Friction Coefficient of a Ladyfinger Banana Peel

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Abstract

The coefficient of static friction of a lady finger banana peel was investigated for varying values of vertical compression force. The peel was placed on a tile surface, with a person placing her Converse sneaker on the peel and pushing down with force ranging from approximately 100 N to 700 N. The foot was pulled forward until it slipped, and the slipping force recorded. It was found that the coefficient of static friction of the banana peel is approximately 0.09 for compression forces below 600 N, and 0.15 for forces above 600 N.

Keywords**:** banana peel**,** friction coefficient, horizontal force, vertical force, lady finger banana

I. INTRODUCTION

It is a common gag in cartoons for a character to slip on a banana peel. Everyone knows that stepping on a banana peel can result in a person slipping and falling, yet little research has been done to measure how slippery a banana peel really is, or if there is a difference between the peels of different types of bananas.

Friction is a force which acts in the direction opposite to an object's movement across a surface. For an object resting on a horizontal surface, the force of friction acts horizontally while the normal reaction force acts vertically. The coefficient of friction is defined as the ratio of the force of friction between two surfaces and the normal reaction force acting between the surfaces. The coefficient of static friction (μ_s) is the ratio of the maximum static friction force between two surfaces which are not moving with respect to each other, and the normal reaction force acting between the surfaces. The coefficient of kinetic friction (μ_k) is the ratio between the force of kinetic friction of two surfaces in relative motion, and normal reaction force acting between the surfaces[1].

The equation that relates the coefficient of friction to friction force is:

$$F = \mu N \qquad \text{Equation 1}$$

where F is the friction force, μ_s is the coefficient of friction (of the banana peel), and N is the vertical (normal reaction) force[1]. In cases where the coefficient of friction is constant, the force of friction will be proportional to the normal reaction force, and the slope of the F-N graph will be the coefficient of friction.

In research conducted by Kiyoshi Mabuchi, Kensei Tanaka, Daichi Uchijima, and Rina Sakai[2], the coefficient of kinetic friction between a cavendish banana peel and the floor was measured. They stepped on a banana peel placed on a surface and measured the normal force and kinetic friction force as the peel was pulled from under the shoe.

Mabuchi et al defined a safety condition to determine whether a person would slip or not, which depends on the step impact angle and the coefficient of static friction, as shown in figure 1. When walking, people exert both a horizontal force and vertical force on the floor as they take a step, exerting a force of friction between the shoe sole and the floor surface. For their measured coefficient of kinetic friction of 0.066, the stepping impact angle, θ, should be less than 3.8 degrees to maintain the safety condition. Typical stepping angle is about 15 degrees, hence the chance of slipping on a banana peel is very high. It has also been shown that if the coefficient of friction is lower than 0.1, the risk of slipping and falling is greater than 90%[3].

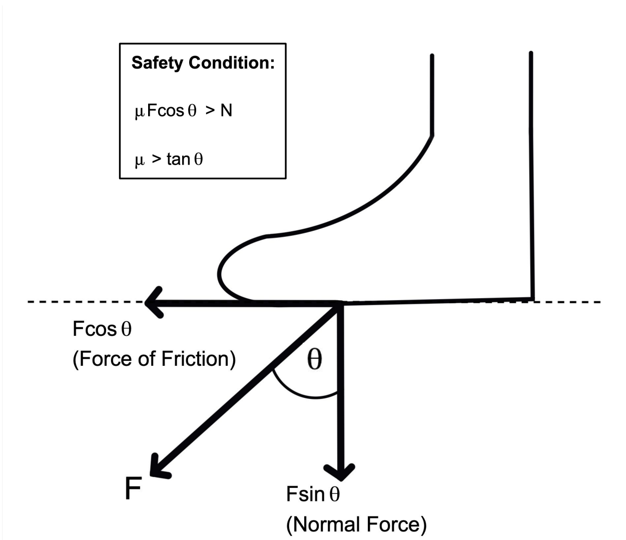

Figure 1. Safety conditions estimated as a function of μ and the stepping impact angle, θ.

When banana peels were microscopically observed, follicular gel, composed of polysaccharide and protein, was found in the skin. Polysaccharide follicular gel was estimated to play a dominant role in the lubricating effect of banana peels, as other fruit skins (such as apples and citrus) that had a higher coefficient of friction had less polysaccharide compared to banana skin[2].

