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Image-Processed Mango Sizing Machine

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ABSTRACT

Development of mango sizing machine is based upon linear relationship between projected area and weight of mango.

The machine comprises a portable TV camera taking a picture of moving mango by the control of the photocell. The picture will be scanned, white-pixel counted and compared with the number of white pixel of the standard size mango by 32 bit, 68008. Then, it will give signal to a solinoid mounted on the conveyor to tap the mango into the corresponding rotary bin.

Sizing machine testing exhibited sizing capacity of 1 ton per hour at the sizing efficiency of 89.77% with ignorable mechanical damage. The machine could size mango (Namdog Mai No.4) into 4 classes (Extra fruit weight > 360 g., No. 1 fruit weight 310.1 to 360 g., No. 2 fruit weight 250.1 to 310 g., and No. fruit weight 200 to 250 g.) at belt speed 37.8 cm/sec.

INTRODUCTION

Exporting data of mango in 1989 showed that 9,400 tons of mango had been exported and valued about 30.17 million baht (Sutpakti, T. 1990). Quality of mango is classified according to its variety, skin colour, taste and the size which meet the standard. In Thailand, mango is graded into 4 class corresponding to its weight which are Extra class, class I, class II and class III (Chantraburee Horticulture Experiment Station, 1988). mango is usually graded by man. Unfortunately, training people for doing this job needs time, strength of these graders also have limit and can not do a lot of work in limitted time. After a period of time they can not control the accuracy.

Grading of mango by mean of weight different in between each class, the sizing machine usually operates by using the known weight comparison mechanism. Other sizing method is done by directly weight the fruit to determine its weight in gram.

In a study of physical characteristic of mango done by Bundit Jarimopas et al, 1989, they found that the projected area and weight of fruit has linear relation with coefficient of correlation $R^2 = 92\%$. And this fact was used for the design of a prototype of a mango sizing machine, by using a TV camera to take a picture of fruit and processed into a personel imcro-computer using Digital Image Processing unit developed in Thailand. The performance of the machine was found to be 89% efficiency at feeding rate of 0.42 tons/hour.

However the estimated price of the machine was found to be uneconomic, as a computer system was used for processing data, some parts of this system had not been utilized, hence the price of this machine could be reduced if those parts have been removed.

OBJECTIVE

To design, construct, test and modify the mango sizing machine to higher its performance, easy to use and economic.

Structure design of the mango sizing system

Design criteria of the mango sizing system

1. the system must not complicate but strong enough and not so expensive that farmer can afford to buy this machine.

2. must has the capability to grade the exporting variety fruit such as Namdogmai etc.

From the previous work done by Bundit Jarimopas *et al* 1989, it was found that the previous

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design system meet with this design criteria, hence this research will use that system as a basis for the modification.

Design

The mango sizing machine consists of 3 main components which are

1. Transporting system
2. Sizing system
3. Rotating bin

- Transporting system consists of

a) Frame (figure 1,2) This is a cubic structure frame with 82 cm high, 60 cm wide and 600 cm long, made from 1 inch angle bar.

b) Driving unit use 3 KW electric motor connected to a variable speed transmission gear with the revolution speed range from 0 to 1,400 rpm, power was transmitted through v-belt to drive an endless 4 ply flat belt of 10 cm wide and 1020 cm long. The flat belt was hooked into 3 inch pulley at both end of the machine, there were 2 tensioners at the middle of this belt. Power also transmitted to drive 4 rotary bins.

- Grading System has structure and function devided into 2 parts which are

a) Hardware structure. This system was modified from the old PC system but reduce the construc-

