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Development and Evaluation of Pummelo (*Citrus grandis* L.) Fruit Sorter

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Abstract: ***Pummelo fruits play an important role in the market. However, sorting is necessary to meet costumer's quality standard and enhance its market value. This study was conducted to design, fabricate, and evaluate the performance of a machine that could attain high sorting capacity and efficiency. Three conveyor belt speeds in three replications a total of nine experimental units were used in the actual field test. Completely randomized design (CRD).in one-way ANOVA was used to differentiate significant differences among treatment means. Belt speeds considered as treatments in the test were 7-8, 11-12, and 27-28 meter per minute. Further test of significant differences among means treatment means was done using Duncan's Multiple Range Test at 5 percent level of significance. The performance of pummelo sorter versus manual sorting was compared. Results showed that the highest sorting capacity of Pummelo fruit sorter was 507 pieces per hour using the conveyor belt speed of 27-28 m/min. The highest mean sorting efficiency was recorded at 96.97% at conveyor belt speed of 11-12 m/min. Lowest mechanical damage mean of 0.48% was at conveyor belt speed 7-8 m/min. The manual sorting has an average mean capacity of 477 pieces hour and mean efficiency of 72.78 %. Pummelo sorter at conveyor belt speed of 27-28 meter / min. with sorting capacity of 507 fruits per hour has total estimated sorting output of 973,440 fruits per year. It has an operating cost of at Php0.088 per piece with a custom rate of Php0.118 per fruit. The machine sorter has to sort 384,536 pieces of pummelo fruits to attain its breakeven cost of operation at Php45,375.25. The fabrication cost of the machine was Php41, 385.00. It has an estimated net income per year of Php29, 467.45 and a payback period of 1.4 years.***

Keywords: sorter, pummel

1. Introduction

The Philippines produced an average of 36,686MT of pummelo spreading over five major producing areas namely; Davao City, Isabela, Cagayan, Nueva Viscaya, and Davao Oriental. The Philippines exported pummelo in 1999-2001, but due to increasing domestic consumer demand, the country imported pummelo from other countries (Lustria et al., 2009).

Davao City, as the number one producer of Pummelo was able to produce 12,672 metric tons of pummelo in 2009 which was 34% of the total production. It is followed by Isabela which produced only 6,917 metric tons which was only 18%. The volume showed and proved that pummelo is a signature fruit and landmark of Davao City.

Pummelo plays an important role in the market; however sorting is necessary to meet costumer's quality standard and enhance its market value. Sorting is one of the important operations that dictate acceptance of the fruit to consumers in national and even international market (Mangraj et al., 2009). Fruits undergo postharvest preparation especially sorting before transporting from field to market.

Manual sorting and grading of fruit are a globally adapted practice for fruits including the pummelo, but these operations need qualified staff for the consideration of some factors through their physical parameters by visual inspection (More & Saxena, 2003). Size and weight are the very common features to classify a certain fruit. Manual weighing is time consuming, inconsistent and less efficient.

Moreover, becomes expensive due to shortage of labor during peak seasons which totally affects the operations (Londhe et al., 2013). Hiring of inexperience sorter affects quality of work in terms of efficient classification which needs extra checking of their sorted fruits, mentoring of newly hired workers and additional cost of supervision.

Research found out that farmers are already educating their children to elevate their mode of living and to move away from farm works. Nowadays, the unavailability of workers has become a problem in the farming industry. The situation is supported by the decreased in the labor force in 2004 (Briones, 2009). As of today, majority of small pummelo traders and farmers in Davao rely on manual sorting actually experienced the above-mentioned problems. Based on the situation, it reveals the need for the development of an automated grading and sorting machine to address the shortage of farm laborers.

In order to alleviate and sustain quality agricultural produce, an affordable and portable fruit sorting machine must be designed and developed.

Objectives of the Study

The general objective of the study was to design, fabricate and evaluate the performance of pummeloa fruit sorter. The specific objectives of study were the following:

1) To design an automated pummel sorter;
2) To fabricate pummelo sorter;
3) To evaluate the performance of the pummelo sorter in terms sorting capacity, sorting efficiency, mechanical damage and power requirement;
4) To compare the performance of the fabricated sorter machine to the manual sorting; and,
5) To calculate the cost of operation.

