椪柑分級機械之研製*

Development of Sorting Machine for Ponkan Fruit (Citrus Ponensis)

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摘　要

本文係著者在1982年7月16日，中興大學與加大 Fresno 分校合辦「1982年現代農業科學聯合研討會」中宣讀的報告。

本研究對椪柑進行靜壓荷重及撞擊基本測試；根據基本測試結果，並且研製一台適合椪柑分級之試驗機，摘要如下：

1.椪柑最大容許靜壓荷重以及容許堆積高度，可經由果實所產生之砂囊破壞結果決定：L級椪柑靜壓荷重 1kg 以上，在1分鐘內砂囊即有可能引起破壞，而荷重0.5 kg 60小時，與荷重 0.3 kg 120 小時者，砂囊尚未破壞。椪柑在長時間堆積下，其安全堆高為 30 cm，最底層果實其安全荷重限界為 0.55 kg。

2.L級椪柑撞擊三合板，撞擊力若大於 10 kg (20 cm 落高)，即有可能造成砂囊破壞。當落高在 30 cm 以上時，砂囊破壞機會與程度顯著增加，此一事實指出 L 級椪柑，其安全容許落高為 20 cm 。軟質海綿之緩衝效果，可保護果實減少撞擊力，減低砂囊破壞。20~30 mm 厚之海綿，只要落高在 40 cm 以下，足以減少撞擊力低於容許外力 (10 kg) 以下，防止落果之砂囊損傷。

3.研製之椪柑分級試驗機，經試驗結果其分級精度可達80%以上。分級後之椪柑，經用 T. T. C 藥液檢定結果，無損傷跡象。

Introduction

The production of ponkan fruit in Taiwan is 150.000 MT every year which occupies overall production of orange about 43%. In order to have convenient trade in market after harvestig the ponkan, it is necessary to sort them respectively. Up to the present, to sort ponkan, all are done by hand method. Only few of them are sorted by machine. However, there are oil cells over outward at ponkan peel, besides, its flesh is considerably subject to be damaged by external force and the present ponkan sorting machinery are not designed according to ponkan's physical property. Therefore, to sort the ponkan, there will have hurt somewhat and that will affect the storage quality. Considering this, we think that to successfully develop a ponkan sorting machine, first of all, we have to completely understand ponkan's physical property and

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explore how its hurt is and in what kind of external factor. The designed sorting machine won't be achieved until it can shoot all external factors which are possibly damage the ponkan and can reach a certain reasonable safe level. During sorting processes by machine, the most damages to ponkan are caused by falling impact, static load and rolling friction. Here we will study about these basic problem first, then, design and try to make a proper sorting machine for ponkan.

EXPERIMENTAL MATERIALS & METHODS

1. Experimental materials: The ponkan used in the experiment and research are from the origins, Cho Lan aad Shih Kang. In order to keep fruit fresh, besides of to harvest and test on the same day, all are put to refrigerated compartment (dry bulb temperature 6°C, wet bulb temperature 5°C, relative humidity 85%) to preserve them so that they won't lose water and change the physical properties.

2. Experimental methods:

   (1) Static load test:

   Experiment (*A*), To have 3 kilogrammes of static load to different sizes of ponkans for one hour and observe the conditions of fruit deformation and juice sac break: Test S, M, L, 2L, 3L and 4L-sized fruits respectively by testing device developed by Nelson(4). And test the firmness by Magness-Taylor Pressure Tester.
   To measure the amount of free-flowing juice in the segment, first of all, carefully peel off the ponkan and separate the testing segment from the flesh of a fruit which has been tested, then, lightly press two sides of segment by hand and absorb the oozed juice by blotting paper sheet. The weight increased to the blotting paper sheet is the weight of the juice which oozed from the broken juice sac(5).

   Experiment (*B*), To observe how juice sac is damaged in different static loads and treating time: Have static load to L-sized fruit respectively in different weights, 0.1, 0.3, 0.5, 1, 2, 3, 5, 7 and 10 kg and observe how juice sac is damaged by the time of static load.

