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Separation of Extraneous Matter from Agricultural Products by the Difference in the Coefficient of Restitution

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SEPARATION OF EXTRANEEOUS MATTER FROM AGRICULTURAL PRODUCTS BY THE DIFFERENCE IN THE
COEFFICIENT OF RESTITUTION.

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C. ABSTRACT

The effect of the parameters on separation by the coefficients of restitution was investigated with the aid of an experimental unit. The effects of roller and divider adjustment on separation efficiency were determined in relation to potato and clod size. A simulation model was used to study the relationship between the size distribution of the feed material and the correct separator adjustments. Impingement angle effect on the rebound distance and on interference between falling and rebounding objects was studied experimentally and with the aid of a simulation model. To achieve a satisfactory rebound distance, yet still minimize interference, a compromise in inclination angle is recommended.

Forces involved when a product receives an impact that changes its trajectory, without total deceleration, were determined by mounting an accelerometer on the product and dropping it from different heights on an inclined surface or a roller. Tests were performed with onions and potatoes. After the impact the bulbs were examined for external and internal damage. Results have shown that there was no visual damage, that is later detectable, to onions and potatoes by drop height used in this separation method (300 mm or less).

These results contributed to the development of clod separator which is already used for all the potato crop in Israel, and is widely used in Europe. These machine's are being used also for cleaning flower bulbs.

D. OBJECTIVES OF THE ORIGINAL RESEARCH PROPOSAL

- a. Development of a method and equipment for separation of extraneous matter and agricultural products in the field according to the difference in the coefficient of restitution.
- b. Development of laboratory techniques for determining the optimal values of the parameters and the required combinations of separation stages.
- c. Development of a field unit for separation of clods from potatoes.
- d. Feasibility tests for application to other crops and various types of extraneous matter.

The only deviation from the objectives is that we developed a unit for use in the packing house rather than in the field, due to handling problems and according to the preference of the users.

E. DESCRIPTION OF RESEARCH WORK AND ACHIEVEMENTS

1. Development of a clod separator.

This part of the work is reported in the following publications: Feller & Zacharin, 1984; Feller et al., 1985. Briefly, the effect of the parameters on separation by the coefficient of restitution was investigated in the laboratory with an experimental unit. As a result, machines were developed with two separation stages. The second stage recovers the small amount of product rejected in the first stage. A simulation model was used to study the relationship between the size distribution of the feed material and the correct separator adjustments. Clod separators, based on this method, are being used now for all the potato crops in Israel and are already widely used in Europe. Test results are presented using this machine as a precleaner in a packing house. In addition to the clods, most of the stems and a considerable part of the rotten tubers are also separated. These machines are being used also for cleaning flower bulbs, mainly for daffodils.

2. Analysis of the process

Interference between falling and rebounding objects when they collide in the vicinity of the separating roller was found to be a major factor in this process, and a limitation to the feed rate through the machine. Interference effect was studied with the aid of a simulation model, illustrating the compromise required in inclination angle of the impact surface and the feed conveyor velocity in order to obtain good separation at an acceptable feed rate. This part of the research is reported in Feller et al. 1986.

3. Forces imparted to the product during impact and its effect on bruise damage.

Introduction:

Considerable testing has been done to determine the magnitude of the forces imparted to potatoes and onions during impact. These include studies to determine the effect of drop height and product mass on the impact force and a subsequent evaluation of the bruise damage to both potatoes and onions. We have evaluated the impacts with a flat plate and the forces involved when a product object receives an impact that changes the trajectory of the fruit without total deceleration to a zero position. Changing the trajectory is the action that occurs in the subject sorter. This action imparts considerable less force to the product than a drop to a fixed horizontal surface.

Experimental Procedure

A drop test equipment setup was used as the system for investigating the impact parameters that affect onions and potatoes. The system included the product sample with a mounted accelerometer, a vertical adjustable holder to keep the product stationary while making provisions for changing the drop height, an impacting surface made from circular steel plates or a horizontal roller, data acquisition consisting of a 12 bit, 16-channel Burr-Brown A to D converter, an Apple IIe computer and a printer.

