge on the physical properties of the coconut was substantial in designing the tender coconut trimming machine. Hence, 50 of intact tender coconuts from west cost tall (WCT) variety were selected and measured to determine the diameter, height and husk thickness of each tender coconut using the vernier caliper. It is important to ensure that the tender coconuts were free from physical damage beforehand. Each tender coconut was dehusked manually to determine the husk thickness.

Machine Design

The design concept was to trim the vertically rotating tender coconut by applying an inclined knife in translation motion in order to get the desired shape of the tender coconut. The tender coconut trimming machine consisted of a main frame, spring arm, sliding slot, tender coconut holder, a shoulder trimming knife, a bottom cutting knife and power transmission unit. **Fig. 1** illustrates the engineering diagram of the machine and its important components.

The horse power of motor required to rotate tender coconut holder was calculated by using the following formula (Khurmi and Gupta, 2006),

Hp required to operate tender coconut minimal processing machine = $2\pi NT / 4500$

Where,

N= rpm of tender-nut holder,

T= Torque, kg-m,

Self weight of the spring arm = 4.5 kg

Average tender coconut weight = 1.2 kg

Force required to trim the tender coconut (0.4 cm) = 19.8 kg

Diameter of tender coconut holder = 0.09 m

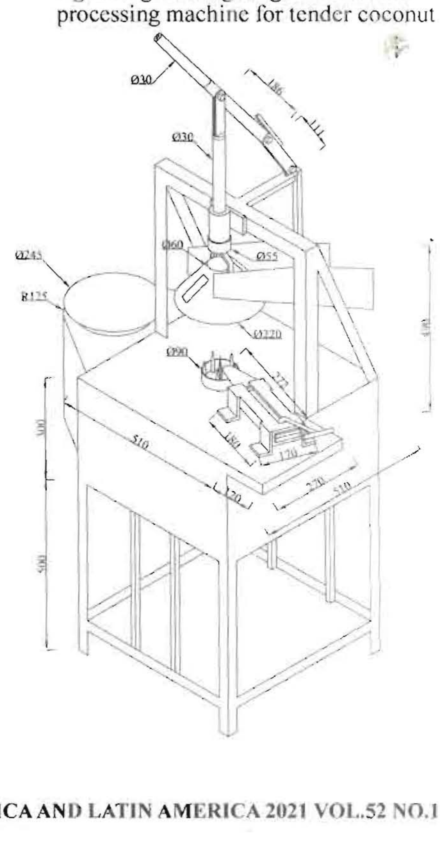
Speed of tender coconut holder = 450 rpm

Torque required = load × distance = 25.5 × 0.09 = 2.295 kg m

Hp required to operate tender coconut trimming machine = $(2\pi NT \times 2.295 \times 450) / 4500$ = 1.44 hp ≈ 1.5 hp

The machine was driven by a single phase electric motor. An AC motor of 1.5 hp with maximum speed of 1,425 rpm was used. However, around 400 to 450 rpm was normally applied for trimming the

Fig. 1 Engineering diagram of minimal processing machine for tender coconut



tender coconuts (Yahya and Mohd Zainal, 2014).

Calculation of diameter of pulley required to rotate tender coconut holder

$D_1 N_1 = D_2 N_2$

$N_1 / N_2 = D_2 / D_1$

Where,

D_1 = Driving pulley diameter (mm)

N_1 = Revolutions of driving pulley (rpm)

D_2 = Driven pulley diameter (mm)

N_2 = Revolutions of driven pulley (rpm)

$1425 / 450 = D_2 / 75$

Diameter of driven pulley = 237.5 mm

The standard size of pulley available in market is 250 mm. Hence, the bottom holder rotates at 428 rpm.

The bottom holder consisted of a circular platform in the middle and was surrounded by six peg teeth. The top holder comprised a handle, a spring arm, sliding slot and a cone. The spring arm with sliding slot was used to clamp the top portion of tender coconut based on the height of tender coconut. The function of cone was to tighten the top portion of tender coconut. A shoulder trimming knife attached on the cone to perform the trimming operation. According to Yahya and Mohd Zainal (2014), high carbon stainless steel blade was best to undertake the trimming process. Hence, we used high carbon stainless steel blade to trim the shoulder part and to cut the bottom portion of tender coconut. The most suitable angle of the shoulder trimming knive (60°) were determined according to the short trimming time, appearance and defect rate of the final trimmed tender coconut. The AC motor (1.5 hp, single phase, 1,425 rpm, 50 Hz, 220/230 V) was attached through V belt to drive the bottom holder. About 250 mm diameter pulley was used to reduce the rpm of 1,425 to 428.

Fig. 2 Performance evaluation of developed tender coconut trimming machine

Performance Evaluation

To evaluate the performance of the machine, WCT was chosen as the test variety. A total of 100 freshly harvested WCT coconuts were obtained from Farm Office, Central Plantation Crops Research Institute, Kasaragod. To evaluate the machine performance, 50 intact tender coconuts, which have uniform shape and size, were selected. The tender coconuts were trimmed continuously using the prototype minimal processing machine and the performance of the machine was evaluated. The production rate was calculated based on the finished produce capacity per hour whereas product quality was evaluated in terms of appearance of the final trimmed coconut.

A single operator was required to perform the trimming operation. Once the tender coconut was fitted with the holder, the operator starts the trimming process (**Fig. 2**). During the trimming process, the shoulder part of coconut trimmed first and then the high carbon stainless steel knife was used to penetrate the husk of the rotating tender coconut thus resulting in a cutting of bottom portion of the tender coconut. At the end of the trimming process, machine capacity was measured and percentage of defects was calculated using fallowing equations (Jarimopas and Ruttanadat, 2007).

