J. Trop. Agric. and Fd. Sc. 40(2)(2012): 281–287

Performance of papaya sizing machine

(Prestasi mesin penentuan saiz papaya)

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Keywords: papaya, size, grading, mechanical system

Abstract

Manual determination of weight and size of papaya is a difficult and labour intensive element of the commercial fresh fruit market. To overcome this problem, a prototype machine was developed for determination of weight and size of papaya. Load cell made of four strain gauges in a Wheatstone bridge configuration was used to determine fruit weight and size. The evaluation results showed that the prototype machine was capable of weighing and sorting the fruits into different sizes (i.e. large, medium and small) with average accuracies of 94.7% and 86.6% respectively.

Introduction

Papaya (*Carica papaya* L.) is a popular fruit native of tropical America. It is usually grown for its small to large melon-like fruit (Chan 2009). The papaya is rapidly becoming an important fruit internationally, both as fresh and processed products (Sankat and Maharaj 1997). Papaya has an excellent potential as an export crop in Malaysia. In Malaysia, it is a smallholders' crop and planting is widespread throughout the country (Rahman et al. 2008).

The advantage in papaya cultivation is the rapid return of investment due to its early maturation, intensive cultivation and high yield. Most papayas in the tropics can be harvested 8 or 9 months after sowing and yields can range from 60 – 100 t/ha/year for improved varieties (Chan 2009). Production of papaya in Malaysia has increased due to higher demands compared to other fruits. Malaysia's annual papaya production in 2010 was 44,704 tonnes (Crop Statistics 2010).

Fruit grading is an important process to ensure the high quality of fresh fruits both for export and domestic markets. Size is one of the major parameters that the consumer identifies with the quality of the fruits (Aleixos et al. 2002). According to Federal Agricultural Marketing Authority (FAMA), the papaya can be classified into three sizes, i.e. large (L), medium (M) and small (S) depending on the weight of the fruits (*Table 1*).

Nowadays, many local fruit producers and packers are still very much dependent on manually weighing and classifying the fruits into different sizes. This manual sizing operation is time consuming and labour intensive. To overcome the problem, an automated grading system is needed to eliminate the tedious tasks. Over the past few years, a number of automated sorting and grading systems using a combination of mechanical, electronic and computer technologies have been developed.

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Table 1. Specification of papaya size

Size classes	Code	Weight (g)		
		Sekaki	Eksotika	Solo
Large	L	>1600	>650	>650
Medium	M	1,200 – 1,600	451 – 650	451 – 650
Small	S	800 – 1,199	250 – 450	250 – 450

Moreda et al. (2007) used an optical ring sensor system for the on-line size determination of non-spherical fruits such as tomatoes and kiwifruits. The effect of both the controlled and random orientation of fruits on the reliability, i.e. accuracy and repeatability of measurements, was analysed. Results showed that random orientation negatively affects the reliability of volume measurements due to the swinging movement of the fruit itself when crossing the optical ring sensor.

A fruit sizing system based on photoelectric sensor was developed by Zhang and Li (2006). The system consists of an AT89C51 microcomputer as its core, a signal gathering circuit, a processing circuit, an output circuit and a display/ keyboard unit. When in operation, the microcomputer receives digital signals from the photoelectric sensor. These digital signals are processed by the system software and each fruit sizing level is deduced. Then, the output signals of the system activate the respective sorting mechanism to dynamically measure size and sort in real time. The experimental results indicated that the system works well and can control the sizing of fruits efficiently. The system can be used for multipurpose tasks by setting different sizing parameters in the system software to sort different kinds of fruits.

The image processing and analysis techniques are also widely used to automatically determine the size of fruits. Nagata et al. (1997) used the image processing and analysis techniques to grade the size and shape of 600 fresh strawberries. The results showed that the techniques were capable of sorting the strawberries with an accuracy of 94 – 98% into three shape grades and five size grades. Sizes of tomatoes, potatoes, raisins and apples can be estimated in different ways using image analysis technique as shown by Sarkar and Wolfe (1985), Toa et al. (1990), Okamura et al. (1991) and Varghese et al. (1991) respectively.

However, these fruit sizing systems and techniques cannot be directly used for classification of papaya sizes due to the physical characteristics of the fruit. The objective of this study was to design and develop the first prototype machine for determination of weight and size of papaya. Performance of the prototype machine was evaluated at the Mechanization and Automation Research Centre, MARDI, Serdang, using papaya samples taken from the Malaysian Agrifood Corporation Bhd. (MAFC).

