

Maximization of Oil Output of a Treadle-Powered Peanut Oil Press

by

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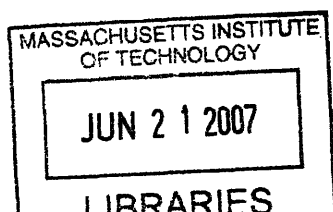
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ABSTRACT

The manual processing of food products has become a substantial part of the daily routine of a typical household in the developing world. Consumption of oil is an essential part of an individual's diet and thus, the production of oil is an essential activity. In many communities, this oil is obtained by manually pressing it from peanuts. In order to more efficiently and easily express oil from peanuts, a design for a treadle-powered peanut oil press was created.

My thesis work will attempt to further increase the amount of oil extracted by optimizing the design of this peanut oil press. The press transfers the motion of the treadle to the horizontal motion of a piston that presses the peanuts via a rotating cam. The focus of this thesis will be optimizing the design of the cam with respect to oil yield. The shape of the cam determines the displacement profile of the piston's compression of the peanuts. I will determine the optimal profile by designing and performing experiments on a variety of different displacement profiles and measuring the amount of oil extracted from the pressed peanuts. The results of these experiments will then determine the optimal cam design.

Thesis Supervisor: Amy Smith

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Contents

1	Introduction	7
2	Background	8
2.1	History of Oil Press Technologies for the Developing World	8
2.2	Current Peanut Oil Press Design	10
2.3	Cam Design	12
2.4	Peanut Mechanics	14
3	Experimental Procedure	18
3.1	Experimental Apparatus	18
3.2	Experiment Design	20
4	Results	22
5	Discussion	23
5.1	Peanut Pressing Behavior	23
5.1.1	Displacement Profile	23
5.1.2	Force Profile	26
5.2	Proposed Cam Designs	27
6	Conclusions and Future Research	30
	References	32
A	Full experimental results of peanut pressing	34

List of Figures

1	Women in Mwape, Africa pressing peanuts for oil [12]	7
2	Trial of the Bielenberg Press in Mwape [12]	9
3	CAD model of treadle-powered peanut oil press [6]	11
4	Proof of concept prototype (non-functional) of treadle-powered oil press [6] .	11
5	Template for cam design	14
6	Model of a screw press used in past research [5]	15
7	Relationship between pressure and oil yield on pressing groundnuts [3]	16
8	Applied pressure and oil output as a function of time for pressing rapeseeds in a piston-cylinder rig [7]	17
9	Instron machine used for testing	19
10	Piston pressing peanuts in the cylindrical chamber	19
11	Chambers used to hold peanuts during compression	20
12	Force-displacement curve for smaller container	23
13	Force-displacement curve for larger container	24
14	Speed of pressing vs. oil yield for the small container (top) and large container (bottom)	25
15	Remaining peanut mass after pressing	26
16	Stages in compression	26
17	Proposed cam design	29

List of Tables

1	Profiles tested for small container	21
2	Profiles tested for large container	21
3	Results for Small Container	22
4	Results for Large Container	22
5	Full data set for experiments with small container	34
6	Full data set for experiments with large container	35

1 Introduction

Communities in developing countries rely mainly on subsistence farming to feed and provide for their members due to the lack of a local market supplying food products. As a result, people in these societies spend an inordinate amount of time farming, preparing, and cooking food. The processing of food products is a necessary activity in many regions of developing countries, particularly sub-Saharan countries in Africa.

The motivation for this project came through a series of trips to developing regions in Africa when MIT D-Lab teams recognized a need for improved oil expression techniques. Oils are often an essential part of individual diets, and the processed oil available in the open market is often imported from other countries and can be prohibitively expensive. Therefore, in many regions, much of the oil used in households is extracted from peanuts using a large pestle and mortar as shown in Figure 1. This process is both time consuming and physically strenuous and is done only on a household by household basis. Still, peanut oil expression is a necessary part of a household's routine activities; thus, the need for an appropriate technology to more efficiently extract oil from peanuts is starkly evident.



Figure 1: Women in Mwape, Africa pressing peanuts for oil [12]

The mechanical power necessary for extraction can be harnessed from a person in a more effective and less physically demanding manner using an ergonomically designed peanut oil

press. While some oil press designs have enjoyed success in the developing world, other methods of harnessing human power input more effectively have only recently been explored. One of these methods is being developed by D-Lab and uses treadle power to move a piston into a chamber of peanuts. Over longer periods of time, treadle power places less strain on a user's body than a device utilizing the upper body. In addition, a treadle-powered device has proven to be manufacturable in developing countries, as evidenced by projects such as treadle-powered water pumps.

The focus of this thesis is to optimize the efficiency of the oil press powered by a human treadle motion by focusing on the motion of the piston. Successful completion of this research will attempt to lead to the design of a final machine that will extract the maximum amount of oil from a given amount of peanuts. A variety of tests were conducted to obtain the displacement profile of the piston's motion that optimizes oil output. These tests involved pressing peanuts at varying speeds and determining the oil yield as well as the force required for pressing.

2 Background

Broadly speaking, this thesis is focused on the mechanical properties of peanuts and the application of these properties to optimize oil expression in the particular treadle-powered design. To form the basis of this research, modern oil press technologies for the developing world will be evaluated, and the theory behind oil expression from groundnuts will be presented.

2.1 History of Oil Press Technologies for the Developing World

The project of creating a more efficient mechanical method of extraction of oil from peanuts has been going on for over two decades. The first device to make a significant impact in communities in the developing world was developed by engineer Carl Bielenberg in the late 1980's [10]. The mechanism involved a ram press, as shown in Figure 2, which

required the user to pull down a lever that pushes a piston, crushing the peanuts. The design of the press represented an improvement upon previous expression methods because it was exclusively human powered and could be run continuously. In contrast, other methods often expressed oil from peanuts in batches. In addition, the length of time at which the user is physically strained is reduced using the Bielenberg press.



