DOI: http://doi.org/10.4038/tare.v22i1-2.5483

*Tropical Agricultural Research & Extension* 22 (1 & 2): 2019

# INVESTIGATION OF THE VIBRATION ASSISTANCE ON THE BARK PEELING TOOL TO REDUCE THE FORCE REQUIRED FOR CINNAMON (*Cinnamomum zeylanicum*) PEELING

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## Abstract

**Cinnamon (*Cinnamomum zeylanicum*) is the predominant spice among other export crops in Sri Lanka. The bark peeling process of cinnamon requires high skilled labour and the force required is subordinate only to the bark rubbing step. Since the traditional tools used for peeling are inefficient, a study was conducted to explore possibilities of using a vibration-assisted peeling knife to reduce the required force for cinnamon peeling and to enhance productivity. Three types of eccentric rotating mass motors (RF-555, R260 and MABUCHI RF-M50WA) were fixed to induce mechanical vibrations to the peeling knife. Vibration generated from the selected motors was changed by means of frequency and acceleration through the supply voltage, and respective values were recorded by an accelerometer. Selected cinnamon sticks (diameter 3.5 cm and length 10 cm) were tested by peeling out of 5 mm width bark strip from the stick at each frequency – acceleration rate values. As a control test, sticks with similar diameter and length were peeled without the vibration assistance. The motor RF555- ERM, offered the highest advantage for the peeling force reduction (73.22% - 78.6%) when compared to the control test. The results showed that the potential of using ERM in vibration-assisted tools to reduce the bark peeling forces of cinnamon sticks.**

## INTRODUCTION

Sri Lankan cinnamon (*Cinnamomum zeylanicum*) is an imperative multifaceted crop that exists in the coastal belt of the Southern part of Sri Lanka. In the context of soil and climatic factors of cultivation areas, the unique chemical composition mixture in the plant provides various by-products for diverse types of industries (Weerasinghe *et al*. 2006). At present, nearly 30,000 ha of land is extended with Cinnamon cultivation. With the higher demand prevails for Sri Lankan Cinnamon products in the world market, ninety per cent of Cinnamon production is in the export platform (Gunarathne 2011).

Cinnamon processing steps in the processing centres can be stated as the sequence of scrapping or removing the outer corky layer from the sticks, rubbing of bark, bark peeling and quill making, which requires highly skilled full labour source (Weerasinghe *et al* 1998). Peeling bark is carried out with the use of a peeling knife a traditional hand implements. This tool consists of a sharp-edged curved blade. The shape and size of the peeling knives are very common all over the areas of cinnamon processing (Weerasinghe *et al.* 2006). According to the findings of the previous study, the peeling force known as the force needed to detach the bark from the stem was tested and illustrated. The average peeling force of peelable sticks (3.134 ± 0.97 N) and unpeelable sticks (6.766 ± 2.29 N) indicated

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significant variations (P = 0.000) to each other according to the results of the test carried out with force gauge mounted traditional peeling knife. In the same study, the peeling force was reported as the second highest force required among other steps (Bandara *et al*. 2018). With those associated difficulties, the upcoming labour shortages, especially lack of skilled labourers for processing steps has become a major threat of cinnamon industry (Pushpitha 2006). The previous attempts made for the mechanization of scraping and peeling events have not been reached up to the commercial level (Bandara *et al*. 2013). The mentioned above results pointed out that the mechanization of bark peeling process is a timely need in order to reduce the energy expenses of cinnamon peelers and improve productivity. In order to reduce bark peeling force, the application of vibration force on the peeling knife is possible when examining the various types of production process stimulated by different vibration sources. Choi *et al*. 2004 investigated the abrasive effect of a large number of bubbles formed by ultrasonic vibration in liquid medium was experimentally proved to remove the burrs on metal parts successfully. Haidong *et al*. 2016 reported that maximum cutting performance observed for cutting of high-temperature mechanical properties having Inconel 718 nickel-based alloys by Ultrasonic Elliptical Vibration Cutting UEVC method. Similar findings were reported by Shamoto and Moriwaki, 2016 about the successful application of elliptical vibration cutting technique for various difficult -to-cut materials with superior performance on high-quality surface finish, low cutting force and long tool life. With reference to the said applications of vibration force for metal cutting purpose, low frequency and power having vibrational sources can be introduced to increase the efficiency of cinnamon bark peeling process. Therefore, this study was mainly focused to investigate the application of mechanical vibration on the bark peeling knife in order to reduce the required force of bark peeling processing step.