Samples of onions were weighed and maximum diameter of the bulb was recorded. A uniaxial accelerometer (Wistler Model 8604A500) with a sensitivity of 9.91 mV/g and a resonant frequency of 50.4 kHz was mounted centrally on the onion between the crown and stem ends. A solenoid was used to actuate the release mechanism which dropped the instrumented onion bulb. After the first impact the instrumented onion was caught in the air to prevent a second impact from occurring. The digitized output voltage was recorded by the printer and it was subsequently converted into an acceleration.

After impact, the onion bulb was sectioned at the impacted area in a direction transverse to the longitudinal axis. The sectioned area was coated with a 1% solution of benzidine in ethyl alcohol and after 10 minutes a red food color was used to recoat the sectioned area. After 2-3 hours, the sectioned area was inspected for the appearance of translucent scales. The number of affected scales (with a deep red coloration) were counted and their lengths were measured. These measurements were used to derive a bruise index for the onions.

Potato samples were also tested by first weighing the individual tubers. The length of the potato between the apical and basal ends was also measured. An accelerometer was mounted on the surface across from the midpoint of the longitudinal axis. The dropping procedure used for the onions was repeated. The impacted potatoes were stored at room temperature for 48 hours and then the impacted area was sectioned to determine any cuts, slits or development of blackspot (bruising).

Tests were made to determine the amount of skinning of potatoes due to the impact that occurs with a plate or roller in the sorter. A field plot of potatoes (Red Lasoda) was divided into four sections, and two treatments were applied to the four plots. In 2 plots the vines were removed 21 days prior to harvesting. In the remaining 2 plots, the vines were left on the crop. After harvesting, the two types - vine killed and non-vine killed potatoes were drop tested on 3 systems, i.e. the horizontal plate system, the inclined plate system and the rotating roller system. The potatoes used weighed between 250 and 450 gm. The drop tests were aimed at detecting the presence of 'skinning', i.e. the peeling of the potato periderm.

Results

The acceleration-time curves for onions generally show that a single peak acceleration was attained during the impact (Figures 2,3 4). The curve shown in Figure 1 has a major and minor peak and the discrepancy can be explained from the structure of the onion. After sectioning the onion sample used, it was observed that there were large gaps between individual scales and the onion seemed to have been dehydrated. When the test was repeated with an onion sample with firmly attached scales, only a single peak resulted.

The plot of peak force against drop height depicted in Figure 5 shows that peak force increases with increasing drop height.

The severity of bruising for onion samples is represented by the bruise index. The bruise index is defined as the average length of translucent onion scales times the number of translucent scales. The plot of bruise index against drop height (Figure 6), shows that the severity of bruising increases drastically with increasing drop height. At very low drop heights, i.e. up to 30 cm the bruise damage to the onion bulb is very minimal.

The relationship between the bruise index and pre-impact energy (energy before impact) is shown in Figure 7. The curve shows that there is significant bruise damage to the onions as the pre-impact energy is increased beyond 1.2 Joules.

Damage to potatoes due to impact on a flat plate is shown in Table 1.

TABLE 1

Potato Damage due to Impact on a Flat Plate (Red Lasoda Variety)

Drop Height (cm)	Mass (kg)	Length (cm)	Length of Split (cm)	Bruised Volume	Peak Force (N)
15.24	0.3744	11.15	0	0	615.55
30.48	0.3828	12.48	0	0	846.65
45.72	0.4003	13.70	0	0	1483.94
60.96	0.3960	12.01	0	0	1646.82

Each data point is an average of 4 replications.

These results show no bruise damage to the potatoes of this variety.

Results from skinning tests for drop heights of 15.24, 30.48, 45.72 and 60.96 cm showed that there were no cuts or peeled skin for all three systems tested. It appears that the smooth surface of the roller and plates did not present enough frictional resistance to remove the potato periderm (skin).

Both the vine killed and non-vine killed samples retained their skin. Another factor that affected the skinning was the bouncing or restitution effect. On impacting the roller, or plate surfaces, the potato bounced off without allowing time for considerable frictional effects to take place. There was some sliding action with the inclined plate, but the smooth surface of the plate prevented any peeling from taking place.