Materials and methods

System design and development

The prototype papaya weighing and sizing machine (*Figure 1*) was designed and developed to incorporate mechanical parts for fruit feeding, weighing and sorting sections. The fruit feeding section shown in *Plate 1* consists of open bins fitted on a chain conveyor to carry the fruits. The dimension of the open bin is 23 cm (L) X 11 cm (W) X 5 cm (H). A fruit pusher (*Plate 2*) is fitted at the end of the conveyor. The pusher is a 9 cm diameter round disk specially designed to push the fruit out from the bin onto the weighing conveyor. It can be accurately and easily adjusted to suit various shapes and sizes of fruits. The fruits are fed in the bins and conveyed to the fruit weighing section (*Plate 3*).

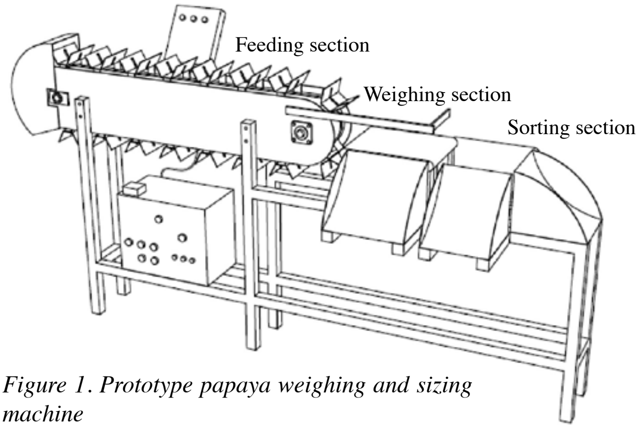


Figure 1. Prototype papaya weighing and sizing machine

Plate 1. Fruit feeding section

Plate 2. Fruit pusher

Plate 3. Fruit weighing section

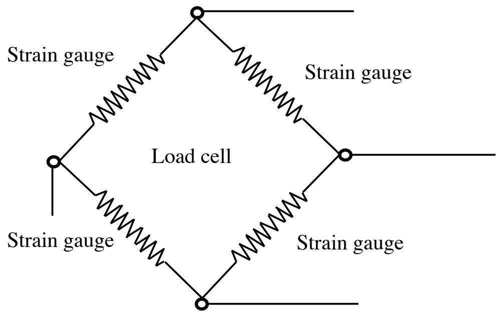


Figure 2. Four strain gauges connected as Wheatstone bridge

The important component of the system is a bending beam load cell (Model: OBBA Series) with a weighing capacity of 10 – 300 kg. The load cell is made of four strain gauges in a Wheatstone bridge configuration (*Figure 2*) to convert fruit weight into an electrical signal. The conversion is performed through a mechanical arrangement where the weight being sensed deforms a strain gauge which then converts the deformation to electrical signals. Mechanical effect must be considered when designing a load cell weighing system. The load cell may fail mechanically or physically if the fruit weight is in excess of the maximum weight the load cell can support. This will cause the cell to distort keeping the strain gauges either in compression or tension conditions. The load cell is mounted under a belt conveyor of the weighing section to determine the fruit weight.

Plate 4. Fruit sorting section

The electrical signal output from the load cell is in a few millivolts and amplified by an instrumentation amplifier to produce appropriate voltage input to the programmable logic controller (PLC). A program to calculate the fruit weight was developed for the PLC to grade each papaya fruit size based on specification. To classify the fruits into different sizes, the output signal was sent to the PLC to control the movement of chutes to sort the fruit into large (L), medium (M), small (S) and rejected grades in the fruit sorting section (*Plate 4*).

Evaluation of prototype papaya weighing and sizing machine

Sampling A total of 100 random samples of physiologically mature papaya of the new Eksotika variety called Paiola were obtained from the MAFC, Lanchang, Pahang. Fruits were weighed using the AND GX 2000 precision balance and classified into L (38 fruits), M (46 fruits) and S (16 fruits) categories based on specification of Eksotika papaya provided by FAMA as shown in *Table 1*.

Verification trials The prototype papaya weighing and sizing machine was tested and verified by using selected sizes of papaya samples that were sorted manually to three groups, i.e. L, M and S based on weight. Time motion of the system components was studied to determine system speed for classifying fruits into a specific size group. The speed was computed by the time taken by the fruit to move from the fruit feeding section on the open bin until the fruit was graded in the fruit sorting section over total fruits.

Statistical analysis

Data on fruit weights were determined by the mechanical system and balance for L, M and S sizes were analysed using the SAS computer program. Separation of the means to compare the accuracy of the system was done using Duncan Multiple Range Test (DMRT) as the test of significance at $p < 0.05$. A linear regression method was also used to analyse the correlation between the fruit weight determined by the system and fruit weight recorded by the digital weighing balance. The aim of the test was to check the accuracy of the system in measuring the size of the fruits, as well as estimating error, in order to evaluate the ability of the system for classifying fruits in relation to their size.