   Experiment (*C*), Test of being damaged in stacking: The experiment is done with L-sized fruit. Separately test the stacked fruit of stem-end upward and stem-end sideways and in eight kinds of stacking layer, 2, 3, 4, 5, 6, 7, 9 and 12 layers to explore how the flesh at the bottom is damaged by different stacking heights.

   Experiment (*D*), To test how static load plus rolling affect ponkan's respiration rate: Have L-sized fruit under room temperature 20°C in 1.5 kg of load and roll each one 2, 4, 6 and 8 times, then, observe how the rolling times under constant load affect ponkan's respiration rate. To test CO_2 respiration rate, a constant flow of air should be controlled to continuously pass fruit samples. As reading is required, have its bubble through bromthymol solution for ten minutes, then, compare the solution's last color by EVELYN photoelectric colorimeter and count its CO_2 respiration rate [1].

(2) Impact tests:

Experiment (A), To observe how different falling heights and falling times affect the damage to juice sac: The experiment is done with L-sized fruit. Have the fruit in lateral position (stem-end sideways) fall down and alternately change the impact position. The test to measure the amount of free-flowing juice of broken juice sac is same as above.

Experiment (B), To observe the buffer effect between buffer material and impact: Respectively fix all different buffer materials on proving ring and impact L-sized fruit in dropping from different height, then, test the impact force by strain amplifier Model KYOWA CO-50 ET and photoelectric recorder Model KYOWA RMS-11. This can determine effect of different cushion and fruit's break condition.

Experiment (C), To observe the relationship between ponkan impacting ponkan and how juice sac is damaged: Drop L-sized fruits from different heights to impact still L-sized fruits which are placed inside a box, then, observe how they are damaged.

RESULT & DISCUSSION

1. Result of static load test:

(1) For big fruit, its peel percent, thickness of peel and fruit's firmness are also great as what indicated in Table 1.
To the ooze amount of damaged juice sac, S and M sized fruits are greater, 2L and 3L sized fruits are smaller.

(2) The relationship between breaking to juice sacs and ponkan under different static loads and treating time:
Have static load over 1 kg to L-sized ponkan, the juice sacs are possibly been broken in 1 minute. In case the static load is over 5 kg, the damage to juice sacs will be obviously caused only in 1 second. With 1-3 kg of static load, breaking to juice sacs will be greater depending on how treating time is lengthened and it will be getting moderate gradually as it is over 60 hours. When

loading 0.5 kg is given in 60 hours and loading 0.3 kg is given in 120 hours, juice sacs will never be broken.

Table 1: Effect of fruit size and fruit properties on the breaking of juice sacs by static loading.

Size	Diameter range	Average weight (g)	Peel percen t (%)	Thickness of peel (mm)	Fruit firmness (kg)	Breaking of juice sac*
S	5. 5—6. 1	83.3	21.6	1.73	2.25	188.8
M	6. 1—6. 7	129.3	23.6	2.07	2.86	61.2
L	6. 7—7. 3	155	28.6	2.8	2.39	12.1
2L	7. 3—7. 9	179	29.7	2.95	2.50	4.8
3L	7. 9－8. 5	235.7	26.2	2.78	2.54	0.2
4L	8. 5—9. 5	273.3	32.3	3.6	3.49	5.4

*Weight of juice oozed from juice sac out in segment (mg/15g segment)
Loading: 3 kg/fruit/hour

(3) Table 2 indicating how ponkan in different stacking heights affect the fruit at the bottom in deformation, loading and breaking to juice sacs.

Owing to long period of stacking which makes early oozed juice congealed, to test oozed juice of juice sacs which are stacked for ten days, the tested juice weight will be a little lower. Comparing stacking in fruit stem-end upward with stem-end sideways, the breaking to juice sacs caused from stem-end upward is smaller. The possible reason is because of buffer function caused in air layer between peel and flesh at the part of fruit stem. Therefore, obviously, stacking and packing in fruit stem-end upward position is better.

