EVALUATION OF POTATO-STONE-CLOD SEPARATION MECHANISMS

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Methods of separating potatoes from stones and soil clods in storage were evaluated and factors affecting performance were determined. The three methods of separation included a rotating brush separator, an electronic separator and an impact roller separator. All separators effectively sorted the stones from the potatoes but the brush separator failed to differentiate between the soil clods and potatoes. Parameters affecting the performance of the brush separator were the feed rate and the brush gap while the performance of the electronic and impact roller separators was affected by the feed rate and the stone/potato ratio, respectively.

INTRODUCTION

The development of mechanisms to separate potatoes from stones and clods has been directed towards mechanical devices located on the harvesters. These devices have been designed to separate potatoes on the basis of physical differences between the potato and the associated material. The differences include rolling resistance, elasticity, specific gravity, terminal velocity, resistance to X-ray penetration, optical reflectance, and vibrational frequency response. Sides and Smith (1970) describe the mechanisms available for separating potatoes and stones. Methods which have been used or investigated over the past several years have also been described by Story and Raghavan (1976). More recently several mechanisms have been developed to operate in storages during postharvest potato handling. The advantage of doing a portion of the separation at storage rather than on the harvester is to reduce the number of people working on the harvester under unfavorable conditions. Often in Eastern Canada from two to four people are required to sort the material on the harvester. Two approaches for in-storage use appear promising and have been developed into commercial machines. A commercial separator developed by Feller et al. (1984) is based on the difference between the coefficient of restitution of the products being separated. The device involves bouncing the objects on a revolving roller and separating them according to their trajectories. A second type of separator available differentiates between potatoes, stones and soil clods electronically. This separator has a series of sensors each consisting of a membrane and an electromagnetic transducer. The magnetic field is influenced by the vibration of the membrane due to impact and the magnetic-field-influencing property of the products being separated. The objective of the study described in this paper was to quantify the performance of the three types of in-storage separators in terms of their capability to separate potatoes from stones and soil clods.

TEST PROCEDURES

The laboratory arrangement included a feeding conveyor on which the products were placed and fed at controlled rates onto each of the three separators. The three separators are shown schematically in Figs. 1, 2 and 3. Russet Burbank potatoes were distributed evenly at a known weight on the conveyor and then either stones or clods were uniformly mixed with the potatoes. The conveyor speed was constant during the tests while the weight of material per unit length on the conveyor was varied to deliver various loading rates to the separators. Prelimi-
The stones used in the tests had an average weight of 79.4 g with standard deviation of ±55.7 g. Clods were gathered in the fall and stored either in opened barrels or in plastic bags in order to obtain two soil moisture levels of 3.5 and 19.0% WB. The average tuber weight was 154.6 g with a standard deviation of ±89.8 g.

The stone/potato and clod/potato ratios were selected on a weight basis and represent ratios often found under New Brunswick conditions. The field stone/potato ratio depends on the soil type as well as to the extent of the stone removal operation. The clod/potato ratio has a higher variability depending on soil type and moisture as well as tillage practices.

The feed rate selected during the evaluation of the separator represents sufficient capacity to handle the output from two harvesters under New Brunswick conditions. A large percentage of growers operate two harvesters in order to meet the requirements of a short harvest period.

Brush Separator

Brush Separator

The critical parameter affecting machine performance is the gap between adjacent pairs of brushes. Eaton and Hansen (1969) found that the separating efficiency was independent of brush speed, loading rate or separator slope. Tests consisting of three replications were randomly conducted with ratios of stones/potatoes of 0.01, 0.055 and 0.1 over a range of feed rates of 9.0, 18.0, 27.0 and 36.0 t/h over 1.3 m of brush width. The tests included brush gap settings of 7.0, 10.0, 13.0 and 16.0 mm. Due to the small difference in specific gravities of soil clods and potatoes initial tests indicated that a low separation efficiency was achieved with the brushes when separating these products. Consequently, only one set of tests was undertaken with soil clods mixed with potatoes. The ratio of clods/potatoes was 0.05 with feed rates of 9.0, 18.0, 27.0 and 36.0 t/h at a brush gap setting of 13.0 mm.