In this paper, lady finger bananas, a banana that grows locally in Thailand, was investigated rather than the cavendish bananas used by Mabuchi et al (figure 2). The coefficient of static friction between lady finger banana peels and a ceramic tile floor was measured and compared to the kinetic coefficient of friction of cavendish bananas measured by Mabuchi et al. The variation of coefficient with increasing normal force was also measured. Through this study, information about the slipperiness of a new type of banana will be gained, and the coefficient of static friction, rather than the coefficient of kinetic friction, will be measured, as the coefficient of static friction is considered to be more relevant to safety because it determines whether your foot will start to slip or not.

II. METHODS

A ceramic floor tile was attached to a Vernier force plate using double sided tape. The force plate was then calibrated. Three Vernier force probes were calibrated and the force probes were assembled on top of a wooden block so that the three force probes could be attached to a single string used to pull the shoe, as shown in figure 3. The sum of the readings of the individual force probes was used to determine the total force pulling the shoe.

Figure 2. A typical lady finger banana (right) and cavendish banana (left).

The bananas were then peeled so that the entire peel of one banana was in one piece. A sharpie marker was used to mark the position of the peel on the center of the tile. Experimenters peeled about five bananas at a time on average to ensure that the condition of the peels was fresh and consistent for all trials.

For the partial weight trials (Normal Force of 150 to 400 N), an experimenter sat on a chair placed behind the force plate wearing Converse high-top sneakers.

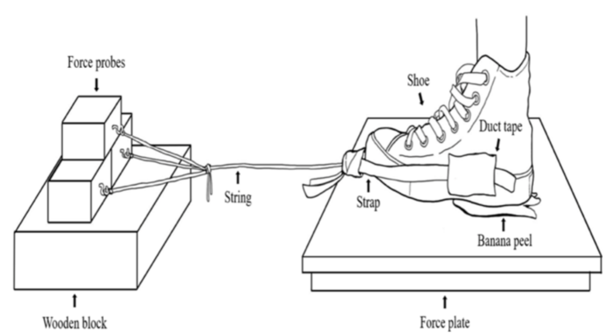

Figure 3. Set up for the collection of static friction data.

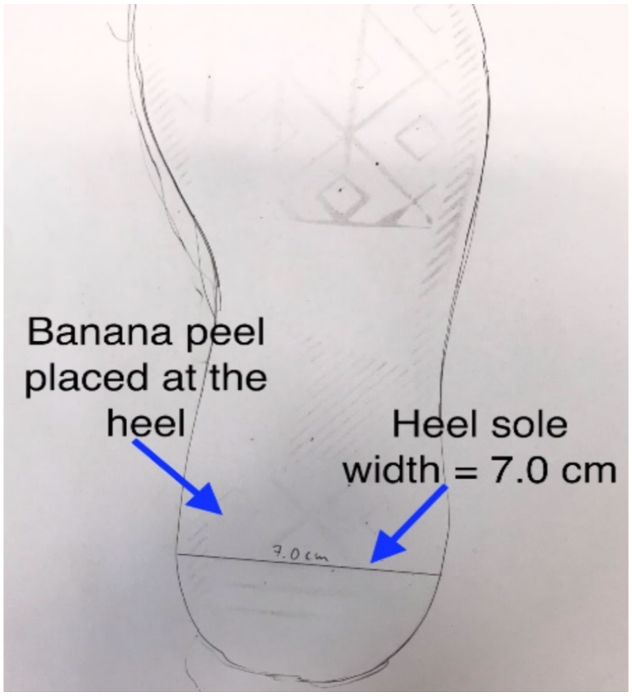

Figure 4. Imprint of the shoe with width of sole and location of the peel when stepped on.

A banana peel was placed inner-side down on the center of the tile and experimenter's shoe was placed over the peel such that the entire width of the sole was in contact with the peel, as shown in figure 4. The experimenter's knee was bent at about 90˚, and weights were placed on top of the experimenter's knee to increase the vertical force on the shoe and banana peel. The experimenter gently lifted the front part of the foot, so that the vertical force was applied only on the heel area where the banana peel was placed. The force probes were pulled smoothly forward until the shoe slipped. All force data were recorded using Vernier Logger Pro. The forces recorded by the force probes were then summed and the peak of the graph was used to determine the maximum horizontal force just before slipping, as shown in figure 5.