Figure 2: Trial of the Bielenberg Press in Mwape [12]

The Bielenberg press demonstrated the usefulness of a productive peanut oil press. Nutritional benefits were observed through surveys demonstrating higher oil outputs and resulting increased consumption of oil. Economic benefits resulted from the creation of a market for oil; because the press allowed for the production of surpluses, some users began to sell oil in the marketplace [4].

The Bielenberg press was particularly innovative not only because of its economic and household benefits, but also because it was an appropriate technology. One of the goals for technology in the developing world is to ensure that it can be manufactured locally and that it is relatively inexpensive. The Bielenberg press achieved these critical aspects in addition to its mechanical advantages to the user.

The concept of the Bielenberg press then motivated the design of a new, more ergonomic mechanism to press peanuts. The ram press required considerable upper body strength to operate and it was difficult to control the speed of pressing since the motion of the pressing is directly determined by the operator. Once the expression of oil began, the speed of pressing should be slowed significantly. However, it is neither ergonomic nor intuitive for a human operator to press the ram at a sufficiently slow rate. Thus a “dwell” time was introduced where the peanuts were not compressed at all since this is the closest to ‘very slow’ that is ergonomically achievable. Ideally, the peanuts would be continuously compressed even at slow rates.

To remedy this issue and in order to decrease physical strain on the operator, other methods of human mechanical input were explored and a treadle powered mechanism was pursued. Other possible types of peanut oil extraction techniques include chemical methods, a screw press, or a hydraulic press. Unfortunately, in a developing country context, these designs run into problems of cost, availability of resources, and manufacturability. Thus, the need for a more user-friendly peanut oil press is apparent.

2.2 Current Peanut Oil Press Design

The design that is the subject of this thesis is a treadle-powered peanut oil press originally developed in the spring of 2006. The original concept of the device, as shown in Figure 3, converts the treadle motion of the user to a horizontal motion that presses the peanuts. The design for actuating the piston device which pressed the peanuts was still maintained but instead of a large lever to move the piston, the motion of the treadles was utilized. Still, in order to incorporate the treadles, a new design for the entire machine had to be created to accommodate the concept. Since the time when the CAD model in Figure 3 was designed, there have been changes to the design which is the subject of research that was done concurrently with this thesis research. The modified design concept is detailed in Daipan Lee’s thesis entitled “Peanut Oil Press Redesign for Developing Countries” submitted in May 2007.

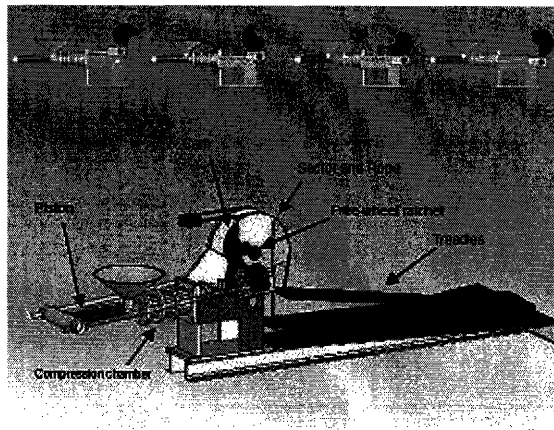


Figure 3: CAD model of treadle-powered peanut oil press [6]

The treadle motion is transferred via a cam (as shown in blue in Figure 3) that is rotated when the “sector” is rotated. The cam moves in one direction, constrained by a bicycle ratchet in place on the shaft. The rotational motion of the cam is then translated into the horizontal motion of the piston.

The peanuts are pressed in a cylindrically shaped chamber with gaps to enable the discharge of oil from the chamber. Note that the chamber is positioned horizontally as shown in Figure 3. The oil is then captured below the cylinder in some kind of tray. An advantage of this design as adapted from the Bielenberg press is that peanuts can be constantly loaded into the cylinder and this therefore eliminates the production of oil in batches.

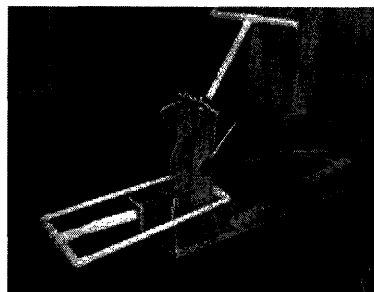


Figure 4: Proof of concept prototype (non-functional) of treadle-powered oil press [6]

Several prototypes have been built in the past year through MIT D-Lab; one such proof of concept prototype is shown in Figure 4. This prototype was the first to be built and was not functional but demonstrated the design concept. Areas of research that are critical to optimization of the oil press include the force applied on the peanuts, the amount of human force input required, operating time, efficiency, and other concerns regarding manufacturability and sustainability. This thesis aims to focus on the optimization of the peanut oil press with respect to the motion of the piston. As stated earlier, this motion is directly related to the design of the cam. Therefore the cam design is a critical component of a product that yields the greatest possible oil output.

2.3 Cam Design

A cam is often used to convert rotary motion into linear motion. In addition, it allows for a more controlled and continuous motion that would incorporate the “dwell” time into the pressing cycle. The cam controls this motion and is a critical feature of the press design.

The design of the prototype converts the treadle motion to a rotary motion and then through a cam converts it to a horizontal linear motion. The shape of the cam directly guides the movement of the piston in and out of the cylindrical chamber. Earlier prototypes of the oil press employed arbitrary shapes for the cam. The cam however can be optimized to move the piston against the peanuts at the optimal speeds.

This particular cam should be designed with four important factors in mind: the length of the chamber, the desired linear speed of the piston, the length of one period (or one revolution), and the proportion of the chamber that the piston should press through. The length of the chamber is a design choice made by the designer of the final product. The length of a period of revolution is also a design choice but is primarily a function of user preferences in terms of ergonomics and throughput.

This research is concerned with the other two variables: the desired linear speed of the piston and the proportion of the chamber that the piston should press through. In order to mathematically and geometrically present the problem of designing a cam, I propose the

following simple mathematical model.