From the experiment, we see that when the stacking height is over 40 cm, the deformation will be clearly getting greater. And the stacking height with fruit stem-end sideway is 38 cm, the oozed juice of broken juice sacs will be obviously getting greater. Therefore, the long period of safe stacking height for the ponkan should be 30 cm. Besides, under static load for a long period, its safe limit should be about 0.55 kg. According to stacking experiment of satsuma mandarin fruit practiced by Shigeyoshi Yamashita[6], the formula for relationship between stacking height and loading of fruit at the bottom is made as follows:

$$L = T \cdot \frac{W}{D} \text{ (kg)}$$

Where

L: Loading (kg)

T: Stacking Height (cm)

W: Average unit fruit weight (kg)

D: Average fruit diameter (cm)

Taking L-sized fruit as example, that is one fruit weighted 157g, diameter 6.8cm (short diameter) to 7cm (long diameter), average 6.9cm. The allowable loading limit for every fruit at the bottom is 0.55 kg, put them into the above formula, then, stacking height $T=\frac{0.55\times 6.9}{0.157}+D$. If every fruit's diameter at the bottom is 6.9 cm, the stacking height should be 31 cm which is corresponding to the result of experiment mentioned above. In this way, we know that the formula is suitable to ponkan also.

Table 2: Effect of stacking height on breaking of juice sac and deformation of fruit.

Ponkan's stacking height			Deformation of fruit at the bottom (mm)		Loading of fruit at the bottom (kg)		Breaking of juice sac* (mg)	
Layer	Height (cm)							
	U	S	U	S	U	S	U	S
2	14	15	3	3	0.18	0.17	0	10
3	21	23	4	3	0.385	0.403	0	30
4	28	29	3	3	0.573	0.54	0	50
5	36	38	3	4	0.81	0.82	0	88
6	41	44	6.5	5.5	0.95	0.95	0	91
7	49	53	6 5	4.5	1.20	1.22	0	97
9	62	68	4.5	8	1.56	1.57	7.2	93
12	79	90	5.5	8.5	2.10	2.17	22	94

* Weight of juice oozed from juice sac out in segment (mg/15g segment)
U: Stacked fruit of stem-end upward
S: Stacked fruit of stem-end sideways
Stacking for 10 days.

(4) Fig. 1 shows how the rolling times affects ponkan's respiratory rate under constant load. The more the rolling times are, the greater carbon dioxide is generated. That is the level of being damaged is greater.

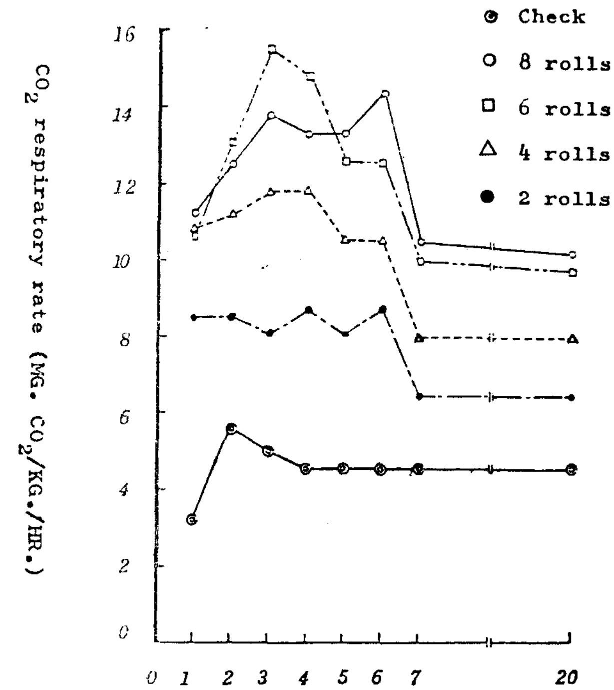

Fig. 1: Under constant temperature 20°C, loading 1.5kg, how ponkan's rolling times affects respiratory rate.

2. Result of impact test:

(1) How the fruit's juice sacs are damaged when ponkan impacts plywood in different dropping height and dropping times is indicated in Fig. 2. When dropping height is 30 cm, juice sacs are considerably slightly been damaged, in 40 cm of dropping height, the breaking to juice sacs is obviously increased. And over 50 cm of dropping height, the breaking to juice sacs is intensively increased. Therefore, the higher dropping height is, the more its dropping times is and the greater juice sac is damaged. From this we know that the proper dropping limit should be about 20 cm.