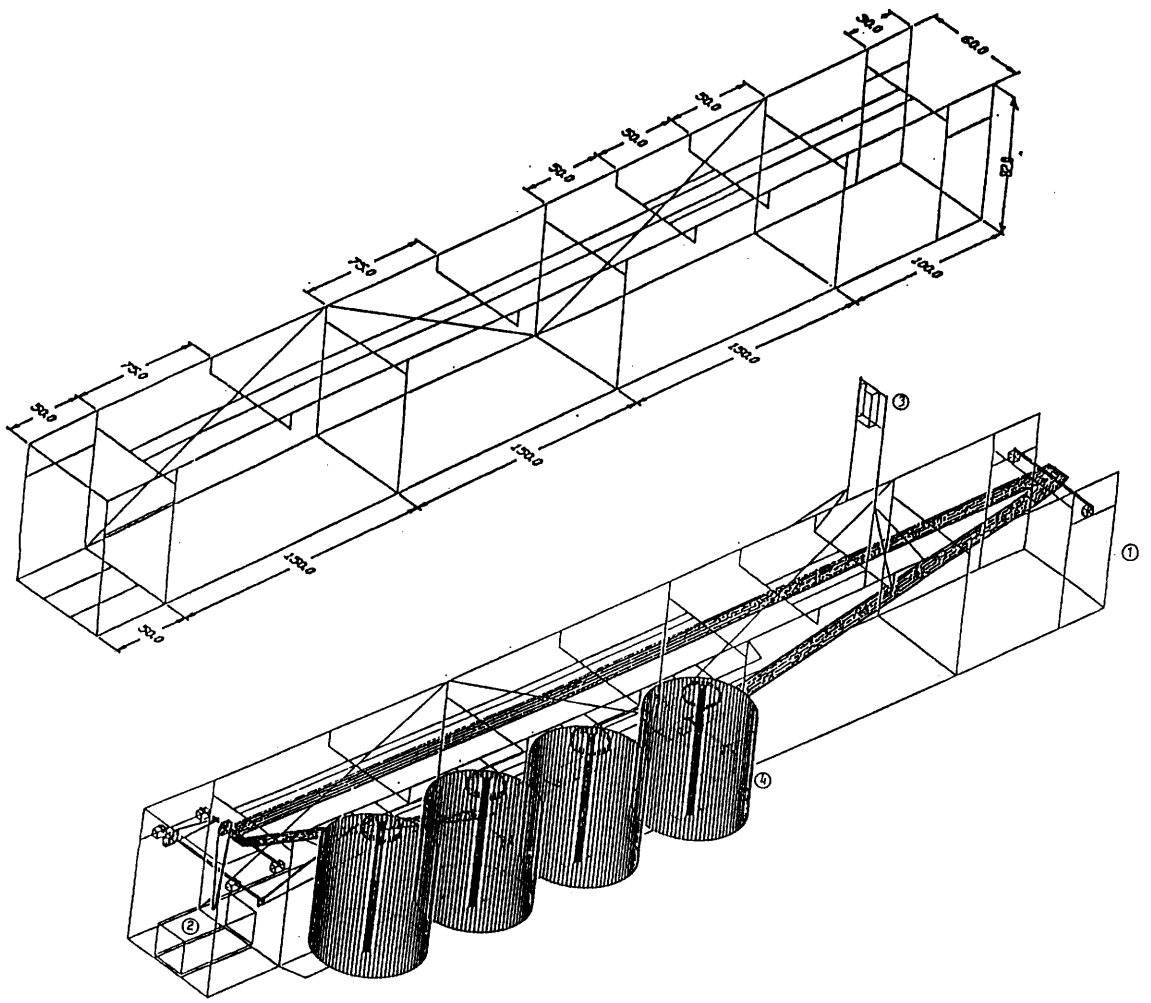
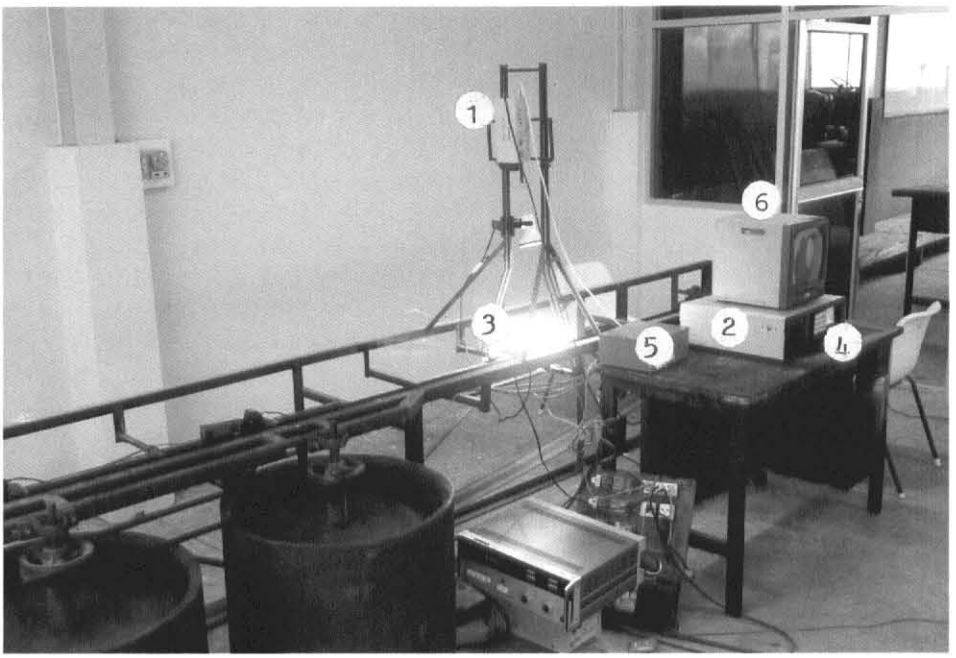