The model will be defined by the desired speeds that the piston moves through a series of N time stages, indexed by the variable k :

- $L \equiv$ Total length of cylindrical chamber
- $p_k \equiv$ Proportion of chamber that piston moves *into* the chamber in the k^{th} stage
- $\alpha_k \equiv$ Desired linear velocity (not speed) of piston through the k^{th} stage
- $T \equiv$ Desired time per period of revolution

Note that $\sum_{k=1}^N p_k$ is strictly less than 1 since the piston is not moving through the entire length of the chamber and also some of the p_k values will be negative to signify moving out of the chamber. Therefore, the piston does not move a distance of L but moves a total distance of $\frac{L}{2} \sum_{k=1}^N |p_k|$. To see this, note that the sum of the positive p_k values should be precisely equivalent to the magnitude of the sum of the negative p_k values since the piston moves in and out of the chamber the same distance. So, $\frac{\sum_{k=1}^N |p_k|}{2}$ is the proportion of L that the piston moves into the chamber.

Figure 5 shows a template for the design of the cam and a sample cam. (Note that this cam is not an actual cam design but merely a sample to demonstrate how it is designed.) The outer diameter will be defined by D_O and the innermost diameter by D_I . In addition, all points on the template will be given in polar coordinates (θ, r) , where θ is measured as the angle from the positive y-axis.

The shape of the cam in the k^{th} stage will be defined by several points beginning with (θ_{k-1}, r_{k-1}) and ending at (θ_k, r_k) . Also, from the above definitions, we have t_k , or the time spent in the k^{th} stage, equal to $\frac{p_k L}{\alpha_k}$.

The final design of the cam is therefore governed by the following equations:

$$\begin{aligned} \theta_k - \theta_{k-1} &= 2\pi \frac{t_k}{T} \\ &= 2\pi \frac{p_k L}{T \alpha_k}, \end{aligned} \tag{1}$$

$$r_k - r_{k-1} = p_k L, \tag{2}$$

$$\frac{\Delta r}{\Delta \theta} = \frac{\alpha_k T}{2\pi}, \tag{3}$$

where $\theta_0 = 0$, $\theta_N = 2\pi$, $r_0 = \frac{D_I}{2}$, and $r_N = \frac{D_O}{2}$. From Equation (3), we can deduce an explicit function for the shape of our cam in the k^{th} stage:

$$r(\theta) = \frac{\alpha_k T}{2\pi} \theta. \quad (4)$$

Figure 5 shows how the different stages are incorporated in the cam. Notice that the first stage represents a more rapid speed since the change in radius is large and the change in theta is small. Similarly, the fourth stage represents a slower speed because the change in radius is small and the change in theta is large. Stages five and six represent the piston moving backwards from its maximum displacement to its initial position.

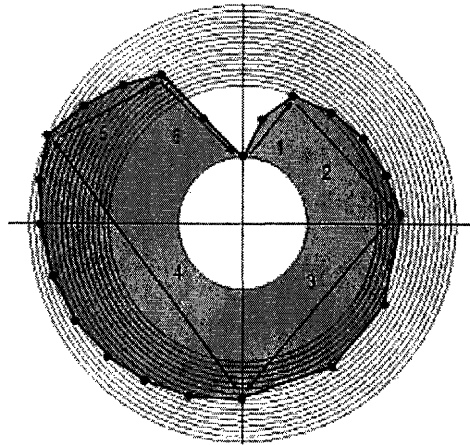


Figure 5: Template for cam design

2.4 Peanut Mechanics

Oil expression from peanuts has been extensively studied in the field of agricultural engineering. Peanuts have a high percentage of oil content compared to other legumes. Peanuts tend to have a oil yield by weight of 43% - 45% if all the oil can be removed from the peanut [5]. Of course, there are limitations on the amount of oil that can be expressed

due to processing restrictions. Previous research has focused both on industrial methods of oil expression as well as on simpler technologies. Pressing has proved to be advantageous because it is less capital intensive, technically less extensive, less labor intensive, and is a continuous process [9]. Most of the research with pressing has used a screw press as pictured in Figure 6; since the purposes of this thesis research is to analyze peanuts under pressure, we can still relate the current literature with my results.

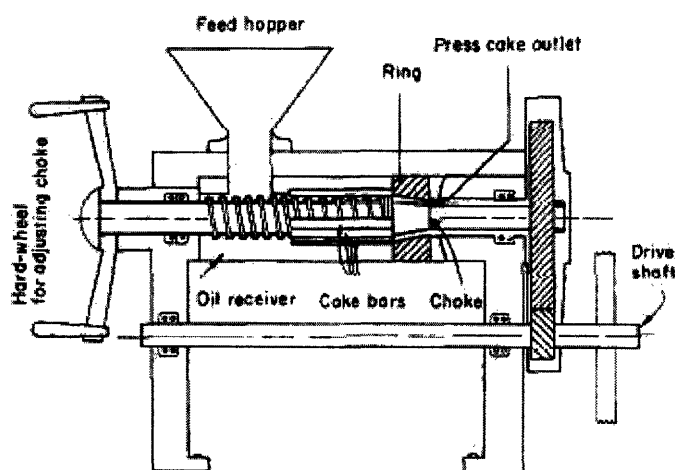


Figure 6: Model of a screw press used in past research [5]

With respect to obtaining oil by applying pressure, research has found that the most critical factors in the amount of oil output are heating temperature, applied pressure, pressing time, and moisture content of peanuts [5]. In my experiments, all the peanuts used were from the same batch and thus on average the moisture content of peanuts used in different trials was roughly the same.

Pressing time and applied pressure are both functions of the speed at which the peanuts are pressed. The literature generally concludes that increased pressing time and applied pressure will contribute to higher oil yields. Hamzat and Clarke determined that increasing pressing time to about one minute significantly increases oil yield but after that point, there is only a slight increase in output [3]. Increasing the magnitude of the applied pressure also

increases the quantity of oil yield. As shown in figure 7, there is a higher rate of yield increase (signified by the slope) at lower pressures and a slower - and even negative - growth rate at higher pressures.