Electronic Separator

Electronic Separator

Preliminary tests were conducted with the electronic separator in order that the sensitivity (amplification) adjustments for clods and stones could be selected. When the optimum setting was reached, tests were conducted at four feed rates of 9.0, 18.0, 27.0 and 36.0 t/h over a 1.3 m width with three stone/potato ratios of 0.01, 0.055 and 0.1. In order to measure the effect that moisture content of soil clods going into storage in early fall and leaving during winter has on the performance of the electronic separator, soil clods with two moisture levels were included in a second test. The tests were randomly conducted at four feed rates of 9.0, 18.0, 27.0 and 36.0 t/h, two soil clod moisture levels of 3.5% WB and 19.0% WB, and one clod/potato ratio of 0.05.

Roller Separator

Roller Separator

Feller et al. (1984) have done an extensive evaluation of the roller separator sorting onion-clod mixtures. They found that the separator was very effective when separating the clods from the onions. Gan-Mor et al. (1985) suggested that a machine similar to the roller separator will not effectively separate the stones from the potatoes due to the small difference in the coefficient of restitution between potatoes and stones. However, in order for the machine to be useful in Eastern Canada it must be capable of handling stones as well as clods. The initial tests indicated that separation of stones from potatoes was possible; consequently, a complete series of tests was performed. The tests included four feed rates of 9.0, 18.0, 27.0 and 36.0 t/h and three stone/potato ratios of 0.01, 0.055 and 0.1.

Separation effectiveness, \( E \), was determined as the product of recovery and rejection (Brown et al. 1951). Feller et al. (1984) also used this method of measuring separation effectiveness:

\[
E = \frac{P_p}{P_p + P_r} \times \frac{S_r}{S_r + S_p} = \left(1 - \frac{P_r}{P_p + P_r}\right) \left(1 - \frac{S_p}{S_r + S_p}\right)
\]

where \( P_p \) = potatoes in the product exit; \( P_r \) = potatoes rejected with the stones; \( S_r \) = stones in the reject exit; and \( S_p \) = stones remaining with the product.

Figure 4. Effectiveness of the brush separator as affected by feed rate and brush gap.
Analysis of variance was carried out on the data using the program Genstat ANOVA 1982. Significant differences of means were examined utilizing Duncan’s multiple range test.

RESULTS AND DISCUSSION

The width of the gap between the brushes was found to be an important parameter for determining the separation effectiveness of the brush separator. The analysis of variance of the data which were accumulated in the process of evaluating the sensitivity of the brushes to gap and feed rate with mixtures of potato and stones indicated that both factors, brush gap and feed rate, were highly statistically significant. Their effects on the effectiveness are shown graphically in Fig. 4. In Table 1, the analysis indicates that a brush gap of at least 13.0 mm is required to maximize the effectiveness of the separator. As indicated by Eaton and Hansen (1969), soil clods could not be separated from potatoes using brushes. In our tests, the mean effectiveness was only 0.15 when attempting to separate the clods and potatoes. The small difference in specific gravities of the two products probably accounts for the low performance.

With the electronic grader, feed rate was found to be the only significant factor affecting performance. Although the moisture level of the clods was found not to be a significant factor on the performance of the electronic separator, the interaction of moisture level and feed rate was highly significant.

The test results with the roller separator indicate that the stone/potato ratio was a significant factor affecting performance. The overall mean of the effectiveness factor of the roller separator for tests conducted was 0.84. This value suggests that the separator can be an effective machine for separating stones from potatoes, although Gan-Mor et al. (1985) indicate otherwise.

The performance of the three separators when separating a mixture of potatoes and stones is shown in Fig. 5. Overall, the performance of the brush separator appears superior.

CONCLUSIONS

From the results of the study, it can be concluded that separating stones from potatoes with any of the three separators is effective. The feed rate and the width of the gap between brushes are factors that affect the performance of the brush separator with stones and potatoes. However, this separator has limited capability to separate soil clods from potatoes. The electronic separator is sensitive to the feed rate when separating mixtures of stones and potatoes. Moisture of soil clods multiplied by feed rate is a significant factor when separating clods from potatoes. The stone/potato ratio becomes a significant factor for the roller separator when separating stones from potatoes.

REFERENCES