Figure 1 Component of Mango Sizing Machine
1. Frame
2. Electric motor
3. TV camera
4. Rotary bin

Dimension in centimeter



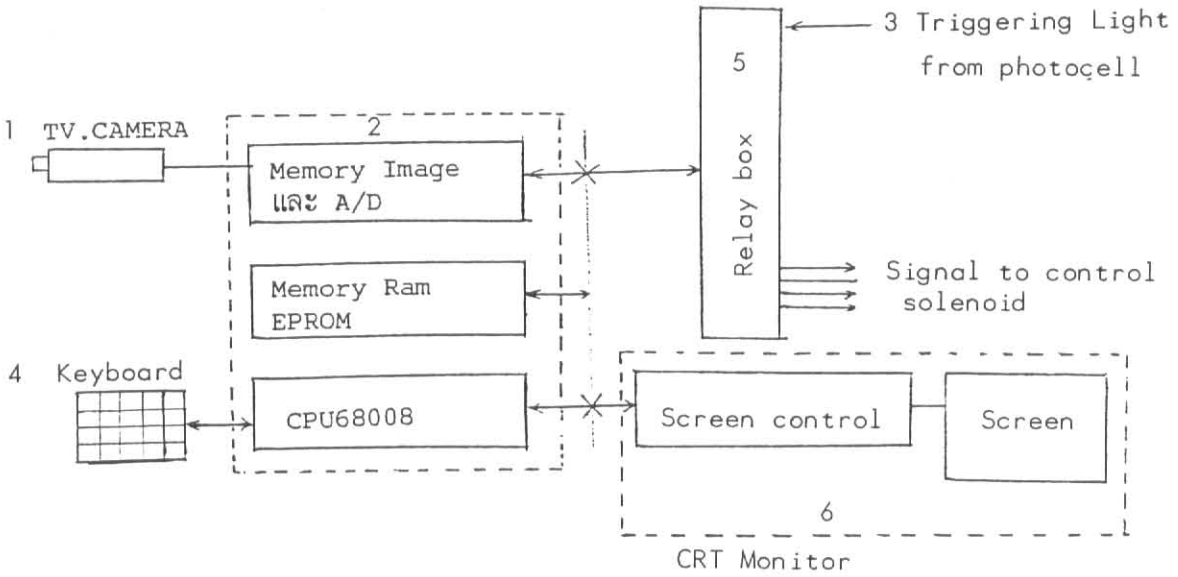


Figure 2 Block diagram

tion cost. As for the old system there were some excess parts such as floppy disk communication system and too much memory capacity. These reduced the accuracy of the system. Hence design of the new system has been done by keeping only necessary parts, so that the cost can keep low and easy to operate even the beginner can operate this system. This system consists of

1. Portable TV camera and memory image, which are the original system used with IBMPC.

2. New additional system design of 68008 CPU which is 32 Bit internal and 8 Bit external operate at 8 MHz. This CPU has been selected for the design beacause of the high capability in mathematics and high scanning speed for memory image, which can control the time for energize solenoid by the programme and do not need to vary the external resistance as in the old system.

3. Monitor, used small size TV set as a monitor, by develop a control card to deliver image signal to

TV monitor. Using this TV set, communication between the system and operator will be convenient as the operator can only press the button or move a cursor to a field that he want to correct the data and fill up the number.

4. I/O unit used for communication and interpretation of those push button pressed by the operator. Beside, it also receive a signal from optical switch used for checking the appearance of mango to the TV set and deliver a signal to energize solenoid and control the function of memory image.

Cost Comparison between old and new system.

For the first design, IBMPC XT had been used as a basis for the design as it was a feasibility study and it provide adaptability to the programme which was kept in a floppy disk. However this system still had some disadvantage which were low accuracy and had some excess parts, such as excess memory capacity, floppy disk drive and too big monitor etc. Thus, for the new system, those excess parts has been removed and remain only needed parts which can increase the accuracy of the system.