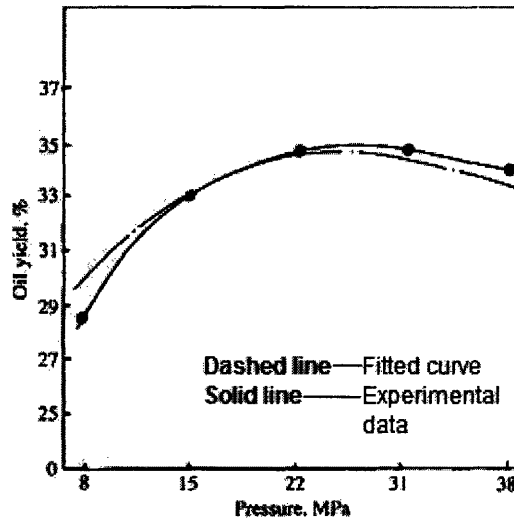


Figure 7: Relationship between pressure and oil yield on pressing groundnuts [3]

The last critical element is therefore the temperature. Various authors have attempted to determine the optimal temperature of the peanuts used in oil expression via pressure. Adeeko and Ajibola found an optimal temperature between 90°C and 115°C and concluded that excessive heating will cause both significant moisture loss and also cause the proteins in the nuts to coagulate, thus reducing the viscosity of the expressed oil [1]. Oyionlola, Ojo, and Adekoya concluded that the optimal temperature is generally above 70°C [9] while Goodrum reported an optimal temperature of 95.6°C [2].

Other elements of peanut expression via pressure do play a factor in oil yield though they are less significant. This includes heating time and coarseness of the nuts. Optimal heating time was found to be approximately half an hour [1]. In addition, past research demonstrated that coarsely ground nuts provide higher oil yields than both finely ground nuts and non-ground nuts [3]. Thus, in the field, the peanuts should be coarsely ground to

demonstrate maximum oil yield.

The physical features of the peanut during oil expression have also been investigated. Peanuts in their original state store oil within the cells that comprise the peanut. The oil expression process proceeds in four distinct stages: oil flows through pores in the individual cell walls; the oil flows through the inter-cell voids; the oil flows from the peanut and fills the ‘inter-peanut’ voids; and finally the oil is pressed out of the bulk of peanuts [8]. The point at which oil appears on the surface of the peanut is called the oil-point. The oil-point pressure is the pressure required to get to the oil-point. This pressure, p_o has been shown to be a function of the rate of deformation of the bed of nuts, R , and the moisture content of the nuts, m ; a general equation that governs the oil-point pressure, in MPa, of oilseeds is

$$p_o = K_1 \exp[K_2 m^\alpha + K_3 R], \quad (5)$$

where K_1 , K_2 , K_3 , and α are constants particular to the type of oilseed [13].

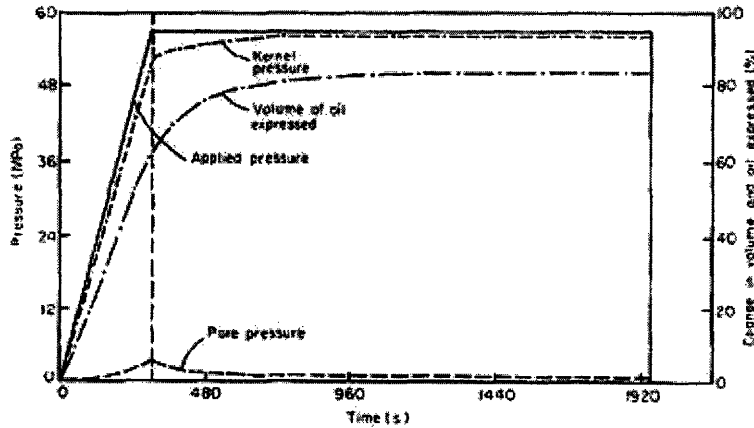


Figure 8: Applied pressure and oil output as a function of time for pressing rapeseeds in a piston-cylinder rig [7]

In addition, the pressure that is applied to the peanuts is distributed between the pressure that the peanuts carry (kernel pressure) and the pressure that the oil fluid carries (pore pressure) [7]. Therefore, when peanuts begin to express oil under load, the pressure that

is used to express more oil from the peanuts reduces. The sharing of the load is relevant because the more oil that remains in the peanut bulk, the less the amount of oil that can be further expressed. Figure 8 shows a rough approximation to the split between the kernel pressure and pore pressure in a rapeseed pressing experiment. Note that as time goes on, more and more of the pressure is being used to express oil from the seeds rather than to push oil from the chamber.

For the particular experiments that this thesis requires, the main concern is the effect of piston speed on the oil yield. Applying the results in the literature, I hypothesize that at slow speeds, there is higher oil yield. This is due to the fact that at slow speeds, the oil is allowed more time to leave the chamber and thus allow a greater portion of the pressure to be the ‘kernel pressure’ that actually contributes to oil expression. On the other hand, at faster speeds, the oil is kept in the chamber for a larger proportion of the time of compression. As a result, the amount of work done on compressing the peanuts for oil is less due to the oil bearing a higher ‘pore pressure.’ In sum, slower speeds will cause the total pressure to be distributed more heavily onto the actual peanuts than the oil in the inter-peanut voids. Therefore, our results should correspond to the literature as well as to a trend that lower speeds correlate to higher oil yields.

3 Experimental Procedure

The intention of my experiments therefore is to determine the displacement vs. time profile for the movement of the piston that maximizes the expression of oil from the peanuts by applying pressure. An optimal cam design can then be derived from the optimal profile.

3.1 Experimental Apparatus

The experiment utilized the Instron machine in MIT’s Mechanics and Materials Lab. This setup also included a cylinder with slits to hold the piston, a piston to press the peanuts in the cylinder, a tray to collect the oil, and a computer attached to the Instron machine to

capture force, displacement, and time data. The Instron machine is shown in Figure 9.

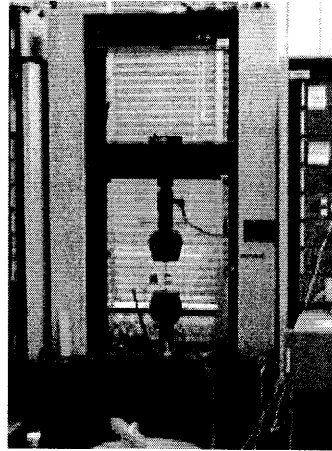


Figure 9: Instron machine used for testing

A piston is attached to the upper bar, which is moved vertically by the Instron machine. The peanut-filled chamber and the tray to collect the oil are placed beneath the piston. The interaction between the piston and the cylinder is shown in Figure 10.