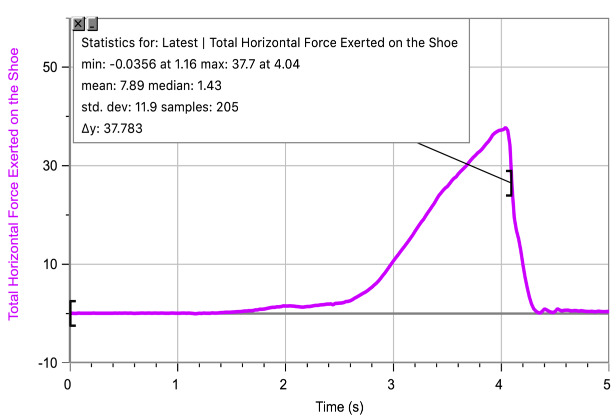

Figure 5. Time vs Force Graph. The peak of the total force curve is the maximum horizontal force.

For the trials with more weight (550 to 680 N), the experimenter stood on the banana peel on one foot, steadied by two assistants. The experimenter's weight was centered on the heel with the front part of the foot lifted up, as before. To vary the vertical force, weights were added into a backpack the experimenter was carrying. As before, the force probes were pulled forward until the shoe slipped. After every trial, the sole of the shoe and the tile were wiped using tissue paper to clean off any excess juices. A new banana peel was used for each trial.

The bananas were bought in two lots, as the experiment was conducted on two separate days a week apart from each other. The bananas were similarly ripe, according to the best judgement of the researchers, however no quantitative assessment of ripeness level was attempted. The average surface area of the banana peels determined to be 45 ± 7 cm^2. This was measured using photo analysis on Logger Pro for a random sample of 10 banana peels. The integral of the graph of the points along the perimeter of a peel was used to calculate the area, as shown in figure 6.

The average thickness of the lady finger banana peels was measured using a Vernier calipers as 1.1 ± 0.2 mm. The average thickness of a cavendish banana peel was measured for comparison and found to be 1.8 ± 0.4 mm. It should be noted that the cavendish bananas available in Thailand are similar, but likely not the same as the cavendish bananas used by Mabuchi et al.

III. RESULTS AND DISCUSSION

It was found that there was a roughly proportional relationship between the normal force and the maximum horizontal friction force between the lady finger banana peel and the ceramic tile, as shown in figure 7. As predicted, increasing the normal force on the peel increased the maximum horizontal force

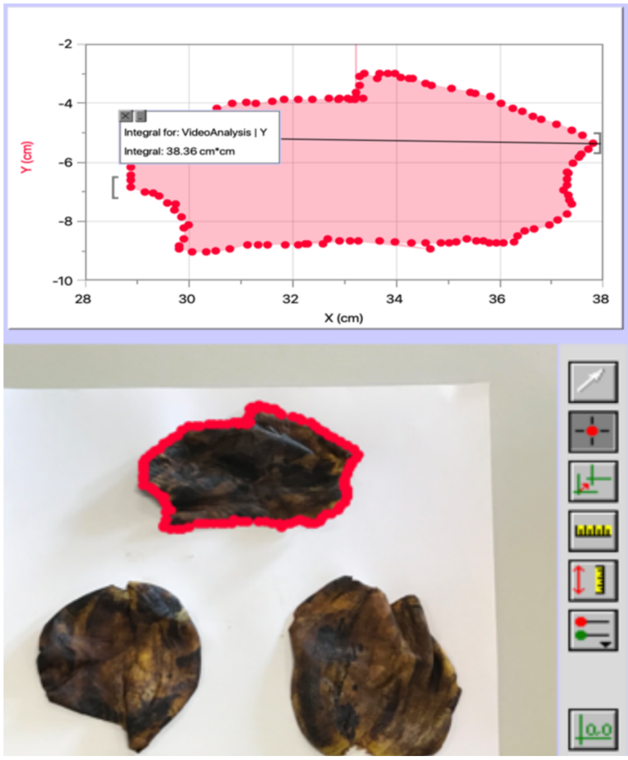

Figure 6. Photo analysis using Logger Pro to measure surface area of banana peels.

before slipping and demonstrated the expected positive trend.

Figure 7 also shows high variability of frictional forces on the banana peel. While the lowest two forces tested showed consistency in data, the data for normal forces above 300 N indicates a high variability of force needed to cause the peel to slip. As there were small differences in the ripeness of bananas, as well as natural variation between peels, such variation was expected. Most data points around 685 N are located above the average proportional fit of the lower forces, thus, the trend is expected to be only valid for vertical forces up to 620N. A different trend is indicated above that value. It is possible that when the force squeezing the peel exceeds a certain limit, a different mechanism becomes important in determining the behavior of the peel.