## MATERIALS AND METHODS

### Selection of vibration source

The study was designed to test the possibility of using eccentric rotating mass vibration motors (ERM) on peeling knife to minimize the force required for peeling cinnamon sticks. Three types of ERM vibration motors, namely, RF-555 micro high-speed vibration motor, R260 vibration motor and MABUCHI RF-M50WA vibration motor were selected for the test (Table 1 and Plate 1).

**Table 1: Specifications of ERM vibration motors selected for vibration-assisted peeling of cinnamon**

| | ERM vibration motor | | |
|---|---|---|---|
| Specification | ERM motor type 01 | ERM motor type 02 | ERM motor type 03 |
| Model | RF-555 | R260 | MABUCHI RF-M50WA |
| Motor diameter | 37 mm | 24 mm | 10 mm |
| Motor height | 58 mm | 27 mm | 25 mm |
| Motor weight | 218 g | 30 g | 9 g |
| Voltage and Current | 12 V, 2 A | 7.5 V , 0.15A | 6 V, 0.11 A |
| Speed (rpm) | 5,500 | 3,000 | 26,600 |

(a) (b) (C)

(a) RF-555 - ERM (b) R260-ERM (c) MABUCHI RF-M50WA ERM

**Plate 1: Types of ERM vibration motors**

**Preparation of peeling knife and mounting structure**

Carbon steel blade mounted iron structure was assembled to the force gauge by two bearings under the modification process of peeling knife. The blade, length (6 cm) and width (1 cm) was permanently fixed with iron bracket and it was fixed to a central axle with the help of two bearings from top and bottom sides by keeping movement ability in a horizontal manner (Plate 2). This mounting process with bearings facilitates to the horizontally movable function of peeling knife, which needs to execute the continuous peeling process with shape irregularities of cinnamon stick. The setup was prepared by mounting the ERM vibration motor on the flat side of the peeling knife.

**The reference data (frequency and acceleration) of applied ERM motors**

The frequency and amplitude of the acceleration of the ERM motors were assessed using an accelerometer of a cellular phone. Reference data were recorded by applying variable rates of voltages (1.5 V, 3 V, 4.5 V, 6 V, 7.5 V, 9 V and 12 V) to the motors for changing rotating speeds.

**Performance test on the variation of peeling force with applied ERM vibration motors**

In this study, a modified peeling knife mounted on the SUNDOO – SH 500 force gauge was used to peel out cinnamon bark with the real-time recording process of peeling force data. Preselected peelable cinnamon sticks with a diameter of 3.5 cm and length of 10 cm were tested under this experiment. As represents of total five sticks for each frequency and acceleration category generated by ERM motor models (RF-555, R260 and MABUCHI RF-M50WA) were used to conduct the performance test (Plate 03). The average peeling force data required to peel out 5 mm width of the cinnamon strip were obtained in one term per stick. This process was repeated three times to get average peeling force value for one stick. As control tests, the same number of samples was tested without supplying power to each type of vibration motor. Modified peeling knife attached with a force gauge (Sundoo SH 500) was mounted on Sundoo electrical vertical test stand for the tension-compression test. Stroke speed of peeling knife movement between bark and wood was adjusted to 40 cm/min rate at the test stand. The force changes at the beginning of peeling process up to the end of each bark strip attributed to the varying contact bond of bark attached to the woody stem of sticks were graphically recorded at 10 data/s rate. With the use of SUNDOO real-time data logging interface operated through a notebook computer, the data recording process was done.

**Statistical Analysis**

According to the frequency (10 data per second ) given to SUNDOO measuring software, the stored data points were more than 200 per one bark strip (5 mm width). Unnecessary data points recorded due to operation


**Plate 2 : Modified peeling knife and accessories of the mounting structure**

handling time were filtered out. One- way ANOVA test was carried out to compare the force required for peeling cinnamon sticks under the application of different EMR vibration motors. The data were analyzed using MINITAB statistical software.

## RESULTS AND DISCUSSION

### Reference values of frequency and acceleration of ERM vibration motors

The separate frequency- acceleration values were received under the application of different voltage values to each motor type since these two parameters are collectively contributed to the output of vibration power (Table 2).