2. Materials and Methods

The study follows the input-output design. The following criteria were considered on the design of pummelo fruit sorter.

1) Properties of crops that are relevant to the design, development, and performance evaluation. The properties include variety, size of the fruits, bulk density and weight class standard for sorting purposes.
2) Input capacity of 500 to 700 fruits per hour and which can accommodate 450 to 650kg of fruits per hour.
3) Standard dimensions from PAES 2008 such as pulleys and belts, including chain sprockets
4) Simplicity of the design for the ease of operation and maintenance.
5) Use of locally available material so that it can easily be constructed in the shop.
6) Use of some standard parts readily available at the local market.
7) Safety of operating the machine.

The Pummelo sorter composed of six main parts: (1) feeding hopper; (2) conveyor belt system, (3) load cell, (4) selector arm, (5) fruit container, and (6) main frame. Figure 1 was operated using an algorithm for sorting mechanism in four weight classifications. The procedures were as follows:

1) Start the machine;
2) Initialize it through the universal asynchronous receiver-transmitter (UART) and analog-to-digital converter (ADC);
3) Clear output open collector (OC) and the Voltage controls the system on a chip (SOC);
4) Check the Pomelo fruits at the load cell;
5) Initialize the over lapped execution circuits (OEC);
6) Determine the weight calculation (ADC conversion) storing as variable ‘w’ for weight;
7) Wait the end of conversion (EOC) Selection to be disabled;
8) Rotate motor at the conveyor for corresponding weight of pummelo;
9) Following weight range is decided:
   a) 801g up
   b) 800-601
   c) 401-600
   d) <400

Decide weight ranged based on:

9.1. If the calculated weight is w>b, then Arm 1 sorts the pomelo fruit;

9.2. If the calculated weight is c<w<a, then Arm 2 sorts the pomelo fruit;

9.3. If the calculated weight is d<w<b, then Arm 3 sorts the pomelo fruit;

9.4. If the calculated weight is w<c, then sort to fourth basket;

10) This process is repeatedly performed in all the above steps until all pomelo fruits are sorted; and,
11) This is the end of the sorting process.