Estimated cost of the old system

1. IBMPC XT set	1 set	23,000 Baht
2. Camera & Memory Image Card	1 set	15,000 Baht
3. Solenoid ejecting mechanism	4 set	7,000 Baht
4. Optical switch	1 set	3,000 Baht
total		48,000 Baht

Estimated cost of the new system

1. 68008 system	1 set	12,000 Baht
2. Camera & memory Image Card	1 set	15,000 Baht
3. Solenoid ejecting mechaniem	4 set	7,000 Baht
4. Optical switch	1 set	3,000 Baht

- Rotary Bin (figure 5) These are 4 cylindrical iron bins of 600 mm diameter and 600 mm heigh. These bins are used for collecting the graded fruit. Inside the bin, there is a sinkable paltform which can lower itself after being load by the graded fruit. The inner wall of the bin is fitted with cushion material for protecting the fruit from mechanical damages.

EQUIPMENTS & METHODS

Equipments used in this experiment consist of

1. 68008 system
2. tachometer
3. stop watch

Experimental methods divided into 3 parts which are

1. Determination of partitioning point. By manually load the graded fruit onto a conveyor belt moving at 37.8 cm/sec and collect the projected area of the fruit appeared on a TV monitor. By doing this, the temporary partitioning point can approximately be fixed and repeating this, more precise or permanent partitioning point and the delay time, for energized solinoid for grading the fruit corresponding to its class, can be determined.

2. Determination of sizing efficiency. After the permanent partitioning point and the delay time for energized the solinoid had been fixed, mix all the graded fruit then feed each of the graded fruit onto the conveyor belt (moving at same speed) by provide the space between each fruit about 30 cm. Repeat this until the changes of incorrectly graded fruit are steady, record the number of correctly and incorrectly graded fruit from each experiment and calculate the sizing efficiency.

3. Determination of physical damage occurred during grading operation. collect 10 fruits from every class of the fruits recevied from the sizing machine and 10 fruits that were not graded by the machine. From each class of the selected fruits, take 4 fruits store at ambient temperature (25-30°C, 65-70%RH), 1 keep at -40°C for further determination of ascorbic acid content and pH, and 5 keep at 10°C for 1 week then transfer to ambient temperature until ripe. After that check for any damage of all fruits.

The experiment in part 1 and 2 was carried out at National Agricultural Machinery Center, When as part 3 carried out at Central Laboratory and Green House Complex, Kasetsart University.

Data Analysis

from the definition of sizing efficiency given by Peleg, 1985

$$E_w = (Pg_1 W_1 G_1) / (P_1 Q)$$
$$P_w = Pg_1 W_1$$
$$C_w = 1\text{-}P_w$$

when $Pg_1 = Ng_1 / Nt_1$

$Nt_1 = Ng_1 + N_{1j}$

$W_1 = K_1 P_1 / K_1 P_1$

$P_1 = N_1 / N_1$

$G_1 = w_1 / t$

$Q = w_1 / t$

where as E_w = Weight sizing efficiency

G_1 = Outflow rate of mango class i (kg/min)

K_1 = Fraction of price of mango among class

N_1 = No. of mango of class i feed to

the sizing machine

N_i = Total No. of mango n class

N_{ij} = No. of mango of class j incorrectly grade into class i

Ng_i = No. of mango of calss i correctly grade into class i

Nt_i = total No. of mango fruit being graded into class i

P_i = Fraction of mango class i before sizing operation

Pg_i = Fraction of mango class i correctly grade into class i

Q = Throughput of mango (kg/min)

t = Total operating time

W_i = weight function

w_i = Total weight of mango collected at class i partition (relate to Nt_i)

w_t = Total weight of fruit being grade (relate to N_i)

P_w = Fraction of correct class of sizing machine

C_w = Fraction of incorrect class of sizing machine

given : - equal sale price is 100 baht
- mango class extra, class 1, class 2 and class 3 represented by letter e, 1, 2, and 3 respectively
- then $K_e : K_1 : K_2 : K_3 = 1 : 1 : 1 : 1$ which mean they are all same price

RESULTS AND DISCUSSION

The data on projected area and weight of mango are shown in table 1. From this data, the most suitable range of projected area used to locate the partitioning point and the time delay to activate the solinoid has been selected (Table 2). Then, the sizing operation has been carried out until there was no significant changes in the performance of the machine, the calculation of sizing efficiency was done and found to be 89.77% which was higher than the old system (Bundit jarimopas et al, 1989). This confirms the first assumption that the projected area correlate with the fruit' weight, since the coefficient of correlation was found to be 0.9. This system showed high sizing accuracy and had good repeatability, since the coefficient of variation of sizing efficiency (E_w) was 2.50. This machine has the capacity of about 1 ton/hour (table 6).