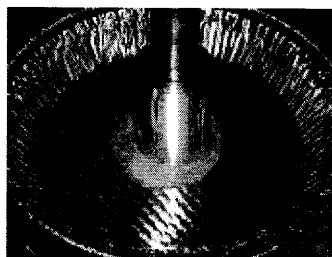


Figure 10: Piston pressing peanuts in the cylindrical chamber

The piston moves at a constant speed in and out of the peanut-filled container. In Figure 10, we see the piston in its downward motion and expressing oil.

3.2 Experiment Design

The experiment was designed to provide a clearer understanding of how differences in the speed of the piston affects the output of oil. The setup was such that a container is filled up with roasted peanuts heated to 100°C and situated underneath a piston with a diameter that fits the inner diameter of the container. Two different size containers were used; a small container and a larger container as pictured in Figure 11 on the left and right, respectively. The Instron machine used for moving the piston can move the piston down at a constant speed and records the force that is being applied in order to maintain the speed.

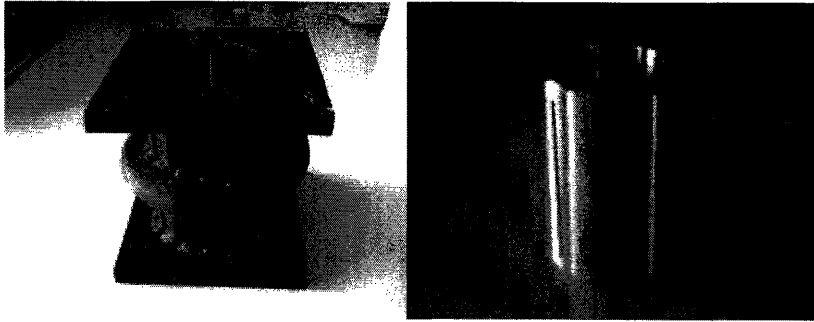


Figure 11: Chambers used to hold peanuts during compression

A single trial is defined as the motion of a piston from the top of the container to the point at which the peanuts are approximately incompressible (i.e. the force required to continue moving the piston becomes large). Each trial is defined by a different displacement profile; these displacement profiles for both container sizes are listed in Tables 1 and 2.

**Table 1: Profiles tested for
small container**

Trial No.	Speed Profile
Trial A1	1 in./min.
Trial A2	0.5 in./min.
Trial A3	0.2 in./min.
Trial A4	0.1 in./min.
Trial A5	0.05 in./min.
Trial A6	0.2 in./min. interrupted by a pause
Trial A7	0.5 in./min. interrupted by a pause
Trial A8	0.5 in./min., then 0.1 in./min.

**Table 2: Profiles tested for
large container**

Trial No.	Speed Profile
Trial B1	0.5 in./min.
Trial B2	0.2 in./min.
Trial B3	0.1 in./min.

The experiment also sought to provide some information on the effects of container size on oil output. The container in which most of the experiments were conducted was a smaller aluminum cylinder with an inner diameter of 31.8 mm and a height of 72.6 mm. There are four evenly spaced vertical slits from which the oil can flow out. The larger container is an actual peanut chamber used in a different peanut oil press. This container is roughly cylindrical and is created by welding multiple bars together on their longer edges. Its relevant dimensions are a diameter of 53.7 mm and a height of 103.4 mm. Both containers are shown in Fig. 11.

Each trial was run four to five times with the same conditions. For each trial, the data collected included the percentage oil yield measured in grams of oil expressed divided by grams of peanuts used. In addition, each trial produced force-displacement-time data. The force-displacement data is of interest to us since it will tell us how far the piston can compress before the mass of peanuts becomes incompressible. It is at this point that the Instron machine can no longer press any further and the forces required increase rapidly. Because the force becomes large, it is unlikely that any further oil can be extracted from the peanuts using the treadle-powered device.

4 Results

The results for oil yield for different displacement profiles are shown in Tables 3 and 4. The raw data for each run of each trial is shown in Appendix A. % Yield is given in weight.

Table 3: Results for Small Container

Trial No.	Speed Profile	% Yield	Standard Deviation
Trial A1	1 in./min.	12.68%	2.82%
Trial A2	0.5 in./min.	16.79%	3.43%
Trial A3	0.2 in./min.	17.34%	4.80%
Trial A4	0.1 in./min.	27.65%	2.65%
Trial A5	0.05 in./min.	26.42%	3.83%
Trial A6	0.2 in./min. interrupted by a pause	16.47%	5.33%
Trial A7	0.5 in./min. interrupted by a pause	15.03%	3.21%
Trial A8	0.5 in./min., then 0.1 in./min.	24.77%	5.38%

Table 4: Results for Large Container

Trial No.	Speed Profile	% Yield	Standard Deviation
Trial B1	0.5 in./min.	16.01%	2.26%
Trial B2	0.2 in./min.	16.19%	5.05%
Trial B3	0.1 in./min.	20.17%	2.56%

Force-displacement data was also collected. Both the force and displacement were recorded in the negative direction due to the downward motion of the piston. Since the curves representing this data had roughly the same shape for each trial, representative curves depicting the data for the small and large containers are shown in Figures 12 and 13, respectively.