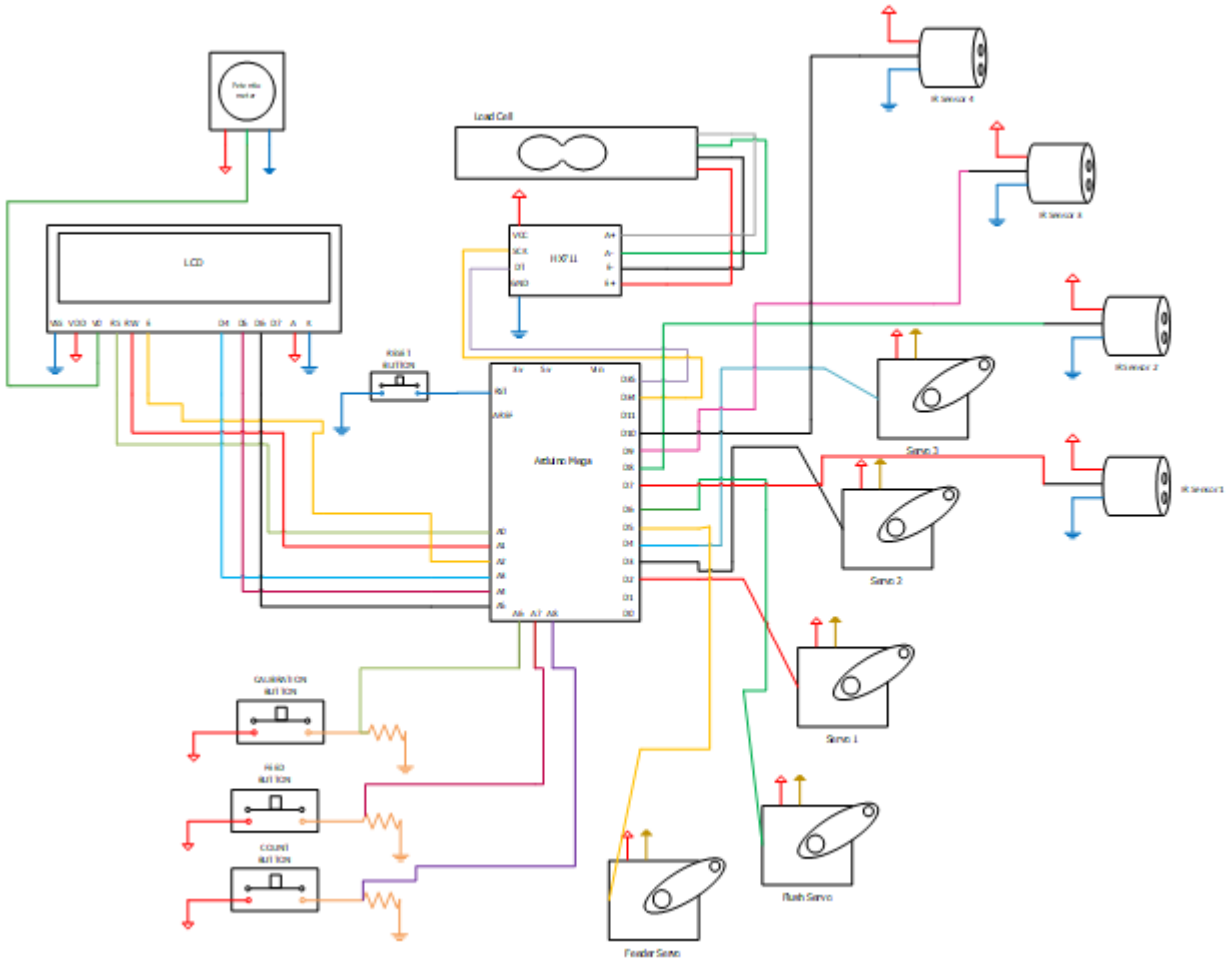

Figure 1: Electronic and Arduino system

Testing of the machine was conducted after its completion in order to see whether the different parts were functioning properly. Checking of chain, sprocket, belt tension, calibration of rpm of the rotated parts and the electronic system. The RPM, power requirement and consumption, belt slippage and other necessary data were gathered while the machine was at no load. The belt speed with the corresponding pulley was 7-8, 11-12, 27-28 m/min, which served as treatment.

For final testing, the study arranged and analyzed statically using the single factor experiments in Completely Randomized Design (CRD) to determine the effect of the different levels of belt speed at (8-9, 11-12, 27-28m/min) on the efficiency, capacity, and mechanical damage on the fruit being tested.

There were three treatments in three replications with a total of 9 experimental units. Each experimental unit was tested using 121 fruits or 97kg of pummelo fruits using the Magallanes variety. A total of 873 kg average of pummelo was used. Significant differences among treatment means were determine through the use of One Way ANOVA. Duncan's Multiple Range Test was used to determine which among the means significantly differ from each other. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS).

Manual sorting activities were observed in a pummelo packing house located in the locality at Davao. Data gathered using survey the questionnaire. The sorting capacity of the pumelo worker was based on the fruits sorted in one-day operation under normal condition. The result was analyzed using t–test of independent samples.

Cost of operation was analyzed using the pummelo sorter. The fixed cost, variable cost, interest on investment and breakeven point analysis were also determined

3. Results and Discussion

The designed pummelo fruit sorter in Figure 2 have the following major components; hopper, conveyor belt system or the power transmission assembly, electronic assembly (which includes load cell, microcontroller and servo motors, and sensors), mainframe, and the fruit container. The pummelo sorter dimensions presented in Table 1.