The data on physical damage occurred from the sizing operation showed in table 7, there was no significant different between the fruit being graded by

Table 1 Projected Area (P.A.) of mangoes producted by mango sizing machine compare with fruit weight.

Number of white dots (pixels)											
Extra Grade			Grade 1			Grade 2			Grade 3		
Code	Weight	P.A.	Code	Weight	P.A.	Code	Weight	P.A.>	Code	Weight	P.A.
A1	458.4	44.42	B1	360.0	35.28	C1	299.3	32.76	D1	244.9	26.69
A2	435.5	41.67	B2	358.1	34.61	C2	299.0	33.72	D2	238.6	26.13
A3	429.9	40.83	B3	357.6	36.81	C3	296.4	31.64	D3	235.9	26.10
A4	426.3	42.11	B4	357.1	34.53	C4	296.2	31.01	D4	234.3	24.27
A5	421.2	40.44	B5	353.6	35.37	C5	289.0	30.65	D5	230.2	24.80
A6	410.9	41.25	B6	351.2	34.80	C6	283.8	31.70	D6	227.5	25.93
A7	406.6	40.77	B7	349.1	33.19	C7	283.7	31.60	D7	226.3	25.15
A8	400.2	39.14	B8	345.9	35.74	C8	269.5	29.06	D8	220.0	27.20
A9	398.9	37.87	B9	344.6	35.09	C9	268.7	29.74	D9	213.4	22.82
A10	397.0	39.12	B10	344.1	34.55	C10	265.1	29.49	D10	210.9	22.17
A11	390.0	36.20	B11	343.4	35.31				D11	207.4	22.87
A12	386.8	37.73	B12	342.3	34.51				D12	196.0	23.21
A13	386.1	38.38	B13	330.2	34.22						
A14	385.8	38.16	B14	327.1	34.40						
A15	382.1	38.46	B15	325.0	34.23						
A16	380.3	37.41	B16	324.3	33.39						
			B17	319.8	34.00						
			B18	316.2	32.61						
			B19	314.0	32.14						
			B20	311.1	32.39						

Table 2 **Range of projected area (P.A.) of mango (Namdoug Mai No. 4) and time delay for solinoid.**

Grade	Weight (gm.)	Range of P.A. (%)	Time delay before solinoid operation (sec.)
Grade	>360	>360	10.3
1	310.1-360	32.51-36.00	8.1
2	250.1-310	27.51-32.50	5.8
3.	200-250	<27.50	3.5

Table 3 **Raw data of mango sizing machine testing.**

Test	Grade (Sum of correct fruit) Number			Grade (Sum of Uncorrect fruit) Number	
1	Extra	(16)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16		
	1	(17)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(3) 18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
2	Extra	(15)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16		
	1	(16)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	Extra	(1) 11
				2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(4) 7,18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
3	Extra	(15)	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1	(1) 3
	1	(16)	1,2,4,5,6,7,8,9,10,11,12,13,14,15,16	Extra	(1) 11
				2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(3) 18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
4	Extra	(15)	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1	(1) 3
	1	(15)	1,2,4,5,6,7,8,9,10,11,12,13,14,15,17	Extra	(1) 11
				2	(2) 1,2
	2	(8)	3,4,5,6,7,8,9,10	1	(4) 16,18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
5	Extra	(15)	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1	(1) 3
	1	(16)	1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17	Extra	(1) 11
				2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(3) 18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
6	Extra	(15)	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1	(1) 3
	1	(16)	1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17	Extra	(1) 11
				2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(3) 18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
7	Extra	(16)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16		
	1	(16)	1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17	2	(1) 2
	2	(9)	1,3,4,5,6,7,8,9,10	1	(4) 7,18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		
8	Extra	(15)	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1	(1) 3
	1	(16)	1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17	Extra	(1) 11
				2	(2) 1,2
	2	(8)	3,4,5,6,7,8,9,10	1	(3) 18,19,20
	3	(12)	1,2,3,4,5,6,7,8,9,10,11,12		

Table 4 Raw data for efficiency Analysis of mango sizing machine.