Machine capacity = Number of trimmed tender coconuts / Time taken (1)

Percentage of defects = Number of broken product + Unsuccessful trim product / Total number of trimmed tender coconut (2)

Results and Discussion

Physical Properties of Tender Coconuts

The average height and diameter of intact tender coconut were 16.10 ± 0.87 cm and 12.51 ± 0.89 cm respectively (**Table 1**). The physical properties were the substantial data which determined the design of the tender coconut holder and trimming knife position and angle settings (Jarimopas et al., 2009). Generally, the upper husk thickness was higher than the bottom husk thickness of all samples. However, left and right sides husk thickness of the tender coconut vary and predominantly depended on the shape of the tender coconuts. Even wide variation

Table 1 Important physical properties of tender coconut (Variety - WCT)

Property	Mean ± SD	Maximum	Minimum
Tender coconut height	16.10 ± 0.87	17.2	14.2
Tender coconut circumference	39.29 ± 2.81	43.50	33.50
Tender coconut diameter	12.51 ± 0.89	13.85	10.67
Thickness of husk at top (stem to shell)	5.05 ± 0.36	5.8	4.4
Thickness of husk at right side	2.88 ± 0.23	3.2	2.4
Thickness of husk at left side	1.94 ± 0.30	2.6	1.6
Thickness of husk at bottom (shell to base)	3.20 ± 0.21	3.6	2.9

in tender coconuts shape, size and husk thickness exist within types and populations (Chan and Elevitch, 2006).

Performance Evaluation

The distance between top and bottom holder of tender coconut was designed according to the average height of WCT variety (160 mm). In order to hold the different variety of tender coconuts including Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD), Malayan Orange Dwarf (MOD) and Malayan Yellow Dwarf (MYD) an additional of 80 mm height was provided. Hence, the total clearance provided between top and bottom holder was 240 mm. Jarimopas et al., (2009) provided shoulder knife height of 180 mm for trimming of "Namhom" variety.

The average holding time taken by the operator to set the tender coconut was 11 s nut^{-1}. This was considered as time consuming as the operator had to manually positions the tender coconut. A total of 2% of the coconuts were damaged during the trimming process due to broken shell as a result of excessive trimming. The optimum operating conditions of the prototype machine were as follows: a) 428 rpm rotational speed; b) the trimming knives need to be changed or sharpened after 80 tender coconuts had been trimmed; c) average shoulder trimming time (machine) was about 9 s/nut; d) average bottom-up cutting time (manual) was about 3 s/nut. The total processing rate of this prototype machine was 160 nuts per hour including the holding, trimming and bottom cutting, which was almost four times faster than conventional manual trimming method. Moreover, the trimmed tender coconut produced by unskilled labors during manual trimming was not presentable due to uneven contour (Yahya and Mohd Zainal, 2014), whereas the developed machine managed to trim the tender coconut uniformly. A shoulder knife angle of 60o gave the best result in terms of final product quality. Jarimopas and Ruttanadat (2007) also found that shoulder knife angle between the knife and the XY-plane (61°) gave the best result in lathe cutting machine mechanism.

As shown in **Fig. 3**, the output of tender coconut using prototype machine had less protruding fibre and there were no marked differences in terms of appearance compared to manual trimming. In comparison with the previous work done by Jarimopas and Ruttanadat (2007) and Yahya and Mohd Zainal (2014), their prototype machine could trim 21 and 49 nuts per hour at 300 and 400 rpm rotation, respectively (**Table 2**).

Fig. 3 Trimmed tender coconut

Conclusion

A prototype of semi automatic tender coconut trimming machine was developed and evaluated. The mechanism used features a sharp inclined knife which operates in translation motion in a vertical plane to trim the fruit, which is clamped tightly and rotates about a vertical axis. Machine components include a main frame, a shoulder-trimming station, a base-cutting station, rotary base holder, and a power drive. Optimal settings included 428 rpm rotation of the trimmed fruit, and a shoulder knife angle of 60°. The cutting edge angles of the shoulder knives have proven to generate smooth trimming with less protruding fibres on the final product. The machine performance test indicated a trimming (shoulder) and

Table 2 Comparison of tender coconut trimming machines

Method	Mechanism	Capacity (nuts. h^{-1})	Product Quality	Operation	Reference
Manual trimming method using knife	Shearing and cutting	35	Shape is depends on skills of labour	Risky operation and time consuming process	Jarimopas et al. (2009)
Young coconut fruit trimming machine	Lathe cutting machine mechanism	21	Uniform shape and size	Safe and time consuming operation (knife angles 61° produced the least amount of fibers)	Jarimopas and Ruttanadat (2007)
Young coconut fruit opening machine	Shearing the rotating trimmed young coconut by a stationary knife	120	Uniform shape and size	Safe operation (An angle of 50° was considered the optimum)	Jarimopas and Kuson (2007)
Automatic trimming machine	Vertical trimming mechanism with 3 fruit holders	86	Uniform shape and size	Safe operation and knife changes were necessary after 50 trimming operations.	Jarimopas et al. (2009)
Young coconut shaping machine	lathe trimming mechanism	49	Uniform shape and size	Safe operation but the trimming knives need to be changed after 30 trimming operations	Yahya and Mohd Zainal (2014)

cutting of bottom portion of tender coconut with total holding and trimming process of about 160 nuts per hour. About 328.5 g of husk can be removed from each tender coconut by trimming operation. The trimming knives need to be sharpened or changed after 80 fruits had been trimmed. Grading and sorting of the tender coconuts are not necessary to perform trimming operation in the developed machine, because of the large clearance (240 mm) and sliding slot between holders. The developed machine could trim the tender coconuts at higher level of efficiency compared to the manual method.

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