(2) Fig. 3 indicates the buffer effect of impact in different buffer materials.

In great impact force to hard plywood, corrugated cardboard or soft thin sponge, the level juice sac broken is also great. However, if thickness of the soft sponge is over 10 mm, the impact force will be decreased. From Fig. 3 we know that to impact 11 mm thick of plywood from dropping height 20 cm, its impact force is about 10 kg, however, if the ponkan impacts sponge thick in 20-30 mm, its impact force will be half, only about 5 kg. Therefore, in 20-30 mm thick sponge, the impact force can be efficiently decreased.

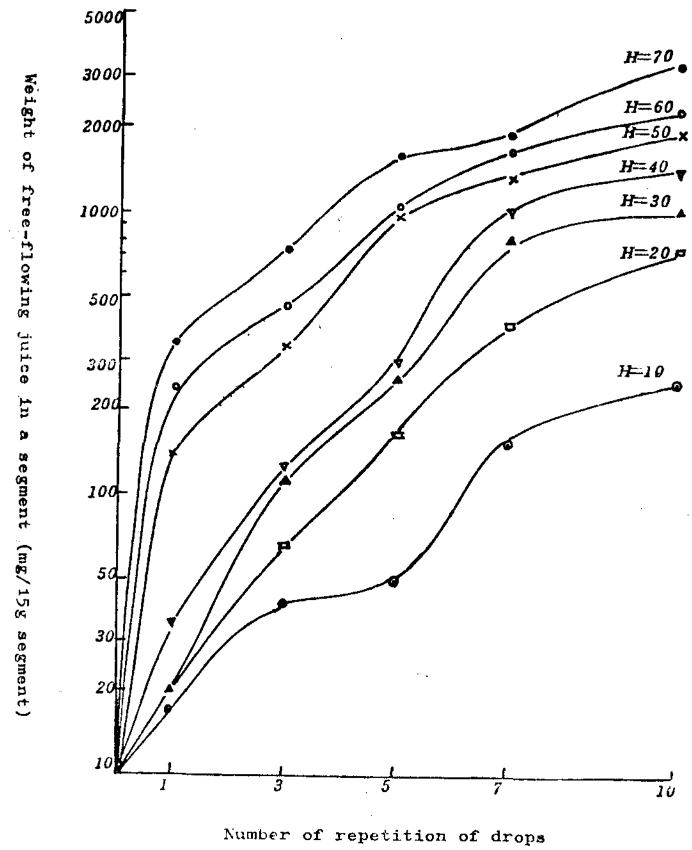

Fig. 2: **Effect of dropping height and dropping times on the break of juice sac (to impact plywood)**
H: Dropping height (cm)

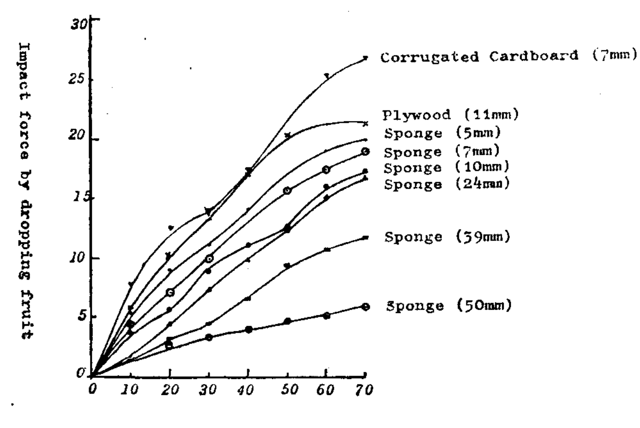

Fig. 3: **Impact force of a fruit when dropped on different materials**

(3) For fruit impacting fruit, the situation of juice sac being broken to the impacting fruit and impacted fruit is:

From result of the experiment, we know that when the dropping height is over 30 cm and dropping times are increased, then, breaking to juice sac will be obviously increased and breaking to impacted fruit is much serious.

In conclusion of the above tests, the allowable limit of impact force for dropping L-sized ponkan is 10 kg, its dropping safe height is 20 cm. Therefore, we have to pay attention to this point during designing sorting machine.