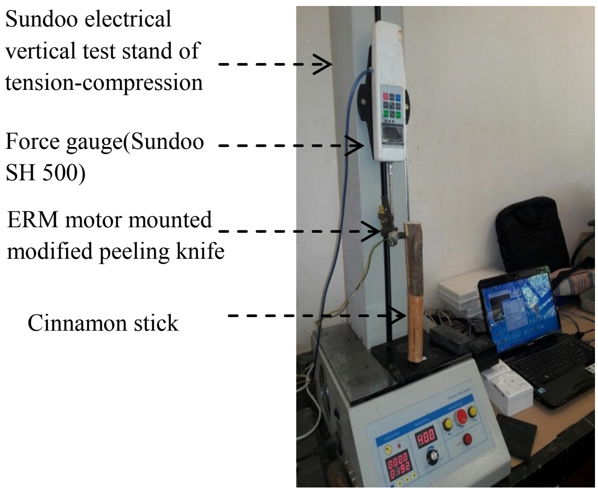


**Plate 3 : The setup used to test the performance of the modified peeling knife**

### Impact of variable frequency and acceleration of ERM motor RF-555 for reduction of peeling force

There was no significant difference among the required peeling force of 5.13 ± 0.29 N resulted by 14 Hz-0.13 ms$^{-2}$ of frequency - acceleration combination compared to the control test (Figure 01). Required average peeling force indicated as 3.92 ± 0.21 N by the 23 Hz - 0.41 ms$^{-2}$ frequency - acceleration combination and it showed a significantly higher value than the lowest peeling force values resulted by frequency - acceleration combinations of 8.5 Hz-2.4 ms$^{-2}$, 10 Hz-2.1 ms$^{-2}$ and 17 Hz$^{-2}$ ms$^{-2}$. These two facts prove that less impact on peeling force reduction by the lowering of acceleration values (0.13 ms$^{-2}$ - 0.41 ms$^{-2}$) although frequency values in higher levels (14 Hz, 23 Hz) for the ERM motor RF-555. There is no significant difference among the required peeling force of 1.14 ± 0.13 N, 1.2 ± 0.2 N, 1.43 ± 0.3 N, which caused by each frequency - acceleration combinations of 8.5 Hz -2.4 ms$^{-2}$, 10 Hz -2.1 ms$^{-2}$ and 17 Hz $^{-2}$ ms$^{-2}$. Those combinations of frequency – acceleration showed significantly lowest peeling force compared to the control test. The peeling force reduction percentages were calculated as 78.6%, 77.52% and 73.22% under the above mentioned respective frequency - acceleration combinations said above. This fact indicates that a higher possibility of application of mechanical vibration force by ERM motor RF-555 on the peeling knife in order to

**Table 2: Reference values of frequency and acceleration of ERM vibration motors under different rotating speeds**

| Operating voltage (V) | ERM motor RF-555 | | ERM motor R260 | | ERM motor MABUCHI RF-M50WA | |
|---|---|---|---|---|---|---|
| | Frequency (Hz) | Acceleration (ms$^{-2}$) | Frequency (Hz) | Acceleration (ms$^{-2}$) | Frequency (Hz) | Acceleration (ms$^{-2}$) |
| 1.5 | 8.5 | 2.4 | 2 | 0.8 | 6 | 1.5 |
| 3 | 10 | 2.1 | 5 | 1.1 | 10 | 0.5 |
| 4.5 | 10 | 2.1 | 7 | 2.4 | 20 | 0.3 |
| 6 | 14 | 0.13 | 9 | 2.5 | 20 | 0.3 |
| 7.5 | 14 | 0.13 | 9.7 | 2.6 | - | - |
| 9 | 17 | 2 | - | - | - | - |
| 12 | 23 | 0.41 | - | - | - | - |

reduce the required peeling force of cinnamon sticks.

### Impact of variable frequency and acceleration of ERM motor R260 for reduction of peeling force

All the categories of frequency – acceleration combinations showed significantly low values of required peeling force (2.49 ± 0.18 N, 2.12 ± 0.27 N, 1.31 ± 0.58 N, 1.89 ± 0.25 N and 2.29 ± 0.36 N) compared to control test (Figure 02). The percentages of peeling force reduction by application of ERM motor R260 were calculated as 42.6%, 51.15%, 69.8%, 56.54% and 47.2% under the respective frequency - acceleration combinations said above. These results revealed that ERM motor R260 has a higher possibility of using as a mechanical vibrator on the peeling knife in order to reduce required peeling force of cinnamon sticks.