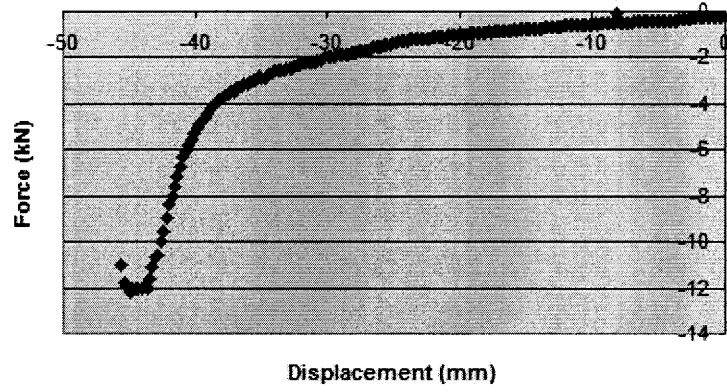


Figure 12: Force-displacement curve for smaller container

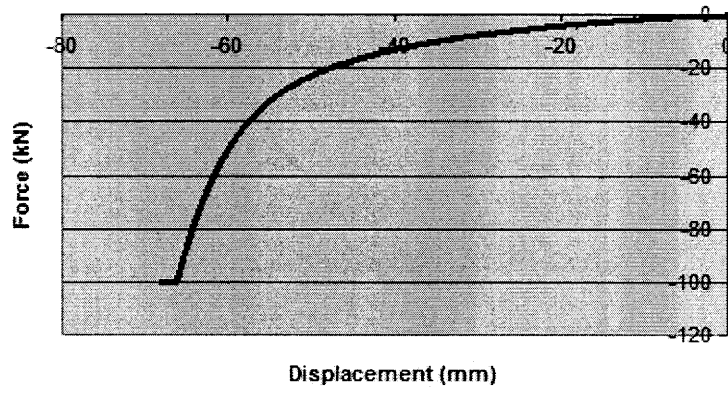


Figure 13: Force-displacement curve for larger container

5 Discussion

5.1 Peanut Pressing Behavior

5.1.1 Displacement Profile

The results show, for the smaller container, that there is a general increase in oil output as the speed of the piston is decreased. The data, as represented in Figure 14 with standard error bars, show that the oil yields decrease roughly logarithmically with the piston speed.

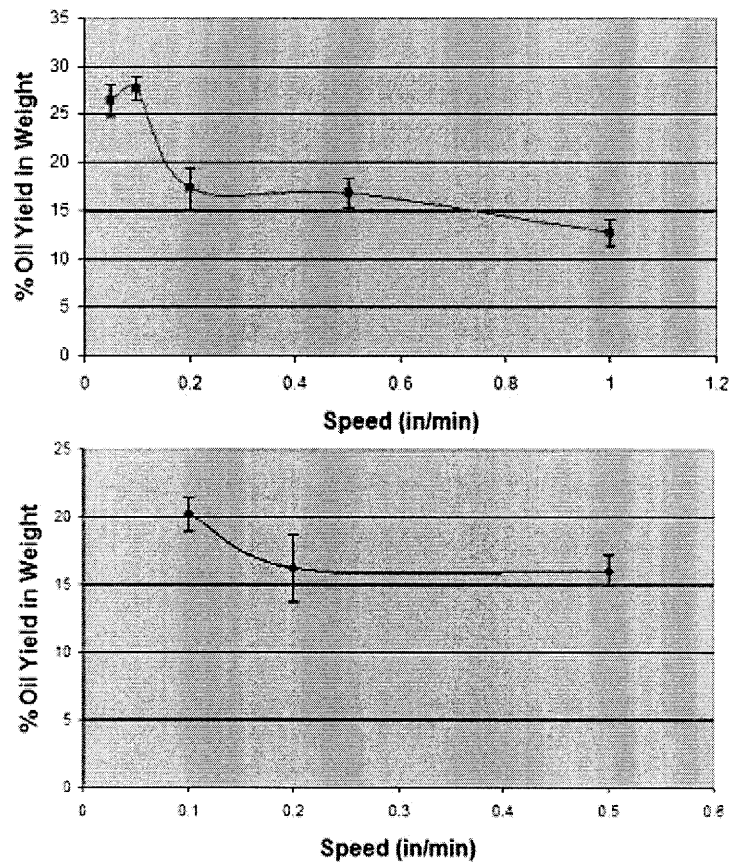


Figure 14: Speed of pressing vs. oil yield for the small container (top) and large container (bottom)

At slower speeds, there is ample time for the oil to be moved from the center of the

container to the outer edge. However, at faster speeds, there is less time. This will cause two things: first, more oil will remain in the chamber and thus there is a lesser oil output; secondly, the more oil that remains in the chamber, the less pressure is used to express oil from the peanuts. As stated earlier, the applied pressure is split up into a kernel pressure and a pore pressure. With more oil remaining in the chamber at faster speeds, a greater proportion of the pressure becomes the pore pressure instead of the kernel pressure which causes actual oil expression.

In addition, from physical observation, the piston pressed through about 30% of the container before the peanuts began to express oil. Throughout this first 30% of time, the peanuts are merely being rearranged and air voids are eliminated. The piston then causes oil output until the piston goes through approximately 60%; 40% remains as dry peanut mass, as pictured in Figure 15.



Figure 15: Remaining peanut mass after pressing

It is worth noting then that 60% of the volume of peanuts (when placed by hand in a container) is comprised of air voids and oil. The first 30% represented the volume of larger air voids as shown in Figure 16. The next 30% (30% to 60%) of the volume represents oil expression and the closing of smaller air voids. This decrease in volume thus corresponds to the amount of oil that leaves the peanuts, which is a little less than 30% by volume. So, it is important to note that of the total displacement that occurred, half of it is used for closing

large air voids and half of it is for oil expression. See Figure 16 for a visual representation of this observation: the first image shows the initial uncompressed state, the second shows the beginning of oil expression at 30% compression of the volume, and the third shows the point at which the peanuts are incompressible when 60% of the volume is compressed.