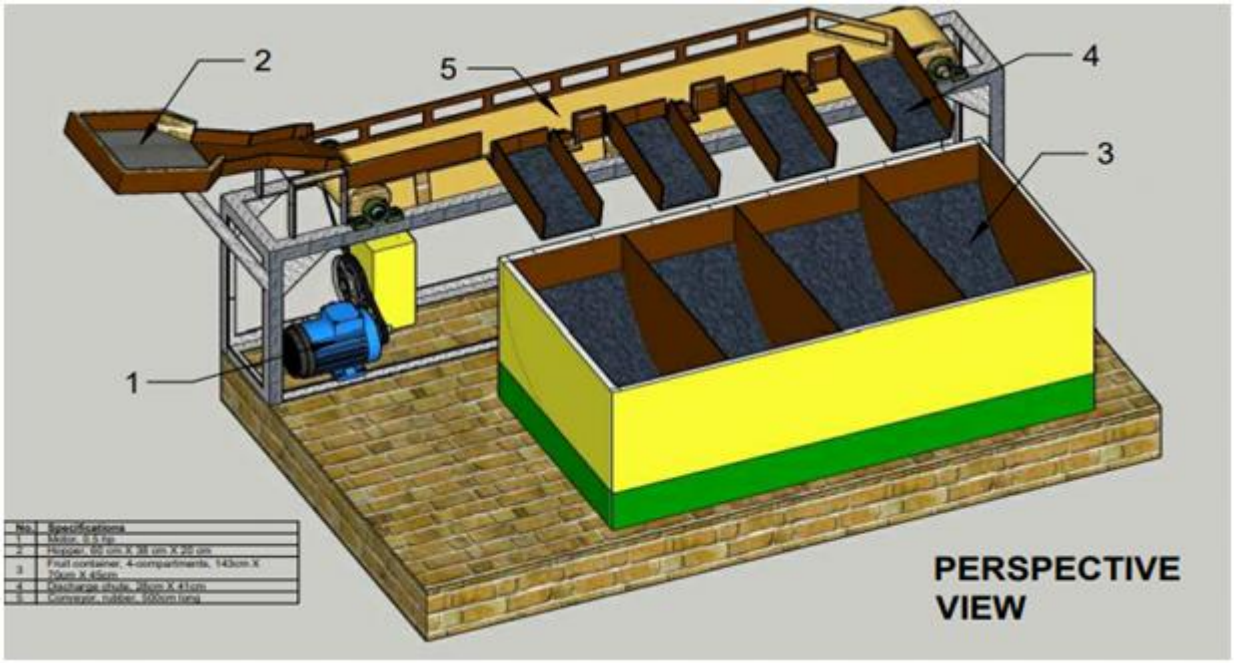

Figure 2: Design of Pummelo sorter in 3D Isometric view

Table 1: Specification of pummelo (*Citrus grandis*L.) sorter

Item	Specification
A. Capacity, pcs. /hr.	507
B. Sorting Efficiency,	95.87
C. Mechanical Damage,	0.79
D. Main Structure	.
Weight, kg	250
Overall Dimensions	
Length, mm	3400
Width, mm	1500
Height, mm	1200
E. Discharge Chute	
Length, mm	280
Width, mm	410
Height, mm	150
F. Fruit Container	
Length, mm	1430
Width, mm	700
Height, mm	450
G. Hopper	
Length, mm	600
Width, mm	380
Height, mm	200
H. Feeding Mechanism	Manual Feeding, Batch Type
I. Prime Mover	220 V, 746 W single phase, capacitor type electric motor coupled with 1:40 Motor Reducer
J. Transmission System	Sprocket Chain Drive and Pulley Belt Combination
Gear Sprocket 1	11teeth
Gear Sprocket 2	28 teeth
Sprocket chain number	60mm
Pulley 1	127mm Single sheave pulley
Pulley 2	152.4mm,101.6mm,50.8mm
Belt type	V-belt, A-36, A-85, A-80
Conveyor Type	Flat Belt 120mmx4000mm
K. Arduino &Electronic System	Arduino Mega, Load Cell, amplifier, Servo Motors, Light Sensors &LCD

Performance Evaluation of the Device

The Pummelo sorter was evaluated by the overall performance in terms of sorting capacity, efficiency and mechanical damage as affected by different conveyor belt speed. Three conveyor belt speed were tested at 7-8, 11-12, 27-28 meter per minute

Sorting Capacity

Table 2 shows the sorting capacity, efficiency and mechanical damage at 8-9, 11-12, and 27-28 conveyor belt speed in meter per minute. It has a highest mean of 507 pieces of pummel fruits per hour at speed of 27-28 meter per minute, followed by 396 pieces at 11-12 meter per minute, while the lowest mean was 371 pieces at the speed of 8-9 meter per minute. The sorter at speed of 7-8, 11-12 and 27-28 meter per minute revealed that as belt speed gets faster, performance capacity is higher.