CONCLUSION

Concluding the above tests, the basic information for design of ponkan sorting machine are offered as follows: Ponkan's allowable dropping height is 20 cm. However, using 20-30 mm thick soft sponge as cushion, its allowable dropping height can be up to 40 cm. If ponkan is under static load which is over 1 kg, juice sacs will be broken in a short period. Therefore, during sorting processes, ponkan's stacking height should be below 40 cm. Besides, in the sorting processes, in order to keep ponkan's quality afer sorting, the loading and rolling conditions to ponkan has to be avoided.

PRACTICAL APPLICATION & DISCUSSION

The basic experiments mentioned above indicate that the ponkan's best allowable dropping height is below 20 cm and it would be better if with 20-30 mm thick sponge as cushion. During sorting processes, the loading and rolling conditions caused to fruit should be prevented.

Presently, although ponkan sorting machines which are used in Taiwan or studying are a little different in model, there are two same points, one is that ponkans are sorted under rolling condition which will cause damage somewhat; another is that they can not sort oval ponkans in required efficiency. The research is specially sort for those problems. Besides, the exper imental machine is been trying and making to do the test according to the basic result of experiments mentioned above. The construction of experimental machine and its result of efficiency in the experiment is as follows:

1. Auto chain-rod interval changing sorting machine[3]: **Shown in** Fig. 4

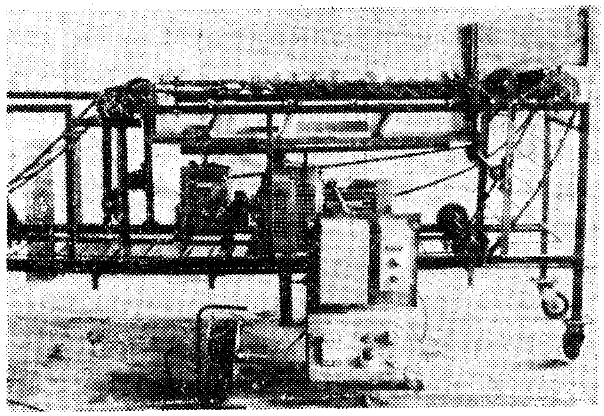

Figure 4 Experimental sorting machine for ponkan

The main theory of this sorting machine is to hit the pins out from chain under the fixed interval and then to separately equip same numerical bearings and sorting rods to slide around the fixed sorting plate and automatically change the interval of sorting rods. Its feature is to make the ponkan during the delivery process of sorting line without rolling and squeezing for continuous sorting from small to big with no damage and friction. This machine is composed of feeding tank, guiding device, sorting device, catch device and power transmission device, total 5 units. The function of the feeding tank is to guide the ponkan entering inside the sorting machine. While the guiding device is composed of guiding bearing and press wheel, as figure 5 shown, the guiding bearing leads the sorting rod to move upon the fixed sorting plate, and the press wheel will press the bearing to move below the fixed sorting plate. The sorting device is composed of chain, sprocket-wheel, sorting rod, bearing, and fixed sorting plate. Due to the function of fixed sorting plate, when the bearings and sorting rods moving, the interval of sorting rod will be increased automatically according to the designed sort of fixed sorting plate. The catch device will catch the ponkan after sorting, and which will fall into the box.

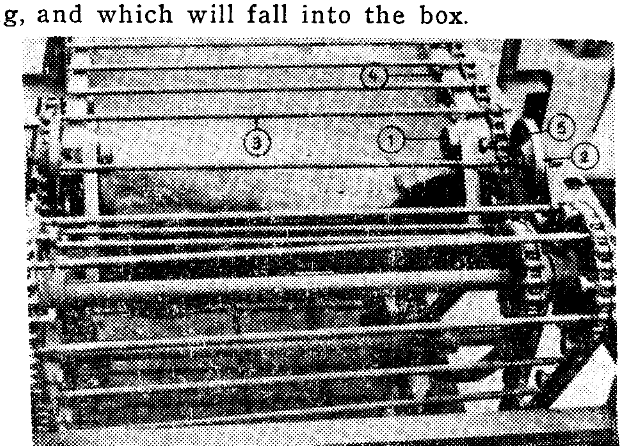

Figure 5 Auto adjusting device for sorting rods' interval
(1) Guiding bearing (2) Press wheel
(3) Sorting rod (4) Fixed sorting plate
(5) Bearing

