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DESIGN OF A PVC PIPE-BASED ECONOMICAL COCOA WINNOWING MACHINE

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Abstract

Current basket winnowing methods utilized in fields are inefficient and very expensive in cleaning nibs from cracked cocoa mixture. To address the issue, a design was created which can be operated with just a electric power supply of less than 700W and a PVC pipe structure. The design underwent a series of system developments from theoretical concept to first prototype, leading to the adjustment of key components. Performance of the machine was determined through testing, and future improvements were suggested based off the performance results. The relative cost of the machine and feasibility of implementation was found in relation to the present machinery.

Keywords: Cocoa; Winnowing: Blower: Nibs and shell: Fan: PVC Pipe.

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Introduction

Reducing cocoa post cracking losses is a necessary step toward ensuring greater global food security as increased future demand will require increased production efficiency. Winnowing is a process of cleaning shell from cocoa mixture initially fermented and cracked from the field, and is conducted by using wind separation to blow lighter shell from cocoa mixture dropped from a height. Currently, developing communities in Industries utilize antiquated winnowing baskets which depend heavily on natural wind for cleaning; there is a reported 1-5% total global cocoa loss from cleaning processes alone as winnowing baskets have limited efficiency in separating cocoa. Consequently, cocoa mixture winnowed by this method also has a reported reduction in quality. This is a significant problem; low-quality cocoa is not only unsuitable for export but it's demand is also low. The use of winnowing baskets is labor intensive and inefficient, requiring workers who traditionally winnow cocoa to input full eight hour work days. Because the performance of winnowing baskets is contingent upon natural wind, the cocoa output quantity suffers from paddy separation losses and is also low-quality. The objective of this paper is twofold: to explore the implementation challenges of creating a design which improves the efficiency and quality of cocoa winnowing, while simultaneously prioritizing the accessibility and ease of design replication. As such, the prototype developed for this paper takes into consideration a number of key constraints and parameters. There are several constraints that are highly relevant in prototype of a winnowing machine. Accessibility of parts and cost of obtaining are related. The two constraints highly influence what materials will be used for construction of the prototype. An assumption is that industry women will be operating the winnowing machine as they are traditionally entrusted with the job, a factor which will influence the physical dimensions and direct physical labor inputs needed of the prototype. For the small scale companies to upkeep a winnowing machine and the availability of local fuel sources are also important constraints in determining the sophistication of the machine, and the source of power used to drive the prototype. Lastly, human health and well-being is of the utmost concern, which influences the overall design when incorporating safety factors and measures undertaken to reduce shell inhalation. Ultimately, the goal is to adequately address the relevant local constraints, in hope that the prototype is well-received and adopted.

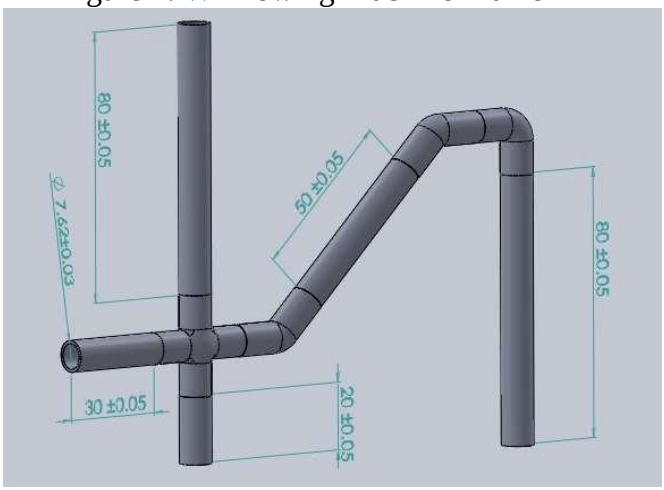
A PVC Pipe structure have been designed in order to make the whole frame of the machine. Since it is PVC material, it is inexpensive. The whole structure will have to be wall mounted and wall hangers will be provided along the machine. A blower is used in this design instead of a vacuum which are used in conventional machine but they cause an increase in cost because they require a hydro-cyclone at the end to collect the shells and if the hydro-cyclone is not used then the vacuum bucket will have to be cleaned again and again, which will make it a batch process instead of a continuous process. So the beans are going to fall from a height in the pipe structure so that the nibs gain enough acceleration to surpass the wind coming in from the blower to push the shell away. Since the nibs are much heavier than the shells they will gain more velocity and acceleration. So they won't be pushed away by the wind and only the lighter shells will be pushed away by the wind. The mixture will eventually pass through a cross T pipe structure and the air coming from the Fan will take the lighter shells out from other pipe line and the nibs will fall straight down whereas the nibs will travel vertically and leave the pipe structure from other end.