### Impact of frequency and acceleration of ERM motor MABUCHI RF-M50WA for reduction of peeling force

Required average peeling forces for 35 mm diameter cinnamon sticks are indicated as 3.52 ± 0.43 N, 3.41 ± 0.24 N and 3.68 ± 0.6 N for the respective frequency - acceleration combinations of 6 Hz-1.5 $ms^{-2}$, 10 Hz- 0.5 $ms^{-2}$, 20

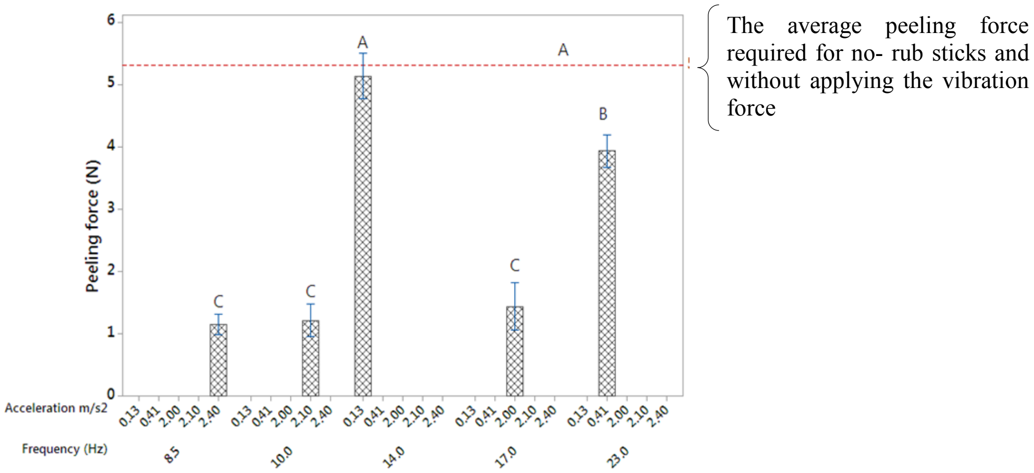


**Figure 1:** Variation of peeling force with the changes of frequency and acceleration of applied vibration force by ERM motor RF-555

Values in each point followed by the same letter (s) are not significantly different at 5% level, P < 0.05

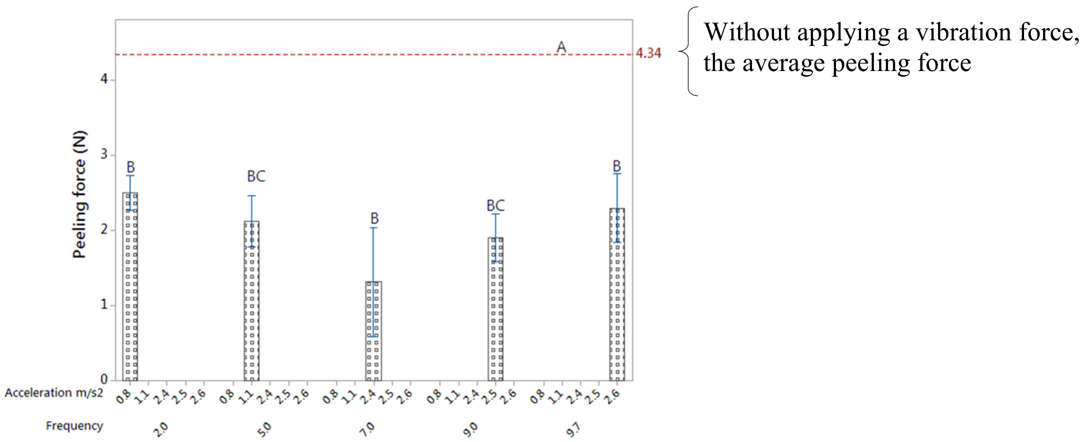


**Figure 2:** Variation of peeling force with the changes of frequency and acceleration of applied vibration force by ERM motor R260.