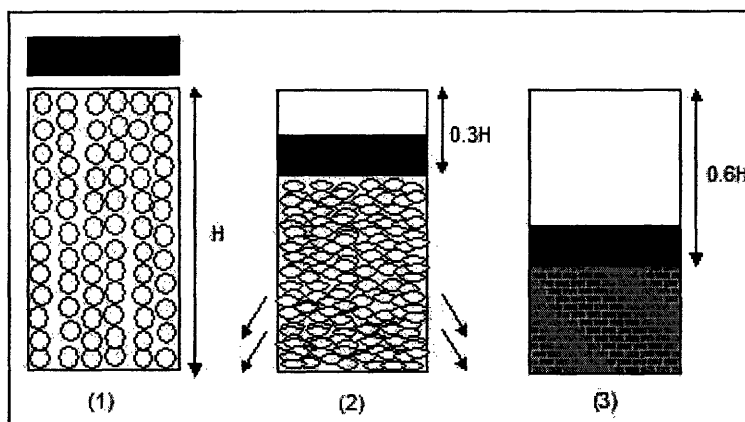


Figure 16: Stages in compression

It is also interesting to note that the larger container had lower yields for the same speeds. This could be due to the fact that oil from the peanuts in the center has a longer distance to travel in the case of a larger chamber. As a result, more oil may be trapped within the peanut bulk at the end of compression in a larger chamber. Therefore, a final design for the chamber should try to minimize the diameter; this, however, is a tradeoff with the overall rate of oil production of the machine since fewer peanuts can be compressed at a time.

With regards to the motion of the piston, the optimal speed is likely the slowest attainable. For a peanut oil press machine, a speed of 0.1 inches per minute is prohibitively slow; therefore, the closest that an ergonomically designed machine can get to a speed of 0.1 inches per minute is optimal given the restrictions. Also, note that because the peanuts are just being rearranged during the first 30% of the volume, the actual motion of the piston can be rapid during this period and then slow for maximum oil output.

5.1.2 Force Profile

While the force profile is not necessary to evaluate for the purposes of designing a new cam, it may be useful in future overall designs of the peanut oil press. With the experiments in the small container, oil began to be expressed at a force of approximately 2 kN, or a pressure of 2.5 MPa. The peanuts were incompressible at approximately 12 kN, or a pressure of 15.1 MPa. For the larger container, oil began to be expressed at a force of approximately 15 kN, or a pressure of 6.6 MPa. The peanuts were incompressible at about 100 kN, or 44.1 MPa. The higher pressures for the larger container likely are because the oil takes longer to reach the outside of the chamber and thus a larger pressure is needed for any oil expression to be visually observed. The most valuable result is that oil expression is most significant in a region of about 3 - 7 MPa.

Figures 12 and 13 also demonstrate that the magnitude of the force increases gradually during the initial part of compression that increases rapidly at later stages. This reflects the fact that during most of the compression, the peanuts are compressible due to the presence of oil and air voids. As the oil is pressed out of the surface of the peanut and all the air is pushed out of the peanut bulk, there is less and less compressibility that the peanut mass can withstand. Also, most of the oil leaves the actual peanut in the region where the slope of the force-displacement is less steep; at steep slopes, most of the pressing likely contributes to pushing the oil from the surface of the peanuts to outside of the chamber.

These results can then inform a designer of any peanut oil press as to the pressures required to express oil from peanuts.

5.2 Proposed Cam Designs

Based on the results, an approximate design for a cam can be created. Figure 17 is a cam design which would roughly maximize oil output while taking into account human user preferences. Ideally, a cam that moved at 0.1 inches per minute would give the most oil. However, since this is unbearably slow, a design that moves fast in the first stages of pressing and then slow for the remainder will suffice.

The proposed cam design is defined by a series of points and straight lines connecting them. As a result, the transitions between stages are abrupt, and would need to be smoothed out with respect to the machine's ergonomics. Smooth transitions are desired so that the user can easily go through one rotation.

Figure 17 depicts the pressing occurring in three distinct stages of compression. First, there is a rapid stage which goes from $\theta_0 = 0$ to about $\theta_1 = \frac{\pi}{3}$. This covers just under half of the total desired displacement.

The next stage is at an intermediate speed and goes to $\theta_2 = \frac{2\pi}{3}$ and covers approximately a third of the total displacement.

The final pressing stage goes to $\theta_3 = \frac{5\pi}{3}$ and covers the remainder of the motion - approximately a fifth of the total displacement. The final two stages represent the piston moving back to the initial position. These two stages are designed so that the movement is smooth and user-friendly.

This cam design is ideal because it does not go at an excruciatingly slow rate and it takes advantage of the fact that more oil is expressed in the latter portion of the piston's motion. As shown by experiments, half of the total displacement is spent in closing air voids. Thus, this stage (the first stage) was rapid. The latter half of the displacement was split up into an intermediate speed and a slow speed so that the time for one rotation is not exceedingly long.