Literature review

Winnowing Machine is not exclusively new. Throughout history, human with the help of wind energy and the use of arms, hands to winnow cocoa nibs from cocoa mixtures. But research found that winnowing can be done using a blower in a machine as well like the winnower designed for rice and paddy mixture [8]. The difference in the mass of rice and paddy is too much so it is easy to separate them by using strong force of wind but while separating the cocoa nibs the calculations for the velocity needs to be very precise as stated by S.T. Becktt [6] as the quality of chocolate depends a lot on the separation of nibs from shell and in order to calculate the yield a lot of formulas and experimental analysis have been provided by a research study done on a cocoa winnowing machine in Vietnam [7], this paper also tells about the conventional cocoa winnowing machine that runs using a vacuum system. S.T. Beckett also stated that the flavours of chocolate depend a lot on the amount of shells left amongst the nibs and also wear the ball mill while grinding.

Design of winnowing machine framework

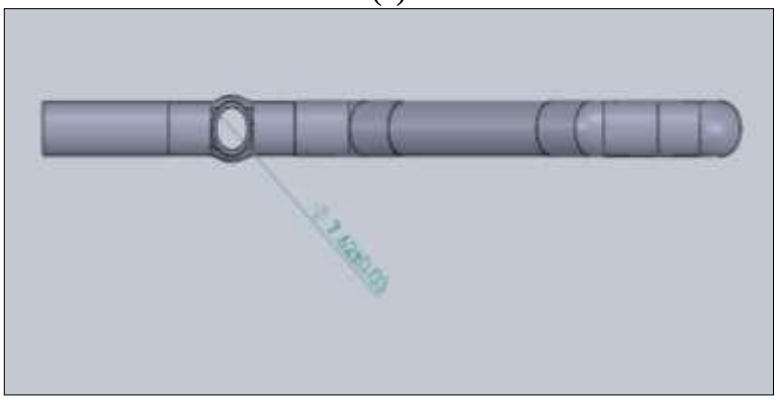
Figure 1: Winnowing Machine Frame



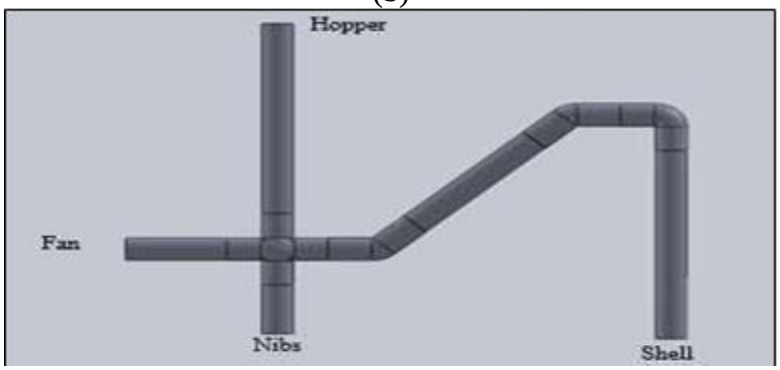
Winnowing machine is based on air velocity which drives away the unwanted matter from the cocoa mixture in order to improve the quality of chocolate. There are two ways of obtaining air velocity – naturally and from the use of electricity. Naturally obtaining velocity entirely depends on natural force and labors have to wait until the air force is enough to screen the cocoa mixture. Next idea is to use any fan, blower, and motor with fan to get the enough air velocity for the cocoa mixture screening purpose. It consists of hopper, natural air concentrator, frame, inner separator and outlet for screened nibs and outlet for shell. Cocoa mixture which is to be winnowed is passed in through hopper hole into the screening PVC pipe structure. By air velocity inside the double cross structure, lighter particles like the shell are blown away through shell outlet and screened cocoa nibs are collected through the nibs outlet. Unlike other winnower, it consists of electric motor (prime motor) or blower for air velocity and just a pipe structure. Due to this it consumes less electricity, it takes less space and it is easy to transport dissemble and transport. The frame is constructed by cutting a long 9ft pipe into different sizes, 2-45 degree turn pipes, 1 elbow turn pipe and one double cross T.