Test	Sum of fruit in correct grade				Total weight (kg)	Grade's weight (kg)			
	Ng_e	Ng_1	Ng_2	Ng_3	w_t	w_e	w_1	w_2	w_3
1	16	17	09	12	18.8066	6.4960	6.1324	3.4930	2.6852
2	15	16	09	12	18.8066	6.1060	6.1733	3.8421	2.6852
3	15	16	09	12	18.8066	6.4636	6.1648	3.4930	2.6852
4	15	15	08	12	18.8066	6.4636	6.1398	3.5180	2.6852
5	15	16	09	12	18.8066	6.4636	6.1948	3.4930	2.6852
6	15	16	09	12	18.8066	6.4636	6.1948	3.4930	2.6852
7	16	16	09	12	18.8066	6.4960	5.7833	3.8421	2.6852
8	15	16	08	12	18.8066	6.4636	6.4641	3.1937	2.6852

Test	Sum of mango in each grade (fruits)				Total (fruits)
	Nt_e	Nt_1	Nt_2	Nt_3	Nt
1	16	18	12	12	58
2	15	18	13	12	58
3	16	18	12	12	58
4	16	18	12	12	58
5	16	18	12	12	58
6	16	18	12	12	58
7	16	17	13	12	58
8	16	19	11	12	58

Table 5 Analysis of the efficiency of mango sizing machine.

Test	Pg_e	Pg_1	Pg_2	Pg_3	Pw	Cw	Ew
1	1.000	0.944	0.750	1.000	0.938	0.062	0.935
2	1.000	0.889	0.692	1.000	0.909	0.091	0.901
3	0.938	0.889	0.750	1.000	0.901	0.099	0.896
4	0.938	0.833	0.667	1.000	0.868	0.132	0.862
5	0.938	0.889	0.750	1.000	0.901	0.099	0.896
6	0.938	0.889	0.750	1.000	09.01	0.099	0.896
7	1.000	0.941	0.692	1.000	09.27	0.073	0.919
8	0.938	0.842	0.727	1.000	0.881	0.119	0.878
AV(%)	96.09	88.96	72.23	100.00	99.33	9.67	89.77 (2.50*)

N_e	N_1	N_2	N_3	K_e	K_1	K_2	K_3
16	20	10	12	1	1	1	1
P_e	P_1	P_2	P_3	W_e	W_1	W_2	W_3
0.276	0.345	0.172	0.207	0.276	0.345	0.172	0.207

* Coefficient of Variation

Table 6 Operating rate of mango sizing machine at linear belt speed 37.8 cm./s

Test	Started time (s)	Finished time (s)	Labors (Man)	Rate (Fruit/hr.)
1	70	5	4	2983
2	64	14	4	3263
3	63	13	4	3314
4	67	14	4	3116
			Average	3169

Table 7 Analysis of Variation of machanical damage K by vary B.

```
>USE MANGO7
Variables in systat file are:
      A          B          C          D          E
      F          G          H          I          J
      K          L
>by B
>stats k/dun                        =      0.05
The following results are for:
                          B         =      1.000
Total observations:                          20

                          K

N of cases                                   20
Mean                                      1.025
Standard dev.                             0.112

The following results are for:
                          B         =      2.000
Total observations:                          19

                          K

N of cases                                   19
Mean                                      1.029
Standard dev.                             0.115
```

```
Summary Statistics for  K
Bartlett Test for Homogeneity of Group Variances = .012
        Approximate F = .012  DF = 1,  4099  Probability = .878
overall Mean = 1.026  Standard Deviation = 0.112
Pooled Within Groups Standard Deviation = 0.113
T Statistic = .036  Probability = 0.971
```

Note : B (=1.000) refers to the mango which was sized by machine
(=2.000) if the control
K refers to the mango which was externally damaged
The internally-injured mango amounts to 0.5% while the control was not injured.
In brief, the internal damage of tested mangoes was insignificant

the machine and the one that was not pass this machine.

CONCLUSION

Mango sizing machine had been designed, constructed and tested by using 68008 grading system. With manual feeding at conveying speed of 37.8 cm/second, the sizing efficiency and the capacity were found to be 87.77% and 3,169 fruits/hour or about 1 ton/hour respectively with ignorable mechanical damages.

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