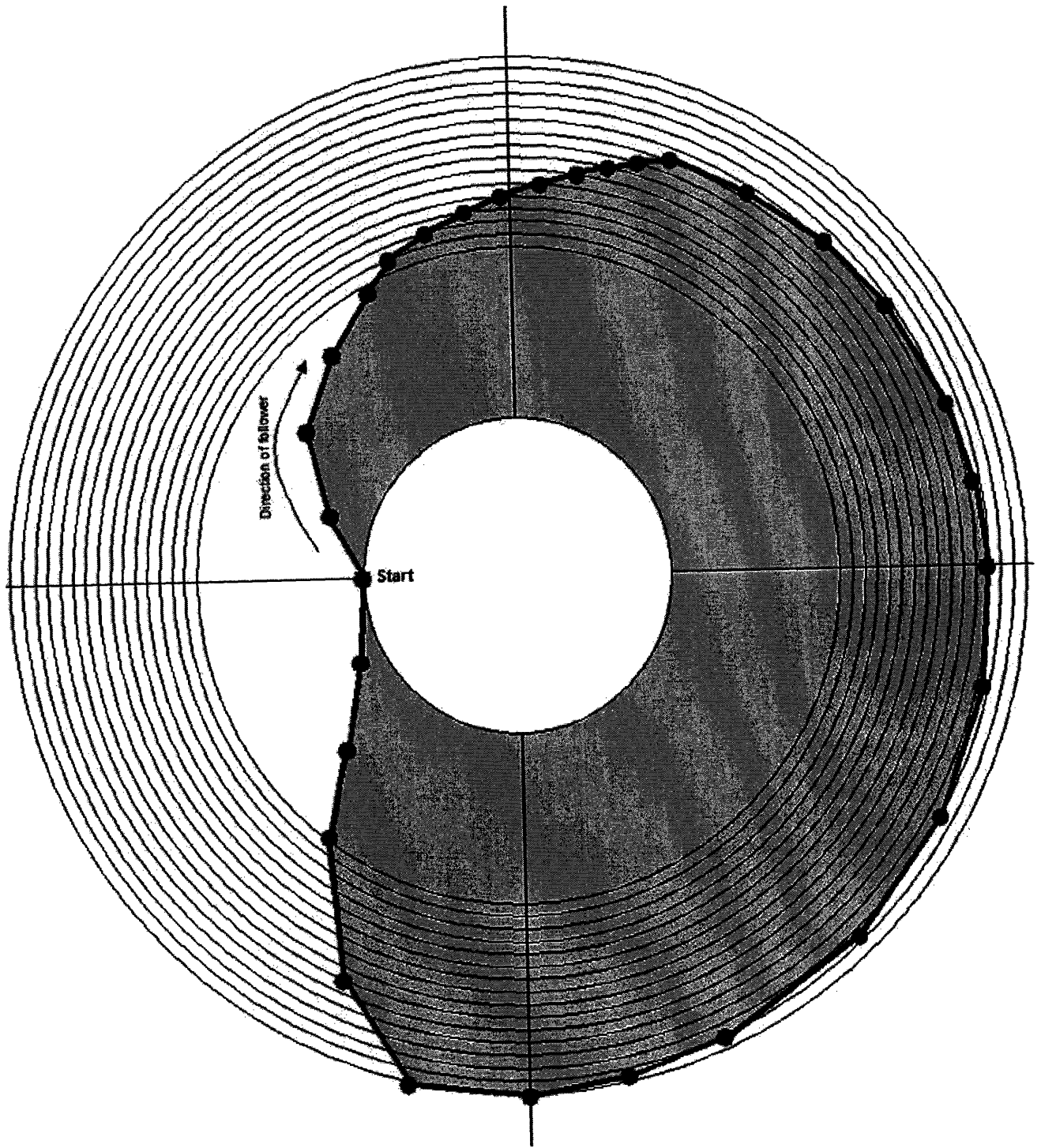


Figure 17: Proposed cam design

6 Conclusions and Future Research

The intention of this thesis was to optimize the displacement profile of a peanut pressing peanuts with respect to the oil expressed from the peanut bulk. The results of the experimentation show that the slower the rate of displacement, the greater the oil yield. This trend seems to level off at around 0.05 inches per minute. These results roughly correspond with past literature concerning oil expression from peanuts.

Experimentation also found that there is not a significant decrease in oil output if a faster speed is used when compressing the first 30% of the volume of peanuts, or 50% of the total displacement, since this mostly involves rearranging the peanuts. Thus, a cam design was created that takes advantage of this fact. The proposed cam design results in a rapid motion for the first half of displacement then a combination of an intermediate speed and a slow speed for the latter half.

The cam shown in Figure 17 is an approximate rendition of such a design. Thus, the treadle-powered peanut oil press can likely experience higher oil outputs if the cam is designed in the aforementioned manner.

Future research should utilize the results of this thesis and determine a design for the cam that corresponds with the newest design for the treadle-powered peanut oil press machine. The cam should be designed with two specifications in mind: first, the optimal displacement profile; and second, user friendliness. Because there is efficiency loss in the machine, the oil output will be less than what was demonstrated by the Instron machine. Therefore, oil output studies should be conducted with the overall machine to see if yields can come close to those experimentally observed.

After integration of the cam into the final machine, the oil press should be tested with human users to test its ergonomics. The smoothness of the cam design is a factor in the user's experience on the machine.

Ultimately, a functional peanut oil press machine should be tested in the field in villages in Africa to determine feasibility of manufacturing and design. In addition, the ability to integrate the machine into the activities of individual households is critical to the product's

success. Further work should be done to promote manufacturing and use of the machine in communities so that the technology becomes self sustainable.

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A Full experimental results of peanut pressing

Tables 5 and 6 show the data for each run of each trial for both the small and large containers.

Table 5: Full data set for experiments with small container

Trial No.	Displacement Profile	Quantity of Peanuts (grams)	Oil Expressed (grams)	% Yield
Trial A1	1 in./min.	33	3	9.09%
		34	4	11.76%
		33	5	15.15%
		34	5	14.71%
Trial A2	0.5 in./min.	33	5	15.15%
		34	4	11.76%
		33	6	18.18%
		29	6	20.69%
		33	6	18.18%
Trial A3	0.2 in./min.	34	5	14.71%
		33	5	15.15%
		33	4	12.12%
		33	7	21.21%
		34	8	23.53%
Trial A4	0.1 in./min.	33	8	24.24%
		31	9	29.03%
		32	10	31.25%
		33	9	27.27%
		34	9	26.47%
Trial A5	0.05 in./min.	32	9	28.13%
		33	9	27.27%
		33	7	21.21%
		33	8	24.24%
		32	10	31.25%
Trial A6	0.2 in./min. interrupted by a pause	34	3	8.82%
		34	6	17.65%
		33	7	21.21%
		33	6	18.18%
Trial A7	0.5 in./min. interrupted by a pause	33	5	15.15%
		34	4	11.76%
		33	6	18.18%
Trial A8	0.5 in./min., then 0.1 in./min.	32	5	15.63%
		33	9	27.27%
		33	8	24.24%
		31.5	9	28.57%
		32	9	28.13%

Table 6: Full data set for experiments with large container

Trial No.	Displacement Profile	Quantity of Peanuts (grams)	Oil Expressed (grams)	% Yield
Trial B1	0.5 in./min.	117	18	15.38%
		115	20	17.39%
		115	15	13.04%
		118	18	15.25%
		116	22	18.97%
Trial B2	0.2 in./min.	123	28	22.76%
		116	21	18.10%
		116	15	12.93%
		114	11	9.65%
		120	21	17.50%
Trial B3	0.1 in./min.	117	26	22.22%
		115	24	20.87%
		114	20	17.54%
		115	20	17.39%
		114	26	22.81%