Figure 2a and b: Top and Front View of Frame

(a)



(b)



Components

Funnel

The funnel is used in order to feed the nibs and shell mixture in the frame in small quantities so that the shells and nibs fall freely and shells aren't surrounded by the nibs cause it won't allow the air to push out the shell. The funnel here is a substitute to a hopper for prototype, This will be

replaces be a hopper once the whole machine is fabricated. Since it is going to be wall mounted the hopper is going to be vertically straight on the end which is connected with the wall the other ends will be tilted by 45° so that they slide into the machine easily and also there's room for extra cocoa mixture.

Frame

It is made of PVC having a diameter of 3 inches and is 9mm thick. Strong enough to hold the nibs and shells, easy to clean and is some of the cheapest materials available. It was the standard thickness available of the pipe.

Fan

The blower/Fan provides a wind stream at an average rate of 38m/s and the reuirement of air velocity calculated in section 4.1 is 6.12 m/s. In order to reduce the velocity of air, the speed of motor of the fan needs to be reduced. Now when it comes to reducing speed of a motor, there are 2 parameters that can be changed, one is number of poles and the other is frequency as shown in equation (1).

$N = 120*f/P$ (1)

N = rpm of Motor

f = Frequency of motor P = Number of poles

In the given design, a variable frequency drive(VFD) is used in order to control the fan speed. At maximum speed of fan i.e. 1500rpm, the maximum frequency of the VFD is 50Hz. Now, while operating this fan with the frame work, air velocity of 6.5m/s was obtained with the help of an anemometer at a frequency of 16Hz which according to equation (1) would give a fan speed of 480 rpm.

Jute Bags

Jute bags have been used because of a little excess air the shells started blowing all over the place. Hence, to avoid that jute bags are attached at the end for collection of nibs and shell which will allow air to pass through as well.

Material and Method

The concept here is to sperate the nibs from shell while falling horizontally with fro of gravity. The nibs gain certain velocity while falling down, so it will not be easily blown away but the shells on contrary are very light weight particles they won't gain the similar acceleration and hence it will be easy to blow them away. The pipe thickness is 9mm which is the standard size available

Velocity of Air Calculations

Specifically 2 components are required to calculate velocity, which will eventually help us decide the fan speed. The 2 components are the vertical component of velocity which The fan needs to overcome to push the shell horizontally and the one to raise the shells to 45degree.

For Vertical component of the frame:

While free falling the velocity gained by the shells under free fall is:

$½ * mv2 = mgh$ (2)

H = .7m

g = 9.81m/s2

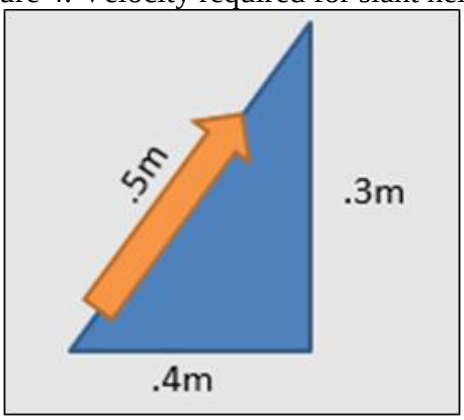
Which gives us v(v) = 3.70 m/s

Figure 3 shows the pipe through which the cocoa mixture is falling.