Results and discussion

The average weights of L, M and S sizes determined by the balance were 766, 525 and 412 g respectively, and by the mechanical system were 772, 537 and 465 g respectively (*Table 2*). *Figure 3* shows the correlation between the papaya weights determined by the balance and mechanical system. The best fit line indicated that there is a good dependency with a R^2 value of 0.9 of the weights determined by the balance and mechanical system. Comparison of fruit weights determined by the balance and mechanical system for L, M and S fruits sizes (*Figure 4*) indicated that the L size was not significantly different while the M and S sizes were significantly different ($p < 0.05$).

Table 2 also showed that the mechanical system is capable of determining fruit weights up to 99.2% for L size followed by 97.7% and 87.1% for M and S sizes respectively. The low accuracy is due to the inaccurate position of the fruit dropping from the bin on to the weighing

Table 2. Comparison of mean fruit weights determined by balance and machine

Sample size	No. of fruits by balance	Av. weight by balance (g)	No. of fruits by machine	Av. weight by machine (g)	No. of fruits classified wrongly	% Accuracy of weight determination	% Accuracy of size classification	Av. speed (s)
L	37	766	37	772	2	99.2	94.6	10
M	47	525	47	537	2	97.7	95.7	10
S	16	412	12	465	5	87.1	69.8	10

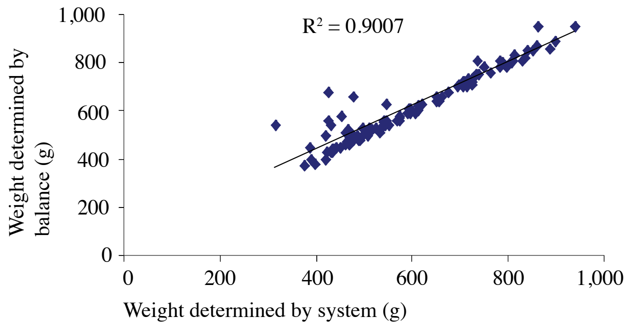
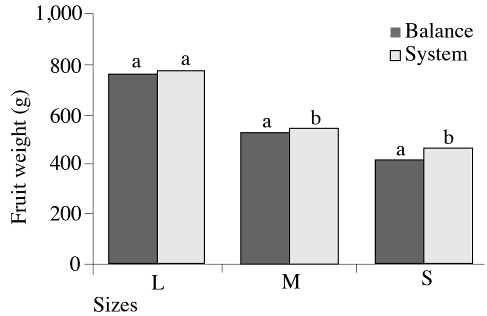


Figure 3. The dependency between weights determined by balance and mechanical system



Different letters within the same size are significantly different (p <0.05)

Figure 4. Comparisom of mean values of fruit weights determined by balance and mechanical system for different fruit sizes

conveyer belt. The fruit must be located at the centre of the weighing conveyer belt for the load cell to determine the fruit weight accurately. Mechanical failure (i.e. shock loading) also caused the mechanical system to produce low weight accuracy. Shock loading occurs when the fruit is dropped suddenly onto the load cell conveyor.

The size verification result (*Table 2*) showed that 9 out of 100 fruits were classified into wrong size grades by the system. The average accuracies of the system to classify the fruits into L, M and S sizes were 94.6, 95.7 and 69.8% respectively. Wrong classification of fruit size is due to the inaccurate weight determined by the load cell of the mechanical system. Speed of the mechanical system to determine weights and sizes of the fruits are shown in *Table 2*. Average speed of the mechanical system to determine weight and size of a fruit was 10 s. The time delay is due to the stopping of the conveyer belt for the load cell to convert a fruit weight into an electrical signal.

Conclusion

A prototype machine for determination of weight and size of papaya was developed. The machine is capable of weighing and sorting papaya fruits into different sizes (i.e. large, medium and small) with average accuracies of 94.7% and 86.6% respectively. The average time taken to determine the weight and size of a fruit was 10 s. This prototype machine can be improved by modifying the current design to reduce shock loading and improve non-stop weighing system by further research to increase the accuracy and speed of weighing and sorting fruits into different size groups.

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Abstrak
Penentuan berat dan saiz buah papaya secara manual adalah sukar dan memerlukan tenaga kerja intensif bagi pasaran komersial buah-buahan segar. Untuk mengatasi masalah ini, sebuah mesin prototip telah dibangunkan bagi menentukan berat dan saiz buah papaya. Sel beban terdiri daripada empat tolok terikan yang dikonfigurasi dalam bentuk *Wheatstone bridge* yang digunakan untuk menentukan berat buah-buahan dan saiz. Keputusan penilaian menunjukkan bahawa mesin yang dibangunkan berupaya menimbang dan mengasingkan buah-buahan mengikut saiz yang berlainan (iaitu besar, sederhana dan kecil) dengan purata kejituan masing-masing pada 94.7% and 86.6%.

Accepted for publication on 27 August 2012