The Red Lasoda variety is usually considered an easily skinned variety. These tests would then generally indicate that skinning occurring in a commercial sorter would be no greater than that occurring in common conveying systems.

4. Conclusions

Results from the studies to date have shown that impact damage to onions and potatoes from drop heights used in the impact separator (30 cm or less) generally do not cause visual damage to the onions or potatoes. In addition, these drop heights have not caused damage that was later detectable.

Studies with potatoes of Red Lasoda variety (usually considered easily skinned) have shown very little skinning due to impact with a roller at angles usually used in the sorter.

These results generally confirm that a sorter based on differences in coefficient of restitution will not damage the product and the sorter can be used commercially. Product which is in a stressed or over mature condition has not been examined and the above conclusion probably does not hold for such a case.

F. DESCRIPTION AND RESULTS OF COOPERATION

Dr. C.G. Coble and Dr. Ron Feller have met about 5 times to go over plans and progress for this project. Dr. Feller has spent a sabbatical at Texas A&M prior to this project, during which time the original concept of an impact separator was developed. They have developed an excellent relationship over the years. Dr. Feller worked extensively with the Israel manufacturers of a commercial clod sorter based on the principal explored in this research. In addition, he, along with Dr. Coble, has made contacts in the U.S. trying to transfer the results of this work to the commercial machinery manufacturers for the benefit of agriculture.

G. EVALUATION OF THE RESEARCH ACHIEVEMENTS

Achievements surpass the expectation of the research plan. The full scale separator that was developed according to the findings of the research was introduced immediately to all the potato packing houses in Israel, and is already widely used in Europe. There was, however, a change from the

initial concept expressed in the research plan. We thought that due to the mechanical simplicity of this method, it will be feasible to perform the separation in the field. However, considering handling problems and the pressure on the farmers during the harvesting season, it was preferred to use the separator in the packing house, both as a stationary or a mobile unit, that cleans the potatoes before putting them into storage.

H. BENEFIT TO AGRICULTURE

Separation of clods and other extraneous matter is a major problem in modern agriculture where the crop is harvested by machines. The separation method that was developed in this research contributes to the solution of this problem in several ways :

1. It performs a considerably better separation than any other method, including expensive electronic separator (packing houses that already has electronic separators replaced them with our separators).
2. Simple and easy to maintain.
3. Can handle high flow rates.
4. Can handle unsorted size mixture of the products.
5. Separates vines and rotten fruits.
6. Can be used as a precleaner at the receiving end of the packing house, to clean the crop as it comes from the field.
7. Prospects for the use of this method on the harvesting machine (Feller & Zacharin, 1984).

I. LIST OF PUBLICATIONS

1. Feller, R. and A. Zacharin, 1984. Separation of clods from potatoes by bouncing on a roller. Proceedings of the International Symposium on Fruit, Nut and Vegetable Harvesting Mechanization. ASAE Publication 5-84, pp. 291-297, ASAE, St. Joseph, MI.
2. Feller, R., Margolin, E., Zacharin, A., Pasternak, H. 1985. Development of a clod separator for potato packing houses. TRANSACTIONS of the ASAE. 28(4): 1019-1023.
3. Feller, R., Margolin, E., Hetzroni, A., Galili, N. 1986. Interference and impingement angle effects on clod separation. Submitted for publication in the TRANSACTIONS of the ASAE.

Figure 1: Plot of Aceleration vs.
Time for a 6 inch Drop

Figure 2: Plot of Aceleration vs.
Time for a 12 inch Drop

Figure 3: Plot of Acceleration vs.
Time for a 6 inch Drop

Figure 4: Plot of Acceleration vs.
Time for a 12 inch Drop

Figure 5: Plot of Peak Force vs. Drop Height for Yellow Onions

Figure 6: Plot of Bruise Index vs. Drop Height

Figure 7: Plot of Bruise Index vs. Pre-Impact Energy.

*Bruise Index = Average Length of Translucent scales * # of Scales