Sorting Efficiency

Sorting efficiency was 96.97% at belt conveyor speed of 11-12meter per minute, followed by 96.69% at 7-8 meter per minute and 95.87% at conveyor belt speed of 27-28 meter per minute. Data showed that sorting efficiency range of 1.65%. Results revealed that, increasing belt speed has positive effect on the performance the machine.

Table 2: Performance of Pummelo Sorter as affected by different belt sped

Conveyor Belt Speed, m/min	Sorting capacity, Pummelo/hr.	Sorting Efficiency %	Mechanical damage,%
7-Aug8	370.85[a]	96.69[a]	0.48[a]
11-12	396.08[a]	96.97[a]	0.65[a]
27-28	506.87[b]	95.87[a]	0.79[a]

Means not sharing the same letter, in row or column, differ significantly by DMRT at 5 level of significant

Mechanical Damage

Table 2 showed the result on mechanical damage of fruits in three conveyor belt speeds at 7-8, 11-12, and 27-28 meter

per minute. The highest mean was 0.79% at conveyor belt speed of 27-28 meter per minute, followed by 0.65% at conveyor belt speed 11-12 meter per minute while the lowest mean of 0.48% was obtained at conveyor belt speed of 7-8 meter per minute. Data revealed that 0.92 %. Pummelo sorter showed less mechanical damage of fruits during testing operation

Comparison of Manual SortingVersus Machine Sorting

Table 3 revealed that manual sorting has a mean capacity of 477 pieces of fruits per hour. Result showed that the Pummelo Sorter has a lead difference in terms of capacity, efficiency and cost per day: 30 pcs. /hr. 23.09% efficient and Php 150 /day respectively.

Table 3: Comparison of Pummelo sorter manual sorting

	Capacity, pcs/hr.	Efficiency,%	Labor cost/day
Pummelo sorter	507	95.87	300
Manual sorting	477	72.78	450

Operating Cost of Pummelo Sorter

The machine has a total fixed cost of Php11, 536.07/yr. These costs entailed a depreciation of Php7,449.30 and Php2,845.22 for an interest of investment. The taxes, insurance, and shelter cost is Php1, 241.55. Variable costs accumulated during operation were repair of maintenance (R & M), energy cost, engine, and labor cost, with a total cost of Php38.47 per hour in which in one-year operation, it would cost Php73, 862.4. The total operating cost of utilizing the machine is, Php 85,398.47/yr. It has an operating cost of Php0.088/pc with a custom rate of Php0.118/pc. Thus, the machine has an estimated gross income of Php114,865.92/yr. and net income of Php29,467.45/yr. with a payback period of 1.4years.

4. Conclusion

The designed pummelo sorter is timely to address the need of the pummelo growers and traders. Also, the fabricated pummelo sorter is functional which has a performance capacity and efficiency. It can sort at a maximum of 4056 fruits per day and 95.87 % efficient. Moreover, there is a significant difference on the performance on the machine in terms of sorting capacity at three conveyor belt speeds. However, there is no significant difference on sorting efficiency and mechanical damage at three conveyor speeds are noted. It is also find that there was no significant difference in terms of capacity between pummelo sorter and manual sorting. However, there is a significant difference in terms of sorting efficiency. It has a lead difference capacity and efficiency of 30 pieces per hour and 23.09 %, respectively. Thus, the pummelo sorter is better than manual sorting. The cost of fabricating the machine is Php41,385.00.00. The projected annual net income of the machine is Php 29,467.45 per year. The designed Pummelo sorter has a payback period of 1.4 years.

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