2. Testing material & methods: The main purpose of this experiment is to test the varied sorting speed affected to the sorting efficiency and the damage condition of ponkan, in order to realize the performance of the sorting machine. When testing, the line speed of sorting rods is between 0.15-0.4 m/s. After the sorting of ponkan, then dip into solution of T. T. C (2,3,5-Triphenyltetrazolium chloride) of 1000 times' diluted for 3 minutes[2]. If the peel get hurt and shed juice containing enzyme which will take chemical function with T. T. C agent to cause the brown spots. And more brown spots shown means that the ponkan's peel get seriously hurt.

3. Testing result & discussion:

The outward of ponkan shows the oval and not the ball, so the sorting efficiency is not very good if use the chain-rod sorting method to sort the ponkan only. Because the ponkans' size is bigger with oval shape, if the thin-flat side running parallel with the sorting rods, then the ponkan will fall easily in smaller sorting place to cause low sorting efficiency. According to the testing result, the sorting efficiency is only 50-60% as figure 6(a) shown. But, if put the round iron rod upon the sorting rod to become a square shape and sort the ponkan based on this sorting line (as Figure 7 shown), then the efficiency will reach 80% (as Figure 6-b shown) with good effects. Using this new discovery to improve the original sorting device as figure 8 shown, the sorting machine after improvement will use the round belts instead of round iron rod upon the sorting rod and have the power transmission to move along with the sorting rod, and both are moving at the same speed, therefore, the ponkan will avoid friction under rolling to keep the sorting of stationary state. So obviously this prototype testing machine includes two characteristics which the customary sorting machine does not have, one is used to sort the oval ponkan, the other is to sort the ponkan under stationary state without worrying about friction or damage. As for the actual effect of sorting, due to the limitation of production season for ponkan, the testing is not yet taken place.

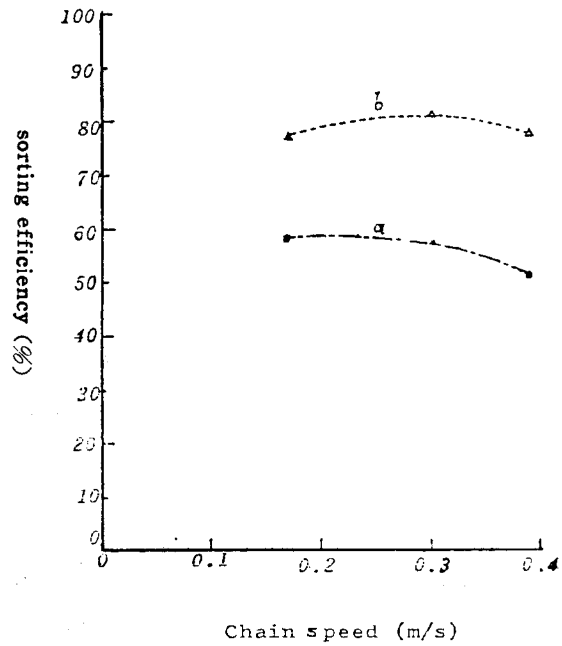

Figure 6. The relation between sorting efficiency of the sorting machine and chain-rod speed.