The coefficient of friction was relatively consistent throughout the trials up to 620N, as shown in figure 8. Values above that point were analyzed separately. The mean coefficient of static friction is shown to be

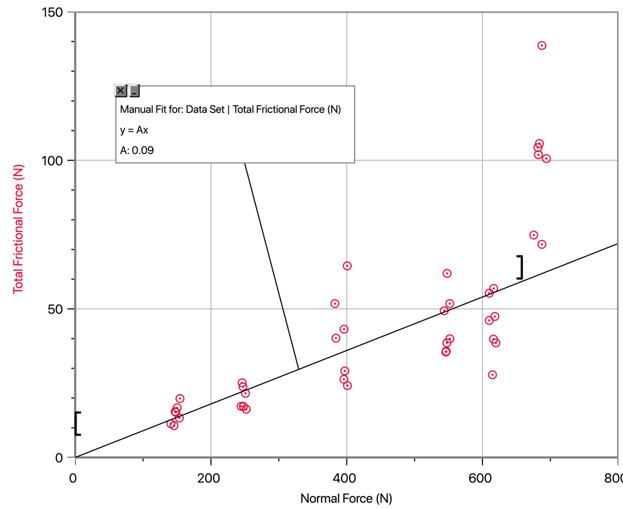

Figure 7. Maximum static friction force and the normal force on the banana peel as the shoe was being pulled until slipping. The slope represents the average coefficient of static friction.

0.09 ± 0.02 for vertical forces up to 620N and 0.15 ± 0.03 above that. Mabuchi et al found the coefficient of dynamic friction to be 0.066 ± 0.028 for cavendish bananas[2]. The coefficient of dynamic friction is lower than the coefficient of static friction for many materials, hence the results of this experiment matches expectations. However, the ripeness of the bananas could not be controlled and the ripeness of the bananas that Mabuchi et al used is unknown, therefore the results of the two experiments cannot be

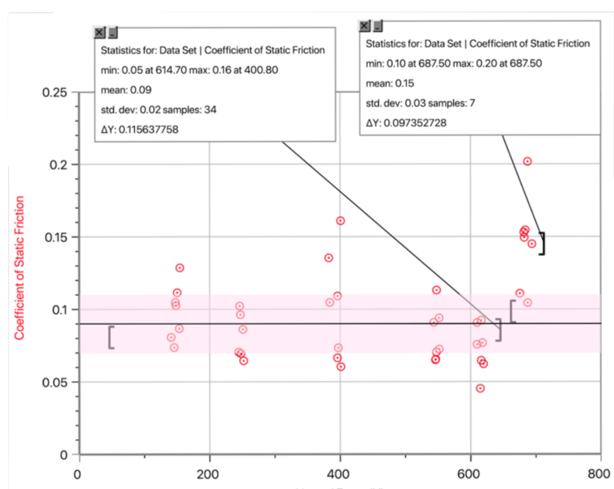

Figure 8. Coefficient of static friction and normal force showing a coefficient of friction of 0.09 ± 0.02 up to 620 N and around 0.15 above 620 N.

compared. The average coefficient of friction for a normal force of 685 N was higher, with a value of 0.15 ± 0.03, likely due to the effect of the increased compression of the cells in the skin between the shoe and the tile. To put our findings into context, the coefficient of friction of ice has been shown to be around 0.05[4]. Since the coefficient of friction for a lady finger banana peel was shown to be around 0.09, the coefficient of friction of ice is slightly over half of this value.

To further our understanding of the risk of slipping on a banana peel, the coefficient of static friction of peels of varying ripeness and for higher forces should be investigated. Research could also be done on other species of banana. Finally, the effect of the time since peeling could be tested, as it is usually old banana peels that people slip on.

IV. CONCLUSION

The coefficient of static friction between a lady finger banana peel and a ceramic floor tile was measured to be approximately 0.09 ± 0.02, which was slightly greater than the coefficient of kinetic friction of a cavendish banana measured by Mabuchi et al. The coefficient of friction stayed fairly constant for lower normal forces, but rose to a value of 0.15 ± 0.03 for a normal force above 620 N.

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