Figure 3: Vertical Free fall of cocoa mixture

Now for slant velocity (45degree) component:
In order to take the shells from lower elevation to higher elevation velocity at slant height needs tto be calculated.
½ * mv2 = mgh H = .3m
g = 9.81m/s2
Which gives us v(s) = 2.42 m/s
Total velocity of air required = V(s) + V (v)
Figure 4 shows the pipe through which the shell is pushed.

Figure 4: Velocity required for slant height



Hence, final theoretical velocity required by the by fan will be:
V= 2.42 + 3.70 = 6.12 m/s

Output calculations

In order to calculate the output of the machine certain parameters were calculated like the percentage of the desired products (nibs), percentage of shells and loss of mix% using the following formulas:
P(shell) = % of shell obtained from the total mixture P(nibs) = % of nibs obtained from the total mixture M = mass of total mixture = 630g
Mn = mass of nibs = 520g Ms = mass of shell = 90g
Ml = mass lost in the machine = 20g.

Table 1: Comparison between manual and machine winnowing

While using winnowing machine	While winnowing manually
P nibs = Mn*100/M	P nibs = Mn*100/M
P nibs = 520*100/630	P nibs = 450*100/630
P nibs = 82.5%	P nibs = 71.4%
P shell = Ms*100/M	P shell = Ms*100/M
P shell = 90*100/630	P shell = 70*100/630
P shell = 14.2%	P shell = 11.1%
Loss of mixture = 3.3%	Loss of mixture = 17.5%

As can be seen from table 2 there is a significant increase of 10% in the nibs% and decrease in Loss of mixture by 14.5%, which will eventually result in higher efficiency.

Experimental Validation

The winnowing machine was built on the basis of the design specification and manufacturing drawing in the local workshop. Several trails and experiments were conducted on the winnowing machine to enhance its productivity. The trials varied from each other by changing the structure inside the chamber like by introducing the concept of cascading, inclined plane, changing the wind speed, using different types of blower, using a VFD. 5 trials were done on the machine by varying designs, wind speed and funnel openings. The table for the output is as follows:

Table 2: Experimental results of the winnowing machine

No	**Specification**	**%Nibs**	**Shell%**	**%loss**	**air. velocity**
1	Small funnel size	70	10	20	14
2	Frim tilted by 45 degree	73	11	16	14
3	Using dryer	88	5	7	6
4	Using blower	85	8	7	9
5	Using fan	82	14	4	12

In the beginning the funnel opening was too small so it had to be manually vibrated it in order to let the cocoa mix. fall, but as the size of the funnel hole was increased, it allowed the mix to flow easily. There was a lot of mixture loss when the doble cross T structure was tilted by 45% so the designed was made vertical in order to avoid mixture loss. A fan was used, a blower, a hair dryer in order to check which works well with the machine and the blower turns out to have the perfect amount of air velocity required. An anemometer was used to measure the wind velocity at the outlet of the shell side. Of all five trials, the fifth trial provides the most optimum result.

Results and Conclusion:

An improved technique for software cost estimations in agile software development using soft computing techniques. The following figure 5(a), (b) and (c) indicates the three different images of shell nibs and cocoa mixture segregation after winnowing. Which proves that our machine is working the right velocity of air is supplied into the frame.

Figure 5: Segregation of Cocoa Mixture

(a)Shells, (b)Nibs, (c)Cocoa mixture

In conclusion, the primary findings of this paper suggest that the cocoa winnowing machine was a successful design and is applicable. The cocoa was winnowed quickly and the quality of the cocoa mixture was improved as per designed. This prototype machine is successfully designed and demonstrated but it still has some areas of improvement. The machine has demonstrated that modern winnowing technology can be incorporated into a cheap and accessible machine which has the potential to improve.

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