a. Chain-rod type

b. Chain-rod+gradual expension round rod

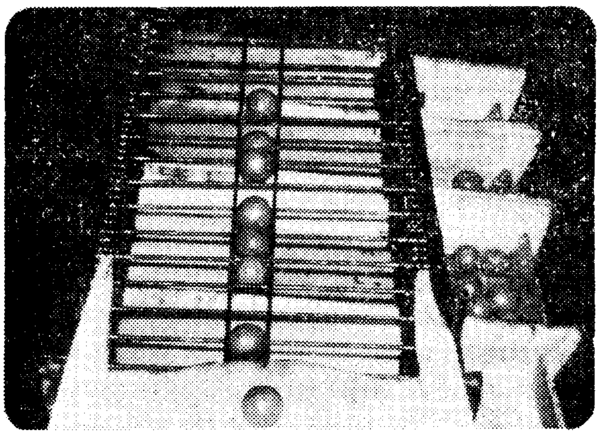

Figure 7. Chain-rod+gradual expension round rod experimental machine

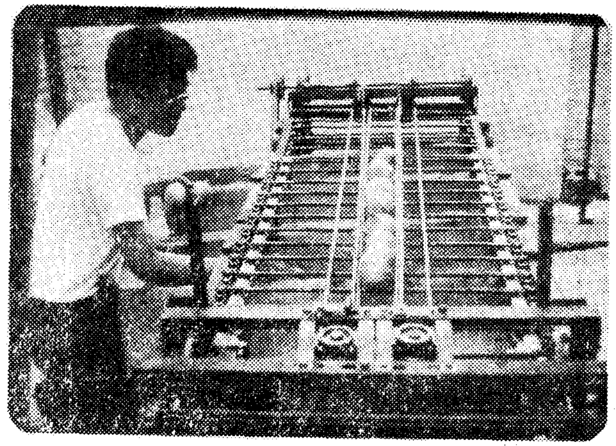

Figure 8 Improvement prototype sorting machine

Abstract

In order to development a sorting machine for preventing ponkan fruits from mechanical injury in the sorting process, allowable external forces exerted upon the fruit by static and dynamic loads were determined under different condition. Based on the information obtained from above basic experiments. A prototype machine suitable for sorting ponkan fruits were developed:

1. Both static loads and stack height allowable for the stacking of ponkan fruit were determined from the results of juice sac breaking produced in stacked fruits. Breaking of juice sacs did not occur within 60 hr. under 0.5 kg static load and within 120 hr. by 0.3 kg loading, whereas under static loads greater than 1kg the juice sac was broken within 1 min. When static loads were exerted on stacked fruits for a 10·day period of time, the allowable load seemed not to exceed 0.55 kg to a fruit. So that the allowable stack height of L-sized fruits was about 30 cm.

2. Impact forces larger than 10 kg may cause the breakage of juice sacs in L-sized ponkan fruits. The extent and frequency of the occurrence of juice sac breakage were sharply increased when initial positions of dropping became higher than 20 cm. This fact indicates that the maximum allowable dropping height of L-size ponkan fruits for preventing mechanical injury is about 20 cm. With initial height less than 40 cm, soft urethane mats with 20-30 mm thickness enough to reduce impact forces below the allowable external force (10 kg) could thoroughly prevent dropped fruits from breakdown of juice sacs.

3. The experimental results indicated that the sorting efficiency of the prototype machine was higher than 80%, and no damage was shown among the test samples by the trail of T. T. C method.

References

1. Claypool, L. L., and Keefer, R.M., 1942 A Colorimetric method for CO_2 determination in respiration studies. Proc. Amer. Soc. Hort. Sci. 40:117-186.
2. Eaks, I. L., 1961. Techniques to evaluate injury to citrus fruit from handling practice. Amer. Soc. Hort. Sci. Vol. 78, 190-196.
3. M. O' Brien, 1968. Sorting, sizing and field filling of fruit and vegetables into bins. J. Agric. Engng Res. 13 (4):318-322.
4. Nelson, C. W. and N. N. Mohsenin, 1968. Maximum allowable static and dynamic loads and effect of temperature for mechanical injury in apples. J. Agric. Engng. Res. 13(4):305-317.
5. 山下重良、北野欣信、八田茂嘉、和田年裕、宇田擴、1979. 溫州ミカンの選果荷造過程における損傷要因と損傷防止に關する研究（第1報），外力による果實組織の破壞樣相と選果荷造工程における果皮の損傷，園學雜。(J. Japan. Soc. Hort. Sci.) 48(2):231-241.
6. 山下重良、森本純平、宇田擴，1979，溫州ミカンの選果荷造過程における損傷要因と損傷防止に關する研究（第4報）果實に對する靜壓荷重と堆積厚さの許容限界，園學雜。(J. Japan, Soc. Hort. Sci.) 48 (3):367-373.