Values in each point followed by the same letter (s) are not significantly different at 5% level

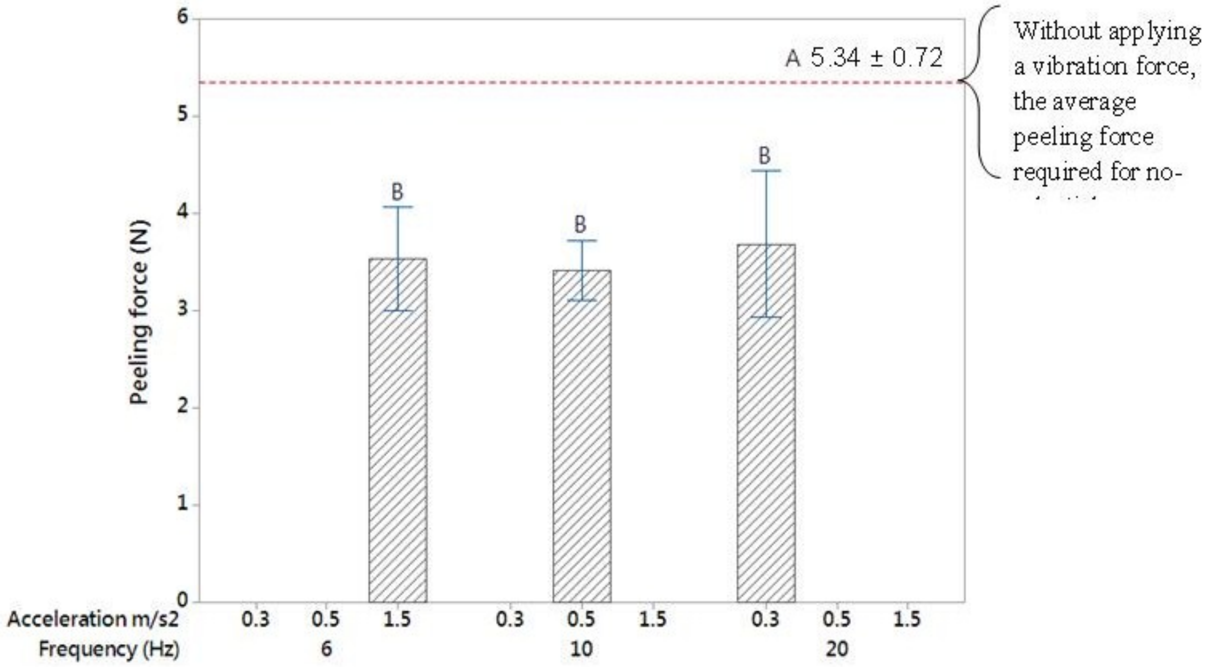


**Figure 3:** Variation of peeling force with the changes of frequency and acceleration of applied vibration force by ERM motor MABUCHI RF-M50WA**.**

Values in each point followed by the same letter (s) are not significantly different at 5% level

Hz-0.3 $ms^{-2}$ (Figure 3). There was no significant difference among required peeling force which is caused by each frequency - acceleration combinations. Compared to required peeling force (5.34 ± 0.72 N) of untreated cinnamon sticks (not- rub and without applying vibration force ), the peeling force reduction percentages were calculated as 34 %, 36.1% and 31% under the respective frequency - acceleration combinations of 6 Hz -1.5 $ms^{-2}$, 10 Hz - 0.5 $ms^{-2}$ and 20 Hz-0.3 $ms^{-2}$ generated by ERM motor MABUCHI RF-M50WA. Reduction of peeling force was occurred due to the low friction on knife running between bark and stem and increment of the bonds breaking efficiency of bark and stem, which were resulted by the vibration-induced amplitude of peeling knife.

## CONCLUSION

Of the three types of eccentric rotating mass motors (RF-555, R260 and MABUCHI RF-M50WA) tested to induce mechanical vibrations to the cinnamon peeling knife, the highest reduction of peeling force ( 78.6%, 77.52 % and 73.22%) was obtained from motor RF555- ERM at frequency -acceleration combinations 8.5 Hz - 2.4 $ms^{-2}$, 10 Hz -2.1 $ms^{-2}$, 17 Hz -2 $ms^{-2}$ and it shows higher potential to use as direct mounted mechanical vibration force applicator on the peeling knife in order to reduce the required peeling force of cinnamon bark. Therefore, with this small-sized ERM motor, vibration-assisted peeling technology is more applicable in developing low power consuming lightweight peeling machines as this facilitates easy handling of peeling knife during the operation and direct installation on the peeling knife.

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